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“On the Efficient Portfolio of Cryptocurrencies’ Values”

of

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I would especially like to thank for the great support, guidance & motivation of my supervisor, Professor Mr. Nikolaos Kourogenis, who has also given me the opportunity to learn about Blockchain Technology and study Digital Currencies, both of which play a very significant role as new technological improvements to the fields of finance and economics.

Thank you,

Christiana Katsampoula
Quotes

“A good portfolio is more than a long list of good stocks and bonds. It is a balanced whole, providing the investor with protections and opportunities with respect to a wide range of contingencies”.

Harry Markowitz

“Some investments do have higher expected returns than others. Which ones? Well, by and large, they are the ones that will do the worst in bad times”.

William Forsyth Sharpe

“There is no other proposition in economics that has more solid empirical evidence supporting it, than the Efficient Market Hypothesis…In the literature of finance, accounting, and the economics of uncertainty, the EMH is accepted as a fact of life”.

Michael Jensen

“…I’ll try and hurry up and release the source code as soon as possible to serve as a reference to clear up all these implementation questions”.

for Bitcoin on 17 November 2008,

Satoshi Nakamoto

“Many investors are interested to invest in Cryptocurrency, especially those with high-risk tolerance”.

Andrianto Y. & DiputraY.

“Cryptocurrencies could be reviewed as assets & have a place in financial markets and portfolio management”.

Dyhrberg
Abstract

In this dissertation, we examine the potential diversification benefits and the allocation of weights for cryptocurrency portfolio optimization. Specifically, two portfolios were created. The first one consisted, exclusively, of the five most popular cryptocurrencies (Bitcoin, Ethereum, Litecoin, Ripple, Monero), which resulted in high risk due to high volatility in the closing values. The second one (mixed portfolio) was composed of the market index S&P500, and the four cryptocurrencies (Bitcoin, Ethereum, Litecoin & Ripple). This showed lower levels of risk by diversification. The returns were much more the same for both portfolios.

The strategic models which were applied in this exercise were the following: a) the Naïve Model (1/N rule, equally weighted assets), b) the Minimum Variance Model, c) the Tangency Model (maximizing Sharpe Ratio, with a zero risk-free rate), and d) the Maximum Utility Model.

Both portfolios were examined with two Rolling Windows each, the first one for 100 days and the second one for 252 days. Furthermore, the constraint of the “long” position (only) was applied, meaning that the values of the weights remained positive during the testing period (short selling is not permitted). Finally, there were no fees & charges to any of the examined portfolios. In conclusion, the mixed-asset portfolio showed better results by diversification.

Keywords: Blockchain Technology, Cryptocurrency Portfolios, Modern Portfolio Theory, Sharpe Ratio, Rolling Windows, Cryptography.
Περίληψη

Σε αυτή τη διατριβή, εξετάζουμε τα πιθανά οφέλη της διαφοροποίησης και την κατανομή βαρών (σταθμών) για την βελτιστοποίηση χαρτοφυλακίου κρυπτονομισμάτων. Συγκεκριμένα, δημιουργήθηκαν δύο χαρτοφυλάκια. Το πρώτο αποτελείται, αποκλειστικά, από τα πέντε πιο δημοφιλή κρυπτονομίσματα (Bitcoin, Ethereum, Litecoin, Ripple, Monero), τα οποία οδήγησαν σε υψηλό κίνδυνο λόγω της υψηλής μεταβλητότητας στις τιμές κλεισίματος. Το δεύτερο χαρτοφυλάκιο (μικτό) αποτελείται από το δείκτη αγοράς S&P500 και τα τέσσερα κρυπτονομίσματα (Bitcoin, Ethereum, Litecoin, & Ripple). Αυτό έδειξε χαμηλότερα επίπεδα κινδύνου μέσω της διαφοροποίησης. Οι αποδόσεις ήταν ελαφρώς παρόμοιες και για τα δύο χαρτοφυλάκια.

Τα μοντέλα στρατηγικής που εφαρμόστηκαν στην εργασία ήταν τα ακόλουθα: α) το μοντέλο Naïve (κανόνας 1/N, ίσα σταθμά), β) το μοντέλο ελαχίστου κινδύνου, γ) το μοντέλο εφαπτομενικότητας (μεγιστοποίηση της αναλογίας Sharpe, με μηδενικό κίνδυνο) και δ) το μοντέλο της μέγιστης χρησιμότητας.

Και τα δύο χαρτοφυλάκια εξετάστηκαν με δύο Rolling Windows το καθένα, για 100 ημέρες και για 252 ημέρες. Επιπλέον, εφαρμόστηκε ο περιορισμός της θέσης αγοράς (μόνο), τα σταθμά παραμένουν θετικά σε όλη τη διάρκεια της εξέτασης. Τέλος, δεν εφαρμόστηκαν προμήθειες και έξοδα σε κανένα από τα δύο χαρτοφυλάκια. Συμπερασματικά, το μικτό χαρτοφυλάκιο παρουσίασε καλύτερα αποτελέσματα μέσω της διαφοροποίησης.

Λέξεις Κλειδιά: Τεχνολογία Blockchain, Χαρτοφυλάκια Κρυπτονομισμάτων, Modern Portfolio Theory, Sharpe Ratio, Rolling Windows, Κρυπτογραφία.
## Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acknowledgments</td>
<td>1</td>
</tr>
<tr>
<td>Quotes</td>
<td>2</td>
</tr>
<tr>
<td>Abstract</td>
<td>3</td>
</tr>
<tr>
<td>Περίληψη</td>
<td>4</td>
</tr>
<tr>
<td>Table of Figures</td>
<td>7</td>
</tr>
<tr>
<td>Tables</td>
<td>8</td>
</tr>
<tr>
<td>Table of Equations</td>
<td>8</td>
</tr>
<tr>
<td>Introduction</td>
<td>10</td>
</tr>
<tr>
<td><strong>CHAPTER 1</strong></td>
<td>12</td>
</tr>
<tr>
<td>1.1 THE BLOCKCHAIN TECHNOLOGY ARCHITECTURE</td>
<td>12</td>
</tr>
<tr>
<td>1.1.1 THE BLOCKS IN THE CHAIN</td>
<td>13</td>
</tr>
<tr>
<td>1.1.2 THE TYPES OF BLOCKCHAINS</td>
<td>15</td>
</tr>
<tr>
<td>1.2 THE PEER-TO-PEER NETWORK</td>
<td>16</td>
</tr>
<tr>
<td>1.3 THE DIGITAL SIGNATURES</td>
<td>16</td>
</tr>
<tr>
<td>1.4 THE CONSENSUS PROTOCOL MECHANISMS</td>
<td>19</td>
</tr>
<tr>
<td>1.5 HOW DOES A BLOCKCHAIN WORK IN A SIMPLE EXAMPLE?</td>
<td>20</td>
</tr>
<tr>
<td>1.6 APPLICATIONS OF BLOCKCHAIN TECHNOLOGY</td>
<td>22</td>
</tr>
<tr>
<td>1.7 SMART CONTRACTS &amp; SMART PROPERTY</td>
<td>22</td>
</tr>
<tr>
<td><strong>CHAPTER 2</strong></td>
<td>24</td>
</tr>
<tr>
<td>2.1 DEFINITION OF CRYPTOCURRENCIES</td>
<td>24</td>
</tr>
<tr>
<td>2.1.1 DEFINITIONS</td>
<td>25</td>
</tr>
<tr>
<td>2.1.2 HOW TO OBTAIN CRYPTOCURRENCIES</td>
<td>28</td>
</tr>
<tr>
<td>2.1.3 CLASSIFICATIONS OF CRYPTOCURRENCIES</td>
<td>28</td>
</tr>
<tr>
<td>2.1.4 THE ESSENTIAL TRAITS OF CRYPTOCURRENCIES</td>
<td>30</td>
</tr>
<tr>
<td>2.2 THE FIVE MOST FAMOUS DIGITAL CURRENCIES</td>
<td>31</td>
</tr>
<tr>
<td>2.2.1 BITCOIN (BTC)</td>
<td>32</td>
</tr>
<tr>
<td>2.2.2 ETHEREUM (ETH)</td>
<td>33</td>
</tr>
<tr>
<td>2.2.3 RIPPLE (XRP)</td>
<td>35</td>
</tr>
<tr>
<td>2.2.4 LITECOIN (LTC)</td>
<td>36</td>
</tr>
<tr>
<td>2.2.5 MONERO (XMR)</td>
<td>37</td>
</tr>
<tr>
<td>2.3 CRYPTOCURRENCIES AND REGULATIVE ISSUES</td>
<td>39</td>
</tr>
<tr>
<td><strong>CHAPTER 3</strong></td>
<td>40</td>
</tr>
</tbody>
</table>
3.1 MODERN PORTFOLIO THEORY (MPT) .................................................. 40
3.2 THE EFFICIENT FRONTIER .............................................................. 41
3.3 MARKOWITZ PRICING MODEL ...................................................... 42
3.4 MARKET MODEL OR SINGLE INDEX MODEL ............................... 43
3.5 CAPITAL ASSET PRICING MODEL (CAPM) ............................... 44
3.6 CAPM & THE EFFICIENT FRONTIER .............................................. 45
3.7 CAPITAL MARKET LINE (CML) ...................................................... 46
3.8 SECURITY MARKET LINE (SML) ..................................................... 49
3.9 THE THREE EFFICIENCY MEASUREMENTS ................................. 49
3.9.1 SHARPE RATIO ......................................................................... 49
3.9.2 TREYNOR RATIO ..................................................................... 51
3.9.3 JENSEN RATIO ......................................................................... 52

CHAPTER 4 ................................................................................. 52
4. LITERATURE REVIEW .................................................................. 52
  4.7 “Portfolio management with cryptocurrencies: The role of estimation risk”, Emmanouil Platanakis, Andrew Urquhart, (2019) .................................................. 59
  4.8 “From bottom ten to top ten: The role of cryptocurrencies in enhancing portfolio return of poorly performing stocks”, Roman Matkovskyy, Akanksha Jalan, Michael Dowling, Taoufik Bouraoui (2019) .......................................................... 60
  4.9 “Should investors include Bitcoin in their portfolios? A portfolio theory approach”, Emmanouil Platanakis, Andrew Urquhart, (2020) ........................................ 62
  4.10 SIGNIFICANT POINTS OF THE LITERATURE STUDIES .......... 63

CHAPTER 5 ................................................................................. 64
5.1 THE CREATION OF TWO PORTFOLIOS ............................................. 64
5.2 THE MARKET INDEX S&P500 ....................................................... 65
5.3 METHODOLOGY OF THE STUDY ANALYSIS .................................. 66
  5.3.1 THE NAÏVE MODEL PORTFOLIOS (1/N RULE) ................................. 66
  5.3.2 THE MINIMUM VARIANCE MODEL PORTFOLIOS ............................. 69
  5.3.3 THE TANGENCY MODEL PORTFOLIOS ........................................ 71
  5.3.4 THE MAXIMUM UTILITY MODEL PORTFOLIOS ............................... 74

CHAPTER 6 .......................................................................................... 78

6.1 RESULTS IN TERMS OF THE SHARPE RATIO .................................. 78

APPENDICES ....................................................................................... 85

REFERENCES ...................................................................................... 91

~*~*~

Table of Figures

Figure 1 ............................................................................................... 12
Figure 2 ............................................................................................... 13
Figure 3 ............................................................................................... 14
Figure 4 ............................................................................................... 17
Figure 5 ............................................................................................... 18
Figure 6 ............................................................................................... 21
Figure 7 ............................................................................................... 25
Figure 8 ............................................................................................... 32
Figure 9 ............................................................................................... 33
Figure 10 ............................................................................................. 34
Figure 11 ............................................................................................. 35
Figure 12 ............................................................................................. 37
Figure 13 ............................................................................................. 38
Figure 14 ............................................................................................. 65
Figure 15 ............................................................................................. 67
Figure 16 ............................................................................................. 67
Figure 17 ............................................................................................. 68
Figure 18 ............................................................................................. 68
Figure 19 ............................................................................................. 69
Figure 20 ............................................................................................. 70
Figure 21 ............................................................................................. 72
Figure 22 ............................................................................................. 73
Figure 23 ............................................................................................. 76
Table of Equations

Equation 1 .................................................................................................................. 43
Equation 2 .................................................................................................................. 43
Equation 3 .................................................................................................................. 44
Equation 4 .................................................................................................................. 44
Equation 5 .................................................................................................................. 44
Equation 6 .................................................................................................................. 45
Equation 7 .................................................................................................................. 45
Equation 8 .................................................................................................................. 46
Equation 9 .................................................................................................................. 46
Equation 10 ................................................................................................................. 46
Equation 11 ................................................................................................................. 46
Equation 12 ................................................................................................................. 47
Equation 13 ................................................................................................................. 47
Equation 14 ................................................................................................................. 47
Equation 15 ................................................................................................................. 47
Equation 16 ................................................................................................................. 47
Equation 17 ................................................................................................................. 47
Equation 18 ................................................................................................................. 47
Equation 19 ................................................................................................................. 47
Equation 20 ................................................................................................................. 50
Equation 21 ................................................................................................................. 50
Equation 22 ................................................................................................................. 50
Equation 23 ................................................................................................................. 50
Equation 24 ................................................................................................................. 51
Introduction

The global Financial crisis which burst out in 2008 in the U.S markets, did create a huge economic disruption in the European Community, as well, while it affected the private wealth and consumption, public expenditures, and governments’ debts. The aftermath of this economic frustration was the collapse of the Banking Systems by switching off the corporate and mortgage financing, which eventually led to a credit crunch.

Additionally, it is worth mentioning the fact that governments could not pay out their obligations to the construction sector while the private insurance companies could not compensate their clients. Every aspect of peoples’ lives was seriously damaged, and the implications of an uncontrolled & loose financial system brought the world upside-down.

However, the financial crisis of our times gave birth to new technologies. It is so true that the recent technological improvements have been growing rapidly during the last twenty years of the 21st century. Civilized populations have been so eager to learn fast and adapt easily to every aspect of these new technological achievements.

One of these new-age developments, is the innovation of Blockchain Technology, a breakthrough, which was inspired and created by Satoshi Nakamoto in 2008. Many theories have been told in respect of the person behind the afore-mentioned name. It is believed to be either a man or a woman, or even a group of people whose anonymity has been kept as a secret until today, using “Satoshi Nakamoto” as a pseudonym.

The first academic paper written by Satoshi Nakamoto is “Bitcoin: A Peer-to-Peer Electronic Cash System” in 2008. It is a common fact that Bitcoin is the invention behind the innovation of Blockchain Technology. In Nakamoto’s paper, it is clearly explained that electronic payments could take place without the participation of any intermediary such as a bank or any Financial Institution or Financial service provider (e.g., Swift, PayPal).

This is the time when updated technological definitions come to enlighten communication and transaction systems providing a different perspective. In the era of the modern technologies that apply in every-day life, a peer-to-peer network appears to be the solution to the double-spending problem, by using the proof-of-work method to record the chronological order of online payments according to Nakamoto’s paper. The whole system is based on econometric applications, algorithms, strong mathematical calculations, and technical features which will not be analyzed in too much detail in this dissertation. All of these are safeguarded by Cryptography.
In case large economies would accept to adapt Blockchain Technology in a regulated system without the existence of centralized core structures, this would mean the beginning of a new world in finance and economics, which is not at all the world as we know it today. It takes a long time for societies firstly to accept change, secondly to implement this change, and thirdly to reach its finalization. Although this seems a rather difficult task to achieve, some of us would suggest that this appears to be a great challenge of dreaming big!

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The structure of this dissertation is composed of 6 chapters. In chapter 1, the architecture of Blockchain Technology is being simply explained. In chapter 2, the main Cryptocurrencies are being presented. In chapter 3, reference is made to the Modern Portfolio Theory. In chapter 4, the Literature Review is based on academic research papers, regarding the various approaches of Cryptocurrency Portfolios as investment strategies. In chapter 5, the concept of the examined portfolios is described. The methodology of the investment strategies is analyzed. In chapter 6, the comparative analysis of results of the two portfolios regarding the different investment model strategies in terms of the Sharpe Ratio is presented.

~*~*~
CHAPTER 1

1.1 THE BLOCKCHAIN TECHNOLOGY ARCHITECTURE

Blockchain Technology came from Bitcoin and is based on cryptography. Blockchain is primarily a decentralized database, distributed by a digital ledger of records, that keeps tracking the history of all transactions taking place in chronological order. Every transaction is related to one another by a cryptographic hash code, which is a digital fingerprint like a unique serial number code. All transactions are grouped by the chronology of their order, then they are placed in a block, which contains the hash code of the previous block of transactions, thus creating a chain of interdependent blocks (transactions), which is highly unlikely to be altered or deleted.

To step from one block to another, a very difficult and complicated mathematical algorithm must be solved, this is called the “SHA-256”. This hash code connects the blocks in the chain, while it allows trust with mathematical accuracy according to Lawrence in 2017. The operation of the hash code is characterized as irreversible, while it works as a digital fingerprint that is unique and cannot be copied or altered. It is a cryptographic protocol containing 64 characters in its code.

The fundamental concepts of a blockchain are the following three: Transaction, Block, and Chain. The transaction is the operation of a placement (payment order), that creates a change in the ledger by the action of record transferring. The Block is created by all transactions that appear within the same period, while its work is to record these transactions in the ledger by a consensus mechanism. The Chain connects all the created Blocks in chronological order, based on the time at which they were first ordered. This is a distributed ledger depicted in figure 1 below, which works along with the support of the peer-to-peer network, the digital signatures, and the consensus protocol mechanism. (Q. Wang and M. Su, 2020).

Figure 1

The distributed ledger.

Chronological Order of transactions. → Creation of Blocks in time sequence. → Structuring of the Chain of transaction data.

(The concept for designing the graph in Figure 1 above, was retrieved from the paper source: Q. Wang and M. Su, Computer Science Review 37, 2020, 100275)
1.1.1 THE BLOCKS IN THE CHAIN

Each block contains all the historical information and data of the current transactions that have taken place, which cannot be altered or deleted once they have been validated and connected in the Chain. The Block also contains its **serial number**, a **timestamp** which is the exact time of its creation, the **current hash code**, that is generated by the transactions that take place (Merkle root, the official definition), the **previous block’s hash code**, and finally the **Nonce, which is** the unique cryptographic solution of the algorithm (a unique code of the transaction).

**Figure 2**

The generation of the Blockchain.

