Università
Ca'Foscari
Venezia

Bachelor's Degree/
Master's Degree
in Economia e Finanza
Curriculum Finance

Final Thesis

Derivatives on Cryptocurrencies: the case of futures contracts on Bitcoin

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Academic Year
2020 / 2021

To who have always and sincerely
believed in me,
thank you for the love and support
over the years.

Summary

INTRODUCTION

One of the most discussed topics in the last years is the one of cryptocurrencies. Even if this type of money was born at the beginning of 2000s, it become more popular in the last few years. It was developed with the help of the technology innovations since it is a completely digital currency. The first cryptocurrency introduced on the financial market and the most famous was the Bitcoin, developed in 2008 by Satoshi Nakamoto.

The innovation of this tool has led some governments, companies and banking institutions to approach alternative payment methods, based on blockchain technology, which is the system that underlies the functioning of digital assets.

Some companies have recently shown their willingness to market their own cryptocurrencies, such as Facebook and J.P. Morgan announced their cryptocurrencies: Libra1 and JpmCoin2, bringing digital asset prices back to the highest levels. Also the CEO of Testa, for a short period, thought to open to a payment on Bitcoin for buying a new car.

The problem with this type of asset is that in the legal field, a clear regulation has not yet been defined and this has favored, for example, the proliferation of illicit phenomena, such as money laundering, terrorist financing or the trading of illegal goods.

Considering Bitcoin, it is possible to say that it is a very risky and speculative asset and without a financial control, many investors choose this currency to speculate trying to obtain high gains and in this last four years it was introduced an option to try to cover the riskiness of Bitcoin. This option is the future contract.

This thesis has the goal to evaluate the volatility of Bitcoin before and after the introduction of futures contract and to investigate if the Bitcoin futures are a good investment instead of the simple Bitcoin price.

In the first chapter it will presented the scenario in which the cryptocurrencies was born and what are futures contracts on Bitcoin.

In the second chapter it will present the recent literature concerning this topics, analyzing how it is possible to evaluate the Bitcoin futures and reporting them results.

Based on what literature reported, in this third chapter it will start an empirical analysis, creating and using a MATLAB codes, on which effects the futures contract have had on the Bitcoin, investigating in particular if the futures make the Bitcoin more volatile.

In the fourth and last chapter, it will compare two portfolios: one portfolio with some stocks plus the Bitcoin prices and the other one with the same stocks plus the Bitcoin futures prices. It will used another MATLAB code and at the end, it will reported if invest on Bitcoin futures improve the returns of a portfolio or if it is more efficient to invest in the simple Bitcoin prices, without options.

Chapter I

I. What Bitcoin are and introduction to Bitcoin futures

During the human history, people have always had the need to exchange something to something else, for example to have food. One of the first and most famous form of this exchange was the bartering, which could be the first form of currency. In the modern world currency can be defined as the primary medium of exchange, which acts as an intermediary in order to make exchanging more efficient. It was during the Ancient Roman Empire (600 B.C.) that was minted the first coin deleting the problems with the bartering system and making easiest to give prices goods and services.

Nowadays, money is used as an instrument of payment that serves three essential purposes: a medium of exchange, a unit of account, and a store of value. The government regulation establishes a currency called *Fiat money*, which has neither intrinsic value nor use value and has value thanks to the government or to the parties engaged in exchange agreeing on its value. In other words, Fiat money is government-issued currency funded by the government that delivered it, instead of by a physical commodity, such as gold or silver, and it is not backed by any collateral. Cash, checks, and bank notes are other examples of fiat money. Fiat money has value only if the government declares it to be legal tender and it can be used to make full and final payment of legal debts. This type of money in the main source of money in today's economy and is supplied by a countries central bank which maintains the stability and supply using it monetary policy.

During the years, technology has increased its use and above all internet is now a fundamental necessity to study, to work or to live. Also the financial markets have followed this growth and it was born other forms of currency, like digital currencies. Digital currencies look like to the electronic storage of regular debit card accounts but they can be exchanged also without the intermediaries, as for example without banks. Dwyer said that some digital currencies are called cryptocurrencies due to the underlying algorithms and security are strictly related to digital cryptographic algorithms. Cryptocurrencies are a form of internet currency, which are not issued by a Central Bank and is not protected by law or regulations.

In 2012, the European Central Bank defined a virtual currency to be like a type of unregulated and digital money, then it has not all the attributes of real currency. To function rightly, money should have got five qualities. The first quality is portability. The second one is that its value should be stable, meaning that the value of money should not fluctuate randomly to any significant extent. The third one is the fungibility or free interchangeability. The fourth one is that it must be easily identifiable to prevent counterfeiting. The last one is that it must be a currency. Cryptocurrency is not free from significant random fluctuations, not fungible, and not sufficiently easy to identify to prevent counterfeiting.

1.1 What Bitcoin are

A cryptocurrency is a digital asset handled as a vehicle of exchange and it uses cryptography to secure transactions, to control the creation of additional value units, and to verify the transfer of assets. The first cryptocurrency developed was the Bitcoin and it was created by a developer or a team of developers, whose identity has not yet been discovered, called Satoshi Nakamoto.

"*What is needed is an electronic payment system based on cryptographic proof instead of trust, allowing any two willing parties to transact directly with each other without the need for a trusted third party*."[1]

With these words Satoshi Nakamoto posted a paper in 2008 titled "*Bitcoin: a peer-to-peer Electronic Cash System*", describing an implementation of a digital currency that uses the *blockchain technology*, which is a public database recording every Bitcoin transaction and so it is a sort of database of Bitcoin in circulation. A peer-to-peer network is a link between two personal computers that can interact with each other without to be connected to a separate server computer. Bitcoins use this peer-to-peer mechanism trying to eliminate the intermediary of the transaction that is the financial institution. In this way, there is no central bank and participants do not need to trust each other and all transactions are managed by direct communications between the counterparties.

[1] Nakamoto S., "Bitcoin: A Peer-to-Peer Electronic Cash System, 2008.

As just said briefly, every Bitcoin transaction can be verified within a network of nodes using thorough computer and cryptographic keys that are recorded into the blockchain, which is a publicly distributed electronic ledger book that acts as a digital financial book storing transactions in chronological order. The Bitcoin blockchain is a ledger that is shared, replicated, and frequently re-finalized in order to achieve a continuous consensus among all blockchain users.[2] The users can see the Bitcoin blockchain as a database management system that facilitates the exchange of Bitcoins for other currencies, products, and services when possible. The Bitcoin buyers use a digital wallets to keep track of their own balance and in this way, a Bitcoin wallet is the software that makes easier receiving, storing, and sending Bitcoins. In Nakamoto's view, a cryptocurrency wallet did the same function as a bank vault.

To add a Bitcoin onto the database, and so increasing the supply of cryptocurrency, is necessary a *mining process* which is done with a computer and is reduced on hashes per second. In a electronic language, a hash function is a computer data and the Bitcoin generation is a mathematical equation where the hash rate specifies how many equation are solved per second. A new hash is created when the miners solve a block (equation) and mines a coin and, in this way, he miner completes the electronic computations needed to create a new investment transaction in a Bitcoin blockchain. Moreover, to pay any miner it can also be use 12.5 new Bitcoins, being used to carry out transactions.

A cryptocurrency like Bitcoin is a decentralized autonomous organization (DAO), an open-source peer-to-peer digital network that enforces the rules it is set up with. Each DAO operates according to a set of rules that has managed by a computer, and they compete against others to gain investors. In this DAO setting, the money supply is set by an algorithmic rule, and the system of th network replaces the need to trust the integrity of human participants.

Cryptocurrencies have some advantages rather than the traditional transactions of money, but risk are still present. The benefit can be low transaction cost, security and the quick processing, and they are readily measurable, but quantifying the risks is more

[2] Clark Francis, "Bitcoins, Cryptocurrencies and BlockChains", New York

difficult. Cryptocurrency like Bitcoin is a currency without an intrinsic value and, for this reason, it can only function if sufficient market acceptance is present and if the belief exists that the currency has the value attributed to it.

Cryptocurrency prices are not based on the value of some collateral, like silver or gold, or any significant stream of income. The prices of cryptocurrencies are based only on expectations about their future prices. This means that the buyer of a cryptocurrency is willing to buy it only because they believe it will sell at a higher price in the future.

1.2 Blockchain system

As said before, blockchain is as a database management and is distinguished from an ordinary distributed database, which is a database with two or more files located in different sites, by its unique structure that linearly connects smaller pieces of the database, called also the blocks. The chaining of this blocks comes in the form of a cryptographic hashing function, which is used to map data of arbitrary size to fixed-size values and his output are called hash values, hash codes, digests, or simply hashes. From one input result a specify output and changing this input will change the output. In the Bitcoin computations, the input data are the history data, as for example returns and volatility, and a change to history data will break the chain on a particular copy of the database and when a chain is broken, the computer program fixes it by replacing any corrupted block with a valid block.

Blockchain is a secure database shared by all parties participating in a distributed network, which records and archives each transaction that takes place in the network, through a sequentially concatenated block structure. The data and its accessibility are encrypted, thus protected, and the use of this cryptography guarantees a significant amount of security, in terms of data protection and traceability of transactions, since it creates an irrevocable and verifiable history of transactions by all nodes participating in the system. However, the blockchain is not immune to cyber-attacks, even if there are low probabilities that this happened.

The Bitcoin protocol stipulates that can exist a maximum of 21 million Bitcoins at some point. Validators are called miner, who has to issue Bitcoin a few at a time and once miners finish to mine all these coins, there won't be more coins rolling out unless the Bitcoin protocol changes to allow for a larger supply. Miners are paid in transaction fees for creating blocks of validated transactions and including them in the blockchain.

As first thing, it has to be specified what is a node an it is a powerful computer that runs the Bitcoin software and fully validates transactions and blocks. Anyone can run a node but is necessary a lot of energy and storage. Some nodes are mining nodes, usually referred to as miners, and to add these nodes to the blockchain it needs to solve a complex mathematical puzzle that is part of the Bitcoin program, and including the answer in the block.

It is possible to think of the puzzle as a number-guessing exercise and it consists to find a number that produces a result that is within a certain range. To do this, it is necessary to combine this number with the data in the block and to pass through a hash function, which converts input data of any size into output data of a fixed length. The way to find this number is to guess at random because the hash function makes it impossible to predict what the output will be. Thus, miners guess the mystery number and apply the hash function to the combination of that guessed number and the data in the block. The resulting hash begins with a certain number of zeroes and there's no way to know which number will be right, because two consecutive integers will give different results. Moreover, there may be several numbers that give the right results, but could be also results not desired. In this case, the miners keep trying to find the right number but with a different block configuration. The required number of zeros at the beginning of the hash string is adjusted frequently, taking on average about 10 minutes to process a block, which is the time that Bitcoin developers assume necessary for a steady and diminishing flow of new coins until the maximum number of 21 million is reached[3].

Each assumption costs real-world resources, for example computing power and electricity, and validators are free to spend as much money on real-world resources as they like to maximize their number of hypothesis. The first validator (V3 in *figure 1*) to strike the right number is permitted to broadcast his ledger update to other validators. The other validators can check whether V3 guessed the right number. If he did right,

[3] www.coindesk.com/learn/Bitcoin-101/how-Bitcoin-mining-works

they update their ledgers to match his, and V3 will earn a premium in the community's currency. At this point, the process starts all over again for the next transaction with a new puzzle and it keeps going on cyclically.

Each block within the system is generated when multiple nodes reach a consensus and approve transactions. At the end of each block the digest summarizes the contents of

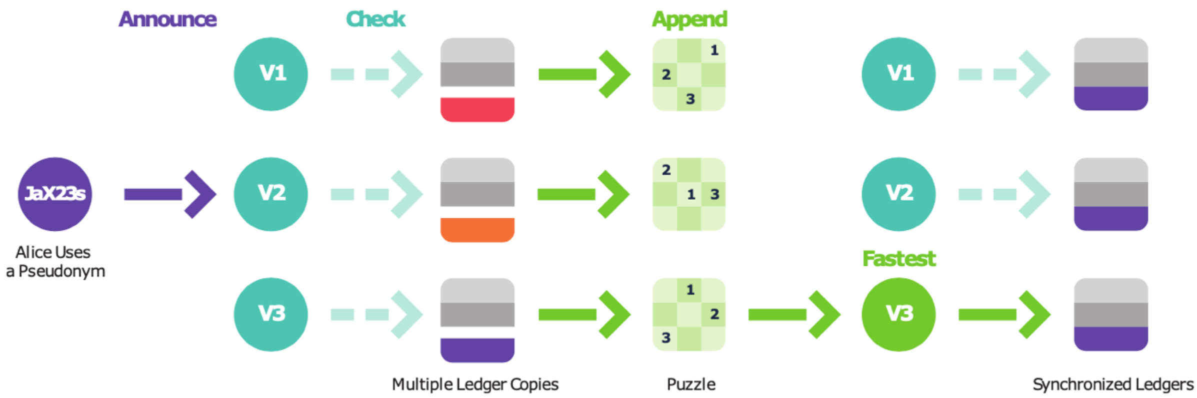

Figure 1

the block and the digest is repeated as the first line of the next block.
The first miner that obtain a resulting hash within the desired range makes known its victory to the rest of the network. All the other miners immediately stop work on that block and begin to work trying to figure out the number for the next one.

1.3 Other famous cryptocurrencies

There are several type of cryptocurrencies and differences among them may involve, for example, the choice of the consensus mechanism, the latency, or the cryptographic hashing functions.

According to coinmarketcap.com, which is the world's most-referenced price-tracking website for cryptocurrencies, the most popular cryptocurrencies after Bitcoin are: Ethereum, Binance Coin, Tether and Cardano. This ranking follow the prices of market capitalization. Important is also Litecoin. In this paragraph, will be introduced briefly the features of these popular cryptocurrencies.

1.3.1 Ethereum

Ethereum was first introduced in a 2013 whitepaper by Vitalik Buterin. It is a decentralized open-source (DAO) blockchain system and it is based on its own cryptocurrency, Ether. Ethereum's own assumptive goal are two: the first is to become a global platform for decentralized applications and services, from social media networks to more complex financial agreements, allowing users to write and run software that is safest and resistant to censorship, downtime and fraud; the second is to create financial products, like bank accounts or loans or insurance, that anyone in the world can have free access to, regardless of nationality, ethnicity, or faith.

Ethereum has pioneered the concept of a blockchain smart contract platform. Smart contracts are computer programs that automatically execute the actions necessary to fulfill an agreement between several parties on the internet. They were designed to reduce the need for trusted intermediates between contractors, thus reducing transaction costs while also increasing transaction reliability[4].

Ethereum design a platform that allow to execute smart contracts using the blockchain. Ethereum's blockchain was projected as a unique computer that in theory can make any program more robust, censorship-resistant and less prone to fraud by running it on a globally distributed network of public nodes.

1.3.2 Binance Coin

An initial coin offering, which is a type of funding using cryptocurrencies used to create a new company, in 2017 launched BNB. It can be used as a payment method for the fees on the Binance exchange, which was funded by Changpeng Zhao, and users of Binance Coin receive a discount for these payments as an incentive. BNB moves the Binance DEX (decentralized exchange) too and its mission is to become the infrastructure services provider for the entire blockchain ecosystem.

You cannot mine BNB as you can do in a proof-of-work cryptocurrency, which is a decentralized consensus mechanism that requires members of a network to solve an arbitrary mathematical puzzle to prevent anybody from gaming the system, because this

[4] coinmarketcap.com

process is much expensive in terms of electricity, but there are validators that earn from securing the network by validating blocks.

Binance coin schedules that quarterly BNB burns to permanently reduce the supply of BNB increasing its value, this means that it has a burn function which can permanently remove a nominated amount of coins from the circulating supply. Thus, quarterly it takes place a Coin burn event and Binance makes an official announcement specifying the amount of BNB coins that were burned, based on the trading volume for that quarter. The Binance's own blockchain is called Binance Chain and the coins is now burned in this blockchain, instead of to be burned on the Ethereum network using a smart contract burn function, as happened before the Binance Chain introduction[5].

