# Is Bitcoin a Good Investment Asset?

JOÃO APOLÓNIA[a] and MARGARIDA ABREU[b]*

[a] ISEG, Universidade de Lisboa, Portugal, Portugal; [b] ISEG, UECE, REM, Universidade de Lisboa, Portugal

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**ABSTRACT**

This paper aims to analyze the consequences of adding Bitcoin to an investment portfolio. The main methodology used is the Mean-Variance model combined with the Monte Carlo Simulation. Results show that Bitcoin can improve the Sharpe Ratio of an already diversified portfolio, however the inclusion of Bitcoin has to be done in proportions averaging 3.83 percent of the portfolio's weight. This paper also found that Bitcoin does not seem to behave as a safe haven/hedge asset during the Covid-19 pandemic.

A CRYPTOCURRENCY, as defined by the Merriam-Webster dictionary, is "any form of currency that only exists digitally, that usually has no central issuing or regulating authority but instead uses a decentralized system to record transactions and manage the issuance of new units, and that relies on cryptography to prevent counterfeiting and fraudulent transactions".

When Nakamoto (2008) first introduced Bitcoin, the goal was to create a virtual, alternative currency that would be completely independent from any financial institution. In 2009 Bitcoin was launched, a cryptocurrency based on a peer-to-peer network that relies on a public ledger of every transaction, called Blockchain.[1] Considered by many as breakthrough technology, Blockchain allows every user to check the balance and the transactions of any Bitcoin wallet, thus providing full transparency. It is not completely anonymous, but rather pseudo-anonymous, in the sense that a person is linked to their Bitcoin address (the pseudonym) but not to their name or home address (Moreno & Shivangee, 2011).

Bitcoins are created by "miners", people that use their Central Processing Unit (CPU) power to validate transactions, thus generating blocks, that are added to the blockchain. The supply of bitcoin is capped at 21 million and its rate is predetermined: in 2140, the last bitcoin will be mined. Brito & Castillo (2013),

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1 Referred to by Nakamoto (2008) as "chain".

Böhme et al. (2015) and Barber et al. (2012) provide a more detailed insight into the technical aspects of Bitcoin and the functioning of Blockchain.

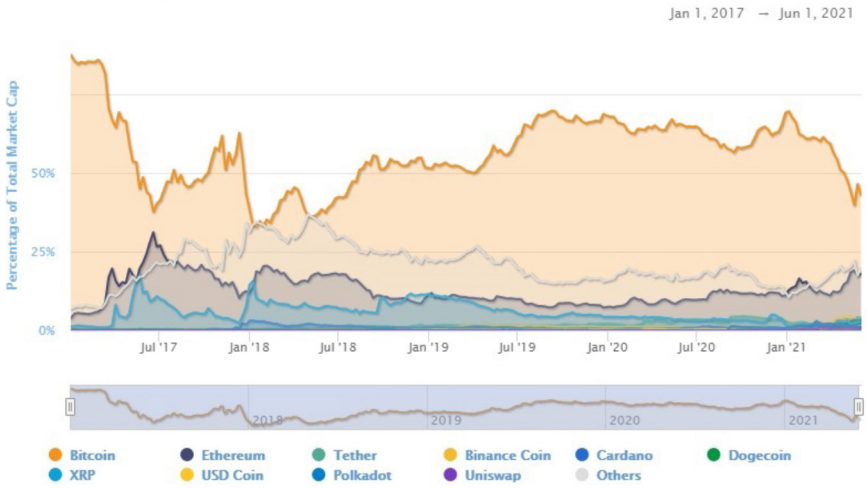
Thousands of cryptocurrencies have since been created, with the total market capitalization surpassing the trillion-dollar mark in Jan 2021 and reaching two trillion dollars just three months afterward (Figure 1). Bitcoin has always been the most relevant cryptocurrency,[2] as it constitutes the biggest share of the cryptocurrency market, around 45 percent in May 2021 (Figure 2), and thus we have chosen to focus on Bitcoin, the most dominant cryptocurrency, for our study.

**Figure 1**
**Total Market Capitalization of Cryptocurrencies**


Source: coinmarketcap.com

2 See Appendix I for Bitcoin's total market capitalization.

**Figure 2**
**Percentage of Total Market Capitalization**




Source: coinmarketcap.com

The literature suggests that Bitcoin does not seem to function as a currency. Instead, it is generally seen as a speculative asset, that people want in order to benefit from its profits when it increases in price. In contrast to the literature, in September 2021, El Salvador became the first nation to consider Bitcoin as legal tender, making it mandatory for economic agents to accept Bitcoin as a means of payment (Hawkins, 2021). This is somewhat controversial particularly regarding the logistics associated with such a move, for instance: how can a small business accommodate Bitcoin transactions? At the same time, the number of people voicing their concerns about the environmental issues associated with Bitcoin mining rises (Badea & Mungiu-Pupazan, 2021), making the future of Bitcoin rather uncertain.

A currency, generally speaking, can be described as anything that is used to buy a good or service or to pay a debt (Abreu et al., 2012). It must fulfill three functions: a medium of exchange, a unit of account and a store of value. As a medium of exchange, a currency should be, in general, accepted by everyone, everywhere. The use of money as a medium of exchange decreases the time spent in the process of exchanging goods and services and overall transaction costs, thus improving economic efficiency. The second role of money is to provide a unit of account, that is, it is used to measure the prices of all the other goods and allows us to compare any two goods by their relative price. A store of value is an asset that holds purchasing power over time, with no intrinsic depreciation.

Recent literature has since posed the question of whether Bitcoin can fulfill these requirements and be considered a currency. The answer seems to be clear: it cannot. In 2012, the European Central Bank (ECB) defined virtual currencies as "a type of unregulated, digital money, which is issued and usually controlled

by its developers, and used and accepted among the members of a specific virtual community". The stance of the ECB changed in 2015, where virtual currencies were no longer considered money, but rather "a digital representation of value, not issued by a central bank, credit institution or e-money institution, which, in some circumstances, can be used as an alternative to money."

Baur and Dimpfl (2017) showed that Bitcoin's volatility can be up to 20 times larger than major currencies, thus it is not able to function as a currency as it fails to fulfill the store of value function of money. Dyhrberg (2016a) and Baur et al. (2017) place Bitcoin somewhere between a fiat currency and a commodity without intrinsic value. The second work also shows that Bitcoin is being used as a speculative investment: By categorizing Bitcoin users into six different types, they found out that currency users,[3] in 2013, represented only 2.25 percent of the total Bitcoin users, and passive[4] and active[5] investors together represent more than 34 percent of all users.

In a similar vein, Glaser (2014) tried to determine what cryptocurrency users want when changing from their domestic currencies to digital currencies. Results suggest that new, uninformed users approaching Bitcoin, are not interested in its original purpose of functioning as an alternative currency, but are looking for an alternative investment vehicle. Along the same lines of reasoning, Yermack (2013) and Kancs and Ciaian (2015) breakdown the features of Bitcoin and conclude that Bitcoin does not behave as a currency since it does not fulfill the three functions of money. Yermack (2013) adds that its behavior resembles "a speculative investment similar to the Internet stocks of the late 1990s".

Kancs & Ciaian (2015) also found that Bitcoin's price is driven by its investment attractiveness and market forces, and as long as this continues, Bitcoin cannot compete with other currencies. Macroeconomic and financial factors were found not to influence Bitcoin's price. This is one of the reasons why it may be interesting to include Bitcoin in a global market portfolio.

This paper discusses Bitcoin not as a currency in itself, but as a financial instrument.

A few authors have tested Bitcoin in financial portfolios, searching for hedging capabilities or other possible instruments that financial analysts could have at their disposal. One of these instruments is, for example, the fact that trading takes place every day, without exception, which provides liquidity advantages (Dyhrberg, 2016b).

Klabbers (2017) includes Bitcoin in a global market portfolio and combining a mean-variance analysis with a Monte Carlo simulation, results show that Bitcoin is an effective diversifier with an allocation between 0 percent and 5 percent.

3 Users that have made more than one transaction; have both sent and received transactions, and with sending transaction sizes below $200.

4 Users that do not send Bitcoin, and only receive Bitcoin in transactions greater than $100; or have received one bitcoin transaction greater than $100.

5 Users that have made more than two transactions and only send Bitcoin in transactions greater than $2000.

However, it does not show any hedge or safe haven characteristics for a global market portfolio. Likewise, but using a dynamic conditional correlation model, Molnár et al. (2017) found that the cryptocurrency acts as a poor haven in most cases, serving only for diversification purposes. However, it actually showed strong haven abilities on the Chinese and Asia Pacific stock markets.

Moore and Stephen (2016) examine the possibility of Bitcoin being part of the international reserves' portfolio of a Central Bank, namely the Central Bank of Barbados. Barbados' currency has a fixed exchange rate with the US dollar, and thus its Central Bank needs a good amount and diversity of international reserves in order to provide some financial stability and prevent speculative attacks. In this sense, the authors use two approaches. The first is a series of four counterfactual simulations, which illustrates what would happen to the international reserves' portfolio (in relation to the actual portfolio), had the Central Bank of Barbados invested 0.01 percent, 0.1 percent, 1 percent or 5 percent of the reserves in Bitcoin, starting from November 2010, up to April 2015. Results showed that the balance would more than double with just a 0.1 percent investment and would be 100 times greater with 5 percent of reserves in Bitcoin, without increasing volatility significantly. The second method is a Monte Carlo simulation, which provides a forecast of four different horizons (1, 2, 5 and 10 years) for the international reserves assuming that there is an incorporation of Bitcoin of 0.01 percent of the reserves by the Central Bank of Barbados. For the 1-year forecast, in no instance were the portfolio losses greater or equal to the initial investment. For the 10-year horizon, there were 47 instances of portfolio losses exceeding the initial investment, contrasted with 629,953 instances of portfolio gains.