(The concept for designing the graph in Figure 2 above, was retrieved from the paper source: scet.berkeley.edu/wp-content/uploads/AIR-2016-Blockchain.pdf)

... *some history of the modern times ...*

“The **first block in the blockchain** is called the **genesis block** and was created in 2009. It is the “common ancestor” of all the blocks in the blockchain, meaning that if you start at any block and follow the chain backward in time, you will eventually arrive at the genesis block. Every node always starts with a blockchain of at least one block because the genesis block is statically encoded within the bitcoin client software, such that it cannot be altered. Every node always “knows” the genesis block’s hash and structure, the fixed time it was created, and even the single transaction within” (Antonopoulos, 2015).

As Antonopoulos emphasizes, a strong & safe chain of blocks can be built with every node acquiring the genesis block as a starting point for the blockchain, describing it as a secure “root”. The Genesis Block consists of 50 coins and is part of an open-source program. Moreover, the impetus for the development of a new monetary system, with the creation of digital currencies using the principles of cryptography (cryptocurrencies), was...
given through the great global economic crisis that took place at the beginning of the last decade.

More specifically, during 2008-2009, and while the global financial system was collapsing, the US Congress rushed to the rescue of the Wall Street banks that had caused the crisis. “This rescue was essentially the financial support of one trillion dollars to the specific banking institutions with the money of the taxpayers, without the consent of the people.” (Baldwin, 2018).

Amid this tense financial uncertainty, a cover story of an unknown blogger from a cryptography forum was published in the Times of London on January 3, 2009, entitled: "Chancellor on brink of second bailout for banks" which in Greek means: "Chancellor on the brink of the second rescue package for banks". This cover story essentially suggested an alternative that would ultimately lead to a completely new monetary system. This title was mentioned and incorporated in the first transaction ever included in the new Bitcoin chain, by Satoshi Nakamoto on January 3, 2009. “The block containing this transaction was named "The Genesis Block" (see Figure 3) and is the first event (block) in the block-chain, the chain of Bitcoin cryptocurrency.” (Zimmer, 2017).

Figure 3

The Genesis Block.

![The Genesis Block](https://www.bitcoinwiki.org/wiki/File:Genesis_block.png)

~*~*~

"The Times 03-Jan/2009 Chancellor on the brink of second bailout for banks"

(Source: Bitcoin Wiki)

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1.1.2 THE TYPES OF BLOCKCHAINS

Mainly, there are two types of structures that obtain the ownership of the hardware (miners) of the Blockchains. The Public type (is like the Internet), is an open-source program, which supports the blockchains of Bitcoin, Ethereum, Litecoin, and Monero. Anyone can participate in building the chain, either by the verification of all transactions taking place, or the execution of contracts, or bitcoin mining, or the purchase of cryptocurrencies.

This type is the safest among the others since no central authority controls the net, while the participation of the IT programmers (nodes) is voluntary and self-supplied, meaning by its resources. Usually, public blockchains are being slowed down by the continuous increase of transactions, which eventually leads to some issues, for example, the lack of storage capacities (Laurence, 2017).

The Private type (is like the Intranet), is a closed source program, while the participants are known and reliable to each other. This Blockchain is running under a closed code among its members, while its members are very small in number in comparison to a public blockchain. The participation of their users is controlled by a central authority, their mechanism is faster due to its small size of transactions, whereas also, there are no delays in the process of the data validation.

Furthermore, their operating costs are low, their data storage capacity is unlimited and very fast built. On the other hand, these type of blockchains is centralized, and not as much safe as the public ones, while they usually do not use cryptocurrency as a means of transaction. To participate in private blockchain permission is needed. There are also the Consortium Blockchains, where the procedure of consent is executed by default, by a certain group of nodes.

In this dissertation, the type of Public blockchain is used for the analysis and description of the mechanism under which transactions are taking place.

The Characteristics of the Blockchain are decentralization, persistency, anonymity, and auditability as described in the article of Myriam Ertz and Emily Boily, published in the International Journal of Innovation Studies in 2019. Decentralization means that each transaction needs to be validated, but the validation process does not occur through a central trusted agency (e.g., a central bank), but through a consensus algorithm to maintain data consistency in a distributed network (Zheng, Xie, Dai, Chen, & Wang, 2017). Persistency means that it is impossible to delete or rollback any transaction once it is included in the blockchain.
However, invalid transactions can be discovered immediately, making the persistency characteristic not too much of a drawback overall. **Anonymity** means that each user can interact with the blockchain in a generated address without revealing the user’s real identity (Kosba, Miller, Shi, Wen & Papamanthou, 2016). **Auditability** means that any transaction must refer to a previous unspent transaction (Nakamoto, 2008). Therefore, transactions can be easily verified and tracked. (Myriam Ertz, Emily Boi, 2019).

### 1.2 THE PEER-TO-PEER NETWORK

The Network of the Blockchain is based on a Peer-to-Peer (P2P) system. This is a network of computers that collectively share and store files. Each participant (node) acts as an individual peer. They are the core “builders” of most cryptocurrencies. According to Satoshi Nakamoto, and as described in the white paper he published in 2008 “Bitcoin: A Peer-to-Peer Electronic Cash System”, (https://nakamotoinstitute.org/bitcoin/), the steps of processing the blockchain network is as follows:

1. New transactions are broadcasted to all nodes.
2. Each node collects new transactions into a block.
3. Each node works on finding a difficult proof-of-work for its block.
4. When a node finds a proof-of-work, it broadcasts the block to all nodes.
5. Nodes accept the block only if all transactions in it are valid and not already spent.
6. Nodes express their acceptance of the block by working on creating the next block in the chain, using the hash of the accepted block as the previous hash.

The new payment system of Nakamoto (October 31st, 2008), namely Bitcoin, omits the interference of any intermediary, while it appears to be the solution to the issues of trust in transactions, privacy protection, as well as fraud and stealing. More specifically payments are executed without the presence of any trusted party, instead of trust, there is a cryptographic proof system, which will be analyzed in the below paragraph. Finally, fraud or stealing cannot take place due to protocol protection of every single transaction data. **In other words, Bitcoin comes against the monetary system which controls money generation and exercises its power over the transactions’ data privacy.**

### 1.3 THE DIGITAL SIGNATURES

The conception of Blockchain Technology has derived from the architecture of Bitcoin, in other words, the Blockchain is intrinsically connected to Bitcoin. However, Blockchain finds application to any transaction of digital assets (cryptocurrencies) conducted online. So, firstly, there was the Bitcoin mechanism.
Since the invention of the internet, financial institutions and banks have supported their businesses through electronic commerce, exchanges, and services they could provide to their corporate, private, and individual clients. However, these electronic activities involve risks. *Therefore banks and financial institutions play, also, the role of a trusted third party, that controls, checks, and validates personal data entries in their systems.* Moreover, this role must be rewarded with rather high costs, not to mention the various expenses and fees that banks charge in many of their banking services.

Furthermore, this personal data must be protected and preserved for a specific time. For this reason, banks and many corporations have enacted since the 25th of May 2018 the General Data Protection Regulation (GDPR) in their business, according to the directive (95/46/EC) of the European Economic Community.

On the other hand, Bitcoin makes use of cryptographic proof, instead of playing the role of the trusted intermediary for online transactions. "*Each transaction is protected through a digital signature* which is sent to the “public key” of the receiver and is digitally signed using the “private key” of the sender. To spend money, the owner of the cryptocurrency needs to prove the ownership of the “private key”. The entity receiving the digital currency then verifies the signature, which implies ownership of the corresponding “private key” by using the “public key” of the sender on the respective transaction.

Moreover, “each transaction is transmitted to every node in the Bitcoin Network and is then recorded in a public ledger after verification. Every single transaction must be verified for validity before it is recorded in the public ledger.” (scet.berkeley.edu/wp-content/uploads/AIR-2016-Blockchain.pdf)

Following Nakamoto’s paradigm in “*Bitcoin: A Peer-to-Peer Electronic Cash System*”, in article 10 about Privacy, the below structure is discussed. "*The traditional banking model* achieves a level of privacy by limiting access to information to the parties involved and the trusted third party. The necessity to announce all transactions publicly precludes this method, but privacy can still be maintained by breaking the flow of information in another place, *by keeping public keys anonymous*. The public can see that someone is sending an amount to someone else, but without information linking the transaction to anyone.”

**Figure 4**

Traditional Privacy Model in Banking.

<table>
<thead>
<tr>
<th>Individual’s Identity (private key)</th>
<th>Transactions</th>
<th>Trusted Third Party</th>
<th>Counterparty</th>
<th>Public (public key)</th>
</tr>
</thead>
</table>

“As a new additional firewall, a new key pair should be used for each transaction to keep them from being linked to a common owner. Some linking is still unavoidable with multi-input transactions, which necessarily reveal that their inputs were owned by the same owner. The risk is that if the owner of a key is revealed, linking could reveal other transactions that belonged to the same owner.” (Nakamoto, 2008)

There appear to be two issues that need validation by the verification node, prior to the recording of any transaction. The first issue is the ownership of the cryptocurrency, held by the sender, through the digital signature verification on the transaction. The second issue is the sufficiency in the cryptocurrency account balance of the sender. This is processed by checking every single transaction in the sender’s account.

In addition to the above, another serious matter is the fact that the transactions do not appear in the correct order as they were generated in the Bitcoin Peer-to-Peer Network. Although the transactions are passed, node by node through the Bitcoin Network, there is no certainty about the correctness of their order at the time they are being received at a node. As a matter of fact, the creation of the double-spending problem had to be avoided by a new mechanism, which would place every transaction in the correct chronological order. “The Bitcoin system orders transactions by placing them in groups called blocks and then linking these blocks through a chain called the Blockchain” (AIR, 2016). In fact, Blockchain technology was created as a solution to the double-spending problem of the Bitcoin Network mechanism.

However, there is one more issue that needs a solution. “Any node in the Network can collect unconfirmed transactions and create a block and then broadcast it to the rest of the Network as a suggestion as to which block should be the next one in the blockchain.” (AIR, 2016). The issue to be overcome is the decision about which block should be the next one in the chain. Various nodes create multiple blocks simultaneously. Blocks arrive at different orders and different positions in the Network. This issue is solved by Bitcoin and by solving a strong and complicated mathematical algorithm. This is called the “Proof of Work” consensus algorithm.

~*~*~

1.4 THE CONSENSUS PROTOCOL MECHANISMS

Proof of Work (PoW)

When the first node solves this difficult mathematical problem, then the block is transmitted to the Network of computers. However, there is more than one node that attempts to solve the problem, and consequently, there are created more than one block, while this is leading to several possible branches in the chain. Although the high level of difficulty of the algorithm, the blockchain will be quickly stabilized, while every node will agree with the ordering of the blocks in the chain. These nodes, which use their resources for the solution to the algorithm and the generation of blocks, are known as the Miners.

Consequently, Proof-of-Work is a consensus mechanism used for Bitcoin mining. The identity of a miner is difficult to be chosen for the structure of each block in the chain. It is then agreed that the solution of the algorithm is a verification of transactions taking place. Not only does it take a lot of work for the miners to solve the mathematical problem, but they also must use their technological resources, computers, and electricity to gain the structure of the next block. They aim to find the correct hash this is the unique fingerprint for the text or data file. For all this hard work the miners receive bitcoin as a reward.

Proof-of-Work, also, deters denial of service attacks and other service abuses, such as spam on a network by requiring some work from the service requester. “The Network only accepts the longest Blockchain as the valid one. That is why it is next to impossible for an attacker to introduce a fraudulent transaction, since it has not only to generate a block by solving a mathematical puzzle but it also has to race mathematically against the good nodes to generate all subsequent blocks, for it to make the other nodes in the Network accept its transaction and block, as the valid one.” (AIR, 2016) Therefore, fraudulent actions are too difficult to be achieved since blocks in the Blockchain are interconnected linearly and cryptographically.

According to Satoshi Nakamoto, Proof-of-Work is essentially “one-CPU-one-vote”. “The majority decision is represented by the longest chain, which has the greatest proof-of-work effort invested in it. If a majority CPU power is controlled by honest nodes, the honest chain will grow the fastest and outpace any competing chains. To modify a past block, an attacker would have to redo the proof-of-work of the block and all blocks after it and then catch up with and surpass the work of the honest nodes.” (Satoshi Nakamoto, 2008, Bitcoin: A peer-to-peer Electronic Cash System, https://nakamotoinstitute.org/bitcoin/)

“The puzzle is mathematically set up to make it impossible to find a shortcut to solve it. That is the reason when the rest of the network sees the answer, everyone
trusts that a lot of work went into producing it. Also, this puzzle-solving is continuous “to the tune of 500,000 trillion hashes per second”, according to Dino Mark Angaritis (CEO of Smart Wallet). Miners are “looking for a hash that meets the target. It is statistically bound to occur every ten minutes. Sometimes it takes one minute and sometimes one hour, but on average, it’s ten minutes.” Angaritis explained how this process works: “Miners gather all the pending transactions that they find on the network and run the data through a cryptographic digest function called the secure hash algorithm (SHA-256), which outputs a 32-byte hash value.” (Tapscott & Tapscott, 2018)

“If the hash value is below a certain target (set by the network and adjusted every 2,016 blocks), then the miner has found the answer to the puzzle and has ‘solved’ the block. Unfortunately for the miner, finding the right hash value is very difficult. If the hash value is wrong, the miner adjusts the input data slightly and tries again. Each attempt results in an entirely different hash value. Miners must try many times to find the right answer. As of November 2015, the number of hash-attempts are on average 350 million trillion. That’s a lot of work!” (Tapscott & Tapscott, 2018).

A very significant type of consensus mechanism, by which a cryptocurrency blockchain network aims to achieve validation of transactions is Proof of Stake (PoS). This consensus algorithm is based on the age & the amount of cryptocurrency that the payer possesses. Although its purpose is like the Proof of Work algorithm, however, the process of the transactions’ validation is quite different. According to Ethan Buchman in 2016, each node will have to guarantee that it holds the exact amount to be validated in the network before proceeding. There is no reward for this validation, however, the node will then receive an amount from each transaction.

Another type is Proof of Existence, which uses Blockchain Technology for the solution of the “SHA-256” mathematical problem, to ascertain the existence or validate the possession, at a certain time, of legal documents. Proof of existence could very efficiently replace the traditional models of notary services, which become more difficult to verify, secure or certify older documents. A similar type of the above consensus algorithm is Proof of Ownership, which solves the issue of authenticity when certifying legal documents. Also, there is Proof of Integrity, which checks documents for their fidelity or any event of forgery.

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1.5 HOW DOES A BLOCKCHAIN WORK IN A SIMPLE EXAMPLE?

There is the sender X who wishes to send Bitcoins to the receiver Y, in a peer-to-peer (P2P) network system, as explained in the previous paragraphs of this chapter.
Figure 6

The transaction processes.

**X – Sender**  →  The request of the transaction is transmitted to the network as a Block. Sender X owns a private & a public key. The order of transaction is placed with the private key of sender X.

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The green block represents the previous transaction in the Blockchain, whereas the purple block represents the current transaction.

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**Y-Receiver** (authorization with the public key)

(The concept for designing the graph in Figure 6 above, was retrieved from the paper: scet.berkeley.edu/wp-content/uploads/AIR-2016-Blockchain.pdf)

**Y - Receiver**, holder of the “public key”, verifies the digital signature (private key) of sender X, by using the “public key” of the sender X. Afterwards, this verification is broadcasted to every Node in the peer-to-peer (P2P) network system as a block. Once a Node has solved the **proof of work** algorithm, that is transmitted to the other nodes in the network as well, who also, must verify the algorithm and then validate the transaction. This is verified through the “public key” of X, while it is registered in the ledger that X is indeed the owner of the Bitcoins & has a sufficient balance in his account. Only then can the block of the transaction be recorded in the public ledger & added to the chain of the other Blocks. Finally, the Bitcoins are to be transferred to receiver Y. The transaction is transparent & protected by encryption, while no third party was involved in the process.
1.6 APPLICATIONS OF BLOCKCHAIN TECHNOLOGY

Blockchain Technology can be applied robustly to a variety of activities in the financial and non-financial sector as well. Financial Institutions and banks are looking for new opportunities and ways to replace traditional business models with the innovative structures and applications of blockchain technology in their fields of expertise. For instance, nowadays digital communications and transactions have emerged, taking many credits and acceptance in a wide range of areas such as in Corporate banking, Factoring, Leasing, Insurance services, and Real Estate Investments as well.

Furthermore, these new technologies might as well apply in non-Financial spectrums such as in Notary Public by keeping track of all legal documentation & private securities, in issuing marriage licenses, in healthcare by tracking patients’ health records in hospitals, in loyalty payments in the music industry. Finally, it is worth mentioning the Blockchain’s applications in the construction sector, the food chain supply industry, the educational institutions, also in law enforcement, governments, and social networks, charities, and finally in the polling process during elections for transparency of votes.

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1.7 SMART CONTRACTS & SMART PROPERTY

The “Smart Contracts” application was invented by Nick Szabo in 1994. It was a rather significant computer program, which automatically executed contracts if the conditions in the agreement between the parties were met. Although it was unique, this application came to light along with Blockchain Technology, the Cryptocurrencies exchange, and online payments.

Blockchain technology works perfectly together with Smart contracts. In this way, Blockchain simplifies the process of registration, verification, and execution of Smart Contracts, making their online payments transparent. The usage of Smart Contracts, functioning under computer protocols and certain conditions, might enhance the work of lawyers to create contracts or the procedures of Banks to provide escrow account services to their clients.

Blockchain supports Smart Contracts. For instance, Ethereum which is an open-source program uses Smart Contracts and owns many capabilities. Anyone can create their cryptocurrency while using it for the execution and payment of Smart Contracts. Ethereum is the cryptocurrency for Smart Contracts and is used by the owner to pay for the services of this programming platform.
Moreover, there is also **Smart property** which plays a relative role in the Blockchain, where the ownership of a property or an asset is under control. The kind of property might be **either tangible**, such as a real estate property, a car, a smartphone, or **intangible** such as the shares of a company. (scet.berkeley.edu/wp-content/uploads/AIR-2016-Blockchain.pdf).

“The blockchain can be used for any form of asset registry, inventory, and exchange, including every area of finance, economics, and money, physical property, and intangible assets (votes, ideas, reputation, intention, health data, and information). Using blockchain technology this way opens multiple classes of application functionality across all segments of businesses involved in money-markets, and financial transactions” (Swan, 2015).