1.3.3 Tether

Tether is a stablecoin, which is a stable-value cryptocurrency, that mirrors the price of the U.S. dollar, issued by a Hong Kong-based company Tether and its symbol is USDT. Stablecoin means a cryptocurrency that aims to anchor their market value to a currency or other external reference point in order to reduce volatility. The principal feature of USDT is the fact that its value is guaranteed by Tether to remain anchored to the U.S. dollar. According to Tether, whenever it issues new USDT tokens, it allocates the same amount of USD to its reserves. This procedure ensures that USDT is fully guaranteed by cash and cash equivalents.

Crypto markets are famous to be high volatility, but USDT is protected from these fluctuations. This property makes USDT a safe haven for crypto investors: during periods of high volatility, they can park their portfolios in Tether without having to completely cash out into USD. Tether allows investors to utilize a blockchain network and related technologies to transact in traditional currencies because this protections minimize the volatility and complexity often associated with digital currencies. In addition, USDT provides a way to transact a U.S. dollar equivalent between regions, countries and even continents via blockchain, without having to rely on a slow and expensive intermediary[6].

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[5] coinmarketcap.com

[6] coinmarketcap.com

1.3.4 Cardano

Cardano is a proof of stake blockchain platform, which is less energy intensive than the proof-of-work algorithm relied upon by Bitcoin. With this process a person can mine or validate block transactions according to how many coins he holds meaning that the more coins owned by a miner, the more mining power they have. Cardano was founded with a research-based approach by engineers, mathematicians, and cryptography experts and its goal is to bring a positive global change using a open-source project that also aims to helping to create a society that is more secure, transparent and fair. It uses a financial operating system of the world that can establish decentralized financial products similarly to Ethereum as well as providing solutions for chain interoperability (the ability to see and access information across various blockchain systems), voter fraud, and legal contract tracing, among other things.

Cardano is used by agricultural companies to track fresh produce from field to fork. The project ensure that all of the technology developed goes through a process of peer-reviewed research, meaning that ideas can be challenged before they are validated.

According to the Cardano team, this academic rigor, since the founders are all researchers, helps the blockchain to be durable and stable, increasing the chance that potential pitfalls can be anticipated in advance[7].

1.3.5 Litecoin

Litecoin (LTC) was introduced on crypto market in 2011 and it was one of the first cryptocurrencies to follow in the footsteps of Bitcoin. It was created by Charlie Lee, a former Google engineer and it is probably famous thanks to its simplicity and clear utility benefits. Litecoin is based on an open-source global payment network without the control of any central authority and uses the script as a proof of work. Although Litecoin is similar to Bitcoin in many ways, it has a faster block generation rate, which is a measure of the time it takes to produce a new block, or data file, in a blockchain network, and hence offers a faster transaction confirmation time, that is the time passed between the moment a blockchain transaction is sent to the network and the time it is recorded into a confirmed block. Litecoin is a cryptocurrency that was projected to

[7] coinmarketcap.com

provide fast, secure and low-cost payments by leveraging the unique properties of blockchain technology.

The cryptocurrency was created based on the Bitcoin protocol, but it differs in some terms, among which the main ones are: the hashing algorithm used, hard cap (the maximum amount of money a cryptocurrency can receive from investors in its Initial Coin Offering (ICO)), block transaction times. Litecoin's main benefit comes from its speed and cost-effectiveness: it has a block time of just 2.5 minutes and extremely low transaction fees, making it suitable for micro-transactions and point-of-sale payments. This makes it an attractive alternative to Bitcoin in developing countries, where transaction fees may be the deciding factor on which cryptocurrency to support.

One reason that some people prefer to use Bitcoins or other cryptocurrencies that are based on the blockchain technology is because these instruments are more difficult to *hack or counterfeit than cryptocurrencies that are not based on the blockchain* technology. The Bitcoin blockchain ledger system records every Bitcoin transaction electronically. Up to date electric copies of this historical database are continuously circulated among those who own and trade Bitcoins.

1.4 Derivatives on Bitcoin

In the last few years, the market of cryptocurrencies was increased and it was born many other cryptocurrencies, some are popular but others are not known by people. Investors has started to see cryptocurrencies as a good instrument to make investments and so they has started to believe in this type of money and in this sense the digitalization process helped because more and more people has begun to use internet. The growth in the cryptocurrency cash markets implies a parallel development of cryptocurrencies derivatives contract and trading platforms, and one popular instrument derivatives was the futures contract. The high volatility of Bitcoin prices leaded Bitcoin not being a useful unit of account.

Before to talk about the Bitcoin futures, it is necessary to remember what futures contracts are. A futures contract is a legal agreement that permit to buy or sell a particular commodity asset, or security at a predetermined price at a specified future time.

Bitcoin futures was introduced in December 2017, respectively on 10th and 18th of December, on the Chicago Board Options Exchange (CBOE) and on the Chicago Mercantile Exchange (CME). Both the CME and the CBOE future contract are cash settled in US Dollars, it means just only for BTC-USD currency. The regulation of Bitcoin and derivatives is governed by the Commodity Exchange Act (CEA) and under the competence of the U.S. Commodity Futures Trading Commission (CFTC). Thus, the CME and the CBOE offer products which are CFTC-regulated. The CBOE decided to stop trading Bitcoin futures in June 2019, and in this way the trading volumes on the CME have been increasing. The CBOE did not say why they chose to stop their issues of futures contract on Bitcoin, but they wrote in a notice that it "is assessing its approach with respect to how it plans to continue to offer digital asset derivatives for trading". The following table make a comparison between the two exchanges.

Table 1. Difference between CME and CBOE Bitocin future.

Variable	Cboe Futures	CME Futures
Product Code	XBT	BTC
First Traded	10th of December 2017	18th of December 2017
Contract unit	1 Bitcoin	5 Bitcoins
Minimum Price Fluctuation	10.00 points USD/XBT (equal to $10.00 per contract)	$5.00 per bitcoin = $25.00 per contract
Position Limits	A person: (i) may not own or control more than 5,000 contracts net long or net short in all XBT futures contract expirations combined and (ii) may not own or control more than 1,000 contracts net long or net short in the expiring XBT futures contract, commencing at the start of trading hours 5 business days prior to the Final Settlement Date of the expiring XBT futures contract.	1,000 contracts with a position accountability level of 5,000 contracts
Price Limits	XBT futures contracts are not subject to price limits	7% above and below settlement price, +/-13% previous settlement, +/-20% for prior settlement
Settlement	The Final Settlement Value of an expiring XBT futures contract shall be the official auction price for Bitcoin in U.S. dollars determined at 4:00 p.m. Eastern Time on the Final Settlement Date by the Gemini Exchange Auction.	Cash settled by reference to Final Settlement Price

Source: Corbet S., Lucey B., Peat M. and Vigne S., (2018), "Bitcoin futures – What use are they?", Economics Letters 172, Pages 23-27.e

The introduction of Bitcoin future appeared to as a sign that the financial system accepted Bitcoin as a tradeable speculative asset and it was important also for Bitcoins traders since they were able to hedge their spot position.

The BTC-USD futures contracts were not largely anticipated until few time before the date of the beginning, only fifteen days before. The derivative introduction improves the price efficiency of the underlying cash market and there is no significant difference in market quality, which can be defined as the prospects for a market participant to successfully match his order at a competitive price on a given trading venue, between BTC-USD and other cryptocurrency exchanges rate. This means that there is an increase in market efficiency, which is the degree to which market prices reflect all available, relevant information, and market quality. Lastly, a reduction in price impact following the futures listing is significant for BTC-USD and is a signal of a raise of market liquidity.

Since the introduction of futures there has been a change in the distributional characteristics of Bitcoin returns. Two fundamental statistics measures changed: the mean changed in sign and the standard deviation doubled. The volatility of the indices increased after the introduction of the futures contracts. It is possible that an appropriately constructed hedge portfolio can be used to manage the volatility of Bitcoin prices[8].

Corbet et al, in their paper titled "*Bitcoin Futures – What use are they?*", showed that hedging increases risk, as indicated by the negative sign of the effectiveness and risk reduction and it also increases the pricing risk inherent in physically holding Bitcoin. Their studies demonstrated that the centralization and relative transparency of futures markets contribute to their large role in price discovery, which is the whole process to find out the spot price. It is also likely that the features of futures contract, as low transaction costs, inbuilt leverage, ease of shorting, and the ability to avoid holding the underlying physical asset, make them an attractive alternative for traders in a wide range of assets.

They concluded that high volatility of Bitcoin prices and the range of prices quoted on various Bitcoin exchanges were seen to damage Bitcoin's usefulness as a unit of account. If the introduction of Bitcoin futures and the ability to trade these would have resulted in a reduction in the variance of Bitcoin prices, or facilitated hedging strategies that could have mitigated pricing risk in the spot market, it is possible that the Bitcoin could

[8] Corbet S., Lucey B., Peat M. and Vigne S., (2018), "Bitcoin futures – What use are they?", Economics Letters 172, Pages 23-27.

have acted as a unit of account, moving it closer to being a currency[9]. In the end, they asserted that Bitcoin should be seen as a speculative asset rather than a currency.

In the "*what is Bitcoin futures had never been introduced?*" paper, Jalan et al studied what happened if Bitcoin futures had never been introduced. They showed that the USD Bitcoin spot market return would be higher, volatility and kurtosis lower, skewness rather negative and finally, market liquidity lower. This means that the introduction of Bitcoin futures had a significant negative effect on return being higher at the beginning and the negative relationship between Bitcoin volatility and return can be explain by the greater risk and is consistent with expected risk premium and volatility. Bitcoin futures made Bitcoin spot market more vulnerable to extreme return values. The high volatility reaches its peak after one wee of the introduction of Bitcoin futures, after which it begins to fall.

1.4.1 Non-regulated derivatives exchanges

Besides the market of US regulated crypto derivatives exchanges, there is a bigger and growing market of non-regulated cryptocurrency derivatives exchanges, with a diffusion of trading platforms and product offerings. The largest non-regulated cryptocurrency derivatives exchanges is the so called BitMex and offer futures contracts for various cryptocurrencies, like Bitcoin, Ethereum and Litecoin[10].

BitMex is a dedicated crypto-only derivative exchange and his data should provide a comprehensive view about Bitcoin market microstructure and, in particular, a study on the price leadership between spot and derivative trades, counting all Bitcoin products its volume is great above CME, CBOE and major spot exchanges[11]. BitMex introduced their derivatives contracts before the CME and CBOE regulated exchange. BitMex have many different features which aim to attract small but crypto-focused traders than regulated financial institutions and the features are: 1 USD contract size, no regulation, Bitcoin-based contract design, minimal margins, and lower trading costs.

[9] Corbet S., Lucey B., Peat M. and Vigne S., (2018), "Bitcoin futures – What use are they?", Economics Letters 172, Pages 23-27.
[10] Augustin P. et al, "The impact of derivatives on cash markets: Evidence from the introduction of Bitcoin futures contracts", 2020
[11] Alexander C. et al (2020), "BitMEX Bitcoin Derivatives: Price Discovery, Informational Efficiency and Hedging Effectiveness", Journal of Futures Markets, 40(1):23-43.

BitMex derivatives have a positive spillover effects, which means that innovations in BitMex have a disproportionately larger influence on the other three markets, have more information than other regulated exchange that make BitMex more efficient than Bitcoin spot prices and are useful as effective hedges against spot price volatility.

Chapter II

II. Bitcoin volatility and futures contracts: literature

Volatility is defined as a measure of dispersion around the mean or average return of a security and it can be measured using the standard deviation (SD). The standard deviation show how closely the price of a stock is bunched around the mean; moreover when prices are closely each other, it is small, while when prices are widely spread apart, it is large.

Markets go up and down continuously and these movements can be measured by the high or low volatility in that moment: higher probability of a decreasing market usually is associated to a higher volatility, whereas higher probability of a rising market usually correspond to a lower volatility[12]. Since Bitcoin cryptocurrency has been introduced, it has been studied his volatility. This type of asset has an high level of volatility due to the fact that it is has an high level of risk for the investors.

As we have previously seen, the volatility influence the price of one financial product and when the price of Bitcoin is considered it is useful to make a different between *transactional* demand and *speculative* demand. The former is a demand which arises when Bitcoin are used in transactions like purchases of goods and services, the latter is a demand that rises when Bitcoin are bought in the hope that their value will increase and this type of demand is considered like a bet on the price of the underlying asset[13].

Now we will focus on some paper that try to understand how prices change before and after the introduction of the futures contracts on Bitcoin and how change its volatility.

2.1 "How futures trading change Bitcoin prices"

This paper has been wrote by Hale G., Krishnamurthy A., Kudlyak M., and Shultz P. and it was published on May 7th 2018 on FRBSF Economic Letter 2018-12.

At the beginning Hale et al make a comparison between the introduction of the blockchain system and the collapse of the home financing market in the 2000s. Mortgage boom means that in those period the houses' prices increased but the rate of

[12] Easterling E., (2021), "*Volatility in Perspective*", Crestmont Research.
[13] Hale G. et al, "How Futures Trading Changed Bitcoin Prices", 7th May 2018, Economic letter 2018-12

interest remained stable attracting people to buy a home, and if someone could no longer pay for the house, then the financial intermediary took it to resell to other persons, speculating on it and creating the so called Housing Bubble. Hale et al. state that the mortgage boom was driven by financial innovations in securitization and the following "*bust was driven by the creation of instruments that allowed pessimistic investors to bet against the housing market*" like wrote the Federal Reserve Bank of San Francisco in an economic letter[14]. In the same way the blockchain introduced a new financial instrument called Bitcoin, which is promoted by the optimistic investors, but the advent of the futures contract on Bitcoin permitted to pessimistic investors to enter into the game. Their game provides to bet on lower than expected prices when they want to sell, and higher than expected prices when they want to sell. In this sense they are pessimistic, because they expected worse scenarios than the expected ones, and they want to gain from these. Bitcoin price rose until the introduction of futures, moment when prices decline and pessimists play a role, betting to the worse scenario, on this reversal of the Bitcoin price dynamics.

Hence, this paper make a different between optimistic, who bet money that the price was going to go up and pessimist investors. Without Bitcoin derivatives was very difficult for pessimists to bet on the decline in Bitcoin price, as opposed to optimists that pushed the price of Bitcoin up, energizing more people to join in and keep pushing up the price[15].

2.2 "Bitcoin futures – What use are they?"

Corbet et al. begin his analysis referring to the Yermack[16] result in his "*Is Bitcoin a real currency? an economic appraisal*" paper, where he demonstrated that the Bitcoin is not a traditional asset but it is a speculative asset since it not satisfy the key functions of a money, which we remember be: a medium of exchange, unit of account and store of value. Corbet et al. want to find out if the introduction of derivatives, in particular futures contract, on Bitcoin can change this view. They use the CBOE future contract price and Bitcoin price from the 26th of September 2017 to 22nd of February 2018 and

[14] Hale G. et al, "How Futures Trading Changed Bitcoin Prices", 7th May 2018, Economic letter 2018-12
[15] *Ibedem*
[16] Yermack, D. (20159, "*Is Bitcoin a real currency? an economic appraisal*", In Handbook of Digital Currency, pp. 31–43. Elsevier

futures was issued on 10th and 17th of December 2017. They use one-minute transaction prices to calculate the log-return and as result they saw that, after the introduction of futures, the mean of Bitcoin returns since futures changed in sign and its standard deviation doubled.

Corbet used two nonparametric statistics: the *Mood statistic*[17] to evaluate changes in volatility, and a *Lepage-(type) statistic*[18] to evaluate changes in location and scale. These two tests showed that there was a significant change in the distribution of Bitcoin prices due to the increase in volatility.