Further literature identified hedging capabilities against the stock market: Bouoiyour and Selmi (2017) analyze the behavior of Bitcoin in relation to the U.S. stock price, in the period after Trump's presidential win, which brought some uncertainty to the markets. Using data spanning from the 8th of November 2016 (the day of the U.S. Presidential election) to the 15th of February 2017, the results show that Bitcoin serves as a weak safe haven for the U.S. stock market in the short run, meaning that, in times of turbulence, it is uncorrelated with other assets.

Brière et al. (2015) show that including a small proportion of Bitcoin in a well-diversified portfolio may drastically improve the risk-return trade-off. Since Bitcoin has a low correlation with traditional financial assets and other alternative investments, it offers high diversification benefits. However, the period analyzed ranges from 2010-2013, which reflects the behavior of Bitcoin at an early stage. This behavior is prone to change in the medium or long-run.

Following Klabbers's (2017) methodological approach, this paper discusses whether Bitcoin enables a more efficient portfolio diversification and if it increases the overall performance of the portfolio. We test these issues with weekly data from January 2013 to May 2021. On the brink of 2020, the Covid-19 pandemic struck, leaving the financial markets with increased uncertainty and higher volatility. This seemed to have led to a wave of new investors joining the cryptocurrencies market (Priem, 2020). We take a closer look at this period and analyze the

potential of Bitcoin as an investment asset under this new, pandemic context. The paper is structured as follows: section 2 puts into context the potential usefulness of Bitcoin in an efficient portfolio approach, section 3 describes the data and the methodology, section 4 shows the results, section 5 details the robustness tests used, section 6 focuses on the Covid-19 pandemic period and section 7 draws some conclusions.

## II. Potential Usefulness of Bitcoin in an Efficient Portfolio Approach

Risk, in the context of financial investments, concerns the uncertainty regarding the future returns of securities. One can differentiate between two main types of risk: Unique, or idiosyncratic risk and market risk. Unique risk is the uncertainty related to a specific security only, while market risk affects a whole system or activity sector (Abreu et al., 2012). It is inherent to macroeconomic elements and cannot be reduced. In this sense, strategies to mitigate risk in financial investments can only be targeted at unique risk. One of those strategies and the one that is inside the scope of this work is portfolio diversification.

Markowitz (1952) first introduced portfolio theory and hypothesized that investors are risk-averse, and thus they do not maximize their returns, but rather look for an efficient trade-off between risk and return (measured by variance or, equally, standard deviation, and expected value, respectively). This can be demonstrated by assuming an N-securities portfolio, with return equal to the weighted average of the returns of the assets:

$$R_p = \sum_{i=1}^{N} w_i R_i \tag{1}$$

Where $w_i$ represents the weight of each security $i$ within the portfolio ($\sum w_i = 1$) and $R_i$ their return. As in Markowitz (1952), we will assume a no short-selling constraint, meaning that no asset can have negative weight ($w_i > 0$, for all $i$). Risk, measured by variance, is given by:

$$V_p = \sigma_p^2 = \sum_{i=1}^{N} (w_i^2 \, \sigma_i^2) + \sum_{i=1}^{N} \sum_{\substack{j=1 \\ j \neq i}}^{N} w_i w_j \sigma_{ij} \tag{2}$$

With $\sigma_{ij}$ being the covariance between two different securities $i$ and $j$.

We can conclude from the above formula that, to compute the risk associated with a portfolio, one should not only consider the individual risk associated to all the assets present in the portfolio, but also the risk of combining those assets together (*i.e.*, the covariance). Furthermore, covariance can be broken down into the equation below:

$$\sigma_{ij} = \sigma_i \sigma_j \rho_{ij} \tag{3}$$

$\rho_{ij}$ represents the correlation between two different assets, and can assume a value between [-1,1]. When $\rho_{ij} = -1$, the assets are perfectly negatively

correlated: Their returns move in opposite directions. When $\rho_{ij} = 1$, there is a perfectly positive correlation between the assets and so they move in line with each other. If it assumes a value of 0, they are not correlated.

Given the correlation value of a given asset in relation to another asset or set of assets, we are able to categorize it into different classes which, in turn, will allow an assessment of its benefits within an investment portfolio.

These classes were defined by Baur & McDermott (2010) and Baur & Lucey (2011) and are as follows:

- Hedge: A strong (weak) hedge is defined as an asset that is negatively correlated (uncorrelated) with another asset or portfolio on average.
- Safe haven: A strong (weak) safe haven is defined as an asset that is negatively correlated (uncorrelated) with another asset or portfolio in certain periods only, e.g., in times of falling stock markets.
- Diversifier: A diversifier is defined as an asset that is positively (but not perfectly correlated) with another asset or portfolio on average.

Given its decentralization from traditional financial institutions, cryptocurrencies, and specifically Bitcoin could potentially be safe haven assets, which investors look for in more turbulent times and therefore improve the general efficiency of the portfolio. As mentioned before, some works have already examined this matter and found contradictory results. Thus, this definition of safe haven must be relativized because it is not consensual among the literature and the safe haven property has been found to change over time and is subject to the asset class, markets studied or even the characteristics of the market turmoil (Ji, Zhang, & Zhao, 2020). In addition, Smales (2019) adds that meeting the criteria of correlation should not be enough to consider Bitcoin as a safe haven, as other attributes come into play, such as volatility, transaction costs, or liquidity.

## III. Data and Methodology

The data consists of weekly returns, from the 7$^{th}$ of January 2013 to the 31$^{st}$ of May 2021, for a total of 438 observations for each time series. The period chosen is meant to capture the first big boom on Bitcoin's price, after Cyprus' bailout, as well as a post-crisis period, following the international financial crisis of 2008, and the European sovereign debt crisis, between 2010 and 2013. We will also focus on the period spanning from January 2020 to May 2021, to study Bitcoin's behavior during the Covid-19 pandemic. Since it consists of a global financial crisis period, it will be a test of Bitcoin's capabilities, especially as a safe haven. Bitcoin data will be the average USD market price across all major Bitcoin exchange platforms and will be retrieved from Quandl, while the remaining data will be retrieved from Eikon-Datastream.

Regarding the optimal number of securities in the portfolio, there is extensive literature on the matter and a heated discussion on the issue continues: While

holding fewer assets may expose the investor to more idiosyncratic risk, having a large number of securities in a portfolio raises transaction cost issues (Alexeev & Tapon, 2012).

Evans & Archer (1968) concluded that the optimal number of securities in a portfolio should be around 10. Further beyond that, the number of additional securities required to decrease the standard deviation significantly is substantial and not economically justifiable. Fielitz (1974), Tang (2004) and Malkiel (1999) complement Evans and Archer's work.

On the other hand, Statman (1987) shows that only from 30 stocks onwards is a portfolio well-diversified and adds that diversification should be increased while the marginal benefits are greater than the marginal costs.

Despite this theoretical discussion regarding portfolio size, it does not suffice to lead an investor to an optimal portfolio. The correlation between the assets composing a portfolio, or lack thereof, is key to efficient diversification.[6]

Furthermore, attention should also be paid to the low correlation of assets coupled with the number of assets. In that sense, the base investment portfolio, (Portfolio A) constructed for this study, will contain a broad variety of markets and consider traditional assets as well as more alternative investments (Table 1): the stock indexes of seven of the biggest markets and three bond indexes representing the American, Asian and European continents were chosen, along with a global commodities index and a real estate index. Its size is also close to the reality of the average, individual investor. A more detailed description of the data can be found in Appendix II. We will then be adding Bitcoin to Portfolio A and further analyze this new portfolio (Bitcoin portfolio) in the next section.

**Table 1**
**Base portfolio (Portfolio A)**

| Stocks | Bonds | Commodities | Real estate |
|---|---|---|---|
| **S&P** | US index | ICE BofA Index | MSCI World Index |
| **FTSE** | Asia index | | |
| **DAX** | Euro index | | |
| **Nikkei** | | | |
| **SSE** | | | |
| **MSCI** | | | |
| **Euronext** | | | |

Similarly to Dyhrberg (2016a) and Klabbers (2017), alongside the base portfolio and the Bitcoin portfolio, a third, already well-diversified, portfolio will also be constructed, with the goal of checking whether adding Bitcoin to such

6 See Jacob, (1974)

a portfolio will bring any diversification advantages, compared to an already hedged portfolio. For this third portfolio (Table 2), the gold bullion and the USD/EUR exchange rate will be added, as they are already well-established safe haven / hedges (Baur & McDermott, 2010). We will be calling it Portfolio B.

**Table 2**
**Portfolio B**

| Stocks | Bonds | Commodities | Real estate | Exchange Rates |
|---|---|---|---|---|
| **S&P** | US index | ICE BofA Index | MSCI World Index | USD/EUR |
| **FTSE** | Asia index | Gold | | |
| **DAX** | Euro index | | | |
| **Nikkei** | | | | |
| **SSE** | | | | |
| **MSCI** | | | | |
| **Euronext** | | | | |

In a similar fashion to Klabbers (2017), this work will use a Mean-Variance Analysis combined with a Monte Carlo simulation.

The Mean-Variance Analysis (Markowitz model) makes use of the average returns, variance, and correlation values of each security under analysis. From this data, the covariance matrix will be computed. Efficient frontiers will then be drawn by optimizing the securities weights of the portfolio that minimizes the risk (measured by variance), subject to a given level of return. This analysis is considered a powerful method to assess diversification effects and is able to incorporate investor constraints, such as short sales. Jorion (1992), however, identifies a shortcoming in relation to this analysis, which is the fact that "it does not recognize the uncertainty inherent in the input parameters, their estimation risk". Jorion highlights the importance of estimation risk in order to account for these imprecisions and defines a series of steps to tackle this. The way these steps will be performed in practice is through the Monte Carlo simulation and are the following: For this study, we will assume the historical data of return and risk as true values and define N as the number of assets and T as the number of weeks; Then, from a normal distribution with the historical values as parameters, a random sample will be pulled for each N return. This process is repeated T times. From these simulated returns, a new mean and covariance matrix will be estimated, and thereafter, a simulated optimal portfolio can be achieved. 100 iterations will be drawn.