“Blockchain-encoded property becomes a smart property that is implemented via smart contracts. The general concept of smart property is the notion of transacting all property in blockchain-based models. The property could be physical-world hard assets like a home, car, bicycle, or computer, or intangible assets such as stock shares, reservations, or copyrights (e.g., books, music, illustrations, and digital fine art). Any asset can be registered in the blockchain, and thus its ownership can be controlled by whoever has the private key. The owner can then sell the asset by transferring the private key to another party” (Swan, 2015).

“Smart property, then, is a property whose ownership is controlled via the blockchain, using contracts subject to existing law. For example, a pre-established smart contract could automatically transfer the ownership of a vehicle title from the financing company to the individual owner when all the loan payments have been made (as automatically confirmed by other blockchain-based smart contracts)” (Swan, 2015).

“Mortgage interest rates could reset automatically per another blockchain-based smart-contract checking a prespecified and contract-encoded website or data element for obtaining the interest rate on certain future days” (Swan, 2015).
CHAPTER 2

2.1 DEFINITION OF CRYPTO CURRENCIES

Cryptocurrencies’ existence has emerged from the 21st century’s innovative Web Technologies. Cryptocurrencies are structured under complicated mathematics and cryptographic algorithms. According to literature studies, cryptocurrencies are considered either as “digital currencies” or in other cases as “speculative assets”, which represent a value. However, this value is determined by the “supply and demand” mechanism. Unlike stocks, cryptocurrencies are unregulated, and thus many carriers and policymakers consider them as “private currencies” for a specific investing market.

Cryptocurrencies also represent web networks, apart from their use as means of exchange, which do not need any third trusted party to verify or secure their use and existence. Cryptocurrencies rely their core structure on cryptography. Furthermore, the complexity of the concept of Cryptocurrencies, in general, is due to the interdisciplinarity of their structure in the sense that to understand their operating system, it is necessary to combine concepts, methods, and elements from three traditional fields of study and more specifically from the fields of economics, encryption and computer science (Berentsen & Schar, 2018).

There are nearly close to 3,896 different Cryptocurrencies on the market up today (December 2020), a total of 1,084 coins plus 2,812 tokens, according to the website https://coinmarketcap.com/all/views/all/. Most of these are essentially variants of the architecture of the popular Bitcoin. “Like all money used as a medium of exchange in transactions, cryptocurrencies raise many questions about their reliability and risk of failure” (Islam et al., 2018).

Additionally, as it is shown in Figure 7 below, depicted in the article of Islam et al., (2018), a schematic comparison of the transactional procedures between traditional currencies and cryptocurrencies is presented. As it appears to be, the traditional coins of the conventional economy (either banknotes or coins) are usually issued by the Governments and are coins that are circulated and marketed through a third party that is a banking institution (Islam et al., 2018).

Cryptocurrency transactions, as depicted in the second case of Figure 7 below, are placed in the Blockchain, and recorded by the validation of the users of the distributed ledgers. These are the nodes of a decentralized network. Consequently, whereas in the first case, there is centralized management by the respective Financial Institutions, in the second, there is the decentralized manner of controlling the trading network.
2.1.1 DEFINITIONS

The word Cryptocurrency was at first described in 1998, by Wei Dai in the Cypherpunks mailing list as "money that is impossible to regulate", supporting the idea of a new form of money that using cryptography would independently control its creation and transactions, without the need of a central authority. Cypher-punk is a person who uses encryption when accessing a computer network to ensure privacy, especially from Government authorities.

For the time being, there is no specific definition of the word "Cryptocurrency", that is universally accepted, although many official carriers have suggested various ones.
"Cryptocurrencies", likewise the term "blockchain", is a new definition that is created from scratch and refers to a wide range of technological developments while using a technique widely known as cryptography. **Cryptography is the technique of protecting information that is achieved by transforming it into an unreadable form.** Cryptocurrencies, such as Bitcoin, use a technique that incorporates an intelligent system of public and private digital keys, as described in Chapter 1.

In table 1 below, there is a synopsis of the definitions that have already been developed by various policymakers at the European and International level, each one of them has approached the issue in different ways.

**Table 1**

Summary of the definitions of Cryptocurrencies.

<table>
<thead>
<tr>
<th>CARRIER</th>
<th>DEFINITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>European Central Bank (ECB), 2012.</td>
<td>&quot;Virtual currencies are a form of uncontrolled digital money, usually issued and controlled by their developers and used and accepted by members of a particular virtual community.&quot; (ECB, 2012) Note: It is the same definition for fictitious currencies, but the category of cryptocurrencies analyzed in the document corresponds to the description of type III, meaning that there are conversion rates for both the purchase and sale of virtual currency and the purchase of such currency, while the purchased currency of this type can be used to purchase both virtual and real goods and services.</td>
</tr>
<tr>
<td>European Banking Authority (EBA), 2014.</td>
<td>&quot;Cryptocurrencies are defined as fictitious currencies which are digital representations of value that are not issued by a central bank or a public authority or are necessarily linked to a fiat currency but are used by natural or legal persons as a medium of exchange and can be transferred, stored or made available electronically.&quot; (EBA, 2014)</td>
</tr>
<tr>
<td>Financial Action Task Force (FATF), 2014.</td>
<td>Cryptosystems such as Bitcoin are virtual currencies that, according to the FATF, can be defined as &quot;remotely convertible mathematical currencies based on mathematics and protected by cryptography.&quot; (FATF, 2014, p.5)</td>
</tr>
<tr>
<td>European Central Bank (ECB), 2015.</td>
<td>&quot;Virtual currencies are defined as digital representations of value, not issued by a central bank, credit institution or electronic money institution, which in some cases can be used as an alternative to money.&quot; (ECB, 2015)</td>
</tr>
<tr>
<td>World Bank Group, 2017.</td>
<td>He (2018) defined cryptocurrencies as &quot;a subset of digital currencies&quot;, which are digital</td>
</tr>
</tbody>
</table>
representations of value expressed in their unit of account, other than e-money, which is simply a digital payment mechanism represented and denominated in conventional money (fiat money). Note: Unlike most other policymakers, the World Bank has defined cryptocurrencies as “digital currencies” based on cryptographic techniques for consensus building of money.” (World Bank Group, 2017, p. IV)

International Monetary Fund (IMF), 2018.

"Cryptocurrencies are considered as a subset of virtual currencies, defined as digital representations of value, made possible by advances in cryptography and distributed ledger technology, issued by private investors and expressed in their unit of account, while they can be transferred between peers (peer-to-peer system) without an intermediary.” (He, 2018)


"Cryptocurrencies are digital currencies or digital currency systems that have the following three (3) key characteristics: First, they are assets whose value is determined by supply and demand in a similar way to commodities such as gold, but with zero intrinsic value. Second, they use distributed calendars that allow remote peer-to-peer electronic value exchanges in the absence of trust between parties and without the need for intermediaries. Third, cryptocurrencies are not executed by a specific person or institution.” (He, 2018)

(Source: EBA, 2014; ECB, 2012; ECB, 2015; ECB, 2017; FATF, 2014; World Bank Group, 2017; He, 2018; He et al., 2016)

The main conclusion that emerges from the various approaches presented above is that there is no commonly accepted definition of the term "cryptocurrency". Among the above, only the World Bank Group and the Financial Action Task Force presented a clearer and a much more appropriate definition. However, Cryptocurrencies are perceived as a subset or form of virtual or digital currencies by most economists and investors.

If any attempt is made to summarize all the above definitions, a good suggestion would be that Cryptocurrency is “a digital representation of value” that is intended to be an alternative peer-to-peer (P2P) solution to the legitimate government currency issued by the Government, which serves as a medium of exchange, acting independently of any central bank or authority, while it is secured due to the cryptographic technique.

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2.1.2 HOW TO OBTAIN CRYPTOCURRENCIES

There are two ways to obtain Cryptocurrencies, either through “mining” or the “buy & sell” exchange. More specifically, all those who deal with “mining” in essence, control the integrity of transactions supported by the respective network, offering power and time from their resources, such as their personal computers, special software utilities, while in return miners receive new Cryptocurrencies as a reward. In this manner, a new Cryptocurrency is being created.

However, the process of “mining” Cryptocurrencies, is the most difficult one in every way. Mining is time-consuming, technically complex, and rather expensive in terms of power energy supply. As experienced miners increase in numbers, so does the volume of transactions, which makes mining a much more difficult task to accomplish. One solution to this is the manufacturing of large mining “farms”, for which a subscription fee is paid to get a specific computer power that corresponds to a significant number of Cryptocurrencies.

As far as the “buy & sell” exchange is concerned, such as the purchase of Bitcoins and/or other Cryptocurrencies, this certainly seems to be a more moderate way as it resembles the operation of a stock exchange or any regulated market. These Cryptocurrency exchanges are addressed to all those who wish to buy and sell Cryptocurrencies but also to those who wish to convert the Cryptocurrencies they hold into other Currencies, either regular (traditional, fiat) or digital.

Moreover, it should be emphasized that the purchase price at which the buyers are willing to buy differs from the selling price set by the sellers. Therefore, the daily fluctuations of the purchase prices, are determined by the supply and demand that sellers and buyers provide for the specific Cryptocurrencies.

In addition to buying Bitcoin or other Cryptocurrencies, exchanges often offer a kind of Bitcoin security service, which is characterized by many investors as an extremely important and critical additional service.

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2.1.3 CLASSIFICATIONS OF CRYPTOCURRENCIES

The term “Cryptocurrencies” in practice is mistakenly used in a much broader sense than we think. A distinction is made between the three (3) categories of Cryptocurrencies that exist (King, 2019). The main component of all this is the concept of blockchain. Bitcoin is only one category by itself since it is the invention of the underlying
innovation of the blockchain. Following Bitcoin, many new blockchains were created, one of which is Altcoins, which are essentially the second type of Cryptocurrency. Finally, there is another class of Cryptocurrencies called Tokens.

As the first category of Bitcoin, will be discussed in more detail in the next section of this chapter, thus it would be better to discuss the other two categories of cryptocurrencies here. Altcoins by most (1,083 in numbers, currently) are alternative versions of Bitcoin with minor changes. This is how the name 'altcoins' came about. However, it is important to understand that not all altcoins are just alternative versions of Bitcoin, as some are very different from Bitcoin having very different goals and objectives (King, 2019). More specifically, some altcoins use different algorithms than Bitcoin. A typical example is Factom which is an altcoin that uses a PoS (Proof of Stake) algorithm and not PoW (Proof-of-Work).

This algorithm uses much less electricity because not many miners use electricity to try to control the same block and instead, there is only one "miner" per block. Another typical example of this type of cryptocurrency is Ethereum which introduced a new encryption technology in 2015. Its first purpose was not to act as a digital currency, while instead introduced the concept of the smart contract. The main feature offered by a smart contract is the automatic execution of transactions under certain conditions.

According to Antonopoulos (2015), “the vast majority of Altcoins are derived from bitcoin’s source code, also known as “forks”. Some are implemented “from scratch” based on the blockchain model but without using any of bitcoin’s source code. Altcoins and alt-chains are both separate implementations of blockchain technology and both forms use their blockchains. The difference in the terms is to indicate that altcoins are primarily used as currency, whereas alt-chains are used for other purposes, not primarily currency. The first altcoins appeared in August of 2011 as forks of the bitcoin source code. “Altcoins continued to proliferate in 2011 and 2012, either based on bitcoin or Litecoin. At the beginning of 2013, 20 altcoins were vying for a position in the market. By the end of 2013 however, this number had exploded to 200, with 2013 quickly becoming the “year of the alt-coins”. The growth of altcoins continued in 2014 with more than 500 altcoins now in existence. More than half the alt-coins today are clones of Litecoin.” (Antonopoulos, 2015). Litecoin will be further analyzed in the following section of this Chapter.

Tokens are the third category of Cryptocurrencies, which is probably the most interesting one, in terms of functionality as compared to the other two. Tokens differ very much, as they do not possess their blockchain while they are used in dApps, meaning decentralized Applications which were built for the use of smart contracts. There appear to be approximately up to 2,812 Tokens until the time we speak, such as Civic (CVC), BitDegree (BDG), and WePower (WPR). Tokens do not need to represent a tangible object such as a real estate property or a smartphone, on the contrary, they could be better used as a means of transaction for purchases on dApps (decentralized applications).
Finally, Tokens always have a market price at which they can be sold, which is the reason for some people to purchase them. While there is the case of some people who "see" them as an investment opportunity and so they buy tokens intending to sell them later at a higher price, instead of buying them only to use them immediately on dApps.

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2.1.4 THE ESSENTIAL TRAITS OF CRYPTOCURRENCIES

Today's Cryptocurrencies have conquered the market since the first appearance of Bitcoin in 2008 and subsequently the creation of the other Altcoins. At this point, it is worth referring to some historical information in respect of the predecessors of Cryptocurrencies back in 1998, as they describe the fundamental concepts that were later implemented.

Wei Dai, a computer scientist & engineer, was the first one to conceive in 1998 the creation of digital money known as B-Money, (http://www.weidai.com/bmoney.txt).

He proposed the idea of an “anonymous, distributed electronic cash system” and therefore published his paper introducing new meanings of that time, such as “untraceable digital pseudonyms”, “community ledger”, and “digital currency”. He was the founder of the cryptographic protocol proof-of-work for the authentication and verification of transactions, while he proposed the necessity of digital signatures or public keys as well. Although Wei Dai’s work was never officially launched, he contributed to the work of Satoshi Nakamoto.

The main characteristics of Cryptocurrencies’ mechanism, are based on Wei Dai’s work, as retrieved from the web page https://en.bitcoin.it/wiki/Wei_Dai, and listed below:

❖ The requirement of a specific amount of computing power, known as the consensus algorithm Proof-of-Work.
❖ Verification of the project carried out by the community updating a transaction book.
❖ The employee receives funds for his effort.
❖ The exchange of funds is carried out with the collective keeping of the accounting book and is validated with cryptographic fragmentation values.
❖ The contracts are enforced through the transmission and signing off digital signature transactions using public-key cryptography.

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2.2 THE FIVE MOST FAMOUS DIGITAL CURRENCIES

Many times, when reference is made to digital currencies, most people think only of Bitcoin. However, this is not the case because it is not the only major digital currency on the market, and this is true. There are improved versions, inspired by Bitcoin, which currently, as of December 2020, are numbering nearly up to 3,896 cryptocurrencies (coins & tokens), according to the coinmarketcap database. Moreover, there appear to be many new ones that show a negligible market value. However, this paper will focus only on the five most famous (Bitcoin, Ripple, Ethereum, Litecoin, and Monero). These virtual currencies are given in Table 2 immediately below.

Table 2

The top famous five (5) cryptocurrencies, as of February 1st, 2021, with (*) are those cryptocurrencies without mining capability.

<table>
<thead>
<tr>
<th>No</th>
<th>Name, Symbol &amp; Abbr.</th>
<th>Market capitalization in USD ($)</th>
<th>Closing Price in USD ($) 01/02/2021</th>
<th>Number of coins on the market (Volume)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bitcoin (BTC)</td>
<td>624,349,044,409</td>
<td>33,537.18</td>
<td>61,400,400,660 (BTC)</td>
</tr>
<tr>
<td>2</td>
<td>Ripple* (XRP)</td>
<td>16,867,989,812</td>
<td>0.3715</td>
<td>34,974,233,953 (XRP*)</td>
</tr>
<tr>
<td>3</td>
<td>Ethereum (ETH)</td>
<td>156,750,867,717</td>
<td>1,369.04</td>
<td>29,210,670,920 (ETH)</td>
</tr>
<tr>
<td>4</td>
<td>Litecoin (LTC)</td>
<td>8,761,704,259</td>
<td>131.95</td>
<td>5,607,159,828 (LTC)</td>
</tr>
<tr>
<td>5</td>
<td>Monero (XMR)</td>
<td>2,562,614,383</td>
<td>143.74</td>
<td>988,331,548 (XMR)</td>
</tr>
</tbody>
</table>

The values & symbols represented in Table 2 above, were retrieved from the website coinmarketcap.com, 2021.

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Moreover, the website https://coin360.com/ is transmitting live while someone could find schematically the performance of Cryptocurrencies, whether they belong to the category of coins or the category of tokens or both, at any time. In the present work, a screenshot is given, in Figure 8 below, from the specific website of the performance of coins & tokens, in USD ($) as of March 4th, 2021.

**Figure 8**

The performance of cryptocurrencies (coins & tokens) as of 04/03/2021

(Source: coin360.com, 2021)

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### 2.2.1 BITCOIN (BTC)

Bitcoin, as already mentioned, was created by an unknown individual or group of people behind the pseudonym Satoshi Nakamoto towards the end of 2008 early 2009. It takes ten (10) minutes for the bitcoin Network to complete a block, which means to fulfill a transaction. **Bitcoin is the first and largest decentralized Cryptocurrency.**

As of February 1st, 2021, the Market capitalization of Bitcoin was $624,349,044,409 (US), while one (1) BTC was equal to $33,537.18 (US). At the beginning of its release, Bitcoin did not gain much public attention and was mostly used for online gambling, especially through the internet service called "Satoshi Dice" (Dabrowski & Janikowski, 2018). Bitcoin Futures was a derivative of Bitcoin that was created in 2018, which gave a tremendous boost to Bitcoin currency, as depicted in the below graph.
On the efficient portfolio of Cryptocurrencies’ Values – Christiana Katsampoula®

Figure 9

Bitcoin’s (BTC) price chart for the time-period (07/08/2015 – 01/02/2021)

Bitcoin, (BTC), was the first cryptocurrency since its appearance in 2013, and for two years, until 2015 its price remained stably low. In figure 9, its demand shows very low values, moving at a rather stable pace for two more years, starting from August 2015 until August 2017. At the same time, there appears to be a slow increase of its value since the second quarter Q2-2017, which increases intensively only after the third quarter Q3 of the same year, while it reaches a peak during Q4-2017, and at the first quarter Q1-2018. At the beginning of 2018, an increasing course starts with a lot of fluctuations in Bitcoin’s values, which lasts until December 2020. These fluctuations are moving upwards until the 1st of February 2021. The closing values for the structuring of the graph in Figure 9, were retrieved from the website coinvault.com, 2021.