After that, they wanted to know how much the risk of losses is lower if a portfolio is hedged with futures contracts on Bitcoin and they investigated two approaches: naïve and OLS based hedging strategies, to find the effectiveness of the hedge, which can be measured by the percentage reduction volatility that results from holding the hedge portfolio. The first approach is a portfolio with one short futures position for every Bitcoin position and the second one is a portfolio that uses the Ordinary Least Square regression. Both results show that hedging increases risk, indicated by the negative sign of the effectiveness and risk reduction results, and the rolling OLS hedge is more effective than the naive hedge[19].

They conclude that the function of Bitcoin as a unit of account is damaged by the high volatility of its prices and by its range of prices on different Bitcoin exchanges. However, in paper the authors have demonstrated that the introduction of Bitcoin futures reduced the variance of Bitcoin prices and the easiness of hedging strategies could mitigate pricing risk in the spot market. Both approaches previously analyzed showed an increase of volatility around the announcement of the introduction of future. But in the end, they

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[17] The *Mood test statistic* is a square rank test for dispersion and it is based on the sum of squared deviations of the ranks of one sample from the mean rank of the combined samples. The null hypothesis is that there is no difference in spread against the alternative hypothesis that there is some difference. This test assumes that location remains the same and it is assumed that differences in scale do not cause a difference in location. (Source: Odiase J.I., Ogbonmwan S.M. (2011) Mood Test. In: Lovric M. (eds) International Encyclopedia of Statistical Science. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-04898-2_378)

[18] In statistics, the Lepage test is a nonparametric test used for jointly monitoring the location (central tendency) and scale (variability) in two-sample treatment versus control comparisons.

[19] Corbet S., Lucey B., Peat M. and Vigne S., (2018), “Bitcoin futures – What use are they?”, Economics Letters 172, Pages 23-27.

stated that it is better to see Bitcoin as a speculative asset rather than as a cryptocurrency and is not altered by the introduction of futures trading.

2.3 "The effects of the introduction of Bitcoin futures on the volatility of Bitcoin returns"

This paper begins assuming the results of the two previously studies, namely Hale et al. who suggest the decreasing of Bitcoin price after introduction of futures and Corbet et al. who indicate the rise of volatility around the announcement of Bitcoin futures' introduction. However, instead of considering a short time like them, Kim et al. considered one year divided in six months before the introduction of futures on Bitcoin and six month after it.

Kim et al. considered five largest cryptocurrencies exchanges, which are bitFlyer (Japan), Coincheck (Japan), Bitstamp (EU), Coinbase (US) and Binance (Hong Kong) using one-minutes prices of every exchange. Remembering that the authors considered six months before the introduction of futures on Bitcoin and six month after it, they divided this year into four sub-periods: *Period 0* covers the six months before the introduction of the Bitcoin futures; *Period 1* runs from December 18th, 2017, to February 28th, 2018; *Period 2* runs from March 1st, 2018, to April 30th, 2018; and *Period 3* is from May 1st, 2018, to June 26th, 2018[20].

As first thing, they calculated the aggregate change in Bitcoin's intraday volatility using the bias-corrected realized volatility after the introduction of futures on Bitcoin. To calculate the bias-corrected realized volatility on day *t*, σ_t , Kim et al. used the following formula:

$$\sigma_t = \sqrt{\sum_{k=1}^{1440} r_{t,k}^2 + 2\frac{1440}{1339}\sum_{k=1}^{1339} r_{t,k} r_{t+1,k}}$$

where $r_{t,k}$ is the *k*th one-minute log return of Bitcoin on day *t*. Note that, there are 1440 returns for each day because Bitcoin is traded for twenty-four hours. They summarized all the results in a table showing that Bitcoin's realized volatility statistically increased in

[20] Kim W., Lee J and Kang K., "*The effects on the introduction of Bitcoin futures on the volatility of Bitcoin returns*", June 08th 2019, Finance research letters 33 (2020)

Period 1 rather than Period 0 consistently with the studies of Corbet et al.. In Period 2 and 3 the realized volatility decreased with respect to Period 0. These result demonstrated that even if the realized volatility rose immediately after the introduction of futures, later it decreased reaching a lever lower than before.

Whereupon they investigated the casual effects of the introduction of Bitcoin futures using the difference-in-difference (DD) analysis[21] with respect of Bitcoin price and Ethereum price from the Binance exchange and they consider the Bitcoin price as the treatment variable and the Ethereum price as the control variable. This analysis suggested that Bitcoin futures contributed to making the Bitcoin market more stabilized after the advent of Bitcoin futures because these futures may not be the cause of the movements of volatility in *Period 1* and *Period 2* with respect to *Period 0* but in *Period 3* could be the answer of the decreasing.

After that, they used the discrete Fourier transform (DFT) to investigate this change more precisely. The discrete Fourier transform is a type of Fourier analysis based on iterating time series and can convert a real sequence of numbers into a sequence of complex numbers of the same length and it is used to represent a function in the frequency domain. This model is fully model-free and non-parametric and his interactivity make DFT model more reliable than the others models. This model is applied to each exchange and they calculated the frequency component[22], which is represented as peaks in the frequency domain, for each sub-period dividing it in low-frequency band, medium-frequency band and high frequency band. The results detected that is the changes in the three frequency components which cause the intraday volatility changes after futures on Bitcoin were introduced.

[21] Difference-in-differences is an analytical approach that facilitates the causal inference. This method compute two differences: the first one takes the before-after difference in treatment group's outcomes and control the factors that are constant over time in that group; the second one takes the before-after difference in the control group, which was exposed to the same set of environmental conditions as the treatment group, to capture time-varying factors. In the end, difference-in-differences cleans all time-varying factors from the first difference by subtracting the second difference from it.
[22] To see in detail what is and which are the frequencies bands, t refers directly to the papers.

As last step, Kim et al. applied the two-regime skewed Student-t GJR model[23] to understand the regime change in the GARCH volatility dynamics of Bitcoin log-returns and they showed that the Bitcoin price process was more stable after the advent of futures on Bitcoin rather than before it.

Concluding, according to Kim et al, the discovery of the increasing's volatility and the increasing of the low-, medium- and high-frequency components of Bitcoin price process after the introduction of future on Bitcoin proved that, in the short period after this advent, the Bitcoin market was not inclined to liquidity-providers because if risk, and so volatility, increases than the liquidity decreases [24].

2.4 The impact of futures trading on Intraday Spot Volatility and Liquidity: Evidence from Bitcoin Market

Shi Shimeng wanted to examine how the Bitcoin spot price changes after the introduction of its futures. He started assuming that the Bitcoin spot price variation could be lowered due to the easiness risk transfer across hedgers and speculators and that cash market could be more liquid since the futures contract are cheaper attracting more informed arbitrageurs[25].

He considered the sample period from December 03th 2017 to December 17th 2017 using the 30-minute Bitcoin spot market data. He computed the mean return, which resulted positive, the kurtosis, which resulted an high excess (so greater that 0), and the skewness, which resulted negative. He used high-frequency data building a non-parametric and model-based volatility measures (GARCH model) and three liquidity proxies, which are: trading volume; Roll's Measure, which is a model to infer the realized spread, and so the effective spread, that the time series properties of observed market

[23] This model is part of the family of GARCH models and it is one of the more efficient advanced model that literature uses to make computations with Bitcoin prices. To see how it works, see the article: Alexander C., Lazar E., Stanescu S., (2021), "*Analytic moments for GJR-GARCH (1, 1) processes*", International Journal of Forecasting, Volume 37, Issue 1, Pages 105-124

[24] Kim W., Lee J and Kang K., "*The effects on the introduction of Bitcoin futures on the volatility of Bitcoin returns*", June 08th 2019, Finance research letters 33 (2020)

[25] Shi S. Shi Shimeng, "The impact of futures trading on Intraday Spot Volatility and Liquidity: Evidence from Bitcoin Market"

prices and/or returns reflected[26]; and Amihud's Measure, which is a low frequency measure that gives the daily price impact of the order flow and he calculated the liquidity level of the market, starting from the average illiquidity of all the stocks[27]. He computed the Jarque-Bera (JB) test to validate the non-normality property of the spot return distribution. He showed that the standard deviation of log trading volume was resulted higher than that of Roll's and Amihud's measures.

As first thing, he computed the realized Bitcoin volatility using the high-frequency data and the following formula[28]:

$$RV_{n,t} = c^{RV} + \alpha^{RV} RV_{n-1,t} + \beta^{RV} Dummy_{n,t} + \omega_{n,t}^{RV}$$

where the $RV_{n,t}$ is the realized volatility and $Dummy_{n,t}$ take the value 1 after the introduction of futures and 0 otherwise. In the literature, various GARCH-type models can be used to investigate the Bitcoin volatility and Shi chose an asymmetric EGARCH model with a generalized error distribution (GED) because this model guarantees the positivity of the conditional variance. He estimated the regression using least squares with heteroscedasticity-consistent standard errors. He compute two tests to confirm the choice of this EGARCH-type model, which are Ljung-Box's[29] (1978) test and McLeod-Li's[30] (1983) test and they showed that the standardized residuals and their squares are serially uncorrelated, respectively. The tests' results showed that the GARCH-type model used in this paper is adequate.

This analysis permitted to Shi to demonstrate that the introducing of Bitcoin futures significantly stabilizes the spot price volatility.

As mentioned above, he consider three liquidity proxies, which support the theory that after Bitcoin futures were introduced, the Bitcoin spot market was more liquid. He noticed that the effect of Bitcoin futures trading on log trading volume was not

[26] Gabrielsen, Alexandros and Marzo, Massimiliano and Zagaglia, Paolo, 2011, "Measuring market liquidity: an introductory survey", University of Bologna - Department of Economics

[27] Amihud Y., (2002), "Illiquidity and stock returns: cross-section and time-series effects", Journal of Financial Markets, Volume 5, Issue 1, Pages 31-56

[28] To see more in details the formulas, see the paper directly

[29] This test is a type of statistical test used to find out if any of a group of autocorrelations of a time series are different from zero

[30] This test is for autoregressive conditional heteroskedasticity both for raw data and for residuals from a conditional mean model, however this test is not used for residuals from a GARCH model, which has a specific test called Li-Mak test.

significant since the positive coefficient of the dummy variable means that attracted more transactions in the spot market. The significantly negative coefficients of the dummy variable confirm that the spot market becomes more liquid in the post-futures trading period according to Roll's and Amihud's liquidity measures.

He concluded arguing that the Bitcoin spot market could benefit from the introduction of Bitcoin futures trading because the spot volatility reduces and the market liquidity increases.

2.5 What if Bitcoin futures had never been introduced?

In this paper, Jalan et al. asked themselves what would have happened if Bitcoin futures had never been introduced, trying to predict the market response that would have occurred had no futures market been introduced, and they investigated in particular the effects on USD Bitcoin spot market return, on realized variance and volatility, on realized skewness and kurtosis and on liquidity. They used hourly data of Bitcoin prices and covered the period from July 1st 2017 to October 10th 2019. Jalan et al. considered Bitcoin prices from the Bitstamp exchange and Ethereum and Litecoin prices from the Kraken exchange and these last two cryptocurrencies was chosen because they are correlated with Bitcoin and Bitcoin futures have no effect in their efficiency.

At first, Jalan et al. computed the log returns, the Realized Variance, the realized skewness and realized kurtosis. These variables are calculate for Bitcoin as well as for Ethereum and Litecoin and the first one was considered as treatment variable, which can have an effect on the other variables, but the second ones were considered as controls. They used a Bayesian structural time-series model, which is a statistical technique used for several important things: feature selection, nowcasting, inferring causal impact, time series forecasting and other applications, working with time data and it is an alternative to the difference-in differences cited before, since it seems to be very flexible and built a diffusion-regression (state-space) model, which is the probabilistic dependence between the a variable and its observed measurement.

They found out that the realized returns was consistently negative even if the model forecasted positive returns if Bitcoin futures had never been introduced. However, this negative influence of Bitcoin futures on spot return decreased over time becoming stable. Considering the effect on realized variance, it resulted positive making the Bitcoin spot market riskier than without the introduction of Bitcoin futures, as well as the futures had a good effect for the market volatility, which increased and reached its peak after one week the introduction of futures on Bitcoin and then it began to decrease. The realized skewness suffered a negative effect that decreased over time and this negative effect may have increased the demand for hedging. The kurtosis resulted lower than before Bitcoin futures but this effect did not last long and it make Bitcoin spot market more liable to extreme swings and fluctuations.

Considering the liquidity, Jalan et al. showed that the advent of futures on Bitcoin has a positive effect on it even if this effect was not large enough to stabilize the market.

Concluding, Jalan et al. demonstrated that if Bitcoin futures had never been introduced, the USD Bitcoin spot market return would be higher, its volatility lower, skewness rather negative, kurtosis lower, and liquidity lower as well[31].

[31] Jalan A., Matkovskyy R. and Urquhart A., "*What if Bitcoin future had never been introduced?*"

Chapter III

III. The volatility before and after Bitcoin futures contract

In this chapter it will see how to compute the analysis of Bitcoin volatility before and after the introduction of Bitcoin futures contracts using a MATLAB code, inserted in the appendices A and B of this thesis. The analysis is based on the literature tell presented in the previous chapter, like in the papers of Corbet et al. "*Bitcoin futures – What use are they?*" and Jalan et al. "*What if Bitcoin future had never been introduced?*".

3.1 Methodology

As first thing, it is necessary to define what is the *volatility,* σ. Volatility is a statistical measure of the dispersion of returns for a given security or market index and, in general, the higher is the volatility, the riskier is the security. Volatility is measured using the standard deviation, which is the square root of the variance. We need to recall that the variance measures how each observations in a considered sample is far from the mean and that returns are computed using the following formula:

$$R_t = \frac{P_t - P_{t-1}}{P_{t-1}}$$

where R are the returns, P_t is the price at time *t* and P_{t-1} is the price at time *t-1*.

Volatility is usually associated to the concept of risk, which is related to the size of changes in a security's value,. High volatility means that a security's value can be spread out over a larger range of values, which means that the price of the security can change a lot over a short time period in either direction; low volatility means that a security's value can have small fluctuations looking to be more steady.

3.1.2 Realized Volatility

Historical volatility, which is called also *Realized Volatility* (RV) is a statistical measure of the dispersion of returns for a given security or market index, in which returns are computed over a given period of time. Typically, this measure is calculated by determining the average deviation from the average price of a financial instrument in the given time period:

$$\sigma = \sqrt{\frac{\sum_i^N (r_i - \bar{r})^2}{N-1}}$$

where r_i is the return at time i, $\bar{r}$ is the mean of the stock price and N is the number of returns.

3.1.2 GARCH volatility

The method used to compute the historical volatility, so using the historical returns, assume that variance is constant through time is statistically inefficient and inconsistent. In real economy, financial data like stock market returns changes with time and this indicates the needs for studying models which accommodate this possible changes in variance. Many studies, like those analyzed in this thesis in the chapter 2, have suggested that volatility of returns in stock markets can be forecasted using the GARCH type models, which seems to be a more complete model[32]. The historical returns assume also the stationarity of the financial data (like as just said the volatility), but in the real life this data are not stationarity. In this sense, the GARCH model overcome the historical method, implying the non-stationarity of the data and thus the residuals, that the process obtains in the end, can be considered like a returns "cleaned" from all possible errors that the stationarity assumption can involve.

The *Generalized Autoregressive Conditional Heteroskedasticity* (GARCH) process is one of the best models[33]. GARCH process was proposed in 1986 by Tim Bollerslev, a doctoral student of that time, to try to solve the problem of forecasting volatility in asset prices and it is an implement on the economist Robert Engle's breakthrough 1982 work in introducing the *Autoregressive Conditional Heteroskedasticity* (ARCH) model. His model was based on the fact that the variation of financial returns was not constant over time but was autocorrelated, or conditional to on each other. The ARCH model show that the volatility is related only to the past squared returns and so it has only one constraint, while the GARCH process consider that the volatility at time t is related both to the past squared returns Y^2_{t-1} but also to the previous variances σ^2_{t-1} showing in this way two constraints.