Klabbers (2017) and Moore & Stephen (2016) also make use of the Monte Carlo simulation in their portfolio analysis as a method of estimation. To measure the performance of the portfolios, the Sharpe ratio, introduced by Sharpe (1994)

is used. The Sharpe ratio is the most commonly used return-risk ratio and is given by $\frac{R_p - R_f}{\sigma_p}$, where $R_p$ is the portfolio's expected return, $R_f$ the return of the risk-free asset, and $\sigma_p$ the standard deviation of the portfolio. Without loss of generality, this work will assume $R_f$ as zero. An additional method of assessing the performance of an investment portfolio is the Conditional Value at Risk, or CVaR, which is derived from the Value at Risk (VaR) method. The VaR is used to measure the downside risk and is defined by the loss that will not be exceeded over a given time horizon at a given confidence level. It can be written as:

$$\zeta_\alpha(w) = \min\{\zeta | \Psi(w, \zeta) \geq \alpha\}, \tag{4}$$

for a confidence level $\alpha$, where $\Psi(w, \zeta)$ is the cumulative distribution function of a loss $z = f(w, y)$, with:

$$\Psi(w, \zeta) = P\{y | f(w, y) \leq \zeta\}, \tag{5}$$

where $\zeta$ is a specific loss, and $y$ the risk associated with the loss.

The CVaR is a more accurate measure of risk since it gives an expected value of the loss, instead of a range of potential losses as in VaR:

$$CVaR_\alpha(w) = \frac{1}{1-\alpha} \int_{f(w,y) \geq \zeta_\alpha(w)} f(w, y) p(y) dy \tag{6}$$

The definitions of VaR and CVar, as well as the above notation, were taken from Eisl et al. (2015). The CVaR analysis will be used as a complement for the main results provided by the Markowitz model and the Monte Carlo simulations.

The next chapter presents the results. The different efficient frontiers and covariance matrixes computed in that chapter were derived from the average of the logarithmic weekly returns $r = \ln\left(\frac{P_t}{P_{t-1}}\right)$, which was then annualized as shown below:

$$r_{annualized} = (1 + r)^{52} - 1. \tag{7}$$

## IV. Results

A summary of the weekly returns, weekly standard deviation, and respective annualized values of all the securities is presented in Table 3. All assets except the Asian market bonds and the Commodity Index present annual positive returns from 2013 to 2021, on average. Bitcoin far exceeds all other assets in terms of return and risk, with 151.78 percent and 93.44 percent, respectively. It provides a return 11.4 times greater than S&P, the second-best option, and is 5.67 times as risky.

**Table 3**
**Descriptive Statistics (2013 – 2021)**

| Security | Avg. Weekly Return (%) | Avg. Weekly Std. Dev. (%) | Annualized Return (%) | Annualized Std. Dev. (%) |
|---|---|---|---|---|
| S&P | 0.24 | 2.28 | 13.34 | 16.47 |
| FTSE | 0.03 | 2.29 | 1.76 | 16.48 |
| DAX | 0.16 | 2.82 | 8.53 | 20.30 |
| Nikkei | 0.23 | 2.85 | 12.61 | 20.53 |
| SSE | 0.11 | 3.25 | 5.61 | 23.43 |
| MSCI | 0.18 | 2.21 | 9.67 | 15.92 |
| Euronext | 0.13 | 2.59 | 7.24 | 18.65 |
| US Government Bond index | 0.00 | 0.55 | 0.08 | 3.95 |
| Asia Government Bond index | -0.01 | 0.71 | -0.27 | 5.14 |
| Euro Government Bond index | 0.02 | 0.54 | 0.90 | 3.89 |
| Commodity Index | -0.03 | 2.77 | -1.51 | 19.96 |
| Gold Bullion | 0.03 | 2.13 | 1.73 | 15.34 |
| Real Estate Index | 0.07 | 2.44 | 3.77 | 17.58 |
| USD/EUR | 0.02 | 1.10 | 0.84 | 7.94 |
| BTC/USD | 1.79 | 12.96 | 151.78 | 93.44 |

Table 4 presents the correlation values between all assets under analysis, and the respective significance levels. Bitcoin does not show any negative correlation with the remaining assets; however, the values are small and very close to zero, with the highest correlation being with the Nikkei (0.18). An initial analysis indicates that Bitcoin presents some diversifying capabilities, or, to some extent, hedging capabilities, according to the definitions presented in Chapter 2.3. Looking at the two more traditional hedges, gold and the US Dollar, they show rather different values: While the US Dollar has negative correlation with a decent number of securities, gold seems to underperform both the Dollar and Bitcoin, as it is quite highly correlated with all bonds and only shows significantly negative correlation with Nikkei and the US Dollar. Yet, most noteworthy is the US Government Bond Index, which, apart from the other two bond indices and gold, shows fairly negative values or is uncorrelated with all securities.

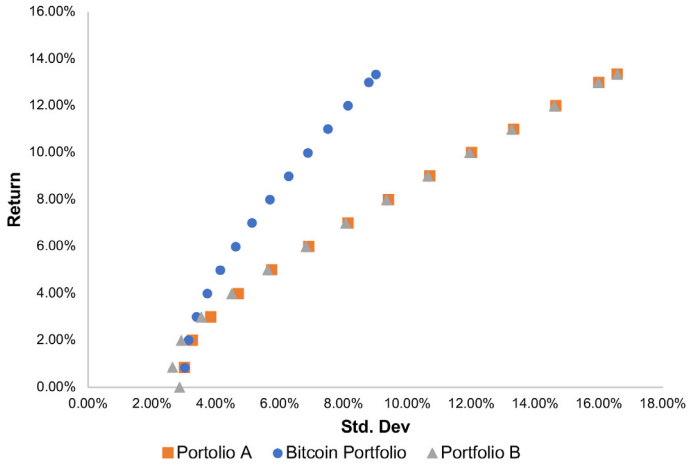
**Table 4**
**Correlation Matrix 2013 – 2021**

Correlation values are marked according to their significance level (*: 10%; **: 5%; ***: 1%)

| | S&P | FTSE | DAX | Nikkei | SSE | MSCI | N100 | US bonds | Asian bonds | Euro bonds | Commodity Index | Gold | Real Estate | USD/EUR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FTSE | 0.79*** | 1.00 | | | | | | | | | | | | |
| DAX | 0.75*** | 0.82*** | 1.00 | | | | | | | | | | | |
| Nikkei | 0.67*** | 0.61*** | 0.65*** | 1.00 | | | | | | | | | | |
| SSE | 0.35*** | 0.32*** | 0.32*** | 0.35*** | 1.00 | | | | | | | | | |
| MSCI | 0.98*** | 0.84*** | 0.81*** | 0.72*** | 0.37*** | 1.00 | | | | | | | | |
| N100 | 0.80*** | 0.89*** | 0.94*** | 0.68*** | 0.34*** | 0.86*** | 1.00 | | | | | | | |
| US Bonds | -0.32*** | -0.28*** | -0.31*** | -0.33*** | -0.14*** | -0.29*** | -0.31*** | 1.00 | | | | | | |
| Asian Bonds | 0.34*** | 0.34*** | 0.29*** | 0.18*** | 0.15*** | 0.40*** | 0.32*** | 0.50*** | 1.00 | | | | | |
| Euro Bonds | 0.11** | 0.15*** | 0.17*** | 0.05 | -0.01 | 0.13*** | 0.21*** | 0.54*** | 0.51*** | 1.00 | | | | |
| Commodity | 0.45*** | 0.45*** | 0.38*** | 0.31*** | 0.23*** | 0.48*** | 0.42*** | -0.36*** | 0.12** | -0.10** | 1.00 | | | |
| Gold | 0.00 | -0.02 | -0.09* | -0.18*** | 0.02 | 0.05 | -0.07 | 0.42*** | 0.34*** | 0.28*** | 0.09* | 1.00 | | |
| Real Estate | 0.75*** | 0.65*** | 0.60*** | 0.54*** | 0.26*** | 0.79*** | 0.64*** | 0.06 | 0.61*** | 0.34*** | 0.28*** | 0.21*** | 1.00 | |
| USDEUR | -0.03 | 0.11** | 0.20*** | 0.10** | 0.03 | -0.11** | 0.19*** | -0.20*** | -0.23*** | 0.12** | -0.07 | -0.38*** | -0.17*** | 1.00 |
| BTCUSD | 0.12*** | 0.09* | 0.10** | 0.18*** | 0.09* | 0.12** | 0.10** | -0.01 | 0.01 | 0.12** | 0.10** | 0.15*** | 0.09* | -0.02 |

Figure 3 presents the efficient frontiers of the three portfolios constructed for the whole time series.[7] The hedged portfolio, portfolio B, very slightly outperforms the Base portfolio, while the Bitcoin portfolio's efficient frontier is much steeper and provides a better risk-return ratio than the other two portfolios from