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2.2.2 ETHEREUM (ETH)

Ethereum was designed in 2013 by two computer programmers Vitalik Buterin and Gavin Wood and was released in July 2015. It is the second-largest cryptocurrency after Bitcoin. It is an open-source Blockchain software program that uses smart contracts. As of February 1st, 2021, the Market capitalization of Ethereum was $156,750,867,717 (US), while one (1) ETH was equal to $1,369.04 (US). The virtual currency with the second-largest market capitalization. Ethereum (ETH) is essentially a smart contracts platform based on blockchain technology that allows developers to create decentralized applications (dApps). ETH is the currency used in the platform Ethereum and acts as a transaction fee for miners in the Ethereum network. It can facilitate the exchange of money, content, assets, shares, or anything of value.
The Ethereum network was launched on July 30, 2015, with 72 million Ethereum coins pre-mined (coinmarket.com, 2020). Ethereum also uses Blockchain technology like Bitcoin to process transactions but differs from it in many ways (Dabrowski & Janikowski, 2018). First, it should be noted that the Ethereum block time is shorter than in Bitcoin (14-15 seconds compared to 10 minutes in bitcoin), which allows for faster trading times. Secondly, while the number of new bitcoins generated decreases over time, in the case of Ethereum, it is observed that a constant number of new currencies are created each year.

Also, another thing that differentiates Ethereum is the different transaction costing methods it uses. Ethereum's year of introduction to the cryptocurrency market was 2015 and trading began in August of the same year and, since its launch, the exchange rate against the US dollar (US $) has increased more than 200 times (Dabrowski & Janikowski, 2018).

Figure 10

Ethereum (ETH) price chart for the time-period (07/08/2015 – 01/02/2021)

In figure 10, the Ether cryptocurrency presents values close to zero starting from the testing period August of 2015 until the 1st of February 2017. At the same time, there appears to be a gradual slow increase of values starting from the last quarter Q4-2016, until Q4-2017. Values suddenly begin to increase intensively only after August 2017 while they reach a peak towards the end of this year. In the early quarter of Q1-2018, a very slow increase seems to be visible until August of 2020. Fluctuations then follow a more normal and steadier pace, when suddenly in Q4-2020 reach at a peak until the 1st of February 2021. The closing values for the structuring of the graph in Figure 10, were retrieved from the website coinmarketcap.com, 2021.

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2.2.3 RIPPLE (XRP)

Ripple was created by Ripple Labs Inc. and was released in 2012. It is a real-time gross settlement system, currency exchange, and remittance system. It is structured on an open-source protocol and accepts tokens that support fiat (paper) currencies, cryptocurrencies, and commodities as well. As of February 1st, 2021, the market capitalization of Ripple was $16,867,989,812 (US), while one (1) XRP was equal to $0.3715. Ripple is the name of a payment clearing system, and its virtual currency unit is called "XRP".

Firstly, Ripple was created and was controlled solely by a private company. Secondly, Ripple was not meant for individual use regarding the purchasing of goods and services, on the contrary, it was created for banks and other financial institutions, mainly involving payment arrangements, currency exchanges, and remittance systems. It is worth mentioning that the business goal of the creators of Ripple was to replace the SWIFT program, used by banking institutions today, to provide security in transactions (Dabrowski & Janikowski, 2018).

Another key difference between Ripple and Bitcoin is that the former does not use Blockchain technology as a decentralized consent mechanism for the validation of transactions through a network of servers. Although XRP uses coins as currencies of exchange, the possibility of their mining is not available as in the case of Bitcoin. Also, the average transaction cost of XRP is currently about 10,000 times lower than in the case of Bitcoin, the trading limit per second is 150 times higher and the trading time is about 3-4 seconds (Dabrowski & Janikowski, 2018). Finally, Ripple uses a negligible amount of electricity compared to Bitcoin.

Figure 11

Ripple (XRP) price chart for the time-period (07/08/2015 – 01/02/2021)
In figure 11, above, the Ripple cryptocurrency presents values very close to zero since the beginning of the investigating period and for two years, from August 2015 until August 2017. The values increase abruptly from Q4-2017, while they reach a peak at the beginning of 2018. Since then (Q1 & Q2 of 2018), there appears to be a continuous decline, where values fluctuate much more smoothly until February 1st, 2021. The closing values for the structuring of the graph in Figure 11, were retrieved from the website coinmarketcap.com, 2021.

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2.2.4 LITECOIN (LTC)

Litecoin was created by Charlie Lee, a computer scientist, a graduate of MIT, and a former Google engineer, and was released in October 2011. It is an open-source Blockchain software program that uses the proof-of-work algorithm as Bitcoin does. It takes only 2.5 (two and a half) minutes for the Litecoin Network to complete a block, which means to fulfill a transaction. As of February 1st, 2021, the market capitalization of Litecoin was $8,761,704,259 (US), while one (1) LTC was equal to $131.95.

The Litecoin (LTC) cryptocurrency was first introduced in 2011 and is considered one of the most important cryptocurrencies after Bitcoin. It is the most common Altcoin. Characteristic is the fact that it became known as "silver to bitcoins gold". It supports a decentralized trading system and uses the Proof-of-Work (PoW) consensus algorithm and script algorithm with a block validation time of 2.5 minutes, a miner gains of 50 LTC, and will continue to be produced until it reaches a total the 84,000,000 LTC. This means that the total amount of Litecoin available for mining and marketing is four times the amount of Bitcoin (Ahmad et al., 2013).

The Litecoin blockchain was part of the Bitcoin blockchain but split when Litecoin was updated. So, while one would say that it is like Bitcoin, it has some completely different characteristics from that and the main reason for its creation was to improve the weaknesses that Bitcoin had. Litecoin is the first cryptocurrency to be used by the Lighting Network, which resolves many cryptocurrency issues, such as scalability, allowing Litecoin to process many more transactions per second. The advantage of using Litecoin is that it is faster and much cheaper than Bitcoin. More specifically, Litecoin transactions only take a few seconds, while a Bitcoin transaction takes 10 minutes.

Also, while Bitcoin transactions can be costly, which makes them pointless for sending small amounts, in the case of Litecoin the cost is much lower. And since Litecoin trading is much cheaper, Litecoin is considered much better for micropayments, which is why it has been nicknamed "Lite" (Ahmad et al., 2013). Litecoin is still only a small temporary improvement over Bitcoin. If Bitcoin improves in the future, so that it can scale and offer cheaper and faster transactions, there may not be much need for Litecoin.
In figure 12, the Litecoin cryptocurrency presents also values very close to zero for almost two years. At the beginning of Q4-2017, there seems to be a rather quick uplift, while Litecoin reaches a peak towards the end of Q4-2017 and the beginning of Q1-2018. Following these events, a decline is obvious until year-end 2018. Finally, intense fluctuations characterize the values of Litecoin until 01/02/2021. The closing values for the structuring of the graph in Figure 12, were retrieved from the website coinmarketcap.com, 2021.

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2.2.5 MONERO (XMR)

Monero was created by Nicolas Van Saberhagen and was released in April 2014, while it represents a private’s network decentralized cryptocurrency, which uses a Proof-of-Work consensus algorithm for the authentication of its transactions. Monero uses an open ledger, however, its transactions are untraceable and not visible to anyone outside the network. It takes two (2) minutes for a block to be built in the chain. As of February 1st, 2021, the market capitalization of Monero was $2,562,614,383 US, while one (1) XMR was equal to $143.74.

Monero was firstly used for transactions that were not legitimate, thus it has caused many reactions and controversy. It was mostly used for purchases on the Dark Web. In July 2017, there was enforcement by law that shut down two darknet markets. Since then, Monero has created its values which are decentralization, security, and privacy.

Monero is mainly a private Cryptocurrency, which uses the appropriate technologies to ensure its structure. More explicitly, its main characteristics are RingCT which is a way
to hide the amount sent to each Monero transaction, **Stealth Addresses**, which is a unique (one-time) address for every Monero transaction. Some other enhancing technologies for Monero cryptocurrency, are Ring Signatures, Transactions over Tor/I2P & Dandelion++. ([https://www.getmonero.org/](https://www.getmonero.org/), 2021).

**Figure 13**

Monero (XMR) price chart for the time-period (07/08/2015 – 01/02/2021)

In figure 13, the Monero cryptocurrency presents values too close to zero since the beginning of August 2015. A year later, there is a point of a slow rise in Monero’s values, which show gradually a slight growth until Q3-2017. During Q4-2017 there seems to be a crucial point for Monero, where values reach their peak abruptly. At the beginning of Q1-2018, values start to decrease & immediately increase sharply until Q3 of the same year. Small fluctuations then follow until 01/02/2021. The closing values for the structuring of the graph in Figure 13, were retrieved from the website coingecko.com, 2021.

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In a conclusion, cryptocurrencies have, so far, shown high volatility in their prices, with sharp ups and downs repeatedly, while this phenomenon depends mostly on their “crazy” demand from a certain party of investors & network users. These underlying circumstances have led to the creation of many “bubbles” starting from Bitcoin while affecting the other cryptocurrencies as well. Especially during 2017 & 2018, the fluctuations in their prices follow the same patterns in most of them, while this is depicted in the graphs from the study analysis of the historical prices in each and one of them separately. This common element is the evidence of the “bubbling behavior” starting from Q2-2017 and lasting until Q2-2018. Also, the launch of Bitcoin Futures in December 2017 has affected their prices as well.

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2.3 CRYPTO CURRENCIES AND REGULATIVE ISSUES

The issue about Cryptocurrencies is that there is no power of control over their creation, use, exchange, and purchase by any regulatory authority or policymaker. This serious issue against cryptocurrency markets, this unregulated system, creates leaks of fraud, manipulation of cryptocurrencies values, illegal purchases, etc.

On the other hand, its payment system structure and technology are rather revolutionary for traditional financial institutions and banks to follow. This is owed to Blockchain Technology. However, nowadays digital economy is taking its accession, by digital banking, which is showing new customer service experience, in such a way that many banking branches are becoming to shrink giving space to digital banking & marketing services to expand.

Furthermore, there are many banking institutions, that are willing to adopt Blockchain Technology or have already adopted it and implement it in their systems. This does not mean that they will also adopt cryptocurrencies as financial assets for investment strategies. Since banks’ policies are structured under requirements to know their customer and work under the anti-money laundering procedures, some guidelines and acts protect their customers and prevent others from fraudulent events, forgery, non-transparent transactions, and ambiguous purchases.

On the other hand, due to this intelligent technological concept, some speculators tried to take advantage of Blockchain Technology and thus created fake Cryptocurrencies to gain profits illegally. It is so much known in the Cryptocurrency markets the case of “One, Coin” and the violators behind it who committed a big fraud and stole from many families and young people who wished to invest in their education. For further information about this fraudulent event, one could just search very easily on the world wide web. (https://www.bbc.com/news/stories-50435014).

The main issue about the use of Cryptocurrencies is trust. People who do not have the knowledge or the expertise about the meanings, the uses, the implications of exchanging their traditional currency with virtual currencies would better not get involved in such endeavors. The Center of International Governance Innovation (www.cigionline.org), presents the role of governance in cryptocurrencies in the below very interesting video: https://www.youtube.com/watch?v=SWghXzC_9NA

In conclusion, for the use of Cryptocurrencies as a medium of exchange, like national currencies, many factors must be resolved while a new regulatory framework is required. The IRS (the United States Internal Revenue Service, 2014) states that: “in some environments, virtual currency operates like a “real” currency..., but it does not have legal tender status at any jurisdiction”. There must be considered some specific criteria
for the integration of cryptocurrencies under a common regulatory framework. There are many unresolved issues to be assessed and reconsidered, such as taxation, exchange rates among cryptocurrencies & national currencies, limitations in the market share, monetary stability. (Mandeng, 2018). This is a lot of work among the governments, the policymakers, the controlling authorities, and the respected cryptocurrency markets involved widely.

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CHAPTER 3

3.1 MODERN PORTFOLIO THEORY (MPT)

Markowitz Harry in 1952 pioneered the efficient frontier of the optimal portfolios, while James Tobin in 1958 introduced the risk-free rate to Modern Portfolio Theory. William F. Sharpe in 1960 developed the CAPM. In 1990 Markowitz, Sharpe and Miller won a Nobel prize for their contribution to the fields of finance & economics.

Modern portfolio theory assumes that an investment's risk and return, should not be examined separately, but should be evaluated holistically by how the investment affects the portfolio's risk and return in an overall perspective. The main purpose of MPT is the construction of a portfolio, which is composed of multiple assets that will maximize its return for a certain level of risk. In other words, given a certain level of expected return, which is desired by an investor, a portfolio can be constructed with the lowest risk possible.

Variance and Correlation are two basic statistical measures of an investment portfolio. The return of the portfolio is less important than how the investment behaves in the context of the entire portfolio, meaning whether it is a highly risky or a less risky investment. The main assumption of MPT is that investors are risk averse. Investors prefer a less risky portfolio to a riskier one, for the same level of return. This implies that an investor’s strategy is based on rationalism, meaning that the higher risk will compensate for higher returns as well.

The expected return of a portfolio is calculated as a weighted sum of each assets’ returns. If a portfolio’s components are five equally weighted assets (20 percent *5=100 percent), with expected returns of 3 percent, 6 percent, 8 percent, 10 percent, and 14 percent, the portfolio’s expected return would be:

\[(0.03 \times 20\%) + (0.06 \times 20\%) + (0.08 \times 20\%) + (0.10 \times 20\%) + (0.14 \times 20\%) = 8.2\%\]
The portfolio’s risk is calculated by the variances of each asset and the correlations of each pair of assets. To calculate the risk of a five-asset portfolio, an investor needs each of the five assets’ variances and ten correlation values. There are ten possible two-asset combinations with the five assets. Due to the correlation of the assets in the portfolio, the total portfolio’s risk (standard deviation), will be lower than what would be calculated by a weighted sum. (Information is retrieved and processed by the author from the Investopedia web page).

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3.2 THE EFFICIENT FRONTIER

The efficient frontier theory was introduced by Nobel prized Harry Markowitz in 1952 and is a cornerstone of modern portfolio theory. According to Markowitz’s theory (Markowitz H. 1954), there are two main criteria, risk, and return. Known as the Markowitz efficient set, the optimal risk-return combination of a portfolio lies on an efficient frontier of maximum returns for a given level of risk based on mean-variance portfolio construction.

Every possible combination of assets that exist can be plotted on a graph, with the portfolio's risk on the axis of X and the expected return on the axis of Y. This plot reveals the most attractive portfolios. For instance, Portfolio A has an expected return of R(p)=8.2% and a standard deviation of \( \sigma(p) = 8\% \), and Portfolio B has the same expected return of R(p)=8.2% and a standard deviation of \( \sigma(p) = 9.5\% \). Portfolio A would be perceived as more "efficient" than Portfolio B because it has the same expected return but lower risk.

The efficient frontier is constructed by connecting the most efficient portfolios, which are represented as combinations of low risks and high returns. This connection draws a curve in the graph. Investing in any other portfolio, not on this curve is not at all desirable.

The efficient frontier is the set of optimal portfolios that offer the highest (expected) return for a desired level of risk. Otherwise, the efficient frontier is the set of optimal portfolios that offer the lowest risk for the desired level of (expected) return. Portfolios that lie below the efficient frontier are not optimal, as they do not provide enough return for their level of risk. Portfolios that are gathered to the right of the efficient frontier are not optimal as they have a higher level of risk for the return they offer. More specifically:

- The efficient frontier comprises investment portfolios that result in the highest (expected) return for an acceptable level of risk.
• Returns are dependent on the investment combinations that consist of the portfolio.
• Lower covariance between the portfolio’s assets results in lower portfolio standard deviation, as this means less risk.
• Successful optimization of the return against risk places a portfolio along the efficient frontier line.
• Optimal portfolios that comprise the efficient frontier are very well to ideally diversified.

(Information is retrieved and processed by the author from the Investopedia web page).

3.3 MARKOWITZ PRICING MODEL

The Markowitz Pricing Model is based on the following principles:

• Valuing the securities that might be included in the portfolio.
• Calculating the desired asset allocation (or a mix of assets).
• Performing calculations to optimize the portfolio to get the maximum amount of return for the minimum amount of risk.
• Using financial analysis to monitor the portfolio to see if it meets expectations and then making changes to the individual financial assets or asset mix when market conditions warrant a change.

Modern Portfolio Theory (MPT) states that adding assets to a diversified portfolio that has low correlations, can decrease the portfolio’s risk without sacrificing return. (Dioskogiannis G., 2019). Diversification helps to improve the portfolio’s gain versus risk profile. The risk cannot be eliminated but decreased. Moreover, adding more risk to a portfolio does not gain an equal amount of return. **Optimal portfolios with high diversification comprise the efficient frontier, in contrast to the not-optimal ones which are not very well diversified.** According to Markowitz's theory, there is an optimal portfolio that could be structured by balancing risk and return. The optimal portfolio aims to balance financial assets with the greatest potential returns with an acceptable degree of risk, or financial assets with the lowest degree of risk for a given level of potential return.

One assumption in investing is that a higher degree of risk means a higher potential return. A risk-seeking investor, who is tolerant of high risk, invests in financial assets that are set on the right end of the efficient frontier, expecting respectively high returns. On the other hand, investors who take on a low degree of risk have a low potential return. These are risk-averse investors who seek financial assets that are set on the left end of the efficient frontier. **According to Markowitz’s theory, the following controversial issues are in question:**
• Investors are rational, whereas most of the times they act rather irrationally,
• Investors try to avoid risk when possible, although reality proves that the market includes risk-seeking investors who wish high gains (speculators),
• There are not enough investors to influence market prices, however, there are large market participants who could influence market prices,
• Investors have unlimited access to borrowing and lending money at the risk-free interest rate, on the other hand, some investors do not have unlimited access to borrowing and lending money.

(Information is retrieved and processed by the author from the Investopedia web page).

3.4 MARKET MODEL OR SINGLE INDEX MODEL

It assumes that there is only one single macroeconomic factor that causes a systematic risk that affects the returns of all Financial Assets in the Market and this can be represented by the market index. According to this model, the return of a stock R(it) is analyzed by the expected return of this only stock due to the “firm’s specific risks” denoted by the alpha coefficient “αi”, also due to the macroeconomic market risks “βi*R(mt)” that affect the market (such as interest rates, labor issues, etc) and finally due to microeconomic unexpected factors (unsystematic risks) that affect the company itself “e(it)”, such as sudden changes in the company’s management. William F. Sharpe (Sharpe F.W. 1964), introduced the model which supported his theory of market equilibrium under conditions of risk. The return R(it) on a Financial Asset e.g., of a stock (i) at the time (t) depends on the return of a market portfolio/index R(mt) at time t plus an error term at random e(it).

Equation 1

\[ R(it) = \alpha_i + \beta_i * R(mt) + e(it) \]

The “α” term represents an intercept while “β” shows the size of market risk in the relationship between the Financial Asset and the Market portfolio/index.