[32] Namugaya J., e al., (2014),"*Modelling volatility of Stock Returns: Is GARCH(1,1) enough?*, International journal of sciences: basic and applied research (IJSBAR), Volume 16, n. 2, pp 216-223
[33] *Ibedem*

GARCH process is a statistical model used in analyzing time-series data where the variance error is believed to be serially autocorrelated and it assume that the variance of the error term follows an autoregressive moving average process (ARMA), which is a model of forecasting where the methods of autoregression (AR) analysis and moving average (MA) are both considered for application to time-series data and it is assumed that the time series is stationary[34].

GARCH models assume that variance of the error term is not constant, which means that the error term is heteroskedastic. Thus, it is possible to affirm that the heteroskedasticity is a property of this model. The reason for the heteroskedasticity is that the error term follows an autoregressive moving average pattern, as said before, meaning that it is a function of an average of its own past values.

Financial institutions typically use this model to estimate the volatility of returns for stocks, bonds, and market indices. The resulting information are used to help to allocate their asset, hedging, risk management, and portfolio optimization decisions.

The GARCH family of models is part of the category of conditional volatility models and are based on using exponential weighting of historical returns to obtain a volatility forecast, where returns on day t are a function of returns on previous days and older returns have a lower weight than more recent returns.

The main object this type of models is to compute the conditional volatility of the returns Y_t and it is assumed that $E(Y_t) = 0$. The formula to make this computations is:

$$Y_t = \sigma_t Z_t$$

where Z_t are the residuals and the most common conditional distribution in the GARCH model is the normal, thus the Z_t follow the distribution:

$$Z_t \sim \mathcal{N}(0,1)$$

To fit this model, it is necessary to start from the computation of the historical logarithm returns. Like said before, the GARCH model is an implementation of the ARCH since one of the biggest problems with the ARCH model concerns the long lag lengths required to

[34] Namugaya J., e al., (2014),“Modelling volatility of Stock Returns: Is GARCH(1,1) enough?, International journal of sciences: basic and applied research (IJSBAR), Volume 16, n. 2, pp 216-223

capture the impact of historical returns on current volatility[35]. To incorporate the impact of historical returns, it is included lagged volatility during ARCH model creation, resulting in the *GARCH(L_1, L_2)* model[36]:

$$\sigma_t^2 = \omega + \sum_{i=1}^{L_1} \alpha_i Y_{t-i}^2 + \sum_{j=1}^{L_2} \beta_j \sigma_{t-j}^2$$

The most common version of this model employs only one lag and is a GARCH(1,1) model:

$$\sigma_t^2 = \omega + \alpha Y_{t-1}^2 + \beta \sigma_{t-1}^2$$

where the ω, α and β are constant.

In the GARCH-type models there are two types of volatility: conditional and unconditional. The unconditional volatility (σ) depends on the entire sample and is a sort of "general" volatility of a random variable when there is no extra information (no conditioning) and the formula is the following:

$$\sigma^2 = \frac{\omega}{1 - \alpha - \beta}$$

The conditional volatility (σ_t) is determined by previous observations and, thus, conditioned by recent returns and it is used the previous formula of the general GARCH*(L_1, L_2)*.

In this thesis, GARCH is important because it compute the *residuals*, which are the difference between the predicted value (ŷ) and the observed value (y) and so they are a sort of "corrected returns", and in this case they are calculated with the following formula, which refers to the returns formula:

$$Z_t = \frac{Y_t}{\sigma_t}$$

At this point, it is necessary compute the correct volatility, starting from residuals instead of the returns, applying the formula of the volatility.

[35] Danielsson J., 2011, "*Financial Risk Forecasting*", John Wiley & Sons Inc

[36] *Ibedem*

3.1.3 Kurtosis and Skewness

It is also important to compute two descriptive statistics in both cases, Realized volatility and GARCH volatility. These statistics are called Kurtosis and Skewness.

In probability theory and statistics, skewness is defined as the third moment of a distribution, where the first moment is the means and the second one is the variance. Skewness is a measure of the symmetry of a distribution, which is skewed if the tail on one side of the mode (the highest point of the curve) is fatter or longer than on the other. If this happen, it means that the distribution is asymmetrical.
When an asymmetrical distribution has a negative skew value, it indicates that the tail on the left side is longer than on the right side (left-skewed), while a positive skew indicates the tail on the right side is longer than on the left (right-skewed).

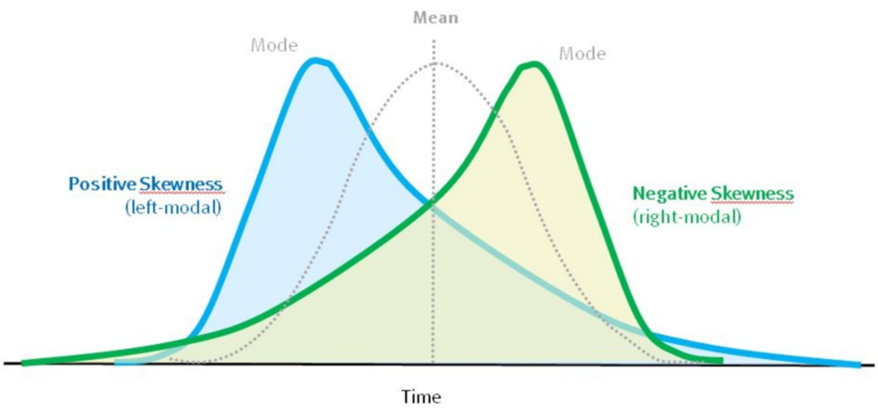

Figure 2. Skewness distributions

The estimator of the Skewness is:

$$Sk = \frac{\sum_i^N (Y_i - \bar{Y})^{\,3}}{(N-1)\sigma^3}$$

where the Y are the returns (or residuals), N is the number of observations and σ is the volatility.

Skewness can have different values:

- → If the skewness is between -0.5 and 0.5, the data are basically symmetrical, which means that the mode is near to the mean,
- → If the skewness is between -1 and – 0.5 or between 0.5 and 1, the data are moderately skewed,

→ If the skewness is less than -1 or greater than 1, the data are highly skewed.

In financial terms, if a return distribution has a positive skew, investors can expect recurrent small losses and few large returns from investment, as well as a negatively skewed distribution implies many small wins and a few large losses on the investment[37].

If the skewness is the third moment in statistics, Kurtosis is the fourth moment of a distribution. It is considered a measure of financial risk meaning that it can be large or small and the formula to find the its value is:

$$\text{Kurtosis} = \frac{\mathrm{E}(Y^4)}{(\mathrm{E}(Y^2))^2}$$

A large kurtosis refers to a high level of risk for an investment because it indicates that there are high probabilities of extremely large and extremely small returns. While, a small kurtosis indicates a moderate level of risk because the probabilities of extreme returns are relatively low[38]. The excess Kurtosis is equal to Kurtosis value minus 3 and indicates the kurtosis of a distribution against the kurtosis of a normal distribution. There are 3 types of Excess Kurtosis: the first is called *Mesokurtic*, where the Kurtosis value is near to zero, both positive or negative values; the second is *Leptokurtic*, where the excess is positive and investment returns may have extreme values on either side and it can be risky; the third is *Platykurtic* and this shows a negative excess, thus small probability that the investment makes extreme returns and should be less risk.

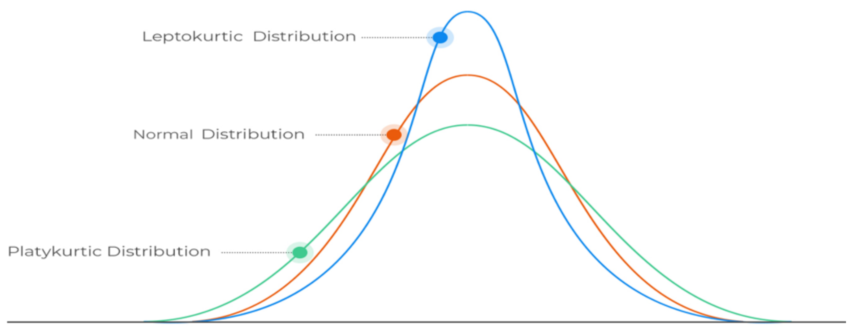

Figure 3. The Kurtosis distributions

[37] Stan Brown, (2011), "Measures of Shape: Skewness and Kurtosis", Oak Road Systems
[38] *Ibedem*

3.2 Data

To find the volatility before and after the introduction of Bitcoin, it is obviously necessary to download the Bitcoin historical prices. It was utilized the website coindesk.com, which is one of the most popular and reliable web site to find this type of data. This analysis start with the download of the daily adjusted close prices of Bitcoin, splitting them into two periods before and after the futures introduction: Period 1 from 1st October 2013 to 18th December 2017 and Period 2 from 19th December 2017 to 14th June 2021.

3.3 Empirical results

In Appendix A it is possible to see the MATLAB codes used to find the following results, both for the computations of Realized Volatility and GARCH Volatility. The first thing calculated are the returns. In the following figure, it is possible to see a black line about at the observation number 1540, which mean that it is in that point where the futures on Bitcoin were introduced.

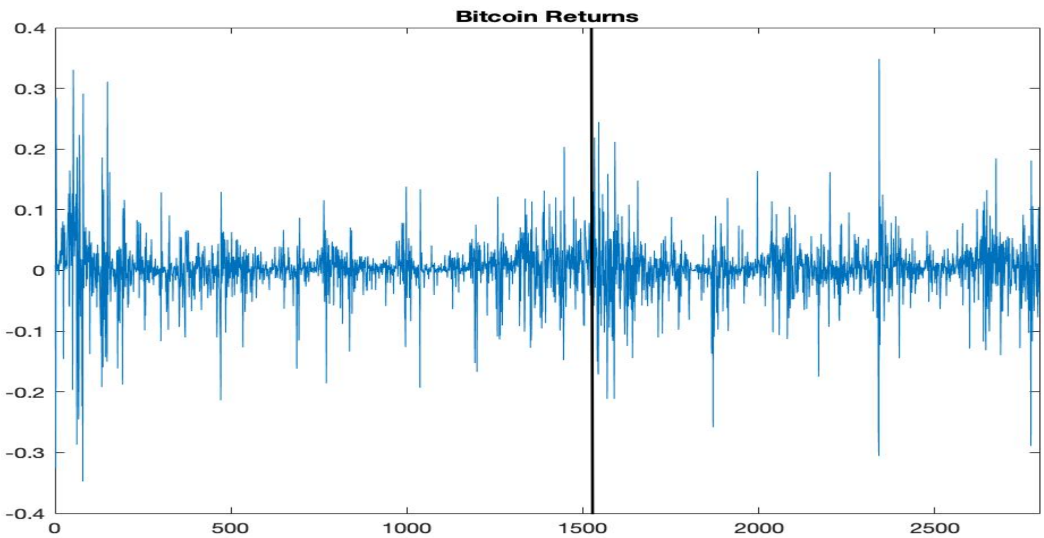

Figure 4. Bitcoin returns (before and after futures contracts)

This figure shows that Bitcoin has always had an high fluctuating behavior, as it can see at the end of 2013 and the beginning of 2014. Then its trend remain stable with a low fluctuations until the introduction of futures contract on Bitcoin on 17th December 2017 (observation number 1540). After that, returns became more instable reaching the highest peak and one of the lowest.

3.3.1 Realized volatility results

After the returns computations, in this part it was analyzed the most popular statistics before and after the introduction of futures and also during all period from the end of 2013. These statistics are summarized in the following table:

	Mean	Variance	Volatility	Kurtosis	Skewness
Before Futures	0.0042325	0.0019519	0.04418	10.936	0.43724
After Futures	0.0015459	0.0020162	0.044902	13.54	-0.52262
All long period	0.0031202	0.0021431	0.046294	14.433	-0.43047

The mean of the returns is significantly higher before futures rather than after futures and it is a bit higher also rather than the mean of the whole period. Hence it is possible to say that the futures make the mean of returns lower.

The volatility, and so the variance, has similar values in all three cases, but there is an increment after the futures contract were introduced, meaning that the Bitcoin is become a little more risky being volatility an indication of an asset riskiness. However volatility is lower than the whole period both for the period before futures and for the following one.

The skewness before futures is positive and so right-skewed but after the futures introduction it decrease becoming a left-skewed, implying that probably there was an increment on the losses side. The value of the whole period is negative meaning that also here it is right-skewed.

The kurtosis indicates that in all 3 cases the distribution is Leptokurtic meaning that, despite futures introduction, this is in general a risky asset, confirming the previous consideration that the returns have great fluctuations. Moreover, also in this case the Kurtosis is higher after the Bitcoin futures than before, as in both cases it lower than in the whole period.

3.3.2 GARCH model results

As said previously, the computation with the historical returns can have some errors and so it is necessary to use a model that try to improve this returns. The model that it was chosen here it is the GARCH process that improve the returns given the residuals, a sort of “right” returns.

Therefore what needs to be done is to replicate the same analysis performed with the realized volatility, but putting in the formula the residuals instead of the returns. The results change a lot rather than with the historical returns, meaning that it could be many errors using this returns. The summarized table in this case is the following:

	Mean	Variance	Volatility	Kurtosis	Skewness
Before Futures	0.069857	1.0211	1.0105	6.7979	−0.34243
After Futures	0.017669	1.0088	1.0044	10.61	−0.66591
All long period	0.046834	0.45396	0.67377	9.1511	−0.40397

The mean of the returns is significantly higher before futures than after, meaning that the futures could make the mean of returns lower, and it is higher than the mean of the whole period too.

The variance and the volatility have similar values in the separate periods, but it is higher before the introduction of futures, meaning that the Bitcoin is become a little less risky. However volatility is lower in the whole period that the two different periods.

With the GARCH process, the skewness is always negative and so left-skewed but also in this case the value decrease after that Bitcoin futures were introduced. This indicate that there should be more losses because the asset became more risky that before the introduction of futures.

As for the historical returns, the kurtosis indicates that in all 3 cases the distribution is Leptokurtic meaning that this is in general a risky asset despite the futures introduction. Moreover, also in this case the Kurtosis is higher after the Bitcoin futures than before but also than the whole period, where this last one is higher than before futures.

It is possible to conclude that using the residual, the results has a little changing, but it in both cases the Kurtosis increases after the introduction of Bitcoin and the Skewness decreases, meaning that the asset can have very high fluctuation in returns reaching extreme values and the skewness become moderately skewed rather than before futures.

With the GARCH model it is possible make other considerations, like a comparison between the returns and the residuals, the analysis of Conditional Variance and the analysis of autocorrelation and partial-autocorrelation functions of the returns and residuals.

Interesting is to compare the historical returns and the new residuals computed with the GARCH process. As said before, the residuals are the new returns corrected, so without errors. The following figure shows that the residual can takes greater values since the y label of the graph is from -0.4 to 0.4 for the returns and from -10 to 10 for the residuals. It is possible to notice that residuals seems to have more fluctuations and this seems to find confirm with the kurtosis results. In fact the kurtosis computed with the GRACH model is higher than those computed with the historical returns. If we focus approximately on the observation number 1500 (when the futures contract were introduced), the impact on returns is greater than the impact on residuals.