**Figure 3**
**Efficient frontiers 2013-2021**



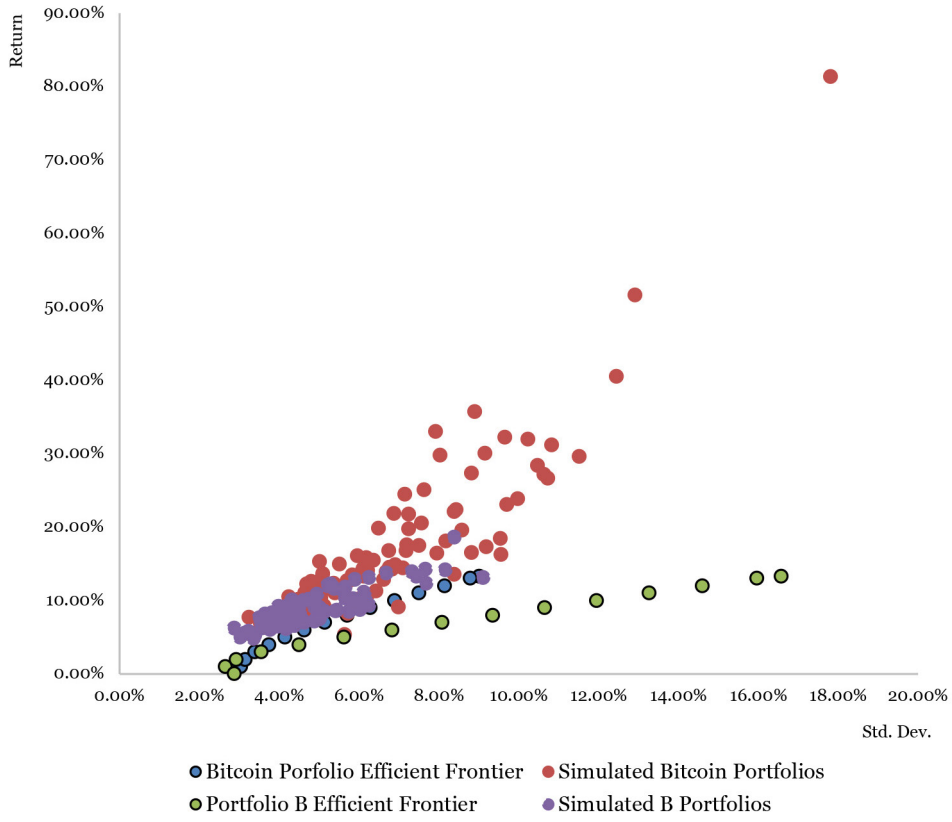

7 The leftmost point on the efficient frontiers that will be shown throughout this work may not always correspond to the minimum variance portfolio. In some cases, the minimum variance portfolio corresponds to a negative return, which is not economically viable.

around the 4 percent level of return and beyond. To compare the performance of the three portfolios over the years, efficient frontiers were constructed for each of the years under analysis (see Appendix III).

The Bitcoin portfolio had a better performance in most of the years analyzed. It is worth highlighting years 2013 and 2016, where the Bitcoin portfolio far outperformed the other two portfolios. In 2015, 2018 and 2021 Portfolio B performed better. Its performance was only equal to Portfolio A and B in 2014. Portfolio B is always equal or better than the Base portfolio, which showcases the advantages of Gold and the US Dollar being included in an investment portfolio. In this context, it makes sense to only compare Portfolio B to the Bitcoin portfolio vis-à-vis the estimation risk analysis and, as such, we will be discarding the Base portfolio for that section of the results.

Figure 4 illustrates the simulated portfolios resulting from the estimation risk, measured through the Monte Carlo simulations. The top and bottom 5 percent of the portfolios, based on the Sharpe ratio, were removed from the 100 iterations to

**Figure 4**
**Simulated Portfolios**



improve the significance of the results, thus leaving 90 simulated portfolios from the Bitcoin portfolio and Portfolio B.

As in Klabbers (2017), it should be noted that most simulated portfolios lie above their respective efficient frontiers. This can be explained by the properties of the Markowitz model, which tend to be very sensitive to assets with high returns. Furthermore, the portfolios do not necessarily have to be suboptimal, since we are drawing a random sample from the distribution.

The simulated Bitcoin portfolios show a lot more dispersion than the simulated B portfolios, however, their overall performance is better. The average Sharpe ratio is 4.85 while the B portfolios average Sharpe ratio is 1.85. An average weight of 3.83 percent of the portfolio is invested in Bitcoin, and for most cases, the share of Bitcoin in a portfolio is relatively small (See Figure 5).

**Figure 5**
**Share of Bitcoin in the Simulated Portfolios**

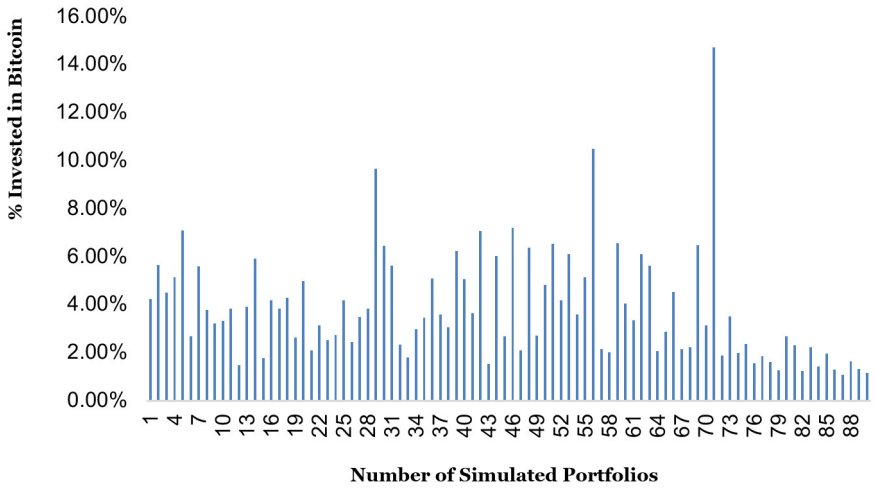



Table 5 shows the results by performing the optimization of the portfolios using the CVaR method, at the 1 percent and 5 percent level. As before, regarding this optimization short sales were restricted ($w_i > 0$) and the total portfolio weight was capped at 100 percent ($\sum w_i = 1$). The objective of this analysis is to complement the Markowitz model, in the sense that this methodology requires returns to be normally distributed, which is not the case for the assets under analysis.[8] The CVaR method can tackle that and help build a more consistent assessment of the results.

8 See Eisl et al. (2015).

At the 5 percent level, including Bitcoin in the portfolio increases the CVaR from 0.90 percent to 1.03 percent, in comparison with Portfolio B, meaning that in the worst 5 percent of returns, the average loss will be 1.03 percent. The Bitcoin portfolio yields, however, a better Sharpe ratio. The optimal weight of Bitcoin is 0.20 percent. At the 1 percent level, which only considers the more extreme values, the optimal portfolio does not include Bitcoin at all, and Portfolio B provides a higher Sharpe ratio and a lower CVaR, which may retract more risk-averse investors to include Bitcoin in their portfolios. These results are consistent with Eisl et al. (2015). Although increasing the CVaR, Bitcoin can be included in an investment portfolio and improve its Sharpe ratio, even if in very small proportions.

**Table 5**
**Portfolio Optimization using CVaR**

| | **Weekly Return (%)** | **Annualized Return (%)** | **Weekly-CVaR (5%)** | **BTC weight (%)** | **Sharpe Ratio** |
|---|---|---|---|---|---|
| Bitcoin Portfolio | 0.02 | 0.89 | 1.03 | 0.20 | 0.29 |
| Portfolio B | 0.01 | 0.54 | 0.90 | - | 0.20 |
| | **Weekly return** | **Annualized Return** | **Weekly-CVaR (1%)** | **BTC weight** | **Sharpe Ratio** |
| Bitcoin Portfolio | 0.00 | 0.08 | 1.83 | 0.00 | 0.03 |
| Portfolio B | 0.01 | 0.44 | 1.24 | - | 0.15 |

## V. Robustness tests

In order to test the consistency of the previous results, two different, additional simulations will be run, each with a slight change in the Mean-Variance model. The remaining analysis and steps taken will be the same as the previous analysis. The first will be achieved by removing the no short-sales constraint ($\boldsymbol{w_i > 0}$ constraint is removed from the model), meaning that an investor would now be able to allocate a negative weight to their securities, a tool used when an investor expects the price of a security to drop. Many cryptocurrency exchange platforms already offer the possibility of trading Bitcoin futures, so this short selling can also be achieved in practical terms for Bitcoin.

The second analysis will consider a weight constraint: No securities can have more than 25 percent of the portfolio's total weight ($w_i > 0.25$ constraint added). This follows the premise of Conover et al. (2009) that an investor is unlikely to allocate more than 25 percent of their portfolio into a single asset.

**Figure 6**
**Simulated portfolios with no short-sales constraint**

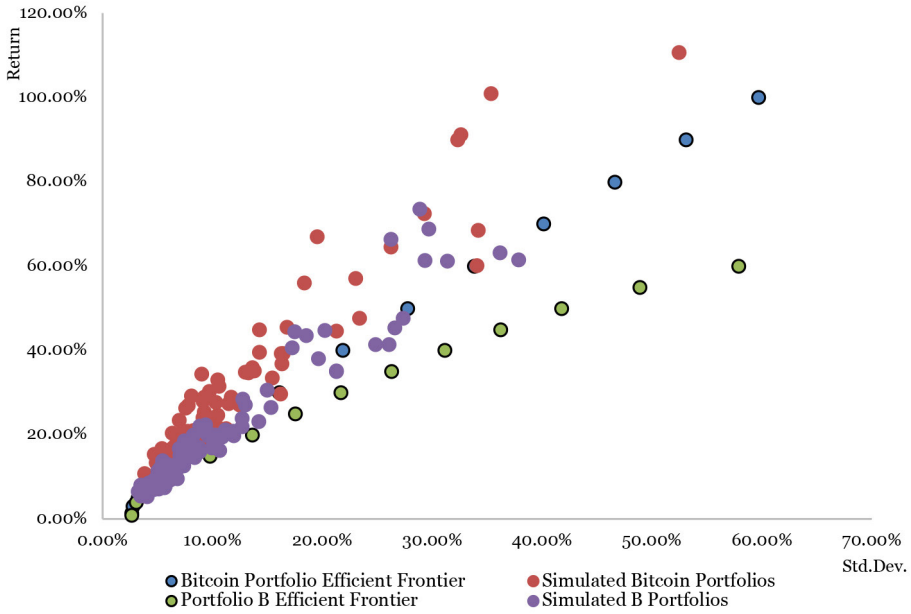
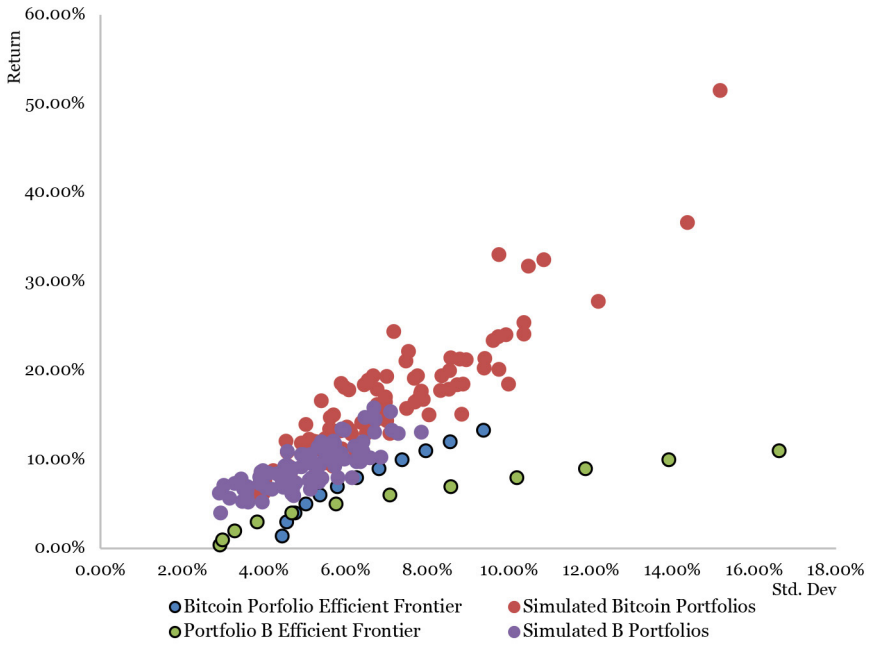