Equation 2

\[ \beta = \text{cov}(ri, rm) / \sigma^2 m \]
Regarding a portfolio of financial assets, formula 1, is transformed with the below form of the equation:

\[ E(R_p) = \alpha p + \beta p * E(r_m) \]

In particular,

- \( E(R_p) \) represents the expected returns of the investor’s portfolio \( p \).
- \( E(R_m) \) represents the expected returns of the market portfolio \( m \).
- \( \alpha p \) = the weighted average of the alpha terms of the financial assets included in the portfolio,

\[ \alpha p = \Sigma w(i) * \alpha(i) \]  

- \( \beta p \) = the weighted average of the beta terms of the financial assets included in the portfolio,

\[ \beta p = \Sigma w(i) * \beta(i) \]

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The Single Index Model helps to limit many calculations that would have been made in the case of a large portfolio while it is based on the following terms:

- Most of the stocks in the portfolio have a positive covariance because they all respond similarly to macroeconomic factors.
- Some of the firms are much sensitive to the macroeconomic factors, while this firm-specific risk (variance) is being compared with the market’s risk (variance) for one or more economic factors.
- Risks (covariances) among Financial Assets derive from different responses to the macroeconomic factors. (Diakogiannis G., 2019).

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### 3.5 CAPITAL ASSET PRICING MODEL (CAPM)

The Capital Asset Pricing Model (CAPM) depicts the relationship between market risk (systematic risk) and the expected return of a financial asset. CAPM consists of a rather simple and clear financial tool, therefore it has become the most widely accepted.
The formula of the CAPM is:

\[
E(\text{ri}) = Rf + \beta_i \times [E(\text{rm}) - Rf]
\]

or

\[
E(\text{ri}) = Rf + \beta_i \times (\text{Mrp})
\]

where:
- \(E(\text{ri})\) = Expected return of an investment in a financial asset (i),
- \(Rf\) = Risk-free rate,
- \(\beta_i\) = Beta coefficient (risk) of the financial asset (i),
- \(E(\text{rm}) - Rf\) = Market risk premium (Mrp), expected return of the market abstracted by the risk-free rate.

The Risk-free rate bears no risk for the investment, whereas the other components of the equation calculate the excess risk that the investor is willing to take over. Particularly \(\beta_i\) represents the financial asset’s beta multiplied by the Market risk premium. The Market risk premium is the return of the Market above the Risk-free rate.

The beta (\(\beta_i\)) is the main measurement of a financial asset’s risk concerning the average risk of the market. In case the financial asset has a beta greater than one (1), this means that the asset is adding risk to the investment portfolio. On the other hand, when the financial asset has a beta of less than one (1), this means that the asset is reducing risk from the invested portfolio. The result of the CAPM formula shows the value of a financial asset (i), via its expected return at an investment.

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3.6 CAPM & THE EFFICIENT FRONTIER

CAPM and the Efficient Frontier could help an investor construct a portfolio at a manageable level of risk with an optimal return. CAPM represents the line that has as a starting point on the axis of y the risk-free rate of return, while it is tangible with the efficient frontier at a certain point of its curve. This tangency point represents all optimal portfolios that offer the highest expected return for a specific level of risk or the minimum risk for a specific level of expected return. (Investopedia,2020)

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3.7 CAPITAL MARKET LINE (CML)

The Capital Market Line depicts the relationship between the expected return of an investment and its risk, while it is applied only for optimal portfolios. This is a linear and positive relationship only if the Market Portfolio “m” is without saying optimal. The CML includes Risk-free rate investments.

Investors could lend or borrow money at the risk-free rate, above the market’s optimal portfolio “m” investors borrow from the risk-free rate, whereas between the risk-free and the market’s optimal portfolio “m” investors tend to lend at the risk-free rate. The measurement of risk in CML is the standard deviation of returns, this is the total risk (systematic & unsystematic risk). The CML depicts the expected return for a specific portfolio compared to the Market’s efficient portfolios. The CML contains all the optimal portfolios. (Diakogiannis G., 2019).

- There is a point “s” of an efficient portfolio on the CML → \( \frac{E(R_s) - R_f}{\sigma_s} \).
- There is a point “m” of the Market portfolio, without saying efficient, on the CML → \( \frac{E(R_m) - R_f}{\sigma_m} \).

\[
E(R_s) = R_f + \left( \frac{\sigma_s}{\sigma_m} \right) (E(R_m) - R_f)
\]

This is the **Risk Premium** that the investor takes over to be protected by the volatility/riskiness of portfolio “s”. **Furthermore, the characteristics of the expected return and the risk of the Portfolio “s” is calculated as follows:**

\[
E(R_s) = E(W_f * R_f + W_m * R_m)
\]

In particular,

\( W_f + W_m = 1 \) or 100% total portfolio Weights.

**Return Calculation:** The return of the portfolio “s” is the linear function of “f” and “m”, where the weights sum up in unit 1. The expected risk and return of the efficient portfolios are shown as follows:

\[
E(R_s) = E(W_f * R_f + W_m * R_m)
\]
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Equation 12

\[ E(R_s) = W_f \times R_f + W_m \times E(R_m) \]

The expected return of the efficient portfolio “s” is the weighted average of the expected returns of the Risk-free rate “f” and the Market’s efficient Portfolio “m”, where the weights are summing up to unit 1.

**Risk Calculation:**

Equation 13

\[ R_s = W_f \times R_f + W_m \times R_m \]

Equation 14

\[ \sigma^2(R_s) = \sigma^2(W_f \times R_f + W_m \times R_m) \]

Equation 15

\[ \sigma^2(R_s) = \sigma^2(W_f \times R_f) + \sigma^2(W_m \times R_m) + 2 \times \text{Cov}(W_f \times R_f, W_m \times R_m) \]

The assumption is that the Risk-free rate bears no risk, so it is counted as a fixed zero term, leading to the following conclusion:

Equation 16

\[ \sigma^2(R_s) = \sigma^2(W_m \times R_m) \]

Equation 17

\[ \sigma^2(R_s) = W_m^2 \times \sigma^2(R_m) \]

Equation 18

Equation 19

\[ \sigma(R_s) = W_m \times \sigma(R_m) \]

Taking into consideration the above equations, the value of the CML is being proved, by the below paradigm, (Diakogiannis G., 2019):

Assumptions:

- \( R_f = 3\% \), \( E(R_m) = 9\% \) & \( \sigma_m = 0.07 \)
- Portfolio “s” with invested capital $10,000 (US), is constructed with weights \( W_m = 50\% \), \( W_f = 50\% \), where \( W_m = $5,000 \) & \( W_f = $5,000 \).

Answer:
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1. \( E(R_s) = W_f * R_f + W_m * E(R_m) \)

\[
E(R_s) = W_f * R_f + W_m * E(R_m) = 50\% * 3\% + 50\% * 9\% = (0.50) * (0.03) + (0.50) * (0.09) = 0.06 \text{ or } 6\%.
\]

2. \( \sigma(R_s) = W_m * \sigma(R_m) \)

\[
\sigma(R_s) = W_m * \sigma(R_m) = 50\% * 0.07 = 0.035 \text{ or } 3.5\%.
\]

The expected return of the portfolio is 6% while its risk is 3.5%.

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The Capital Market Line is not only based on Markowitz’s Theory but is also becoming more extensive by the below assumptions:

- The investors are based on Markowitz’s analysis theory,
- The investors choose the same investing period,
- There is a Risk-free asset, at which investors can either lend or borrow money.
- The Market is perfect, meaning that:
  i) There is no inflation,
  ii) There are no taxes, interests, or fees,
  iii) The information about investment opportunities costs no money, while it appears to be the same for all investors,
  iv) There is not anyone investor, who can affect the prices of the financial assets.

On the other hand, the afore-mentioned assumptions seem rather idealistic:

- Efficient Portfolios are assessed on the grounds of minimum risk, according to Markowitz,
- The same investing period for all investors is not at all a realistic scenario,
- To borrow or lend money with the Risk-free rate is not at all a realistic scenario,
- The assumption of the perfect Market conditions does not exist. The efficient Market consists of an approach of the perfect Market, so balance is achieved.

In conclusion Portfolios on the Capital Market Line optimize their relationship between risk and return, by achieving maximization of performance. There is an allotment of risk-free assets and risky portfolios. Therefore, the CML is the Sharpe Ratio of the market portfolio. An investor could buy assets if the Sharpe Ratio is above the CML and sell assets in case the Sharpe Ratio is below the CML. (Diakogiannis G., 2019).

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3.8 SECURITY MARKET LINE (SML)

The Security Market Line comes from the Capital Market Line. The SML depicts the market’s risk and returns at a specific time while it shows the expected returns of individual assets. The measurement of risk in the SML is the systematic risk or the beta. The SML contains all the priced financial assets. When a financial asset is above the plot of the SML, it means that its returns are too high for the given level of risk and this makes it underpriced. When a financial asset is below the plot of the SML, it means that its returns are too low for the given level of risk and this makes it overpriced.

3.9 THE THREE EFFICIENCY MEASUREMENTS

3.9.1 SHARPE RATIO

The first efficiency measurement is the Sharpe ratio that was developed in 1966, by the American Economist William Forsyth Sharpe (16/06/1934), emeritus professor at Stanford University. A pioneer in his field, Sharpe has won the Nobel Memorial Prize in Economic Science in 1990 and has written many books such as “Portfolio Theory and Capital Markets” in 1970 & 2000, “Introduction to Managerial Economics” in 1973, “Investments” in 1978 and many more.

The Sharpe Ratio is used for investors to measure the return of an investment in comparison to its risk. This means that the ratio is the average return earned more than the risk-free rate per unit of total risk or portfolio’s volatility according to the price fluctuations of its components.

Subtracting the risk-free rate from the mean return allows an investor to better assess the gains derived from the activities that contain an amount of risk. The risk-free rate of return is the return on investment with zero risks, meaning it is the return investors could expect for taking no risk. The investors are risk averse as they wish to get high profits with no risk if possible, while they know very well indeed that risk entails cost. This is an oxymoron belief about investors.
**SHARPE RATIO** is based on the Security Market Line (SML). The formula is calculated as follows:

\[
\frac{E(R(p)) - R_f}{\sigma(p)}
\]

*Equation 20*

Where:
- \( E(R(p)) \) = return of portfolio
- \( R_f \) = risk-free rate
- \( \sigma(p) \) = standard deviation of the portfolio’s excess return

Analytically:

The risk-free rate is subtracted from the mean (expected) return of the portfolio. The risk-free rate could be for instance a 3-month Treasury Bill rate, a 2-year or a 10-year Treasury Bond rate, or yield depending on the investor’s strategy plan. The result is divided by the standard deviation of the portfolio’s excess return. The standard deviation shows how much the portfolio's return deviates from the expected return. The standard deviation also indicates the portfolio's volatility.

The Sharpe ratio adjusts a portfolio’s performance, or expected future performance, for the excess risk that was taken by the investor. This is being compared to the respective ratio of a market index (m).

\[
\frac{E(R(p)) - R_f}{\sigma(p)} = \frac{E(R_m) - R_f}{\sigma(m)}
\]

*Equation 21*

**I.** When \( \frac{E(R(p)) - R_f}{\sigma(p)} = \frac{E(R_m) - R_f}{\sigma(m)} \)
then the investment’s returns are equal to these of the market index, (Security Market Line).

*Equation 22*

**II.** When \( \frac{E(R(p)) - R_f}{\sigma(p)} > \frac{E(R_m) - R_f}{\sigma(m)} \)
then the investment’s returns are better than these of the market index, (Security Market Line).

*Equation 23*

**III.** When \( \frac{E(R(p)) - R_f}{\sigma(p)} < \frac{E(R_m) - R_f}{\sigma(m)} \)
then the investment’s returns are less than these of the market index, (Security Market Line).

A high Sharpe ratio is good when compared to similar portfolios of the market sector with lower returns. **Generally, the greater the value of the Sharpe ratio, the more attractive the risk-adjusted return.** (Diakogiannis G., 2019). The Sharpe ratio has become the most widely accepted model for calculating the risk-adjusted return of an investment. According to Modern Portfolio Theory, adding assets to a well-diversified
portfolio, with low correlations, can significantly decrease the portfolio’s risk without sacrificing return.

Diversification plays a very essential role when creating a Portfolio of assets, while it increases the Sharpe ratio compared to other similar portfolios with a less diversified level. This helps investors to accept the assumption that risk equals volatility, depending on the amount of risk that they are willing to take.

The Sharpe ratio can be used to evaluate either a portfolio’s past performance where actual returns (ex-post) are used in the formula or to estimate an expected portfolio’s performance, based on forecasted results (ex-ante) and the expected risk-free rate as well. The Sharpe ratio explains whether a portfolio's excess returns are due to clever investment decisions or a result of risky decisions that obtain high gains. A good investment is the one that results in high returns which do not stem from an excessive amount of additional risk.

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3.9.2 TREYNOR RATIO

The second efficiency measurement is the TREYNOR RATIO, which is based on the Single Price Index Model \[ r(it) = \alpha + \beta * r(mt) + e(it) \] \& the Capital Asset Pricing Model (CAPM) \[ E(ri) = Rf + \betai * (E(rm) - Rf) \], as far as the portfolio’s beta \( \beta(p) \) is concerned in correlation with the beta of the rest of the market sector \( \beta(m) \), as described above, in previous paragraphs 3.4 & 3.5

Beta is a measure of an investment's volatility and risk as compared to the overall market. The goal of the Treynor ratio is to determine whether an investor is being compensated for taking additional risk above the inherent risk of the market.

The formula is calculated as follows:

\[
\frac{E(R(p)) - Rf}{\beta(p)}
\]

where:
- \( R(p) \)=return of portfolio
- \( R(f) \)=risk-free rate
- \( \beta(p) \)=beta coefficient (risk) of the portfolio’s excess return

The TREYNOR RATIO formula is the return of the portfolio less than the risk-free rate, divided by the portfolio’s beta. (Diakogiannis G., 2019)

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3.9.3 JENSEN RATIO

The third efficiency measurement is the JENSEN RATIO which is based on the Capital Asset Pricing Model (CAPM) and the Single Price Index Model, during period (t). (Diakogiannis G., 2019). The formula is calculated as follows:

\[ R(pt) = R_f + [R(mt) - R(f)] \times \beta(p) \]

where:
- \( R(pt) \) = return of portfolio in time (t)
- \( R(f) \) = risk-free rate
- \( R(mt) \) = return of market sector in time (t)
- \( \beta(p) \) = beta (risk) of the portfolio’s excess return

\[ \star \star \star \] ~*~*~

CHAPTER 4

4. LITERATURE REVIEW


On March 9th, 2018 Yanuar Andrianto and Yoda Diputra have published their research in the Journal of Finance and Accounting. Their study aimed to find the effects of Cryptocurrency on well-formed portfolios. Cryptocurrency offers a small transaction fee while its price movements become volatile. The components of their portfolios were assets such as Foreign Currency, Commodity, Stocks, and Exchange Traded Funds (ETF). The Cryptocurrency they used was Bitcoin, Ripple, and Litecoin, which appear to have the largest trading volume. The data used is based mostly on weekly and monthly prices.

For their research, they created four investment portfolios. The first one consisted of both Foreign Currency and Commodity, the second one was a portfolio comprising a pool of Stock assets and the third one was a portfolio of ETFs. The fourth portfolio was a combined portfolio of the best-performing assets in each portfolio. The risk-free rate used in each of the above portfolios was a 3-month US Treasury Bill.

The portfolio that the researchers created was mixed, consisted of some of the best-performing assets and Cryptocurrency as well. This mixed portfolio showed the best performance among the other portfolios. While the allocation of selected assets was
the allocation that produced the largest Sharpe Ratio, also higher return, and lower standard deviation (risk).

According to their study, they showed that Cryptocurrency increases the effectiveness of the portfolio in two ways. The first is by minimizing the standard deviation (risk) and the second is by creating more allocation options for investors to choose from. The optimum allocation of Cryptocurrency is from 5% to 20%, depending on the risk tolerance of the investor, to get a good Sharpe Ratio. The higher the Sharpe Ratio the better the return but not necessarily the optimal portfolio diversification.

Modern Portfolio Theory has proven to be quite effective as a foundation in the establishment of this portfolio. Based on a brief analysis it appears that the formation of a portfolio including Cryptocurrency has been able to beat the performance of the S&P500 and Dow Jones indexes. (Andrianto & Diputra, 2018). In conclusion, this study showed that Portfolios including Cryptocurrency perform better, so investors would choose to include Cryptocurrency for diversification of their assets, especially those with a high-risk tolerance.

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In their research, they tried to analyze whether an investor, who holds a well-diversified portfolio of stocks, may benefit from investing in Cryptocurrencies, in the market of “digital assets”. In other words, they tried to contribute to the debate on the role of Cryptocurrencies on diversified portfolios with “traditional assets”.

For this reason, they focused their analysis on several capital markets (22 countries of developed and developing economies) and the four most liquid cryptocurrencies (Bitcoin, Ethereum, Litecoin, Ripple). They used country-specific stock market indices and risk-free rates.

According to their results, for most countries, cryptocurrencies fit in the tangent portfolio (maximum Sharpe Ratio), but no – or very little – in the minimum variance portfolio (MVP). Furthermore, the results indicated that Cryptocurrencies’ returns are riskier, but their co-movements with global stock indices, on average, are close to zero. Globally they found that the optimal holding of Cryptocurrencies is represented by Bitcoin (BTC) only, and at a 4.6% share of the portfolio. It is considered that there is no short selling in the portfolio.
Their optimization exercises show that the optimal weight of Cryptocurrencies on the tangent portfolio is extremely sensitive to the period being analyzed. The information is based on the daily prices of cryptocurrencies and stock market indices with a final date as of May 31st, 2019. The results of their research showed that Cryptocurrencies may enhance the performance of global stock portfolios by allowing higher risk-adjusted returns, which was due to higher average returns rather than risk reduction.

Finally, in their research, it is argued that Cryptocurrencies, though appealing to investors, however, they face many challenges, such as the difficulty in evaluating the intrinsic value of these assets as well as in finding a way to regulate their transactional circuit. Not to mention, also, the fact that many fraudulent events have been registered in the Cryptocurrencies ecosystem.

According to their findings, a minority of investors use them as currency. No consensus in the literature implies that Cryptocurrencies are used as currency, in case this was so, Cryptocurrencies would compete with fiat currencies and influence their value as well.