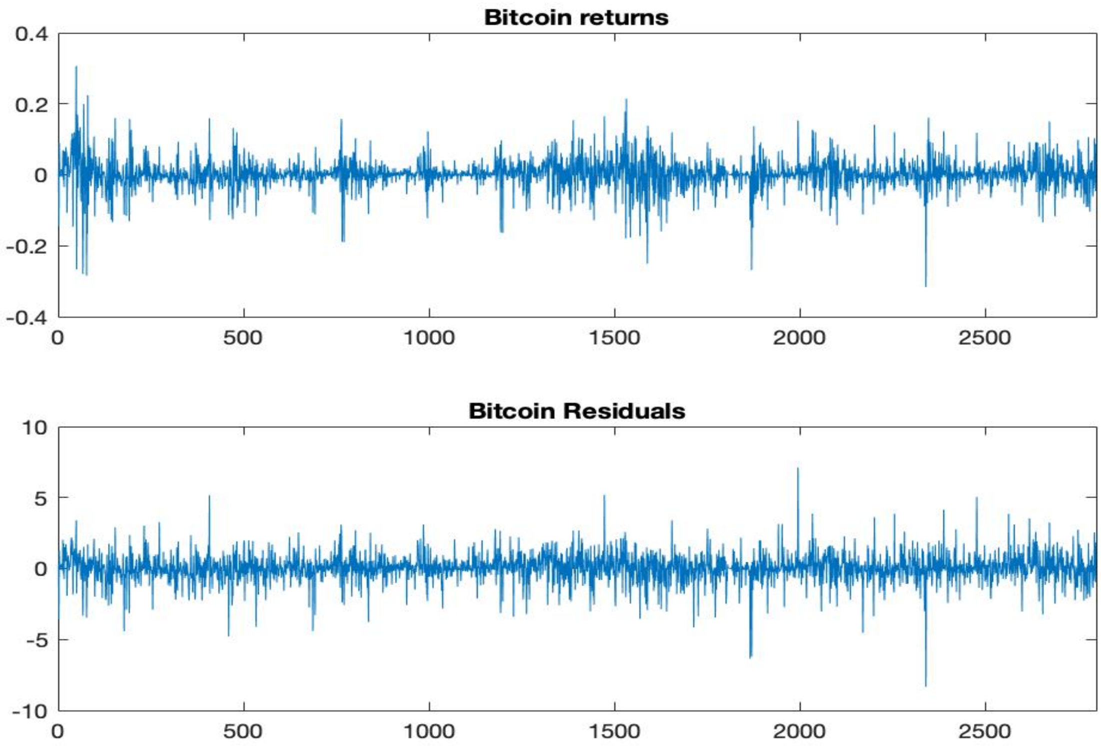

Figure 5. Comparison between the historical returns and the residuals

Like said before, the GARCH model compute the conditional variance. From this analysis it is possible to understand that when the futures were introduced the conditional variance was very instable increasing in the period immediately after. Then the conditional variance decrease even if there is two large increments approximately in the end of 2018 and in the firsts months of 2020, when the Covid pandemic was burn in the world.

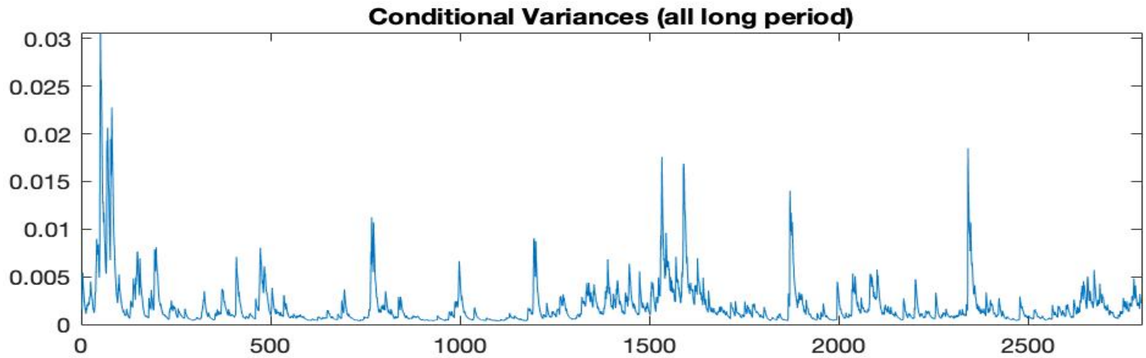

Figure 7. Conditional Variance of Bitcoin whole period

At the end, considerations of autocorrelation function and partial autocorrelation are important to investigate if the model chosen is good or not.

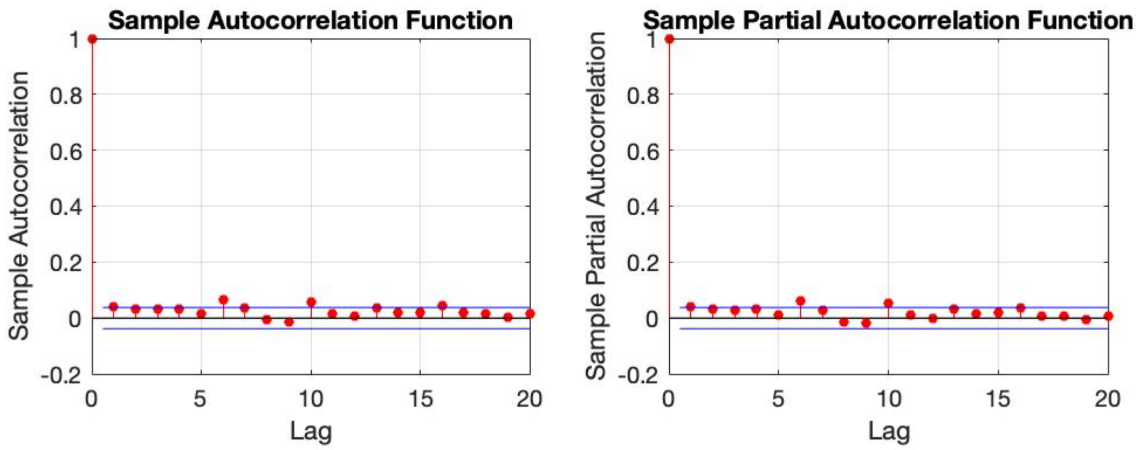

Figure 6. The ACF and PACF functions of residuals

At first, the autocorrelation function (ACF) indicates how data points in a time series are related, on average, to the preceding data points which means that it measures the self-similarity of the signal over different delay time, and it is a time domain measure of the stochastic process memory. A white noise process, which is a random process of random variables that are uncorrelated, have mean zero and a finite variance, has an autocorrelation function of zero at all lags except a value of unity at lag zero, to indicate that the process is completely uncorrelated. Instead, the partial autocorrelation function (PACF) finds correlation of residuals with the next lag value, hence “partial” and not “complete”.

In the case of the ACF of our residuals it possible to see that they are not autocorrelated because some lags are higher than the interval and this assumption is confirmed by the PACF function, which shows the same higher lags. Both ACF and PACF suggests that probably the GARCH model is not sufficient to have the more right results and it should be applied a more advanced model and this evidence can be a starting point to develop a more specific analysis in futures.

In financial terms, the autocorrelation can help to understand if there is a momentum factor inside a given stock. This factor imply that if there is autocorrelation, than if gains (positive autocorrelation) or losses (negative autocorrelation) occur in a given period, respectively gains or losses are expected to occur again in the immediately following period. Hence in our case, it is possible to expect that after a period of gain, there will be a new period of gain because there are a few indicates of positive autocorrelations.

Chapter IV

IV. Bitcoin futures in the portfolios

In general, people tend to invest their savings, like company invests money and when people or companies built a portfolio, they want that it would be as more profitable and less risky as possible. With the developed of cryptocurrencies, people have started to ask themselves if to introduce this type of currencies in their portfolios is a good thing or if these get worse their returns and risks, and besides if the options issued on this cryptocurrencies hedge portfolio or not. Therefore, in the final part of this thesis, it is interesting to analyze if the Bitcoin futures make the risk/performance profile of the better or worse and so if it is convenient include the futures contract on Bitcoin in their portfolios. To do this, it was created a MATLAB code reported in the appendices C and D.

However, before to start this analysis, it is necessary to introduce some peanuts about the portfolio theory. The whole analysis is based on the *Modern Portfolio Theory* introduced by Harry Markowitz in 1952, who published a paper titled "*Portfolio Selection*" in The Journal of Finance. His work was revolutionary and it was an inspiration for other studies that tried to improve this theory. He assumed that the investors were risk averse and that they diversify their investments, moreover they decided where invest according to the expected returns and to the standard deviations. In this way, his process is known as the mean-variance approach. At the end of this process, the investor fund out which optimal weights give to a specific asset in his portfolio. The graphical representation of all the possible efficient risk-return combinations is drawn with the *Efficient Frontier*.

4.2 Data

To build the portfolios that will be analyzed, it was considered the FTSE.MIB index, which is the stock market index for Borsa Italiana, the Italian stock exchange, and it was analyzed its sectors. The common thread to choose which stocks add to the Portfolio is to identify those stocks with more capitalization volume, based on the information on a website[39]. According to such an approach, the stock considered are: Campari, Generali Assicurazioni, Stellantis, Intesa San Paolo, Buzzi Unicem, Tenaris, Eni, Altlantia, Recordati, Exor, Enel, Juventus, STMicroelectronics and Telecom.

All these stock, are used to build two portfolios: one with all the stocks plus Bitcoin and another one with all the stocks plus Bitcoin Futures.

To make a comparison between these two portfolios, it is necessary to cover the period only after the introduction of futures on Bitcoin, thus from 19th December 2017 to 14th June 2021.

4.1 Methodology

The goal of this chapter is to investigate if the Bitcoin futures improve or give worse the volatility/returns profile of a portfolio, using both the realized volatility method and the GARCH process method.

After to have downloaded the data, it needs to create an excel file to put all stock prices together to create the portfolios. The stocks quoted in FTSE.MIB index are exchanged from Monday to Friday, thus 5 days per week, instead the Bitcoin is exchanged seven days per week. Therefore, it was necessary to take only the corresponding prices to the right date with respect to the others stocks.

At first it was computed the returns from the prices for each stock and then some descriptive statistics like mean, variance/volatility, covariance, kurtosis and skewness. Whereupon it was set the portfolio using the mean and covariance measures, it was found out the weights of each stocks and estimated the risk and return of this efficient portfolio, which is those that maximize the returns minimizing the risk. At the end, it was plotted the Efficient Frontier, which is a set of portfolios where the assets are weighted in different ways. The efficient portfolio in our case in computed maximizing the Sharpe Ratio, which is difference between the mean of portfolio returns and the risk-free rate divided by the standard deviation of portfolio returns[40]. In our case the risk free rate is assumed to be 0.

[39] https://www.tradingfacile.eu/blog/composizione-ftse-mib/
[40] https://it.mathworks.com/help/finance/portfolio.estimatemaxsharperatio.html

This analysis begins with the portfolio without futures contract on Bitcoin using the realized volatility and so the historical returns, and then continue by computing the portfolio with futures. To evaluate with portfolio is more efficient between this two portfolios, we compute the Sharpe Ratio (remembering that the risk free is equal to 0):

$$Sharpe\ ratio = \frac{R_P - r_f}{\sigma_P} = \frac{Return\ of\ the\ portfolio - risk\ free}{Risk\ of\ the\ portfolio}$$

The same analysis is made using the GARCH process.

In the end, it is analyzed the efficient frontier of the portfolio with and without futures every six months because in the real market the mean and variance are not constant but change frequently.

4.3 Empirical results

In this paragraph it will analyzed and discussed all the results obtained from the MATLAB code created.

4.3.1 Whole period analysis

Considering the results obtained with the Realized volatility method, it can see that risk and return of both the portfolios considered increase in the one with futures.

	Risk	Return
PTF without Futures	0.014188	0.001039
PTF with Futures	0.015165	0.0010538

The portfolio without futures on Bitcoin is less risky but also have a lower return, while those with the futures is a bit more risky and have a higher return.

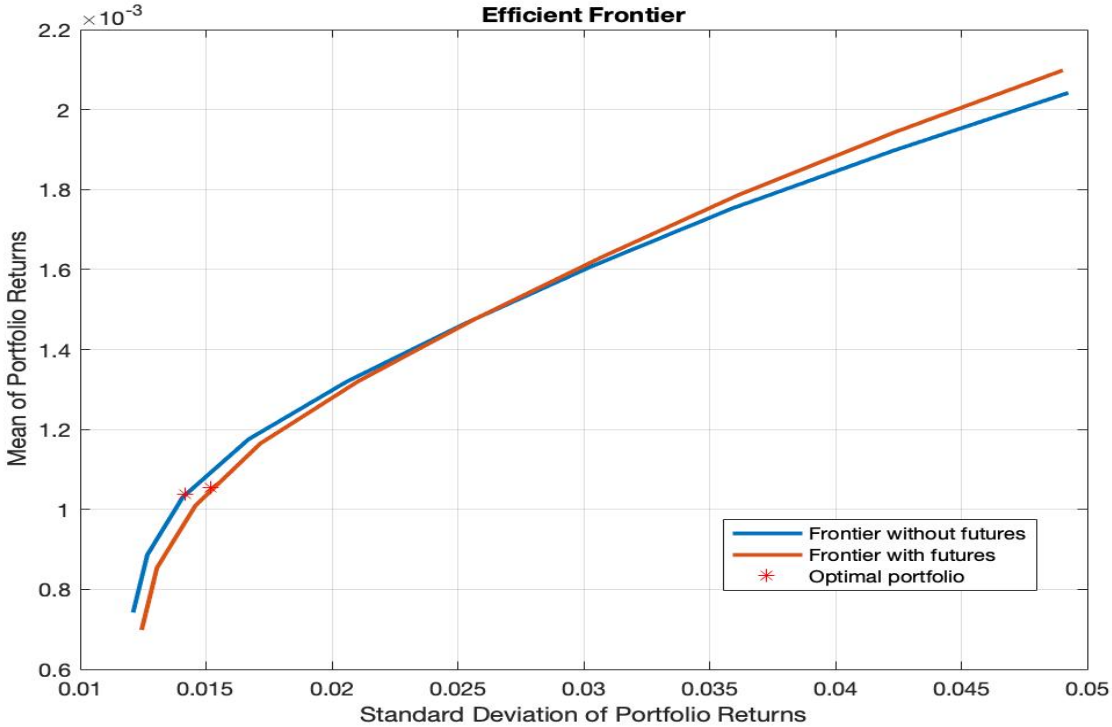

Figure 8. Comparison between the Efficient frontiers with historical returns

In Figure 8, it is possible to see the efficient frontiers of the two portfolios. The blue line is those without futures and the red line is the other one. These frontiers show that at the beginning it seems to be better, in the mean-standard deviation sense, the portfolio without futures probably because the futures destabilize a lot the returns, but when the volatility increases and the market become more risky, the portfolio with futures overcome the other probably because futures, being an option that should hedge an investment, makes it hedge.

Here there is not an absolute more efficient frontiers due to the intersection that happened when the volatility is about equal to 0.0026, where for the investors the two portfolios are equivalent. An investor that is risk averse should prefer lower value of volatility despite lower returns, vice versa a risk seeking investor should prefer higher values of returns despite the increment of risk and so the increment of volatility. Looking at the portfolios that appear to be efficient in both frontiers (marked with a red asterisk), it is possible to state that the futures-free portfolio that maximizes the Sharpe Ratio appears to be more efficient than the one that maximizes it at the frontier with futures. This is confirmed applying the Sharpe Ratio formula:

- Ptf without futures: 0.001039/0.014188 = 0.073

- Ptf with futures: 0.0010538/0.015165= 0.069

Thus 0.073 > 0.069 and the portfolio without futures result to be more efficient.

The last useful consideration is that the portfolio that minimizes the volatility, which is the first portfolio on the left of the efficient frontier, results more efficient on the frontier without futures because for really near values of volatility, the blue line shows a higher returns.

Now, it is necessary to analyze the results with the GARCH process.

	Risk	Return
PTF without Futures	0.35723	0.019331
PTF with Futures	0.3642	0.019448

From a first computation, it is possible to see that the risk and the return are still lower in the portfolio without futures than in the other one.