Figure 6 depicts the efficient frontiers of the Bitcoin portfolio and Portfolio B with the removal of the short-sales constraint, along with the simulated portfolios computed with the Monte Carlo simulations. As before, the top and bottom 5 percent of the portfolios were removed from the 100 iterations. The results are in line with the main analysis.

Bitcoin portfolio's efficient frontier starts yielding better results than Portfolio B's from the 4 percent return onwards. Regarding the simulated Bitcoin portfolios, they are more dispersed than Portfolio B's, although provide a better Sharpe ratio: Bitcoin's portfolio has a Sharpe ratio of 2.49 while Portfolio B has 1.95. The average weight of Bitcoin on the portfolios is 6.20 percent, and in only one iteration Bitcoin was shorted. (See Appendix IV.1). Comparing with the original analysis, we can see that here, the Bitcoin portfolios provide a better return rate on average, however, it is the greater risk associated that worsens the Sharpe ratio.

**Figure 7**
**Simulated Portfolios with weight constraint**




Similar to previous results, with the addition of the weight constraint of 25 percent (Figure 7), Bitcoin portfolio's efficient frontier is also steeper than the B portfolio's efficient frontier, and is above the latter as from the 4 percent level of return. Bitcoin's simulated portfolios are also more dispersed than the simulated B portfolios and yield a better Sharpe ratio (2.32 compared to 1.82).

Bitcoin's allocation is also relatively small, with an average weight of 3.7 percent of the portfolio (See Appendix IV.2).

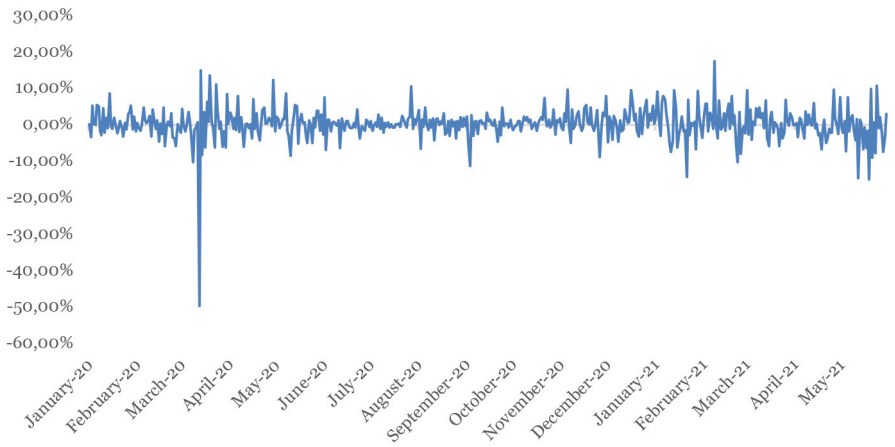
## VI. Focusing on the Covid-19 Pandemic Period

The Covid-19 pandemic brought a significant increase to the volatility of markets throughout the world (Zhang, Hu, & Ji, 2020; Ambros et al., 2020). This ought to be a real, empirical opportunity to test Bitcoin's hedging and safe haven capabilities against traditional assets, proposed in such works as Dyhrberg, (2016b), Moore & Stephen, (2016) or Baur et al. (2015).

Figure 8 shows Bitcoin's returns, in USD, from the 13th of January 2020, the day of the first recorded case outside of China, until the 31st of May 2021, averaging a daily return of 0.31 percent. The worst day over that period, corresponding to a return of -49.66 percent, followed the moment the World Health

Organization (WHO) announced Covid-19 as a pandemic (March 11, 2020).[9] The worst months overall were March 2020 and May 2021, where daily returns averaged -1 percent and -1.31 percent, respectively.

**Figure 8**
**Bitcoin's daily returns (USD) – Data retrieved from Quandl**




Literature regarding the performance of Bitcoin during the pandemic has been consistent and points out that Bitcoin does not seem to serve as a safe haven.

The negative returns and high volatility in the first four months of 2020 can be explained by the fear sentiment around Covid-19 (Chen, Liu, & Zhao, 2020). This indicates that Bitcoin's movement resembles those of other financial assets, rather than safe haven assets, in periods of market distress.

Conlon & McGee (2020) find that Bitcoin has not shown safe haven properties during the Covid-19 pandemic for the S&P 500. Adding to that, it increased the risk (measured by the Conditional Value-at-Risk) of an investment portfolio containing both securities.

Corbet et al. (2020) add that, during the pandemic, Bitcoin, and cryptocurrencies in general, besides not acting as hedges or safe havens, are also contributing to extending the financial contagion effects. However, their status as new financial instruments make their true capabilities as diversifiers still unclear.

Since the Covid-19 global outbreak, the financial landscape has faced some changes. The lockdowns issued throughout the world, which gave people more spare time, as well as the increase in unemployment, and the very low interest rate environment, may have pushed a new wave of individuals to start investing

9 https://www.who.int/director-general/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---11-march-2020 [Accessed on 7/6/21].

(Priem, 2020). These new investors are mainly young males, with less financial literacy than regular investors, who invest in smaller amounts than the latter (Frenay & Bonnet, 2020). For example, 15 percent of the U.S. stock market investors started investing in 2020 (Schwab, 2020).

Regarding the cryptocurrencies market, it has been heavily referred to across the media and by online influencers (BritainThinks, 2021). Additionally, Li, Chen, & Dong, (2021) show that Bitcoin-related events strongly influence Bitcoin's price. Recently, the most notable case is Tesla's CEO, Elon Musk, who announced in February 2021 that Tesla bought 1.5 billion USD worth of Bitcoin, and that they will be accepting it as payment, only to revert that decision months later for environmental reasons.[10] These announcements were followed by significant increases and decreases in Bitcoin's price. China's crackdown on crypto mining also caused prices to go down.[11]

Park & Chai (2020) and Naeem et al. (2021) have shown that the cryptocurrency market is an inefficient market and that the Covid-19 pandemic has worsened this inefficiency: Prices are heavily influenced by privileged information. Also, the former add that many traders are sentiment-driven, rather than making information-based decisions when investing in the cryptocurrency market. This may be derived from the amount of individual, less sophisticated investors, who make up this market (Panos & Karkkainen, 2019).

To assess eventual Bitcoin changing properties during the present sanitary crisis, we differentiate two periods: A pre-pandemic period, comprising the whole year of 2019 and the first week of 2020, with a total of 53 observations, and the pandemic period, from the 13th of January 2020, the day of the first recorded case of Covid-19 outside China, until May 2021, consisting of 73 observations. The same analysis as in section 4 will be made, in terms of the descriptive statistics, correlation matrix, creation of the efficient frontiers, and estimation risk, but this time focusing only on the pre-pandemic, and pandemic period, to observe more thoroughly what impact a period of high uncertainty can have on the performance of Bitcoin, and subsequently, what impact Bitcoin has on an investment portfolio, in such periods, and if safe haven abilities were demonstrated.

Table 6 summarizes the weekly returns, weekly standard deviation, and respective annualized values of all the securities during this period:

10 https://www.coindesk.com/business/2021/05/12/elon-musk-says-tesla-is-suspending-bitcoin-payments-over-environmental-concerns/ [Accessed on 5/9/21].

11 https://www.coindesk.com/markets/2021/05/21/bitcoin-falls-as-china-calls-for-crackdown-on-crypto-mining-trading/ [Accessed on 5/9/2021].

**Table 6**
**Descriptive Statistics January 2019 – May 2021**

| Security | Pre-Pandemic Period | | Pandemic Period | |
|---|---|---|---|---|
| | Avg. Weekly Return (%) | Avg. Weekly Std. Dev. (%) | Avg. Weekly Return (%) | Avg. Weekly Std. Dev. (%) |
| S&P | 0.49 | 1.74 | 0.35 | 3.77 |
| FTSE | 0.22 | 1.79 | -0.10 | 3.54 |
| DAX | 0.41 | 1.79 | 0.22 | 4.23 |
| Nikkei | 0.28 | 2.01 | 0.30 | 3.69 |
| SSE | 0.40 | 2.40 | 0.22 | 2.87 |
| MSCI | 0.43 | 1.58 | 0.31 | 3.73 |
| Euronext | 0.43 | 1.71 | 0.11 | 3.94 |
| US Govt. Bond index | 0.09 | 0.59 | 0.01 | 0.78 |
| Asia Govt. Bond index | 0.16 | 0.39 | -0.01 | 1.12 |
| Euro Govt. Bond index | 0.09 | 0.46 | -0.03 | 0.69 |
| Commodity Index | 0.33 | 2.35 | 0.23 | 3.85 |
| Gold Bullion | 0.38 | 1.64 | 0.27 | 2.64 |
| Real Estate Index | 0.33 | 1.24 | 0.07 | 4.62 |
| USD/EUR | 0.05 | 0.66 | -0.12 | 1.18 |
| BTC/USD | 1.26 | 8.46 | 2.12 | 12.19 |

During the Covid-19 outbreak, all the securities under analysis had their returns decreased compared to the period before the pandemic, except for Bitcoin and the Nikkei. The FTSE, the Asian and Euro bond indexes, and the USD/EUR exchange rate even saw negative average returns. In addition, the standard deviation rose for all assets. Bitcoin's return increased from 1.26 percent to 2.12 percent and its standard deviation from 8.46 percent to 12.19 percent. When comparing this with the security that comes second in terms of return, S&P, Bitcoin is 3.23 riskier but provides a return 6.05 times greater than the American index.