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Liu Weiyi in her paper at Finance Research Letters, examined the role of diversification in the cryptocurrency market, while evaluated the out-of-sample performance of commonly used asset allocation models across cryptocurrencies. The empirical data of ten major cryptocurrencies (Bitcoin, Ethereum, Ripple, Litecoin, Stellar, Monero, Dash, Tether, Nem, Verge) were utilized.

The out-of-sample method means that the parameters involved in the models are estimated via a “rolling window” at each rebalancing date instead of using the entire sample (the in-sample method, which cannot reflect the real investment decisions, is rather a theoretical one and not realistic). Six classical portfolio selection models were applied through the out-of-sample evaluation method. These are the following:

i. 1/N Equally Weighted (EW),
ii. Minimum Variance model (MV),
iii. Risk Parity (RP),
iv. Markowitz optimal portfolio (MW),
v. Maximum Sharpe Ratio (MS),
vi. Maximum utility model (MU)

“We showed that portfolio diversification across different cryptocurrencies can significantly improve the investment results. We also found robust evidence that the
maximum utility model dominates the out-of-sample utility, although none of the models can consistently beat the naïve 1/N portfolio in Sharpe Ratio”, (Liu, 2018)

According to the study, the cryptocurrency dataset covered 977 trading days in total, starting from August 7th, 2015 until April 9th, 2018. They collected those cryptocurrencies whose market capitalization was larger than 1 billion US Dollars ($). They first investigated the performance of individual cryptocurrencies. They calculated the mean, the volatility, the annualized return, the maximum draw-down, the Sharpe Ratio, and the Utility of each cryptocurrency.

Compared to the individual results for each cryptocurrency they observed that the Sharpe Ratio and utility of portfolios were greatly increased, implying that diversification across cryptocurrencies enhanced the investment results. Most cryptocurrencies had a considerably high return, Sharpe ratio, and utility. This stylized fact inspired the research team to further investigate the investment values of cryptocurrencies. Among the ten cryptocurrencies, Bitcoin performed in a relatively lower reach compared to the newly issued cryptocurrencies, e.g., Nem and Verge. Tether seemed quite different from others while it was like a traditional currency with a flat trend of prices.

Furthermore, they examined the combination of cryptocurrencies by designing the efficient frontier of the portfolios under the short-selling constraints. Tether and Verge were located on the efficient frontier, representing the lowest volatility and highest expected return among all the cryptocurrencies, respectively. The maximum Sharpe ratio and maximum utility could be achieved on the efficient frontier, through reasonable asset allocation across the cryptocurrencies. The relatively low correlations among different cryptocurrencies indicate that there is a benefit by combining several cryptocurrencies into a portfolio.

The minimum variance model achieved the smallest out-of-sample volatility, less risky with the maximum draw-down, but performed less attractive in Sharpe Ratio and utility. The maximum utility model attained the highest out-of-sample return and utility. The maximum utility model did not maximize the out-of-sample Sharpe Ratio. None of the sophisticated models could beat the naïve 1/N rule in the criterion of the Sharpe Ratio, due to estimation error of the mean estimator ($\mu^*$).

According to the research of Liu Weiyi and her team, the complexities of the cryptocurrency market are far from fully explored. The results in their research paper indicate that the estimation error in mean and covariances may offset the gains from optimal diversification, raising a problem about how to improve the estimation with sufficiently considering the stylized facts of cryptocurrencies.

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In their research article at the Economics Letters, Emmanouil Platanakis and his research team examined the diversification benefits of cryptocurrencies by employing weekly data for four popular cryptocurrencies (Bitcoin, Litecoin, Ripple, and Dash). They showed little difference between the performance of naïve (1/N) and optimal (Markowitz) diversification in a portfolio, while they based their results on different levels of risk-aversions and estimation windows.

Moreover, they referred to the literature that has been written regarding the method of optimal diversification and whether this could outperform the naïve method diversification. They supported the findings of De Miguel et al. (2009), who showed that employing estimated means and variances performs worse than a naïve strategy of simply holding equal positions in every asset (1/N). On the other hand, Ackermann et al. (2017) showed that mean-variance analysis did outperform the naïve 1/N strategy in currency markets since interest rates provide a predictor of future returns that are free of estimation error.

Emmanouil Platanakis and his research team added to the above debate by examining the performance of optimal and naïve diversification in Cryptocurrency markets. The results showed a very little difference in terms of expected returns, Sharpe ratio, and Omega ratio (gain-loss ratio, the ratio of the average gain to the average loss) between naïve diversification and optimal diversification indicating that the gain from optimal diversification is more than offset by estimation error, consistent with the findings of De Miguel et al. (2009) for equities.

In conclusion, according to their empirical results, they reported that in terms of the Sharpe and Omega ratios, while enabling the short selling, there proved to be little difference between the naïve (1/N) and the optimal diversification.

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Alexander Brauneis and Roland Mestel published their research on Finance Research Letters, related to Cryptocurrency portfolios in Markowitz’s mean-variance framework. They used daily data for the period between (01/01/2015 – 31/12/2017) of the 500 most capitalized cryptocurrencies, while they related risk and return of different mean-variance portfolio strategies to single cryptocurrency investments and two benchmarks,
the naively diversified portfolio and the CRIX (a market capitalization-weighted cryptocurrency index). They used the out-of-sample analysis with the below portfolio strategies:

i. Naively diversified (1/N), equally weighted portfolio of all cryptocurrencies at time t.
ii. Cryptocurrency Index (CRIX), value-weighted cryptocurrencies index.
iii. Bitcoin optimized (BTC\_\text{opt}), maximum return due to Bitcoin’s volatility.
iv. Tangency portfolio (PFT), the portfolio with the highest Sharpe ratio given a zero risk-free rate.
v. Maximum return (max R), one single cryptocurrency featuring the highest return over the past f days at time t.
vi. Minimum Variance Portfolio (MVP), cryptocurrencies portfolio featuring the lowest achievable risk.
vii. Efficient Frontier Portfolios, portfolios along with the efficient frontier are differing concerning the mean return.

According to their research paper, there has been empirical evidence in the literature that Bitcoin and other cryptocurrencies are extremely volatile assets with a bubble behavior. Sharp fluctuations in their prices have been detected during recent years (2013 – 2018) of their existence. Moreover, discrete daily returns point at high mean and high volatility. However, due to their liquidity cryptocurrencies are a good investment for a diversified cryptocurrency portfolio as a means of mitigating risk exposure in cryptocurrency markets. Their results showed that an equally weighted portfolio might be the best choice in building a cryptocurrency-only portfolio. The 1/N portfolios yield the highest returns.

Analytically, the 1/N portfolios seem to have superior risk-return patterns compared to the optimized portfolios. Furthermore, they investigated this point by comparing the Sharpe Ratios as well as the certainty equivalent returns of all portfolio strategies in the different parameterizations previously described. In line with the previous considerations, the 1/N portfolios outperformed mean-variance optimal portfolios as well as individual cryptocurrencies. It turned out that the minimum Sharpe Ratio of all 1/N portfolios exceeded the Sharpe Ratios of more than 75% of the optimal portfolios. The average Sharpe Ratio of the 1/N investments was also higher than that of the CRIX.

In conclusion, this was the first study to investigate the effects of diversified cryptocurrency investments in a traditional Markowitz mean-variance framework. The results showed that there is substantial potential for risk reduction when several cryptocurrencies are mixed.

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In their research in 2017 (Economics Letters), they studied the tail behavior of the returns of the five major cryptocurrencies, Bitcoin, Ethereum, Ripple, Bitcoin Cash & Litecoin, of that time. Their methodology was to employ an extreme value analysis and estimation of the Value–at–Risk (VaR) and Expected Shortfall (ES) as tail risk measures. They pointed out that the examination of the tail behavior of the returns of cryptocurrencies and the underlying distribution is of high importance. This resulted in finding that Bitcoin Cash was the riskiest cryptocurrency, while Bitcoin and Litecoin the less risky.

Gkillas & Katsiampa agree with the literature review of Osterrieder et al. (2017) & Phillip et al. (2018), in the fact that cryptocurrencies behave differently to traditional fiat currencies, while their returns are not only more volatile and riskier but also exhibit a heavier tail behavior. They also refer to Dyhrberg (2016), by mentioning his words “Cryptocurrencies could be reviewed as assets & have a place in financial markets and portfolio management”.

Furthermore, Gkillas and Katsiampa in their paper extended the study of Osterrieder et al. (2017), by using an updated dataset of the major cryptocurrencies as described above. In this way, they contributed to the literature by providing more accurate results based on an extreme value distribution namely the Generalized Pareto Distribution (GPD), which they considered as the only relevant source of information for their study. Considering GPD they followed Balkema and De Haan (1974) & Pickands (1975) to support their findings.

According to their methodology, they used public data of daily closing prices (Coindesk Index). They took into consideration the risk measures of VaR and ES as functions of the parameters of the GPD, where VaR quantifies the maximum gain or loss & ES (as a conditional mean) quantifies the expected size of the exceedance over the Value at Risk (VaR). Moreover, they applied stationary time-series for the returns of the cryptocurrencies, taking heteroskedasticity in mind, a procedure followed by Longin and Pagliardi (2016) as well. They made a risk analysis of the cryptocurrency returns using the peaks-over threshold method to extract extremes, using VaR and ES as extreme quantiles of the GPD.

Finally, their results were consistent with the results of Osterrieder et al. (2017), meaning that Litecoin and Bitcoin are safer investments than the other three cryptocurrencies, Ethereum, Bitcoin Cash, and Ripple. However, all cryptocurrencies show higher values of risk than traditional currencies, also meaning that investors in cryptocurrencies are exposed to a high level of risk.
Gkillas and Katsiampa, with their examination of the tail behavior of cryptocurrencies, contributed in such a way to literature, which protects and informs both investors and policymakers about the cryptocurrency markets, the potential losses, or gains of each cryptocurrency, but also the potential bubbles due to exceedingly high returns as well. Additionally, they did not only try to extend previous research on the risk of cryptocurrency markets, but they also tried to prove that these markets cannot stay for a long time unregulated. On the other hand, investors who prefer to gain high returns do not thoroughly comprehend that high returns go along with higher risk in cryptocurrency markets.

In conclusion, they strongly suggest that policymakers should establish a framework since many investors are uninformed in the cryptocurrency trade. Taking into consideration the high capitalization of these markets there should be controls and limits which will further inform and protect investors from trade positions that entail a significantly high financial risk.

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4.7 “Portfolio management with cryptocurrencies: The role of estimation risk”, Emmanouil Platanakis, Andrew Urquhart, (2019)

Platanakis and Urquhart in this paper tried to compare the performance of the three models: the naïve diversification (1/N), the Markowitz diversification, and the advanced Black-Litterman model with Variance Based Constraints (VBCs). They agree with the literature that cryptocurrencies are considered highly volatile, causing a higher potential for estimation errors when composing a portfolio.

According to their point of view, this new & advanced technique (alternative estimations regarding the input of parameters with VBCs), seems to outperform both the (1/N) naïve portfolio and the Markowitz portfolio optimization framework when applied to cryptocurrencies only. Four of the most liquid cryptocurrencies are selected to compose the portfolio, these are Bitcoin, Litecoin, Ripple, and Dash. The data were collected weekly rather than daily, where this would result in a large turnover and thus more transaction costs.

Platanakis and Urquhart contributed to the literature on cryptocurrencies and risk management by urging investors to use more sophisticated portfolio techniques that control for estimation errors in the parameters of such portfolios. In conclusion, in their empirical results, they reported that the Black – Litterman model showed a lower risk portfolio and better out-of-sample risk-adjusted returns, than the other two (the naïve (1/N) & Markowitz). However, they characterized their findings as robust to the inclusion of
transaction costs and short selling, which is preferred when managing cryptocurrency portfolios in respect of their opinion.

4.8 “From bottom ten to top ten: The role of cryptocurrencies in enhancing portfolio return of poorly performing stocks”, Roman Matkovskyy, Akanksha Jalan, Michael Dowling, Taoufik Bouraoui (2019)

Roman Matkovskyy et al. in their research tried to explain whether cryptocurrencies could diversify effectively and efficiently a portfolio structured by stocks with bad performance. For this purpose, they selected the top ten (10) cryptocurrencies in respect of market capitalization as of June 7th, 2019. These were Bitcoin (BTC), Ethereum (ETH), Ripple (XRP), Bitcoin Cash (BCH), EOS, Litecoin (LTC), Binance Coin (BNB), Tether (USDT), Stellar, and Cardano (ADA).

Furthermore, they selected the ten (10) of the worst-performing stocks in the S&P100, S&P400, and S&P600 indices, aiming to match those of the ten (10) best performing in their respective group. Stocks, as traditional financial assets are represented by the above equity indices comprising small, medium, and large-capitalization companies, respectively.

According to Roman Matkovskyy et al., the categorization between the size of the companies in the three (3) S&P index portfolios, plays a significant role in their study. Different capitalization means different sensitivities to risk factors, which are important for pricing assets (Hu and Li, 1998). “Small Capitalization companies have greater exposure to risks” (Chan et al., 1985; Chan and Chen, 1991).

Companies with small market capitalization, have restrained balance sheets, low levels of liquidity, dependence on the banking system, and high cost of capital to attract investors. Due to the low capitalization, they sell their stocks in bearish markets, which entails higher risks in contrast to companies with larger market capitalization.

To begin with, when structuring their methodology, they collected daily data of closing prices of the top ten cryptocurrencies for one year and a half, (1/1/2018-6/6/2019), from Coinmarketcap.com. They found out that since the launch of Bitcoin futures in December 2017, the Bitcoin market has had efficiently increased, which made them focus exclusively on the post-launched period and not before that. The stock data was daily, while it was derived from Thompson EIKON.

Moreover, for their study analysis, they applied the Probabilistic Utility model (PU), using various estimates, with different algorithms and time horizons. They also used the Maximum Expected Utility model (MEU), as well as the Bayesian approach of
Rossi et al. (2002) for the calculation of errors as an uncertainty factor of parameter determination. They calculated the returns of each stock index to ensure stationarity. They also used the research paper of Livan et al. (2012), who has proved that the non-stationary behavior of stock prices can impel major drawbacks in portfolio selection. In this way, they concluded to the top & bottom ten firms in each index.

Following the above findings, their methodology was based on the uncertainty of the expected returns. They seem to agree with Michaud (1989), that Markowitz’s (1952) classical portfolio approach using the Maximum Expected Utility model (MEU), presents some drawbacks such as extreme and hardly plausible portfolio weights that are highly sensitive to changes in expected returns. They aimed to surpass these obstacles, so they utilized the Probabilistic Utility model (PU) approach, like Rossi et al. (2002) and Marschinski et al. (2006).

In their methodology, for creating the portfolio weights they used a utility function that guaranteed the direct implications of time horizon on the portfolio’s allocation. This procedure was based on the expected value of the portfolio’s weights that were parameters of the distribution. The PU approach allowed for constructing an improved portfolio selection procedure. However, for the portfolio’s optimization process the MEU was also used along with the PU model. The targeted returns were equal to the average return of the respective top ten companies.

Additionally, the empirical results showed that small-size capitalized firms were highly boosted by improving their returns in contrast to the large-size firms. For the medium size capitalized firms, the results were much lower while diminishing over time. From the top ten cryptocurrencies, the most efficient ones were the BTC, ETH, and LTC, which boosted the stock returns in the longer time horizon.

In conclusion, Roman Matkovskyy et al. succeeded in proving that the addition of cryptocurrencies to a traditional stock’s portfolio gives value-added, regarding the enhancement of returns. To this extent, their results were consistent with the literature studies on the hedging and diversification properties of cryptocurrencies against traditional financial assets, such as equities, currencies, and commodities. Their results are in line with the findings of Platanakis and Urquhart (2019), who reported higher risk-adjusted return on the inclusion of Bitcoin in the asset portfolio. This is also consistent with the results of Chan et al. (2019) and Bouri et al. (2019), who documented strong hedging properties of the Bitcoin against equity.

Finally, they contributed to the existing literature by researching the role of the top ten cryptocurrencies in terms of market capitalization & investigating the cross-sectional impact on different equity indices based on firm size, acting as pioneers in their field.
4.9 “Should investors include Bitcoin in their portfolios? A portfolio theory approach”, Emmanouil Platanakis, Andrew Urquhart, (2020)

Platanakis and Urquhart were the first ones that published a journal in “The British Accounting Review”, examining the advantages of including Bitcoin in a traditional stock-bond portfolio. Their analysis employed a limited number of portfolio optimization strategies, they used an out-of-sample framework, and the study was based on the historical mean asset returns, as return forecasts and the historical return variances and covariances.

However, they believe that historical returns show low estimates for future returns when it comes to Bitcoin, because of the high volatility in the daily closing prices of cryptocurrencies. Furthermore, they agree with Guesmy, Saadi, Abid, and Füti (2018) that Bitcoin owns hedging capabilities and gives benefits of diversification against many different financial assets. On the other hand, there is evidence in literature by Klein, Thu, and Walther (2018) that Bitcoin does not offer hedging capabilities as gold does.

In addition to the above research from literature, it is worth mentioning that “there is growing research examining the portfolio diversification benefits of Bitcoin, where Briere, Oosterlinck, and Szafarz (2015) show that the correlation between bitcoin and other assets is exceptionally low and the inclusion of bitcoin dramatically improves the risk-adjusted returns of the portfolios.” (Platanakis & Urquhart, 2020)

For their research they used the following eight asset allocation strategies: the Markowitz mean-variance portfolio optimization, Markowitz with Generalized constraints, the Bayes–Stein shrinkage portfolio approach, Bayes–Stein with Generalized constraints, the Black-Litterman portfolio construction model, the Minimum Variance model with Generalized constraints, the equally weighted 1/N naïve portfolio approach (with rebalancing, enabling short selling) and finally the 3 fund portfolio combination.

The collection of their data was applied every week. The chosen period was from October 2011 until June 2018, which provided a more comprehensive review of the performance of Bitcoin. Also, in this way the sample period did not only include the bull market but also the bear market period forming more realistic results. The closing prices were collected from Coindesk and the Bitstamp Bitcoin price.