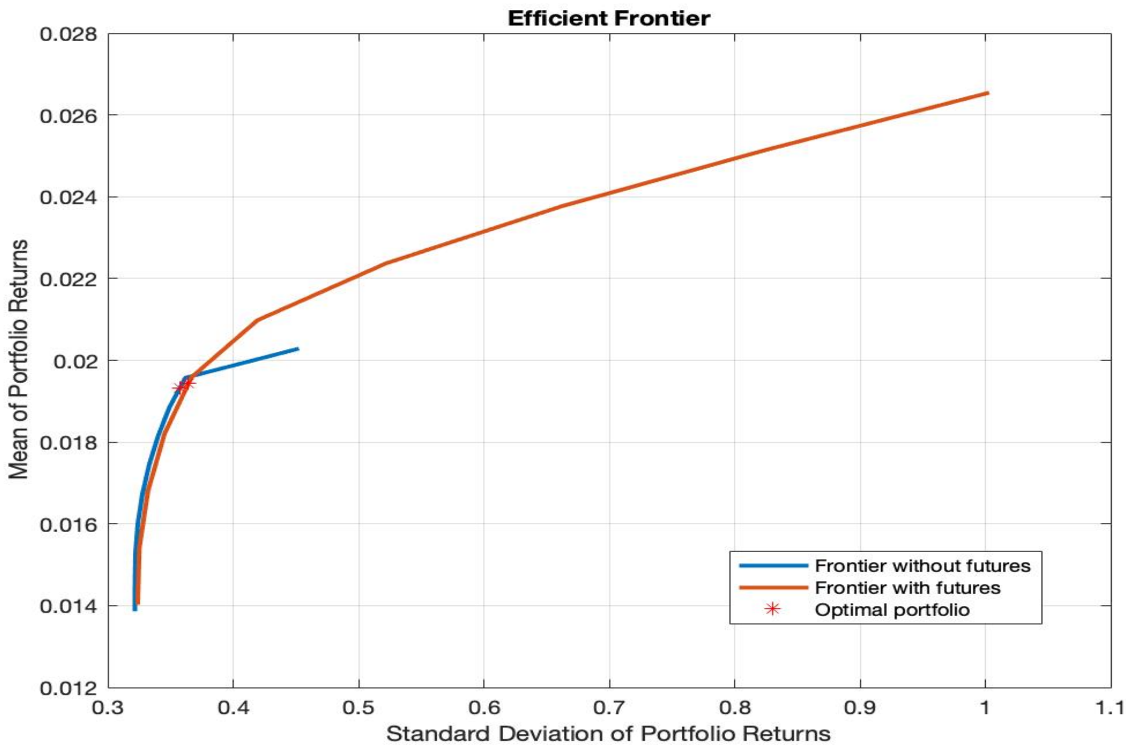

Figure 9. Efficient Frontier with the GARCH process

In figure 9, it is evident that the volatility in the portfolio with the futures on Bitcoin reaches very high level of the risk/performance profile that in the other portfolio does not do. Also in this case, there is not an absolute more efficient frontiers due to the intersection that happened when the volatility is about equal to 0.0036, where the two portfolios are equivalent for the investors. A risk averse investor should prefer a lower volatility value despite lower returns and therefore will choose the portfolio without futures which appears to be more efficient in this part; conversely, an investor looking for risk should prefer higher return values despite the increase in risk and therefore the increase in volatility and will choose the portfolio with futures, also because in this case the one without futures does not reach a high volatility value such as does the one with futures.

Looking at the portfolios that appear to be efficient in both frontiers (marked with a red asterisk), it is possible to state that the portfolio without futures that maximizes the Sharpe Ratio appears to be more efficient than the one that maximizes the Sharpe Ratio on the frontier with futures. This is confirmed applying the Sharpe Ratio formula:

- Ptf without futures: 0.019331/0.35723= 0.054
- Ptf with futures: 0.019448/0.3642= 0.053

Thus 0.054 > 0.053 and the portfolio without futures result to be more efficient in this case too.

Considering the portfolio that minimizes the volatility, which is the first portfolio on the left of an efficient frontier, results more efficient on the frontier with futures because the yellow line shows a small higher returns despite a small higher volatility.

Hence, both methods give the same results which are that for a risk seeking investor it is more efficient to choose the portfolio with futures for higher level of volatility because probably this option protect against possible losses that could occur in the future due to strong price fluctuations caused by high level of volatility. Vice versa a risk averse investor should choose the portfolio without futures because for a low level of volatility, the portfolio give a higher returns.

4.3.2 Subperiod analysis

Until now, it was assumed that the mean and variance was constant from the beginning to the end of the whole period analyzed before, but in the real economy the volatility can change also intraday. So to do a more precisely analysis, we consider the efficient frontiers of the portfolios computed with the GARCH process since this model consider the changing of the variance giving the most recent squared residual, where the new information is captured, precisely, by the change in volatility.

We split the whole period from 19th December 2017 to 14th June 2021 in 7 subperiods, each six months long.

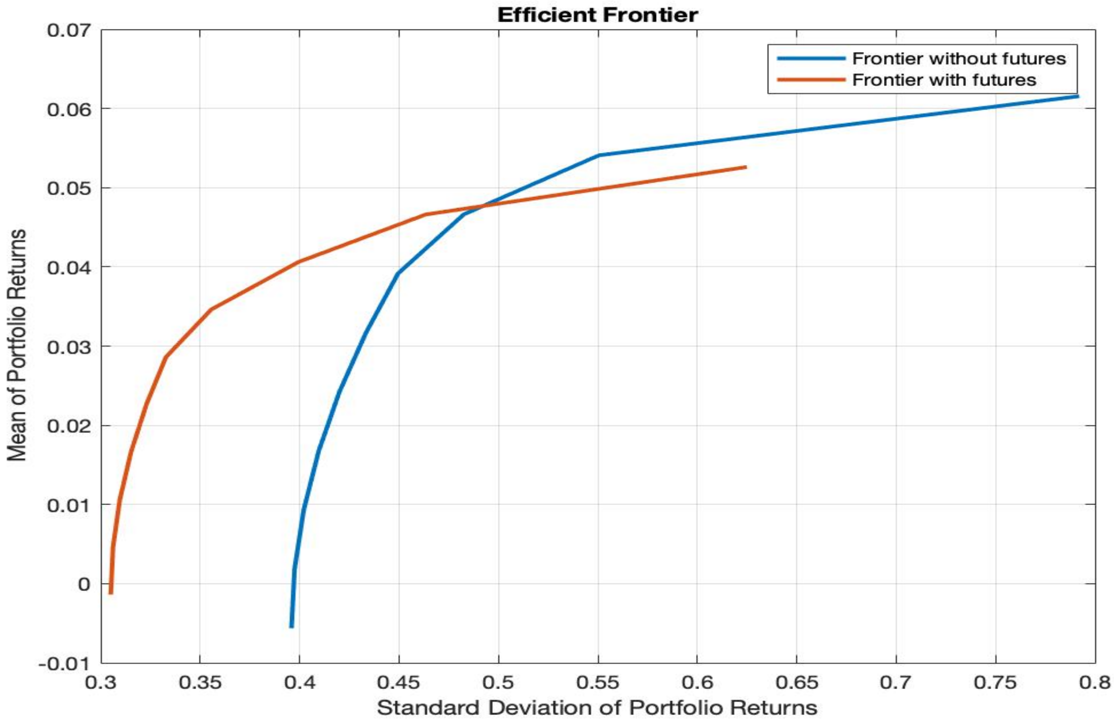

Figure 10. Efficient frontier in the first subperiod

In figure 10 is represented the first subperiod which is from 19th December 2017 to 19th June 2018 and the efficient frontier of portfolios without futures is better than the other frontier in case of high volatility instead what said before, because its efficient frontiers overcome the efficient frontier of the other portfolio, which however is better in case of low volatility. What happen here is that a risk averse investor does not choose the portfolio without futures in case of low volatility as if we consider the whole period like previously done, but he will invest in the one with futures. The opposite thing happen to the risk seeking investor, who will choose the portfolio without futures in case of high level of volatility instead of the one with futures. Considering the portfolio that minimize the volatility is more efficient the one with futures because it has higher returns despite a significant lower volatility rather than the one with futures, which has high values of volatility with lower returns.

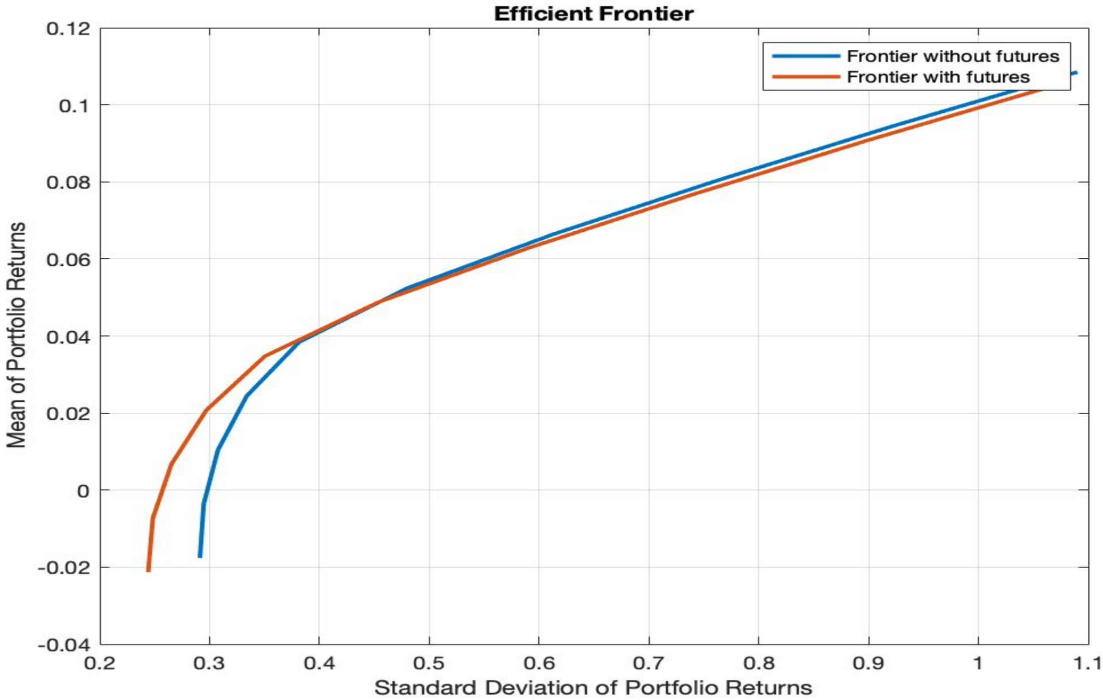

Figure 11. Efficient Frontier in the second subperiod

In the second subperiod, which is from 20th June 2018 to 19th December 2018 reported in figure 11, happen the same thing than before since the efficient frontier of portfolios without futures on Bitcoin is more efficient with high volatility but worse with low volatility than the other frontier. Also in this case a risk averse investor will choose to invest in the portfolio with futures, while a risk seeking investor will choose a portfolio without futures in case of high level of volatility. Considering the portfolio that minimize the volatility, there the one without futures in more efficient since despite the higher volatility, it gives a less losses.

The third period in the following figure 12 is from 20th December 2018 to 19th June 2019 and in case of very low volatility the efficient frontier of portfolios with futures is better but in general it seems to be worse that the frontier of portfolios without futures. Thus probably both risk averse and risk seeking investor will choose a portfolio on the frontier without futures. Also considering the portfolio that minimize the volatility, despite the very small difference on volatility, it is more efficient the one without futures, which give a higher returns.

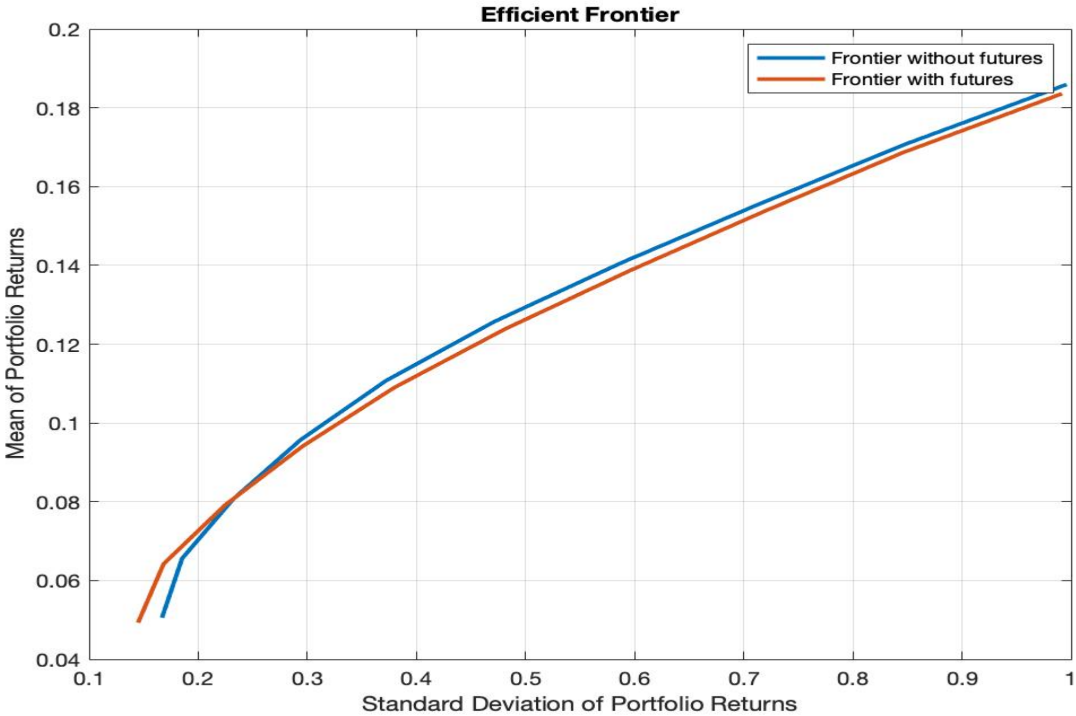

Figure 13. Efficient Frontier in the third subperiod

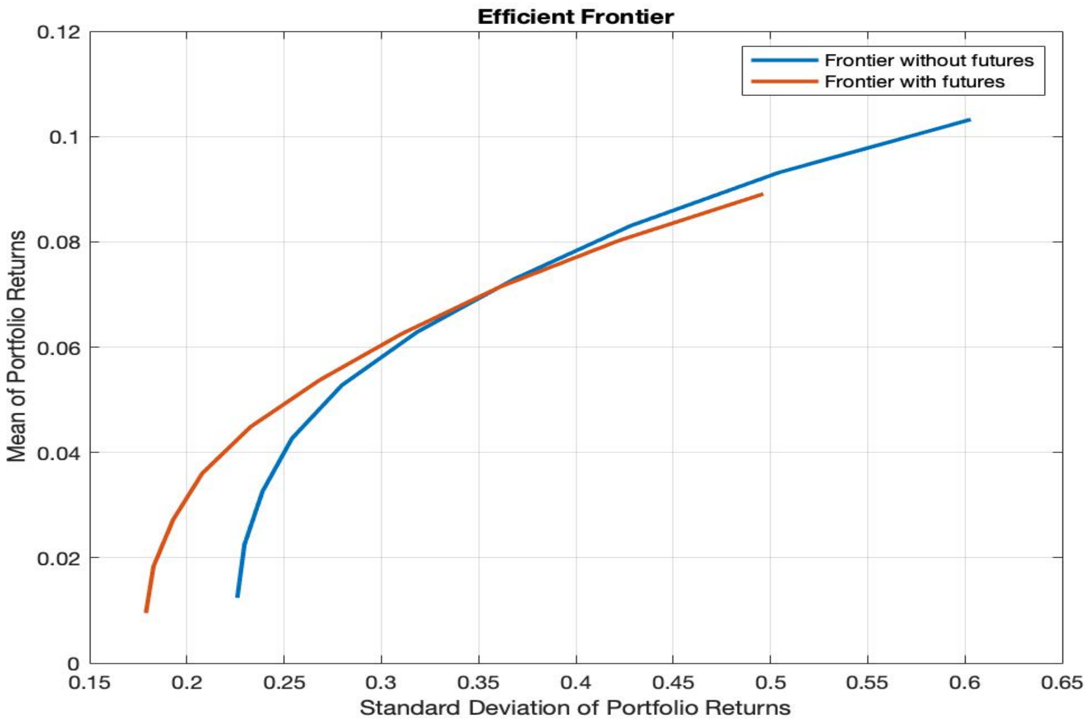

Figure 12. Efficient frontier in the fourth subperiod

In figure 13 is represented the fourth period, from 20th June 2019 to 19th December 2019 and also in this case when the volatility is lower, the efficient frontier of portfolios with futures is better but when the standard deviation is high the efficient frontier is better.