**Table 7**
**Correlation Matrix on the Pre-pandemic period**

Correlation values are marked according to their significance level (*: 10%; **: 5%; ***: 1%)

| | *S&P* | *FTSE* | *DAX* | *Nikkei* | *SSE* | *MSCI* | *N100* | *US bonds* | *Asian bonds* | *Euro bonds* | *Commodity Index* | *Gold* | *Real Estate* | *USD/EUR* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *FTSE* | 0.78*** | | | | | | | | | | | | | |
| *DAX* | 0.79*** | 0.67*** | | | | | | | | | | | | |
| *Nikkei* | 0.77*** | 0.55*** | 0.79*** | | | | | | | | | | | |
| *SSE* | 0.38*** | 0.34** | 0.48*** | 0.33** | | | | | | | | | | |
| *MSCI* | 0.99*** | 0.77*** | 0.83*** | 0.82*** | 0.43*** | | | | | | | | | |
| *N100* | 0.87*** | 0.82*** | 0.86*** | 0.72*** | 0.47*** | 0.88*** | | | | | | | | |
| *US Bonds* | -0.56*** | -0.46*** | -0.66*** | -0.73*** | -0.28** | -0.59*** | -0.55*** | | | | | | | |
| *Asian Bonds* | 0.02 | -0.06 | -0.21 | -0.30** | 0.01 | 0.01 | -0.04 | 0.65*** | | | | | | |
| *Euro Bonds* | -0.15 | -0.06 | -0.18 | -0.36*** | -0.06 | -0.18 | -0.09 | 0.62*** | 0.64*** | | | | | |
| *Commodity* | 0.61*** | 0.51*** | 0.56*** | 0.57*** | 0.52*** | 0.65*** | 0.52*** | -0.57*** | -0.16 | -0.24 | | | | |
| *Gold* | -0.20 | -0.25* | -0.39*** | -0.36*** | 0.01 | -0.17 | -0.32** | 0.54*** | 0.52*** | 0.43*** | -0.07 | | | |
| *Real Estate* | 0.38*** | 0.10 | 0.15 | 0.11 | -0.01 | 0.36*** | 0.22 | 0.08 | 0.32** | 0.11 | 0.11 | 0.17 | | |
| *USDEUR* | 0.04 | 0.26* | 0.08 | -0.13 | -0.10 | -0.06 | 0.16 | -0.08 | -0.16 | 0.15 | -0.08 | -0.53*** | -0.11 | |
| *BTCUSD* | -0.26* | -0.24* | -0.15 | -0.18 | 0.24* | -0.22 | -0.31** | 0.14 | 0.01 | -0.01 | 0.05 | 0.38*** | -0.19 | -0.28** |

**Table 8**
**Correlation Matrix January 2020 – May 2021**

Correlation values are marked according to their significance level (*: 10%; **: 5%; ***: 1%)

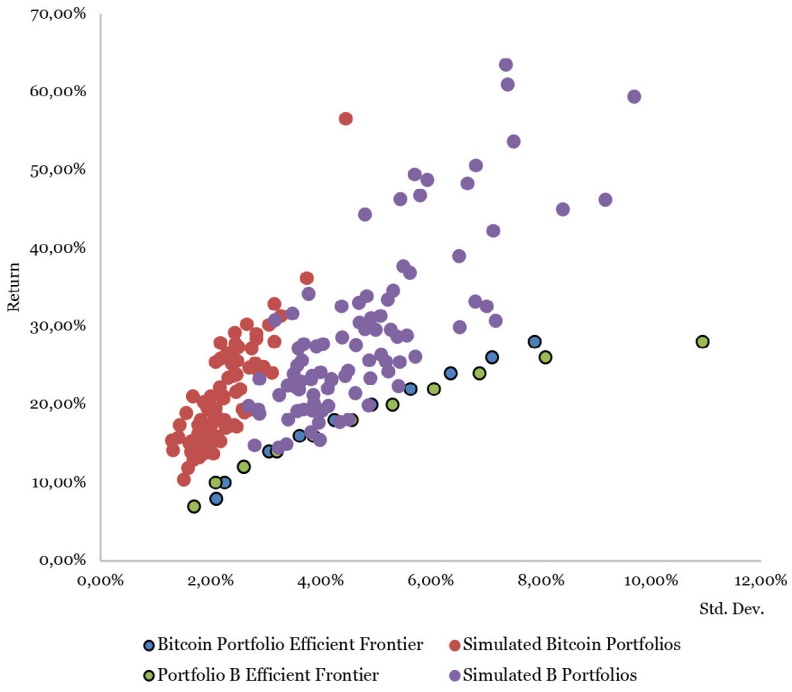
| | *S&P* | *FTSE* | *DAX* | *Nikkei* | *SSE* | *MSCI* | *N100* | *US bonds* | *Asian bonds* | *Euro bonds* | *Commodity Index* | *Gold* | *Real Estate* | *USD/EUR* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *FTSE* | 0.88*** | | | | | | | | | | | | | |
| *DAX* | 0.86*** | 0.90*** | | | | | | | | | | | | |
| *Nikkei* | 0.82*** | 0.83*** | 0.81*** | | | | | | | | | | | |
| *SSE* | 0.44*** | 0.37*** | 0.38*** | 0.44*** | | | | | | | | | | |
| *MSCI* | 0.99*** | 0.90*** | 0.89*** | 0.87*** | 0.46*** | | | | | | | | | |
| *N100* | 0.87*** | 0.94*** | 0.96*** | 0.86*** | 0.41*** | 0.90*** | | | | | | | | |
| *US Bonds* | -0.31*** | -0.36*** | -0.31 | -0.25** | -0.10 | -0.27** | -0.32*** | | | | | | | |
| *Asian Bonds* | 0.51*** | 0.42*** | 0.43*** | 0.44*** | 0.36*** | 0.56*** | 0.40*** | 0.36*** | | | | | | |
| *Euro Bonds* | 0.25** | 0.25** | 0.28** | 0.36*** | 0.01 | 0.30*** | 0.33*** | 0.50*** | 0.45*** | | | | | |
| *Commodity* | 0.52*** | 0.58*** | 0.58*** | 0.48*** | 0.36*** | 0.53*** | 0.59*** | -0.52*** | 0.20* | 0.03 | | | | |
| *Gold* | 0.23* | 0.23* | 0.20* | 0.25** | 0.18 | 0.28** | 0.23** | 0.38*** | 0.39*** | 0.50*** | 0.02 | | | |
| *Real Estate* | 0.87*** | 0.79*** | 0.76*** | 0.77*** | 0.41*** | 0.90*** | 0.77*** | -0.09 | 0.70*** | 0.38*** | 0.39*** | 0.38*** | | |
| *USDEUR* | -0.33*** | -0.21* | -0.12 | -0.23* | -0.23* | -0.37*** | -0.12 | -0.30*** | -0.57*** | -0.20* | -0.02 | -0.36*** | -0.49*** | |
| *BTCUSD* | 0.29** | 0.36*** | 0.34*** | 0.40*** | 0.21* | 0.33*** | | | 0.17 | 0.35*** | 0.34*** | 0.33*** | 0.27** | -0.07 |

Table 7 and 8 show the correlation between all the securities in analysis, during the pre-pandemic and pandemic period, respectively. As expected, the correlation values rose, in general, especially between the more traditional assets. This is in line with the results of Zhang et al. (2020). The US Dollar showed good safe haven capabilities and was negatively correlated with every asset. On the contrary, Bitcoin and the gold bullion increased their correlation values significantly. Bitcoin only maintained or decreased its correlation level with the US

bonds and the SSE index. This may disprove the hypothesis that Bitcoin could act as a safe haven, as in times of market volatility like the Covid period, the cryptocurrency tends to accompany other, more traditional, securities.

The estimation risk performed with the Monte Carlo simulation, and the efficient frontiers constructed, are shown in figure 9, for the period preceding the Covid-19 outbreak, and in figure 10, for the pandemic time frame. Again, the top and bottom 5 percent of the portfolios, based on the respective Sharpe ratio, were removed from the 100 iterations. Regarding the efficient frontiers during the Covid-19 pandemic, the results remain in line with the main results. Bitcoin portfolio's efficient frontier is steeper and from the 4 percent return onwards is always to the left of Portfolio B. Portfolio A was discarded, as it always performs equal or worse than Portfolio B in both periods (See Appendices III.10 and III.11). Bitcoin simulated portfolios show way more dispersion in this period compared to the pre-pandemic period and the Sharpe ratio dropped by half, from 9.26 to 4.63. They also show more dispersion relative to the other portfolio estimated, Portfolio B. The average allocation of Bitcoin is 6.39 percent, a significant increase in the relative weight on the portfolio, which had 1.01 percent allocated to Bitcoin before the Covid-19 outbreak.

**Figure 9**
**Simulated Portfolios on the Pre-pandemic period**



Portfolio B also saw its Sharpe ratio decrease 40%, from 6.09 to 3.65, but still remained below the Bitcoin portfolio despite the smaller decrease. Regarding the traditional hedges, they had opposite movements in terms of their average weights: the weight of the USD decreased from 6.63% to 3.78%, while gold saw an increase to 12.24% compared to the average of 8.02% pre-pandemic.