Platanakis and Urquhart aimed to analyze the benefits of Bitcoin, by examining the perspective of a U.S investor holding a portfolio of stocks and bonds, as Daskalaki and Skiadopoulos studied in their research in 2011. For this purpose, they used the S&P500 index for stocks and the Barclays US Aggregate for bonds, both collected from Bloomberg, while they collected the 1-month risk-free rate from the database of Kenneth French for the risk-adjusted return calculations.
Finally, the out-of-sample analysis along with the risk aversions that were performed for the study of the eight different strategies, showed that Bitcoin plays a very significant part as a new alternative investment. In conclusion, according to the authors’ findings, Bitcoin should be included in a traditional portfolio as it substantially increases not only the excess returns of the investment but the ratios of Sharpe, Omega, and Sortino as well.

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4.10 SIGNIFICANT POINTS OF THE LITERATURE STUDIES

In respect of the literature studies, as described in this Chapter, it is obvious that the academic community has shown a great interest in researching cryptocurrencies as financial assets, and their behavior in a portfolio. In many cases, it is proved that cryptocurrencies work very efficiently as diversifiers in a traditional portfolio.

According to the literature reviews, cryptocurrencies are used mostly as speculative assets rather than means of exchange or traditional currency. Moreover, cryptocurrencies might fit in the tangent portfolio (maximum Sharpe Ratio), but not at all in the minimum variance portfolio. However, the Sharpe Ratio and the utility of portfolios were greatly increased, implying that diversification across cryptocurrencies enhanced the investment results according to the study of Liu Weiyi, (2018).

According to the research paper of Alexander Brauneis & Roland Mestel, (2019), there has been empirical evidence in the literature that Bitcoin and other cryptocurrencies are extremely volatile assets with a bubble-behavior. Sharp fluctuations in their prices have been detected during the recent years (2013 – 2018) of their existence. Moreover, discrete daily returns point at high mean and high volatility.

Gkillas and Katsiampa resulted in the fact that all cryptocurrencies show higher values of risk than traditional currencies, also meaning that investors in cryptocurrencies are exposed to a high level of risk. Roman Matkovskyy et al. in 2019, succeeded in proving that the addition of cryptocurrencies to a traditional stock’s portfolio gives value-added, regarding the enhancement of returns.

It is also proven that the appearance of Bitcoin futures in December 2017, has effectively boosted the cryptocurrency markets, resulting in higher prices of Bitcoin and the other cryptocurrencies as well. However, there is a consensus in the literature that cryptocurrency markets cannot stay unregulated for a long time due to the inherent financial risks they present.

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CHAPTER 5

5.1 THE CREATION OF TWO PORTFOLIOS

For this study-analysis, the performance of two (2) portfolios is being examined. Each portfolio consists equally of five (5) assets. Portfolio A contains Bitcoin (BTC), Ether (ETH), Ripple (XRP), Litecoin (LTC), and Monero (XMR), whereas the only difference with Portfolio B, is the replacement of Monero (XMR) with the market index S&P500, a traditional financial asset. More specifically, the assets in Portfolio A are Bitcoin, Ether, Ripple, Litecoin, Monero, while Bitcoin, Ether, Ripple, Litecoin, and the S&P500 are presented as the components of Portfolio B.

The collection of data is perceived daily, starting from 7th August 2015 until 1st February 2021 (2006 observation days). The sources for their selection are the web pages of Coinmarketcap.com regarding the cryptocurrencies and Yahoo.Finance.com regarding the S&P500. Cryptocurrencies are trading daily while the market index S&P500 trades according to N.Y.S.E (New York Stock Exchange), which is 252 trading days.

In respect of Portfolio B, there was matching in the non-trading days of the S&P500 with the trading days of the Cryptocurrencies. More specifically, for the non-trading days, the values of the exact previous trading days were used. In this way, the returns were not affecting the Portfolio’s returns overall since the same prices of the previous and next days resulted in zero returns. The goal was to maintain the same number of observations between the two Portfolios A & B, as to achieve balance with equal terms of examination.

The beginning of the selected period for this study analysis is based on the event of Ethereum’s platform release in the cryptocurrency markets, which was the 7th of August 2015 (07/08/2015).

The main aim for both portfolios is the estimation of the average capital returns, with a Rolling Window of one hundred days (100). This means that the value of each portfolio is evaluated daily, calculating the weights of each asset day by day, creating 1905 observations in total for analysis. Furthermore, the analysis is expanded by examining the allocation of the weights with a second Rolling Window of two hundred and fifty-two days (252), which is a trading year. The observation days of this Rolling Window are 1753.

Before we proceed to the analysis of the methodology used, some information on the S&P500 market index is given in the next paragraph (5.2) of this chapter.

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University of Piraeus, March 2021
5.2 THE MARKET INDEX S&P500

The Market Index S&P500 trades on the N.Y.S.E (New York Stock Exchange), it represents five hundred (500) companies with large capitalization. The activities of these corporations involve Health Care (e.g., Johnson & Johnson), Energy (e.g., Marathon Petroleum), Industry (e.g., Boeing Company, Delta Airlines), Information Technology (e.g., Apple, Hewlett Packard), Communication services (e.g., Facebook), Consuming products (e.g., Amazon, Coca-Cola), the Financial and Insurance sector (e.g., American Express, AON, Goldman Sachs Group, Bank of America, BlackRock) as well as companies that provide Utility Services. The daily data of the S&P500 market index were retrieved from the website finance.yahoo.com, as is shown in figure 14 below.

Figure 14

S&P500 Market Index values for the time-period (07/08/2015 – 01/02/2021)

Since the beginning of August 2015, the values have presented a steady course for two years long, between the range of 1,5 to 2,5 thousand US $, until August 2017. Immediately after this period, the price increases above 2,5 thousand reaching 3,0 thousand during the third quarter Q3-2018, though there appears to be a slight drop below 2,5 thousand towards the end of 2018. However, at the beginning of 2019, the values begin to rise again, reaching a high price nearly at 3,5 thousand until Q2-2020. Although this is a very crucial point, it becomes obvious that an intense fall in the values of the index decreases the price down to 2,5 thousand. Finally, in Q3-2020, the index gains again its grounds in the market going upwards, overcoming the value of 3,5 thousand US $.

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5.3 METHODOLOGY OF THE STUDY ANALYSIS

Firstly, the capital returns were calculated regarding the 2005 daily data. Secondly, the average value of both portfolios was estimated with two Rolling Windows, one of 100 days & the other one of 252 days. This means that the value of each portfolio was evaluated daily with an average return of the roll-overs as described above, the moving average, resulting in 1905 & 1753 observations, respectively. In this respect, the weights of each asset, Bitcoin, Ethereum, Ripple, Litecoin, Monero, S&P500, were defined by the structuring of the following model strategies:

- The Naïve Model, 1/N rule (equally weighted assets),
- The Minimum Variance Model,
- The Tangency Model (maximum Sharpe Ratio, with a zero risk-free rate),
- The Maximum Utility Model,

The restriction that applies to all strategic models is that the weights (w) are taking only positive values, (0<w<1) adding to one (1), during the examination period. Only the “long” position of the investment strategies is permitted for both portfolios. The rebalancing of the portfolios with short selling is not permitted.

Except for the naïve portfolio model (for which the weights were calculated in excel), all the other models were implemented in R-Studio software, especially for the calculation of the weights of each asset, and the optimization of both portfolios as well. The packages that were used for the calculation of the weights in R-Studio, is the NMOF package with R-tools regarding the minimum variance model, and the ROI solvers with Portfolio Analytics, by Ross Bennett (May 17, 2018), concerning the tangency model (maximum Sharpe Ratio) and the maximum utility model. The main purpose was to find the best weights that optimize both portfolios regarding the three investment strategies with different Rolling Windows, a longer-term window of 252 days and a shorter one of 100 days.

~*~*~

5.3.1 THE NAÏVE MODEL PORTFOLIOS (1/N RULE)

To begin with, each portfolio consists of five (5) assets. The equal weights of twenty percent, 1/N=1/5=0.20, for each asset Bitcoin, Ethereum, Ripple, Litecoin, Monero & S&P500, are used to calculate the daily weighted returns for both portfolios. These represent the Naïve Model Portfolios of the 1/N rule. The scope of this analysis is to examine both portfolios’ values by the equal allocation of weights in each asset, for Portfolio A (Bitcoin, Ethereum, Ripple, Litecoin, & Monero), and Portfolio B (Bitcoin, Ethereum, Ripple, Litecoin & S&P500). In the below graph, figure 15, it is depicted that Portfolio
A presents a higher level of risk in comparison to Portfolio B, concerning the rolling window of 100 days. This is owed, mainly, to the high volatility in the cryptocurrencies’ values. On the other hand, in Portfolio B the contribution of the market index S&P500 is making the difference by diminishing the levels of risk in the portfolio. More specifically, the highest level of risk in Portfolio A is 0.078, while the lowest is 0.019. For portfolio B, the highest level of risk is approximately 0.062 while the lowest is 0.010.

Figure 15

RISK in comparison, RW100 for the time-period (16/11/15 – 01/02/21)

Figure 16

RETURNS in comparison, RW100 for the time-period (16/11/15 – 01/02/21)
Comparing both portfolios returns’, with a rolling window of 100 days, it is obvious that they almost follow the same pattern, with a slight difference between them for the time-period 16/07/2016 until 16/11/2016. In this case, an investor could much more easily invest in portfolio B, since for the lower levels of risk, he or she could enjoy the same profits, meaning that the sacrifice in the returns is of very little value. However, the final decision is taken in terms of the Sharpe Ratio, for which the results are shown in figures 17 & 18 below, for the RW100 and the RW252, respectively.

**Figure 17**
Sharpe Ratios for Both Portfolios, RW100 for the time-period (16/11/15 – 01/02/21)

**Figure 18**
Sharpe Ratios for Both Portfolios, RW252 for the time-period (16/04/16 – 01/02/21)

Finally, both portfolios seem to follow more mild fluctuations in terms of the Sharpe Ratio, regarding the long-term Rolling Window 252 (figure 18 above). The minimum point of Sharpe Ratio is (-0.1076) for Portfolio A, whereas for Portfolio B is a little
better (-0.1057). The maximum point of Sharpe Ratio is (0.2930) for Portfolio A, whereas for Portfolio B is (0.2879). Eventually, in terms of Sharpe Ratio, the discrepancies are minor in the details.

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5.3.2 THE MINIMUM VARIANCE MODEL PORTFOLIOS

The minimum variance model strategy optimizes the portfolio by minimizing the level of risk of its assets. Therefore, the weights of each asset are calculated in a way to minimize the variance of the portfolio. For the calculation of the weights, the NMOF package of R-studio software is being used with R-Tools, as already mentioned in paragraph 5.3 of this Chapter. In Appendices section 1, the code for the minimum variance model is analytically depicted. As already mentioned, the main aim is to obtain the optimal weights that minimize the risk of portfolios A & B.

In figures 19 & 20 below, the weights are illustrated for both Portfolios, according to the Rolling Windows of 100 and 252 days, respectively. Regarding Portfolio A (figure 19), it appears that Bitcoin plays the most significant part for both Rolling Windows. The large window of 252 days calculates zero weights for a large time-period concerning Litecoin, Ether & Monero. Although Ripple has succeeded in taking high scores close to one (1), it comes second after Bitcoin in the Portfolio’s optimization. The Rolling window 100 calculates shorter periods of zero weights regarding Litecoin, Ether & Monero.

Figure 19

Portfolio A - Weights with RW 100, for the Minimum Variance Model.
Portfolio A - Weights with RW 252, for the Minimum Variance Model.

Regarding Portfolio B (figure 20), it appears that the S&P500 plays the protagonist role for both Rolling Windows. It appears to mirror Bitcoin, meaning that they fulfill each other in the portfolio optimization, however, Bitcoin takes much lower values of weights most of the time. On the other hand, Litecoin & Ether are almost omitted in both windows, taking zero values for very large time-periods. Although Ripple tries to stand up in the portfolio it cannot boost the Portfolio’s optimization.

**Figure 20**

Portfolio B - Weights with RW 100, for the Minimum Variance Model.
5.3.3 THE TANGENCY MODEL PORTFOLIOS

The Capital Asset Pricing Model (CAPM), as described in Chapter 3, represents the line that has as a starting point on the axis of y the risk-free rate of return, while it is tangible with the efficient frontier at a certain point of its curve. **This tangency point** represents all optimal portfolios that offer the highest expected return for a specific level of risk or the minimum risk for a specific level of expected return.

For the Tangency Portfolio optimization, the first assumption made was that the risk-free rate is zero, while the assumption of the maximization of the Sharpe Ratio is taken (see also equation 20). ROI solvers with Portfolio Analytics ([Ross Bennett, 2018](https://arxiv.org/)) optimizes the Sharpe ratio with commands of constraints and objectives, while constructing the following portfolio:

```r
  t.portf <- add.constraint(portfolio=t.portf, type="full_investment")
  t.portf <- add.constraint(portfolio=t.portf, type="long_only")
  t.portf <- add.objective(portfolio=t.portf, type="return", name="mean")
  t.portf <- add.objective(portfolio=t.portf, type="risk", name="StdDev")
```

The “Full investment” constraint is applied to the entire portfolio with “long position” only for rebalancing the portfolio (no short selling is permitted). The fraction of return to risk is maximized as an objective for the calculation of the weights that optimize...
both portfolios’ performance. Regarding the full code of the Tangency Model, see at the Appendices section 2. At figures 21 & 22, the optimal weights are depicted.

**Figure 21**

Portfolio A - Weights with RW 100, for the Tangency Model.

![Graph 1](image1.png)

Portfolio A - Weights with RW 252, for the Tangency Model.

![Graph 2](image2.png)

The results regarding Portfolio A (figure 20 above), show that there are many sharp ups and downs in the values of the weights ($0<w<1$). There are many outliers (either 0 or 1) especially for the Rolling Window of 100 days, while the time-periods of zero values are short. The Rolling Window of 252 presents larger spaces of zero prices, while less
sharp ups and downs. Litecoin is most of the time excluded from the optimization for both windows. Bitcoin is pretty much used, like Ether for the Rolling Window 100, whereas Ripple and Monero play a secondary role in the Portfolio’s optimization. Litecoin is the last one to follow.

The results regarding Portfolio B (figure 22 below), show once more the significance of the S&P500 in the optimization of the Portfolio. It seems from the density of the high values of the weights, in both windows, that it is ahead of Bitcoin and the other Cryptocurrencies. Rolling Window 252, depicts very large time-periods of zero weights for Ripple, Litecoin, and Ether, whereas of the Rolling Window 100, these periods are shorter for the same cryptocurrencies, respectively.

**Figure 22**

Portfolio B - Weights with RW 100, for the Tangency Model.
5.3.4 THE MAXIMUM UTILITY MODEL PORTFOLIOS

The father of the maximum utility theory is the economist of the classical economic theory, Alfred Marshall (1842 – 1924). He was the first to introduce the supply & demand curves in microeconomics. He has published many of his works, such as “The Pure Theory of Foreign Trade: The Pure Theory of Domestic Values” in 1879, “Principles of Economics” in 1890, “Industry and Trade” in 1919, “Money, Credit and Commerce” in 1923. His work has been applied to modern economic theories.

From a finance perspective, Utility (U) measures how much benefit investors could gain from a portfolio’s performance. The Utility function has the following general form:

\[ U = E(r) - \frac{1}{2}A \sigma^2 \]

where:

- \( E(r) \) is the expected return,
- \( \sigma^2 \) is the variance of the return,
- The “A” parameter is the level of risk aversion, that the investor is taking over.

The “A” parameter controls how much of the portfolio variance is penalized. Regarding our study, we will follow the same level of Risk Aversion, which is 0.25, that was implemented by Ross Bennett, (2018) in Portfolio Analytics, as described further in this...
paragraph. Moreover, there appear to be many scales of the “A” parameter, depending on how much risk-averse the investor is. Furthermore, in our case study of the five assets in each portfolio, equation 26 will take the below general form:

\[ U = \sum w_i \cdot E(r_i) - \frac{A}{2} \cdot \sigma^2. \]

In respect of the Maximum Utility Model’s optimization, the assumption is taken on the maximization of the utility in returns. ROI solvers with Portfolio Analytics along with quadprog plugin, regard this as a quadratic problem. The Utility is optimized with commands of constraints and objectives (Ross Bennett, 2018), while constructing the following portfolio:

```r
mu.portf <- portfolio.spec(assets=funds)
fi_constr <- weight_sum_constraint(type="full_investment")
lo_constr <- box_constraint(type="long_only", assets=mu.portf$assets)
qu_constr <- list(fi_constr, lo_constr)
ret_obj <- return_objective(name="mean")
var_obj <- portfolio_risk_objective(name="var", risk_aversion=0.25)
qu_obj <- list(ret_obj, var_obj)
```

The “Full investment” constraint is applied to the entire portfolio, along with the “long position”(only), for the rebalancing of weights only with positive values, 0<w<1, meaning that no short selling is permitted during the examination period. Its work is to combine the constraints in a list, then to create the return objective. Afterward, it creates the variance objective by specifying the risk aversion of the “A” parameter that controls how much of the variance is penalized. For this study-analysis, the level of 0.25 risk aversion is adopted, such as in the study of Portfolio Analytics (Ross Bennett, 2018).

Finally, it combines the objectives into a list. Regarding the full code for the Maximum Utility Model in R-Studio Software, see Appendices section.3. In figures 23 & 24, the optimal weights are depicted for Portfolio A. There appear to be many outliers in the values of the weights especially for the long-term window 252, whereas most of the cryptocurrencies take zero scores in the values of their weights. The shorter period window depicts better weights but with sharp ups and downs.
Figure 23

Portfolio A - Weights with RW 100, for the Maximum Utility Model.

Portfolio A - Weights with RW 252, for the Maximum Utility Model.
For the maximization of the utility, in Portfolio B, the values are almost zero for most of the weights, as far as the Rolling Window 252 is concerned. On the other hand, concerning the Rolling Window 100, most of the assets show sharp fluctuations in the values of their weights. Overall, the shorter time-period window of 100 days allocates the weights with shorter periods of zero values, whereas the longer-term window calculates many more zero values. ~*~*~

Figure 24

Portfolio B - Weights with RW 100, for the Maximum Utility Model.

Portfolio B - Weights with RW 252, for the Maximum Utility Model.
CHAPTER 6

6.1 RESULTS IN TERMS OF THE SHARPE RATIO

The statistical analysis results showed that the patterns of the cryptocurrencies’ portfolio A (Bitcoin, Ethereum, Ripple, Litecoin, and Monero), were in a way like the patterns of portfolio B (S&P500, Bitcoin, Ethereum, Ripple, and Litecoin). The common element between the two Portfolios is the very low values for nearly two years, starting from August 2015 until February 2017, as shown in chapter 2, at the graphs of their daily values. Although, towards the end of the second quarter (Q2) of 2017, there was an increasing rise in the cryptocurrencies values, which reached a peak in the first quarter (Q1) of 2018. However, this sharp uprising of the values, begun to follow a decreased course immediately afterward.