Hence a risk seeking investor choose a portfolio without futures, while a risk averse investor will choose a portfolio with futures.

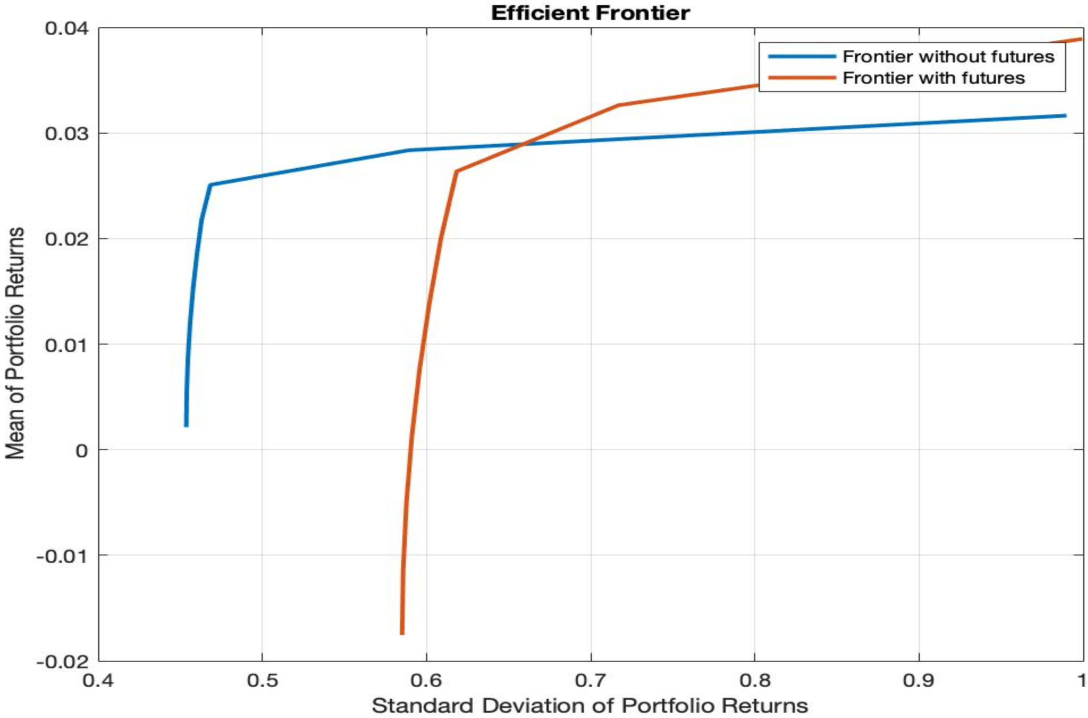

Figure 14. Efficient Frontier in the fifth subperiod

The fifth period in figure 14 is from 20th December 2020 to 19th June 2020 and here there is a different situation. For this period it is necessary to remember that is was developed and spread the COVID pandemic in the world, so the financial markets was very instable. In general there has been a situation of great uncertainty due to the unknown effects and cures of this type of virus and all share prices have fallen while volatility in financial markets has increased rapidly. The impact of the lockdown and the closure of activities and businesses was also important, generating in this way loss of job and unemployment and the non-circulation of money. In this scenario, the more efficient frontier in case of high volatility is the one with portfolios with futures, while in case of low volatility portfolios without futures give better results. Considering the portfolio that minimize the volatility, it is evident that the one without futures is more efficient since with low volatility, it gives a higher returns.

The sixth period in the following figure 15 is from 20th June 2020 to 19th December 2020 and it is evident that the efficient frontiers of portfolios without future is more efficient for the entire period, meaning that the introduction of the futures does not help to hedge the risk of losses, implying that both risk averse and risk seeking investor will invest in a portfolio without futures and that portfolio that minimize the volatility is the one the blue line .

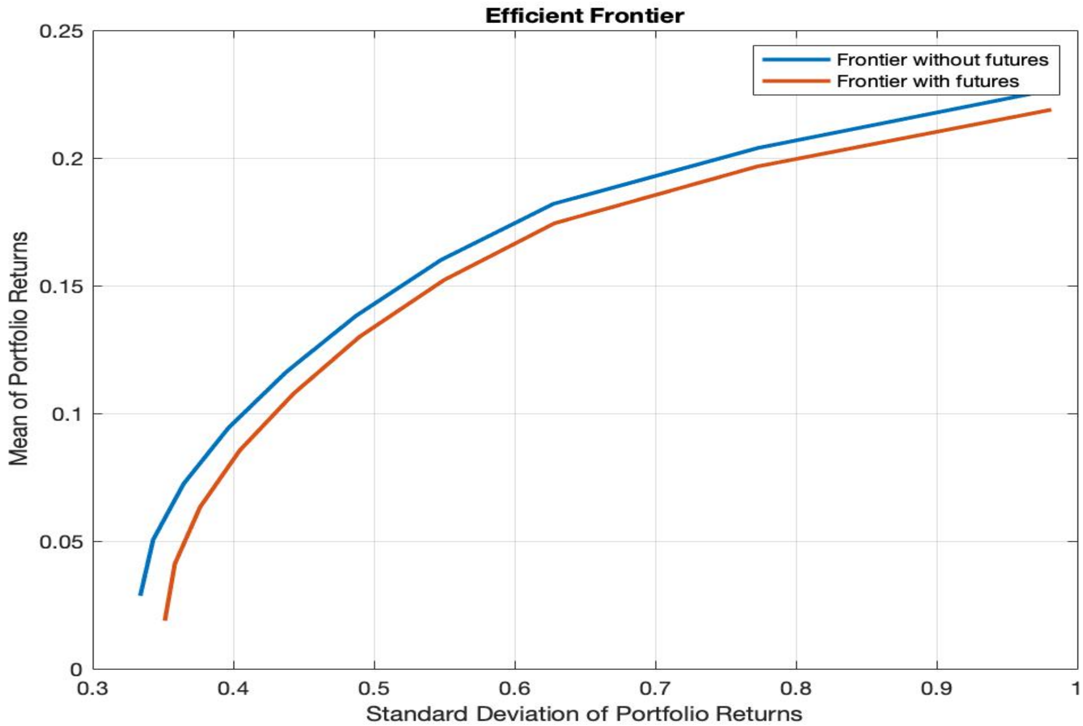

Figure 15. Efficient Frontier in the sixth subperiod

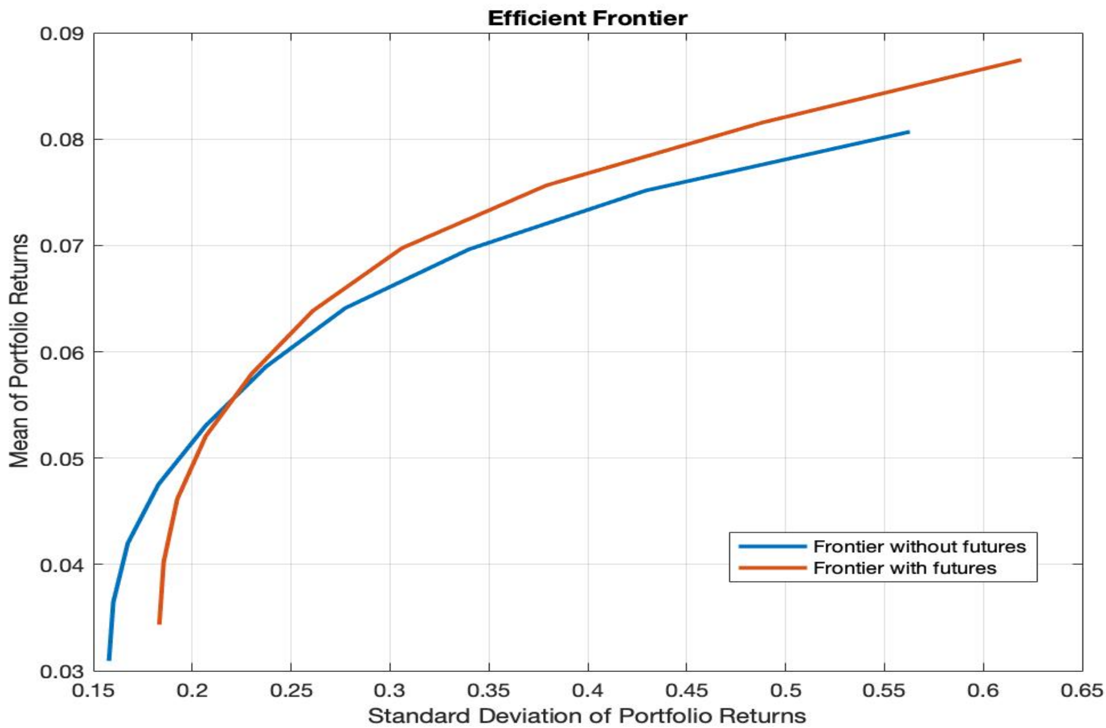

Figure 16. Efficient frontier in the seventh subperiod

The last period is represented on figure 16 and it is from 20th December 2020 to 19th June 2021, so really near to today. In case of low volatility the efficient frontier of portfolios without futures is more efficient and in case of high values is better the other one, meaning that in this case, like in period 5, a risk averse investor will invest on a portfolio of the efficient frontier without futures while a risk seeking investor will choose a portfolio on the frontier with futures. Evaluating the portfolio which minimize the volatility, it is more efficient the one with futures.

Concluding, considering the entire period portfolios with futures on these efficient frontiers seems to improve the risk/performance profile of the efficient portfolios in case of high risk; but splitting this period, for the most subperiods the portfolio without futures results better. Therefore probably the introduction of Bitcoin futures in a portfolio does not improve its returns but increase the risk.

This change of results from the whole period to the different periods can be due to the frequently changes of volatility. At the beginning of the subperiods analysis, it was said that the volatility can change also day per day and hence the analysis period per period should be more precisely. Assumed this, it is possible to conclude that the introduction of Bitcoin futures have not improved the portfolio for a risk seeking investor because he will choose to invest in a portfolio without futures; on the other side the futures introduction has the potential to improve a portfolio of a risk averse investor.

Conclusions

In this thesis, it was investigated how the Bitcoin market changes with the introduction of an option, which is the future contract, and if to include this option on a portfolio can improve its return.

To do this, at the beginning it was presented the history of money, from the barter to the developing of a new type of currency called cryptocurrency. It was pointed out that the introduction of cryptocurrencies was happened thank to the technological development grew more and more from the 2000s onwards. In fact, this new type of currency needs of internet since it is a digital money and financial intermediaries are not necessary anymore. After this general presentation, it was explained what is the first and most popular cryptocurrencies: Bitcoin. It was presented the specific technology behind Bitcoin, which is called blockchain, and then the principal others cryptocurrencies that was born in recent years.

Subsequently, it was introduced what is a future contract since it is the only option developed for Bitcoin. In this part, it was investigated what the recent literature has analyzed of futures on Bitcoin and their results. All the authors affirmed that after the introduction of futures the volatility increases making the financial Bitcoin market more instable.

The second part of this thesis concerned an empirical analysis, based on the previous literature, of how the volatility changes and if it is better to include the option of futures contract on Bitcoin on the portfolio or not. To do this, it was developed four MATLAB codes, attaching in the appendices. In our computations, it was used two methods: the historical returns and the GARCH process and both approaches showed that the mean decreases after the futures introduction, volatility (and variance) and kurtosis increase and the skewness decreases. This means that in general futures contract make Bitcoin more risky and subject to greater fluctuations over time. It is resulted also that the GACRH (1,1) considered here probably is not the best model to use because at the end of the process, there was still few autocorrelations between residuals, which means that they are still a little bit distorted. Hence in future analysis, it will be able to consider more advanced models.

In the last chapter it was analyzed two portfolios: one with fourteen stock plus the Bitcoin and the other one with the fourteen stocks plus the Bitcoin futures. It was considered the whole period from the introduction of Bitcoin futures on 19th December 2017 until today, on 14th June 2021. It was resulted that the analysis considering the whole period can be not enough accurate because it gives a different results rather than the analysis of seven subperiod (splitting the whole period on 7 subperiod, each six month), which should be more complete since the quickly changing of volatility. Evaluating this division, the introduction of Bitcoin futures have not improved the portfolio for a risk seeking investor because he will choose to invest in a portfolio without futures; on the other side the futures introduction has the potential to improve a portfolio of a risk averse investor.

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APPENDIX A

```
%% Realized_Volatility_Bitcoin.m

    % Realized volatility

% Collect the historical prices for the asset.
% Compute the expected price (mean) of the historical prices.
% Work out the difference between the average price and each price in
the series.
% Square the differences from the previous step.
% Determine the sum of the squared differences.
% Divide the differences by the total number of prices (find
variance).
% Compute the square root of the variance computed in the previous
step.

clc
clear all

%% Before Futures contract

% Returns
T_b = readtable ("BTC_before_F.xlsx");
[nrT,ncT] = size(T_b);
Adj_clo_P_b = table2array(T_b(:,3)); % Bitcoin prices

format short
return_b = Adj_clo_P_b(2:end,1)./Adj_clo_P_b(1:end-1,1)-1;
figure % plot returns
plot(return_b)
xlim([0,nrT-2])
title('Bitcoin Returns before introduction of futures')

% RV before
exp_ret_b = mean(return_b);
square_diff_b = sum((return_b - exp_ret_b).^2);
var_b = square_diff_b/(nrT-2);
RV_b = sqrt(var_b) % realized volatility before Bitcoin futures
k_b = kurtosis(return_b)
sk_b = skewness(return_b)

%% After Futures contract

% Returns
T_a = readtable ("BTC_after_F.xlsx");
[nrT,ncT] = size(T_a);
Adj_clo_P_a = table2array(T_a(:,6)); % Bitcoin prices

format short
return_a = Adj_clo_P_a(2:end,1)./Adj_clo_P_a(1:end-1,1)-1;
figure % plot returns
plot(return_a)
xlim([0,nrT-2])
% ylim([-0.4, 0.4])
title('Bitcoin Returns after introduction of futures')

% RV after
exp_ret_a = mean(return_a);
square_diff_a = sum((return_a - exp_ret_a).^2);
var_a = square_diff_a/(nrT-2);
```

```
RV_a = sqrt(var_a) % realized volatility after Bitcoin futures
k_a = kurtosis(return_a)
sk_a = skewness(return_a)

%% RV all period

% Returns
T = readtable ("BTC_USD_all.xlsx");
[nrT,ncT] = size(T);
Adj_clo_P = table2array(T(:,6)); % Bitcoin prices

format short
ret = Adj_clo_P(2:end,1)./Adj_clo_P(1:end-1,1)-1;
figure % plot returns
plot(ret)
xlim([0,nrT-2])
title('Bitcoin Returns')

% RV
exp_ret = mean(ret);
square_diff = sum((ret - exp_ret).^2);
var = square_diff/(nrT-2);
RV = sqrt(var) % realized volatility
k = kurtosis(ret)
sk = skewness(ret)

%% Final table
IndicatorNames = ["Mean", "Variance", "Volatility", "Kurtosis",
"Skewness"];
Rows = ["Before Futures", "After Futures","All long period"];
m = [exp_ret_b, exp_ret_a, exp_ret];
variance = [var_b, var_a, var];
vol = [RV_b, RV_a, RV];
kur = [k_b,k_a, k];
ske = [sk_b, sk_a, sk];
Table_statistics = table(m', variance', vol', kur',ske',
'VariableNames', ...
    IndicatorNames, 'RowNames', Rows)
writetable(Table_statistics, "Bitcoin statistics (Realized
Volatility).xlsx")
```