**Figure 10**
**Simulated Portfolios January 2020 – May 2021**


## VII. Conclusion

The literature has proven that Bitcoin has not been used as a currency, as originally intended by Nakamoto (2008), but rather as an investment asset. In this sense, this paper sees Bitcoin as a potential tool that is capable of improving an investment portfolio, in terms of its Sharpe ratio, or as a diversifier that is uncorrelated with the more traditional assets.

The results of this study, using the Mean-Variance model, showed that, when applied to an investment portfolio, Bitcoin improves the efficient frontier of that portfolio, compared to an already hedged portfolio, from the 4 percent level of return onwards. Moreover, the Monte Carlo simulations reveal that the Sharpe

ratio rises from 1.85 to 4.85. However, this improvement can only be achieved if Bitcoin is allocated in small percentages (average of 3.83 percent), which is in line with other similar works (Eisl et al., 2015; Klabbers, 2017). These results are robust when the short-sales constraint is removed and when a ceiling of 25 percent weight for each individual asset is included. Performing the portfolio optimization with the CVaR also yields similar results and complements the analysis: Bitcoin improves the Sharpe ratio of the portfolio if included in very small proportions, but at the same time it increases the CVaR of the portfolio.

Bitcoin, in general, does not show a good level of uncorrelation (expected from a hedge of a safe haven asset) with other traditional assets, in times of crisis, and particularly, during the Covid-19 pandemic, where the correlation levels rose compared to a pre-pandemic period. This, allied with its high volatility, does not work in favor of considering Bitcoin as a safe haven. During the pandemic, the portfolio's Sharpe ratio decreased by half, while the hedge portfolio suffered a smaller decrease, but still with a ratio below that of the Bitcoin portfolio.

Results drawn from the methodology adopted seem to indicate that there is a place for Bitcoin in an investment portfolio. These results should be interpreted with caution given the assumptions of the methodologies used (e.g., the assumption of normal returns in the Monte Carlo simulations). Moreover, the mixed signals from the different economic agents, namely its acceptance from companies and countries, its huge volatility, the environmental issues and the very probable future issuance of central digital currencies lead one to believe that the future of Bitcoin is uncertain, either as a currency, or as an investment asset.

For future research, a similar analysis could be done, testing other cryptoassets against Bitcoin. Today, the market is still dominated by Bitcoin but, with the surge of other cryptoassets with differentiating projects, it could be interesting to observe if any of them, at a further stage, could provide more benefits than Bitcoin in the context of portfolio diversification.

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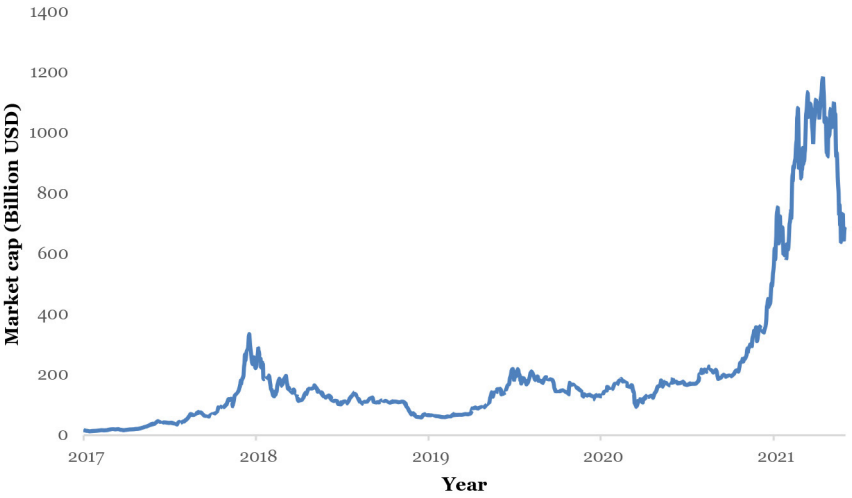
## Appendix I – Bitcoin's Market Capitalization

**Figure I.1**
**Bitcoin's Market Capitalization (Billion USD)**




Source: Data retrieved from Quandl

## Appendix II – Data retrieved

**Table II.1**
**Data retrieved from Datastream**

| Security | Datastream Name | Asset Class | Datastream Code |
|---|---|---|---|
| *S&P* | S&P 500 COMPOSITE | Equity | S&PCOMP |
| *FTSE* | FTSE100 | Equity | FTSE100 |
| *DAX* | DAX 30 PERFORMANCE | Equity | DAXINDX |
| *SSE* | SHANGHAI SE A SHARE | Equity | JAPDOWA |
| *Nikkei 225* | NIKKEI 225 STOCK AVERAGE | Equity | CHSASHR |
| *MSCI* | MSCI WORLD U$ | Equity | MSWRLD$ |
| *Euronext* | EURONEXT 100 | Equity | EUNX100 |
| *US bonds* | ICE BofA US Treasury Index | Fixed Income | MLTRSML |
| Asian Bonds | ICE BofA Asian Dollar Government Index | Fixed Income | MLAGTSL |
| *Euro bonds* | ICE BofA Euro Government Index | Fixed Income | MLDGVCL |
| *Commodity Index* | MLCX Spot Index | Commodity | MLCXSPT |
| *Gold Bullion* | Gold Bullion LBM $/t oz | Commodity | GOLDBLN |
| *Real Estate Index* | MSCI WORLD REAL ESTATE $ | Real Estate | M2DWR2$ |
| *USD/EUR* | EURO TO US $ (RFV) | Exchange Rate | USEURO. |

**Table II.2**
**Data retrieved from Quandl**

| Security | Quandl Name | Asset Class | Quandl Code |
|---|---|---|---|
| BTC/USD | Bitcoin Market Price USD | Alternative Investment | BCHAIN |