In the present chapter, subsequently to the analysis of the four strategic models in chapter 5, where we showed the performance of the weights that optimize both portfolios, we examine the strategic models in terms of the Sharpe Ratio. More specifically, as shown in figure 25 below, the four statistical models are presented with a Rolling Window of 100 days. It seems that for Portfolio A, the best Sharpe Ratio is performed by the Tangency Model (blue line), which indeed is maximizing the Sharpe Ratio. The second in a row appears to be the Maximum Utility Model (purple line), while the Naïve follows in the third place (red line), while in some time-periods succeeds the Tangency Model. Within a little difference, in comparison to the Naïve, comes the Minimum Variance Model (green line), the fourth in the row.

Figure 25

Portfolio A – 4 Strategic Models in terms of Sharpe Ratio for the time-period (16/11/2015 – 01/02/2021) – RW 100.
In the case of investigating a certain period, for instance starting from 30\textsuperscript{th} March 2017 until 30\textsuperscript{th} September 2017 (a semester), where there is a high peak in the cryptocurrencies values, the results are a little bit different. More specifically, the Sharpe Ratio is showing better results for the Naïve Model strategy (red line), which follows the Tangency Model (blue line) in the first place. In the third place is the Minimum Variance Model (green line) and the last one is the Maximum Utility Model (purple line). This is showing that the higher values of an asset are minimizing its utility. In respect of cryptocurrencies, their high values equal high volatility.

Furthermore, the results of Portfolio B in terms of the Sharpe Ratio, with a Rolling Window of 100 days, are depicted in figure 26 below. First in line, for once more, is the Tangency model (blue line), while second comes the Maximum Utility Model (purple line), third the Naïve Model (red line), and the last one is the Minimum Variance Model (green line).

**Figure 26**

Portfolio B – 4 Strategic Models in terms of Sharpe Ratio for the time-period (16/11/2015 – 01/02/2021) – RW 100.

Moreover, in the case of investigating a certain period, for instance starting from 30\textsuperscript{th} March 2017 until 30\textsuperscript{th}, September 2017 (a semester), where there is a high peak in the cryptocurrencies values, the results are somewhat different. More specifically, the Sharpe Ratio is showing better results for the Naïve Model strategy (red line), which follows the Tangency Model (blue line) in the first place. In the third place is the Maximum Utility Model (purple line) and last is the Minimum Variance Model (green line). This is showing that the market index S&P500, is contributing to the Portfolio by maximizing its utility.
In figures 27 & 28 below, in terms of the Sharpe Ratio, the four strategic models are presented with a Rolling Window of 252 days for both Portfolios. This longer-term window affects the fluctuations in the ratios, while it calculates them with more mild edges. There are no very sharp ups and downs. We could for once more focus on a certain period, at which we could more clearly observe the performance of the model strategies implemented. This is because during this specific time-period the values of the assets have shown an increasing rise, reaching their peak, starting from 30th March 2017 until 30th March 2018 (one-year-period), while it is depicted that the same pattern is followed as in the short-term window for both portfolios.

**Figure 27**

Portfolio A – 4 Strategic Models in terms of Sharpe Ratio for the time-period (16/04/2016 – 01/02/2021) – RW 252.

![Sharpe Ratio 252 - Portfolio A](image)

Furthermore, the long-term window is much more easily examined. Especially, for the one-year-period, starting from 30th March 2017 until 30th March 2018. The Tangency model (blue line) is excellently working by doing its job, which is to maximize the Sharpe Ratio. Another protagonist in this condition, is the simple-minded equally weighted asset portfolio, with the 1/N rule of the naïve model (red line). It is so simple, though simultaneously so efficient, and effective!

According to the literature studies and more specifically to Liu Weiyi (2018), “none of the sophisticated models, meaning the minimum variance model and the maximum utility model, beat the naïve 1/N rule in the criterion of the Sharpe Ratio”, as analytically described in Chapter 4, paragraph 4.3. This is proven in our study as well, for this specific time-period.
The long-term window for Portfolio B, (figure 28), is further examined regarding the one-year-period (30th March 2017 - 30th March 2018). The Tangency model (blue line) is maximizing the Sharpe Ratio in the first place. Once more, the simple-minded equally weighted asset portfolio, the naïve model (red line) precedes the Tangency Model (purple line) and the Minimum Variance Model (green line). Therefore, the graphs of the one-year-period, were designed as shown in the below figures 29 & 30, respectively.

Figure 29
Portfolio A – 4 Strategic Models in terms of Sharpe Ratio for the one-year-period (30/03/2017 – 30/03/2018) - RW 252.
Consequently, we have decided to retrieve the descriptive statistics from the Rolling Window of 252 days, for the whole examination period (16/04/2016 – 01/02/2021). Comparing both portfolios, it is realized, that Portfolio B (the mixed-asset portfolio) was more efficient in terms of the Sharpe ratio, presenting lower levels of risk (standard deviation), since the five cryptocurrencies in portfolio A presented higher volatility compared to the mixed-asset portfolio B.

Finally, this choice may seem safer since the pattern of the S&P500 market index is more likely uncorrelated with the patterns of the five cryptocurrencies.

More analytically, the descriptive statistics for both portfolios A & B, with the Rolling Window of 252 days have estimated the below results, as shown in Tables 3 & 4, respectively.
Table 3
Portfolio A – RW252 – Descriptive Statistics (16/04/2016 – 01/02/2021)

<table>
<thead>
<tr>
<th>Portfolio A</th>
<th>Naïve 1/n</th>
<th>Minimum Variance</th>
<th>Tangency (Max Sharpe)</th>
<th>Maximum Utility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.095233196</td>
<td>0.079744011</td>
<td>0.124621189</td>
<td>0.102376783</td>
</tr>
<tr>
<td>Standard Error</td>
<td>0.002455953</td>
<td>0.00219166</td>
<td>0.00229814</td>
<td>0.001747116</td>
</tr>
<tr>
<td>Median</td>
<td>0.086378087</td>
<td>0.072354282</td>
<td>0.116276724</td>
<td>0.109480317</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.102827903</td>
<td>0.091762258</td>
<td>0.096220465</td>
<td>0.073149716</td>
</tr>
<tr>
<td>Sample Variance</td>
<td>0.010573578</td>
<td>0.008420312</td>
<td>0.009258378</td>
<td>0.005350881</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>-0.988715808</td>
<td>-0.709435904</td>
<td>-0.966247641</td>
<td>-0.793493456</td>
</tr>
<tr>
<td>Skewness</td>
<td>0.063924601</td>
<td>0.240621095</td>
<td>0.097591324</td>
<td>-0.322619818</td>
</tr>
<tr>
<td>Range</td>
<td>0.400660907</td>
<td>0.389145655</td>
<td>0.387819398</td>
<td>0.315322035</td>
</tr>
<tr>
<td>Minimum</td>
<td>-0.107627091</td>
<td>-0.104086872</td>
<td>-0.066566684</td>
<td>-0.066566682</td>
</tr>
<tr>
<td>Maximum</td>
<td>0.293038816</td>
<td>0.285058783</td>
<td>0.321252713</td>
<td>0.248755353</td>
</tr>
<tr>
<td>Count</td>
<td>1753</td>
<td>1753</td>
<td>1753</td>
<td>1753</td>
</tr>
</tbody>
</table>

Portfolio A, (table 3 above), shows the below performance in terms of the highest mean in Sharpe Ratio among the four Model Strategies:

- **Tangency Model** performs the highest mean ratio of **0.124621**.
- **Maximum Utility Model** follows in the second place with a ratio of **0.102376**.
- **Naïve Model** takes the third place with a ratio of **0.095233**.
- **Minimum Variance Model** comes last in performance with the lowest mean ratio of **0.079744**.

Portfolio B, (table 4 below), shows the below performance in terms of the highest mean in Sharpe Ratio among the four Model Strategies:

- **Tangency Model** performs the highest mean ratio of **0.131996**.
- **Maximum Utility Model** takes the second place with a ratio of **0.101045**.
- **Naïve Model** follows in the third place with a ratio of **0.087092**.
- **Minimum Variance Model** comes last in performance with the lowest mean ratio of **0.067364**.
Table 4
Portfolio B – RW252 – Descriptive Statistics (16/04/2016 – 01/02/2021)

<table>
<thead>
<tr>
<th></th>
<th>Naïve 1/n</th>
<th>Minimum Variance</th>
<th>Tangency (Max Sharpe)</th>
<th>Maximum Utility</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Portfolio B</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>0.08709293</td>
<td>0.067364333</td>
<td>0.131996616</td>
<td>0.101045675</td>
</tr>
<tr>
<td>Standard Error</td>
<td>0.002369349</td>
<td>0.001277037</td>
<td>0.00224753</td>
<td>0.001554483</td>
</tr>
<tr>
<td>Median</td>
<td>0.071201941</td>
<td>0.069813027</td>
<td>0.12447085</td>
<td>0.102894235</td>
</tr>
<tr>
<td><strong>Standard Deviation</strong></td>
<td><strong>0.099201908</strong></td>
<td><strong>0.05346805</strong></td>
<td><strong>0.094101482</strong></td>
<td><strong>0.0650844</strong></td>
</tr>
<tr>
<td>Sample Variance</td>
<td>0.009841019</td>
<td>0.002858832</td>
<td>0.008855089</td>
<td>0.004235979</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>-0.760251249</td>
<td>-0.611778108</td>
<td>-0.489357375</td>
<td>-0.705176592</td>
</tr>
<tr>
<td>Skewness</td>
<td>0.248967577</td>
<td>0.069164362</td>
<td>0.273204756</td>
<td>0.012503325</td>
</tr>
<tr>
<td>Range</td>
<td>0.393707402</td>
<td>0.295860528</td>
<td>0.460912288</td>
<td>0.312305295</td>
</tr>
<tr>
<td>Minimum</td>
<td>-0.105753901</td>
<td>-0.075021815</td>
<td>-0.116142844</td>
<td>-0.061499487</td>
</tr>
<tr>
<td>Maximum</td>
<td>0.287953501</td>
<td>0.220838713</td>
<td>0.344769444</td>
<td>0.250805808</td>
</tr>
<tr>
<td>Count</td>
<td>1753</td>
<td>1753</td>
<td>1753</td>
<td>1753</td>
</tr>
</tbody>
</table>

Although the results of the Naïve Portfolio are not consistent with the findings in the literature studies for the whole period of our study, there is consistency for the one-year-period (30th March 2017 - 30th March 2018), where the Naïve portfolio strategy shows better performance in terms of the Sharpe Ratio, compared to the other two models, the minimum variance, and the maximum utility model.

In conclusion, in our study we also showed that the contribution of the market index S&P500 plays a rather significant role in Cryptocurrency Portfolios. We showed that the index minimizes the levels of risk in the portfolio, thus it makes it more attractive. Although cryptocurrencies are used, as diversifiers to traditional asset portfolios, for boosting the returns, on the other hand they appear to be more volatile and riskier, when acting exclusively in a Portfolio.

~*~*~
APPENDICES

1. **R-script for Minimum Variance Model.**

```R
library(readxl) # (either Portfolio A_Returns or Portfolio B_Returns)
CrypRet <- read_excel("C:/Users/Christiana/Documents/PortfolioA_Returns.xlsx",
col_types = c("date", "numeric", "numeric",
"numeric", "numeric", "numeric"))
View (CrypRet)
w=100 / w=252
nr<-nrow(CrypRet)
nr1<-nr-w
mean_ret<-matrix (0, nr1,5)
for (i in 1:nr1) mean_ret[i,]<- colMeans(CrypRet[i:(i+w-1),-1])
#install.packages("NMOF")
library(quadprog)
ddd <-as.Date(as.character(CrypRet[[1]]), format="%Y-%m-%d")
ddd1<-ddd[w+1:nr]
library (NMOF)
wei<-matrix (0 ,nr1,5)
for (i in 0:nr1-1) wei[i+1,] <-t(matrix(minvar(cov(CrypRet[(i+1):(i+w),-1)]),0,1)))
install.packages("zoo")
library(zoo)
wei<-zoo(as.ts(wei), ddd1)
 funds<-colnames(CrypRet[,]-1)
colnames(wei)<-funds #weights of the minimum variance portfolio
```

---

University of Piraeus, March 2021
plot.ts(as.ts(wei))

ts.plot(wei)

#View(wei)

write.zoo(wei, file = "MinVarWeights.csv", index.name = "Date", row.names = FALSE, col.names = TRUE, sep=";")

~*~*~

2. **R-script for Tangency Portfolio (Maximum Sharpe Ratio)**

#install.packages("Portfolio Analytics")
#install.packages("ROI.plugin.quadprog")
#install.packages("ROI.plugin.glpk")
#install.packages("ROI")
#install.packages("interactors")
#install.packages("foreach")

library(readxl) #(either Portfolio A_Returns or Portfolio B_Returns)

CrypRet <- read_excel("C:/Users/Christiana/Documents/PortfolioA_Returns.xlsx",
  col_types = c("date", "numeric", "numeric",
  "numeric", "numeric", "numeric"))

View(CrypRet)

w=100 / w=252

nr<-nrow(CrypRet)

nr1<-nr-w

mean_ret<-matrix(0,nr1,5)

for(i in 1:nr1) mean_ret[i,]<-colMeans(CrypRet[i:(i+w-1),-1])

View(mean_ret)

#weitg= weights of the tangency portfolio (Max Sharpe Ratio) with zero risk free rate.

weitg<-matrix(0,nr1,5)
On the efficient portfolio of Cryptocurrencies’ Values – Christiana Katsampoula®

View(weitg)

ddd<-as.Date(as.character(CrypRet[[1]]), format="%Y-%m-%d")

ddd1<-ddd[w+1:nr]

funds<-colnames(CrypRet[,1])

library(PortfolioAnalytics)

library(foreach)

library(iterators)

library(ROI)

library(ROI.plugin.quadprog)

library(ROI.plugin.glpk)

#construct Tangency portfolio

t.portf<- portfolio.spec(assets=funds)

t.portf<- add.constraint(portfolio=t.portf, type="full_investment")

t.portf<- add.constraint(portfolio=t.portf, type="long_only")

t.portf<- add.objective(portfolio=t.portf, type="return", name="mean")

t.portf<- add.objective(portfolio=t.portf, type="risk", name="StdDev")

#transformation to time-series

CrRet<-as.ts(CrypRet[,1])

CrRet<-zoo(CrRet,ddd)

for(i in 0:nr1-1) weitg[i+1,]<-t(matrix(optimize.portfolio(R=CrRet[(i+1):(i+w),],portfolio=t.portf, optimize_method="ROI", maxSR=TRUE, trace=FALSE)[[1]])

weitg<-zoo(as.ts(weitg),ddd1)

colnames(weitg)<-funds

#weights of the tangency portfolio

plot.ts(as.ts(weitg))
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3. R-script for Maximum Utility Model.

#install.packages("Portfolio Analytics")
#install.packages("ROI.plugin.quadprog")
#install.packages("ROI.plugin.glpk")
#install.packages("ROI")
#install.packages("interators")
#install.packages("foreach")

library(readxl) #(either Portfolio A_Returns or Portfolio B_Returns)

CrypRet <- read_excel("C:/Users/Christiana/Documents/PortfolioA_Returns.xlsx",
                         col_types = c("date", "numeric", "numeric",
                                      "numeric", "numeric", "numeric"))

View(CrypRet)

t=100 / w=252

nr<-nrow(CrypRet)

nr1<-nr-w

mean_ret<-matrix(0,nr1,5)

for(i in 1:nr1) mean_ret[i,]<-colMeans(CrypRet[i:(i+w-1)],-1])

View(mean_ret)

weimu<-matrix(0,nr1,5)

View(weimu)

ddd<-as.Date(as.character(CrypRet[[1]]),format="%Y-%m-%d")
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```r
#dd<--dd[1:1]

funds<-colnames(CrypRet[-1])

library(PortfolioAnalytics)
library(foreach)
library(iterators)
library(ROI)
library(ROI.plugin.quadprog)
library(ROI.plugin.glpk)

#construct the Maximum Utility portfolio
mu.portf<- portfolio.spec(assets=funds)
fi_constr<-weight_sum_constraint(type="full_investment")
lo_constr<-box_constraint(type="long_only", assets=mu.portf$assets)
qu_constr<-list(fi_constr, lo_constr)
ret_obj<-return_objective(name="mean")
var_obj<-portfolio_risk_objective(name="var", risk_aversion=0.25)
qu_obj<-list(ret_obj, var_obj)
mu.portf

#transformation to time-series
CrRet<-as.ts(CrypRet[-1])
CrRet<-zoo(CrRet,ddd)
for(i in 0:nr1-1) weimu[i+1,]<-t(matrix(optimizing.portfolio(R=CrRet[(i+1):(i+w)],portfolio=mu.portf, constraints=qu_constr, objectives=qu_obj, optimize_method="ROI", trace=TRUE)][[1]]))
weimu<-zoo(as.ts(weimu),ddd1)

colnames(weimu)<-funds

#weights of the maximum utility portfolio
plot.ts(as.ts(weimu))
```
ts.plot(weimu)

View(weimu)

write.zoo(weimu, file = "MuWeights.csv", index.name = "Date", row.names = FALSE, col.names = TRUE, sep=";")

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University of Piraeus, March 2021
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❖ Coin360.com, (2019). Coin360 Map Table. [online] Available at: <https://coin360.com/?period=1m&slicen=all>


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Fiat Currency. In 2018 International Conference on Information and Communication Technology for the Muslim World (ICT4M) (pp. 69-73). IEEE.


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**Literature Review - Research Articles:**


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Internet Web Pages:

- https://www.investing.com/crypto/
- https://finance.yahoo.com
- https://www.investopedia.com
- https://nakamotoinstitute.org/bitcoin/
- http://www.weidai.com/bmoney.txt
- https://coin360.com/
- https://coinswitch.co/
- https://www.cigionline.org
- https://www.getmonero.org/

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This is the last page of the dissertation.

The author takes full responsibility for the information used in this dissertation, which was achieved with respect and sincerity towards the existing economic theories, the scientific bibliography, the academic research papers, and the data sources, all of which were derived for guidance and decent delivery of this study. The author also keeps all reservations of any minor inconsistencies which might have occurred with no such intentions.

22nd March 2021

Christiana Katsampoula

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