APPENDIX B

```
%% GARCH_volatility.m


clc
clear all

%% GARCH Before F
% Returns
T_b = readtable ("BTC_before_F.xlsx");
[nrT,ncT] = size(T_b);
Adj_clo_P_b = table2array(T_b(:,3)); % Bitcoin prices
format short
return_b = log(Adj_clo_P_b(2:end,1)./Adj_clo_P_b(1:end-1,1));
figure % plot returns
plot(return_b)
xlim([0,nrT-1])
title('Bitcoin Returns before Futures contract')

% Create GARCH model
Mdl = garch(1,1);
[EstMdl,EstParamCov,logL,info]=
estimate(Mdl,return_b(2:end),'E0',return_b(1));

% Infer
v_b = infer(EstMdl,return_b); % v = conditional variances
inn_b = return_b./sqrt(v_b); % inn = standardized innovationS
figure
subplot(2,1,1)
plot(v_b)
xlim([0,nrT])
title('Conditional Variances before Bitcoin futures')

subplot(2,1,2)
plot(inn_b)
xlim([0,nrT])
title('Standardized Innovations before Bitcoin futures')

% Residuals
res_b = (return_b-EstMdl.Offset)./sqrt(v_b);
figure
subplot(2,2,1)
plot(res_b)
xlim([0,nrT])
title('Standardized Residuals before Bitcoin futures')

subplot(2,2,2)
histogram(res_b,10)
subplot(2,2,3)
autocorr(res_b)
subplot(2,2,4)
parcorr(res_b)

% Volatility GARCH before
exp_ret_b = mean(res_b);
square_diff_b = sum((res_b - exp_ret_b).^2);
var_res_b = square_diff_b/(nrT-2);
Vol_b = sqrt(var_res_b)
k_b = kurtosis(res_b)
sk_b = skewness(res_b)
```

```
%% GARCH After F
% Returns
T_a = readtable ("BTC_after_F.xlsx");
[nrT,ncT] = size(T_a);
Adj_clo_P_a = table2array(T_a(:,3)); % Bitcoin prices
format short
return_a = log(Adj_clo_P_a(2:end,1)./Adj_clo_P_a(1:end-1,1));
figure % plot returns
plot(return_a)
xlim([0,nrT-1])
title('Bitcoin Returns after Bitcoin futures')
% Create GARCH model
Mdl = garch(1,1);
[EstMdl,EstParamCov,logL,info]=
estimate(Mdl,return_a(2:end),'E0',return_a(1));

% Infer
v_a = infer(EstMdl,return_a); % v = conditional variances
inn_a = return_a./sqrt(v_a); % inn = standardized innovations

figure
subplot(2,1,1)
plot(v_a)
xlim([0,nrT])
title('Conditional Variances after Bitcoin futures')

subplot(2,1,2)
plot(inn_a)
xlim([0,nrT])
title('Standardized Innovations after Bitcoin futures')

% Residuals
res_a = (return_a-EstMdl.Offset)./sqrt(v_a);
figure
subplot(2,2,1)
plot(res_a)
xlim([0,nrT])
title('Standardized Residuals after Bitcoin futures')

subplot(2,2,2)
histogram(res_a,10)
subplot(2,2,3)
autocorr(res_a)
subplot(2,2,4)
parcorr(res_a)

% Volatility GARCH after
exp_ret_a = mean(res_a);
square_diff_a = sum((res_a - exp_ret_a).^2);
var_res_a = square_diff_a/(nrT-1);
Vol_a = sqrt(var_res_a)
k_a = kurtosis(res_a)
sk_a = skewness(res_a)

%% GARCH all period
% Returns
T = readtable ("BTC_USD_all.xlsx");
[nrT,ncT] = size(T);
Adj_clo_P = table2array(T(:,3));
format short
```

```
ret = log(Adj_clo_P(2:end,1)./Adj_clo_P(1:end-1,1));
figure % plot returns
plot(ret)
xlim([0,nrT-2])
% ylim([-0.4, 0.4])
title('Bitcoin Returns (all long period)')

% Create GARCH model
Mdl = garch(1,1);
[EstMdl,EstParamCov,logL,info]= estimate(Mdl,ret(2:end),'E0',ret(1));

% Infer
v = infer(EstMdl,ret); % v = conditional variances
inn = ret./sqrt(v); % inn = standardized innovations

figure
subplot(2,1,1)
plot(v)
xlim([0,nrT])
title('Conditional Variances (all long period)')

subplot(2,1,2)
plot(inn)
xlim([0,nrT])
title('Standardized Innovations (all long period)')

% Residuals
res = (ret-EstMdl.Offset)./sqrt(v);
figure
subplot(2,2,1)
plot(res)
xlim([0,nrT])
title('Standardized Residuals (all long period)')

subplot(2,2,2)
histogram(res,10)
subplot(2,2,3)
autocorr(res)
subplot(2,2,4)
parcorr(res)

% RV GARCH all period
exp_ret = mean(res);
square_diff = sum((res_a - exp_ret).^2);
var_res = square_diff/(nrT-1);
Vol = sqrt(var_res)
k = kurtosis(res)
sk = skewness(res)

%% table
IndicatorNames = ["Mean", "Variance", "Volatility", "Kurtosis",
"Skewness"];
Rows = ["Before Futures", "After Futures","All long period"];
m = [exp_ret_b, exp_ret_a, exp_ret];
variance = [var_res_b, var_res_a, var_res];
vol = [Vol_b, Vol_a, Vol];
kur = [k_b,k_a, k];
ske = [sk_b, sk_a, sk];
Table_statistics = table(m', variance', vol', kur',ske',
'VariableNames', ...
    IndicatorNames, 'RowNames', Rows)
```

```
writetable(Table_statistics, "Bitcoin statistics (Realized
Volatility).xlsx")
```

APPENDIX C

```
%% Portfolio_Hist_ret.m

% The stocks choosen to create both portfolios was taken from this
website:
% https://www.tradingfacile.eu/blog/composizione-ftse-mib/
% They are one stock per sector that have greater capitalization-

clear all
clc

%% Portfolio without Bitcoin futures

% Data without futures
T = readtable("portf_BTC.xlsx");
[nrT,ncT] = size(T);
dailyRet = table2array(tick2ret(T(:,2:end)));

% Statistics without futures
m = mean(dailyRet);
C = cov(dailyRet);
exp_ret = mean(dailyRet);
square_diff = sum((dailyRet - exp_ret).^2);
var = square_diff/(nrT-2);
Vol = sqrt(var); % realized volatility
k = kurtosis(dailyRet);
sk = skewness(dailyRet);


% Creation Portfolio Bitcoin without futures
p = Portfolio;
p = setAssetMoments(p, m, C);
[assetmean, assetcovar] = getAssetMoments(p);
p = Portfolio('assetmean', m, 'assetcovar', C, ...
    'lowerbudget', 1, 'upperbudget', 1, 'lowerbound', 0);
figure('Name', 'Efficient frontier without Futures on Bitcoin')
plotFrontier(p)
% The Sharpe ratio is the ratio of the difference between the mean of
    % portfolio returns and the risk-free rate divided by the standard
    % deviation of portfolio returns.
% The estimateMaxSharpeRation function maximizes the Sharpe ratio
    % among portfolios on the efficient frontier.
pwgt = estimateMaxSharpeRatio(p); % pwgt =  Portfolio on the efficient
    % frontier with a maximum Sharpe ratio, returned as a NumAssets
vector.
[risk, ret] = estimatePortMoments(p, pwgt);
    % risk = Estimates for standard deviations of portfolio returns
for
        % each portfolio in pwgt, returned as a NumPorts vector.
    % ret = Estimates for means of portfolio returns for each
portfolio
        % in pwgt, returned as a NumPorts vector.

ris = sprintf('%0.5f',risk)
retu = sprintf('%0.5f',ret)
```

```
%% Portfolio with Futures
% Data
T_f = readtable("portf_BTC_FUT.xlsx");
[nrT_f,ncT_f] = size(T_f);
dailyRet_f = table2array(tick2ret(T_f(:,2:end)));

% Statistics
m_f = mean(dailyRet_f); % mean
square_diff_f = sum((dailyRet_f - m_f).^2);
var_f = square_diff_f/(nrT_f-2);
Vol_f = sqrt(var_f); % realized volatility
C_f = cov(dailyRet_f); % covariance
k_f = kurtosis(dailyRet_f);
sk_f = skewness(dailyRet);

    % Creation Portfolio Bitcoin with Futures
p_f = Portfolio;
p_f = setAssetMoments(p_f, m_f, C_f);
[assetmean_f, assetcovar_f] = getAssetMoments(p_f);
p_f = Portfolio('assetmean', m_f, 'assetcovar', C_f, ...
    'lowerbudget', 1, 'upperbudget', 1, 'lowerbound', 0);
fig2 = figure('Name', 'Efficient frontier with Futures on Bitcoin')
plotFrontier(p_f)
% The Sharpe ratio is the ratio of the difference between the mean of
    % portfolio returns and the risk-free rate divided by the standard
    % deviation of portfolio returns.
% The estimateMaxSharpeRation function maximizes the Sharpe ratio
    % among portfolios on the efficient frontier.
pwgt_f = estimateMaxSharpeRatio(p_f); % pwgt =  Portfolio on the
efficient
    % frontier with a maximum Sharpe ratio, returned as a NumAssets
vector.
[risk_f, ret_f] = estimatePortMoments(p_f, pwgt_f);
    % risk = Estimates for standard deviations of portfolio returns
for
        % each portfolio in pwgt, returned as a NumPorts vector.
    % ret = Estimates for means of portfolio returns for each
portfolio
        % in pwgt, returned as a NumPorts vector.

ris_f = sprintf('%0.5f',risk_f)
retu_f = sprintf('%0.5f',ret_f)

%% Confront between two efficient frontiers

fig3 = figure;
plotFrontier(p)
hold on
plotFrontier(p_f)
plot(risk,ret,'*r');
plot(risk_f,ret_f,'*r');
legend("Frontier without futures","Frontier with futures","Optimal
portfolio")
hold off

%% Table
IndicatorNames = ["Risk", "Return"];
Rows = ["PTF without Futures", "PTF with Futures"];
Ri = [risk, risk_f];
Re = [ret, ret_f]
Table_statistics = table(Ri', Re', 'VariableNames', ...
    IndicatorNames, 'RowNames', Rows)
```

APPENDIX D

```
%% Portfolio_GARCH.m

% The stocks choosen to create both portfolios was taken from this
website:
% https://www.tradingfacile.eu/blog/composizione-ftse-mib/
% They are one stock per sector that have greater capitalization.

clear all
clc

%% Portfolio without Bitcoin futures

% Data without futures
T = readtable ("portf_BTC.xlsx");
[nrT,ncT] = size(T);
Adj_clo_P = table2array(T(:,2:end));
format short
ret = log(Adj_clo_P(2:end,:)./Adj_clo_P(1:end-1,:));

% Create GARCH model
for i = 1:15
    Mdl = garch(1,1);
    [EstMdl(i),EstParamCov,logL,info]=
estimate(Mdl,ret(2:end,i),'E0',ret(1,i));
    % Infer
    v = infer(EstMdl(i),ret);
end
% Residuals
res = ret./sqrt(v);

% Statistics GARCH
m = mean(res);
square_diff = sum((res - m).^2);
var_res = square_diff/(nrT-1);
Vol = sqrt(var_res);
C = cov(res);
k = kurtosis(res);

    % Creation Portfolio NO futures
p = Portfolio;
p = setAssetMoments(p, m, C);
[assetmean, assetcovar] = getAssetMoments(p);
p = Portfolio('assetmean', m, 'assetcovar', C, ...
    'lowerbudget', 1, 'upperbudget', 1, 'lowerbound', 0);
figure('Name', 'Efficient frontier without Futures on Bitcoin')
plotFrontier(p)
% The Sharpe ratio is the ratio of the difference between the mean of
    % portfolio returns and the risk-free rate divided by the standard
    % deviation of portfolio returns.
% The estimateMaxSharpeRation function maximizes the Sharpe ratio
    % among portfolios on the efficient frontier.
pwgt = estimateMaxSharpeRatio(p); % pwgt =  Portfolio on the efficient
    % frontier with a maximum Sharpe ratio, returned as a NumAssets
vector.
[risk, ret] = estimatePortMoments(p, pwgt);
    % risk = Estimates for standard deviations of portfolio returns
for
        % each portfolio in pwgt, returned as a NumPorts vector.
    % ret = Estimates for means of portfolio returns for each
portfolio
```

```
        % in pwgt, returned as a NumPorts vector.

ris = sprintf('%0.5f',risk)
retu = sprintf('%0.5f',ret)

%% Portfolio with Futures
    % Data
T_f = readtable ("portf_BTC_FUT.xlsx");
[nrT_f,ncT_f] = size(T_f);
Adj_clo_P_f = table2array(T_f(:,2:end));
format short
ret_f = log(Adj_clo_P_f(2:end,:)./Adj_clo_P_f(1:end-1,:));

% Create GARCH model
for i = 1:15
    Mdl = garch(1,1);
    [EstMdl_f(i),EstParamCov,logL,info]=
estimate(Mdl,ret_f(2:end,i),'E0',ret_f(1,i));
    % Infer
    v_f = infer(EstMdl_f(i),ret_f);
end
% Residuals
res_f = (ret_f)./sqrt(v_f);

% Statistics GARCH
m_f = mean(res_f);
square_diff_f = sum((res_f - m_f).^2);
var_res_f = square_diff_f/(nrT_f-1);
Vol_f = sqrt(var_res_f);
C_f = cov(res_f);
k_f = kurtosis(res_f);

    % Creation Portfolio with futures
p_f = Portfolio;
p_f = setAssetMoments(p_f, m_f, C_f);
[assetmean_f, assetcovar_f] = getAssetMoments(p_f);
p_f = Portfolio('assetmean', m_f, 'assetcovar', C_f, ...
    'lowerbudget', 1, 'upperbudget', 1, 'lowerbound', 0);
fig1 = figure('Name', 'Efficient frontier without Futures on Bitcoin')
plotFrontier(p_f)
% The Sharpe ratio is the ratio of the difference between the mean of
    % portfolio returns and the risk-free rate divided by the standard
    % deviation of portfolio returns.
% The estimateMaxSharpeRation function maximizes the Sharpe ratio
    % among portfolios on the efficient frontier.
pwgt_f = estimateMaxSharpeRatio(p_f); % pwgt =  Portfolio on the
efficient
    % frontier with a maximum Sharpe ratio, returned as a NumAssets
vector.
[risk_f, ret_f] = estimatePortMoments(p_f, pwgt_f);
    % risk = Estimates for standard deviations of portfolio returns
for
        % each portfolio in pwgt, returned as a NumPorts vector.
    % ret = Estimates for means of portfolio returns for each
portfolio
        % in pwgt, returned as a NumPorts vector.

ris_f = sprintf('%0.5f',risk_f)
retu_f = sprintf('%0.5f',ret_f)

%% Confront between two efficient frontiers
```

```
fig2 = figure('Name', 'Confront between two Efficient Frontiers');
plotFrontier(p)
hold on
plotFrontier(p_f)
plot(risk,ret,'*r');
plot(risk_f,ret_f,'*r');
legend("Frontier without futures","Frontier with futures","Optimal
portfolio")
hold off

%% Table

IndicatorNames = ["Risk", "Return"];
Rows = ["PTF without Futures", "PTF with Futures"];
Ri = [risk, risk_f];
Re = [ret, ret_f];
Table_statistics = table(Ri', Re', 'VariableNames', ...
    IndicatorNames, 'RowNames', Rows)
```