## Appendix III: Yearly Efficient frontiers

**Figure III.1**
**Efficient Frontiers 2013**

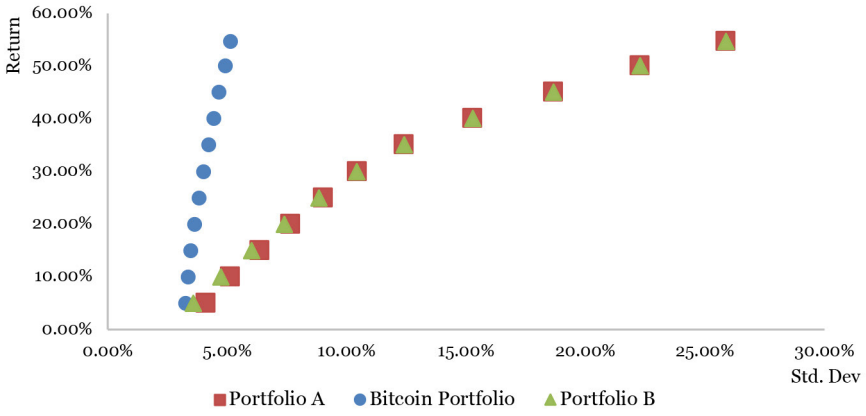



**Figure III.2**
**Efficient Frontiers 2014**

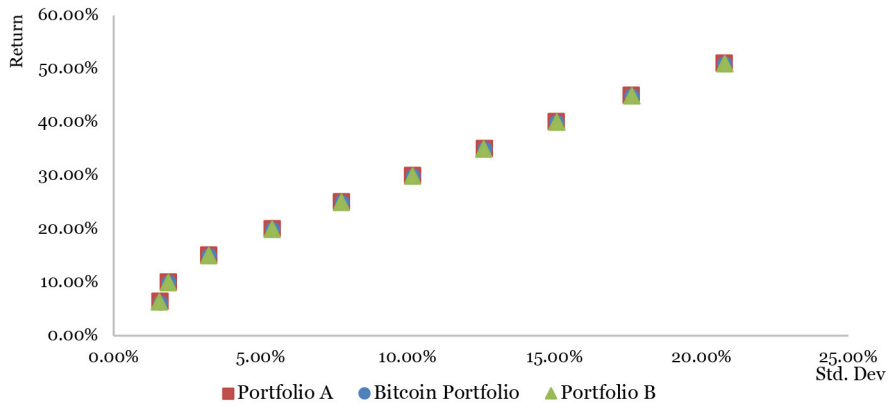


**Figure III.3**
**Efficient Frontiers 2015**

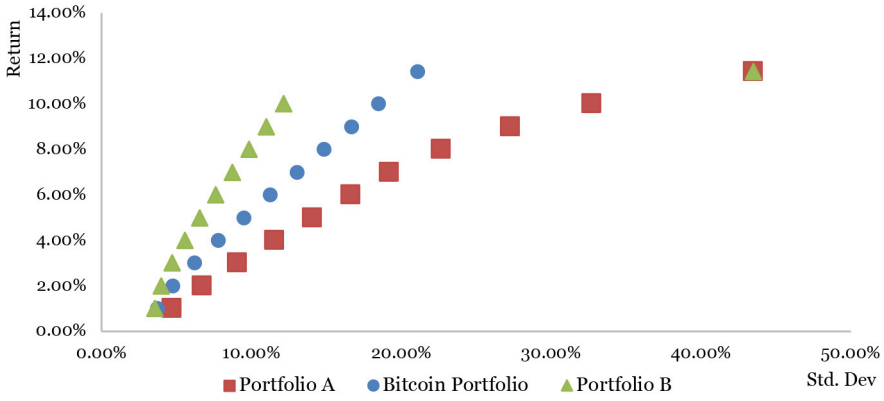



**Figure III.4**
**Efficient Frontiers 2016**

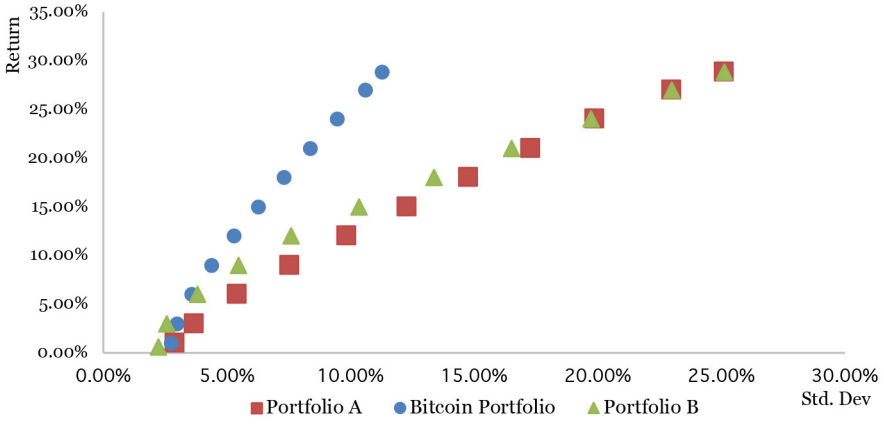


**Figure III.5**
**Efficient Frontiers 2017**

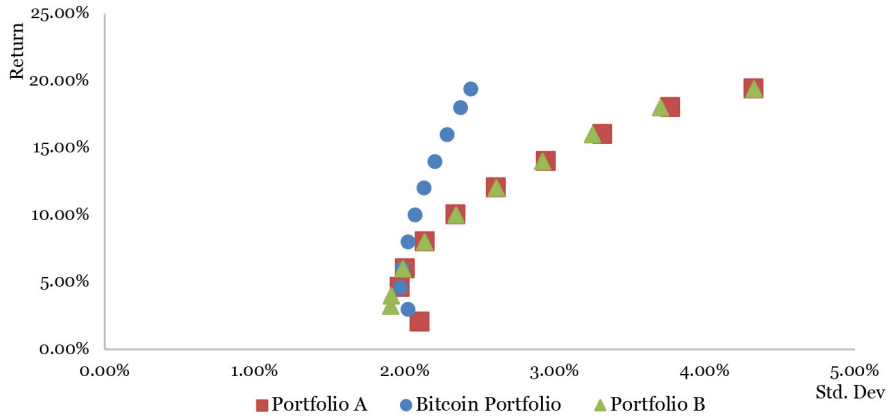



**Figure III.6**
**Efficient Frontiers 2018**

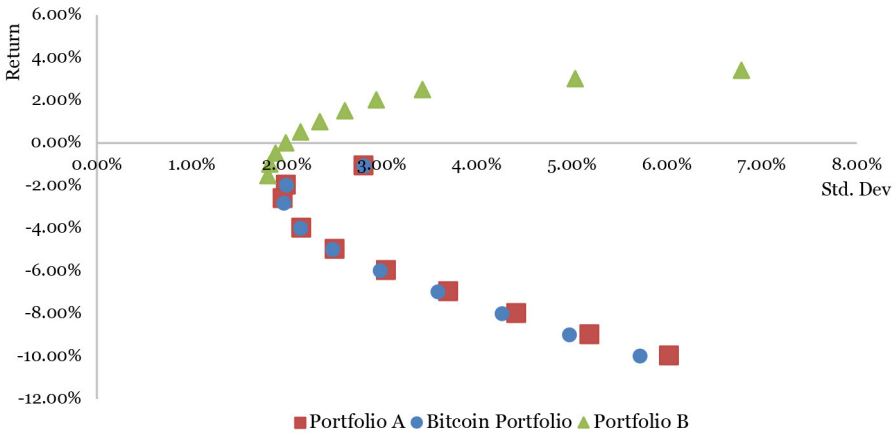


**Figure III.7**
**Efficient Frontiers 2019**

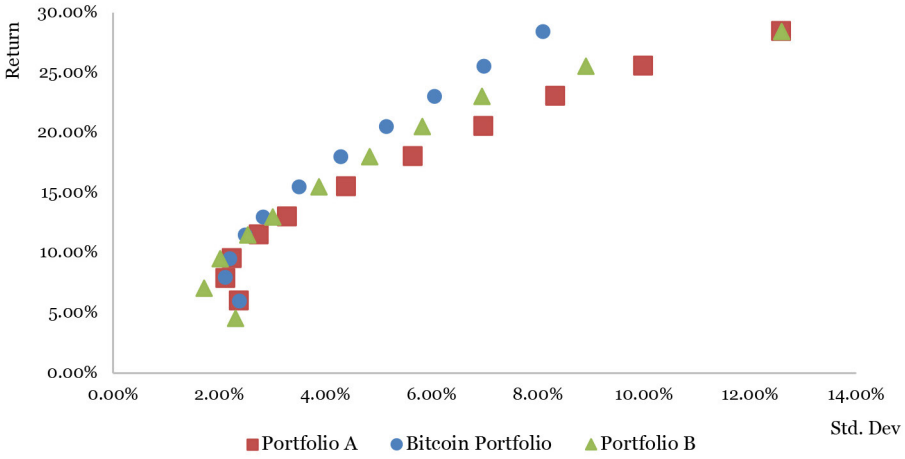



**Figure III.8**
**Efficient Frontiers 2020**

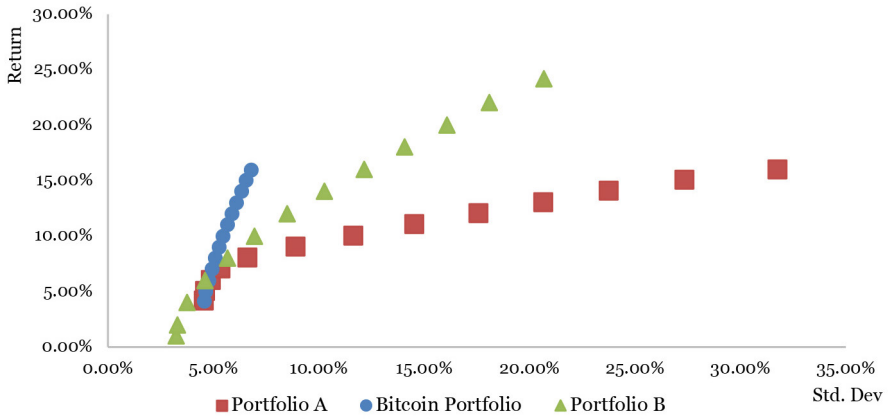


**Figure III.9**
**Efficient Frontiers 2021 (until May)**

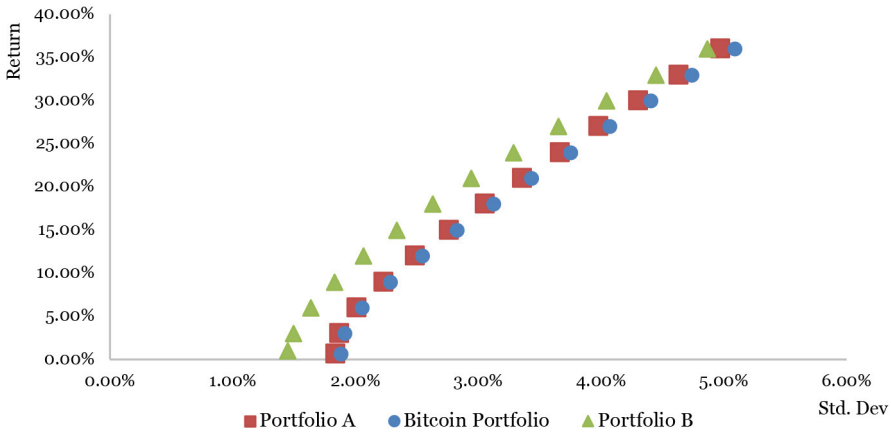



**Figure III.10**
**Efficient Frontiers 2019 – Jan. 2020 (Pre-pandemic period)**

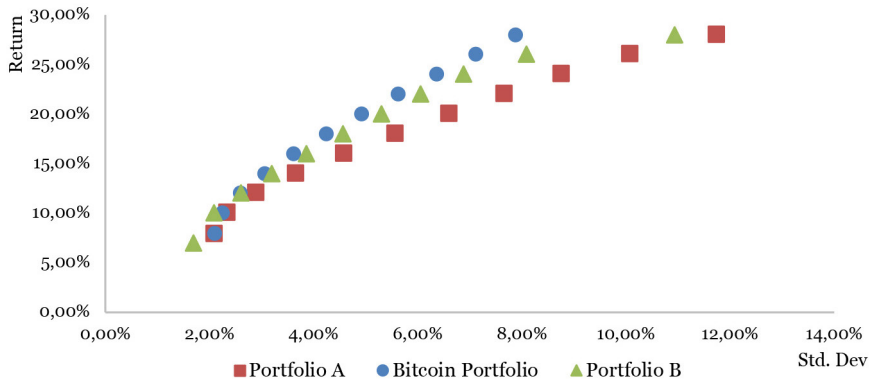
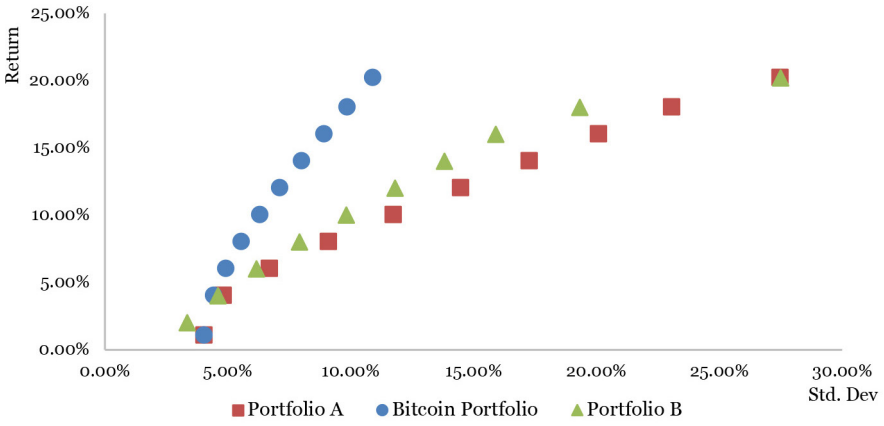


**Figure III.11**
**Efficient Frontiers Jan. 2020 – Jan. 2021 (Pandemic period)**



## Appendix IV – Bitcoin's share in robustness tests

**Figure IV.1**
**Share of Bitcoin in the simulated portfolios with no short-sales constraint**

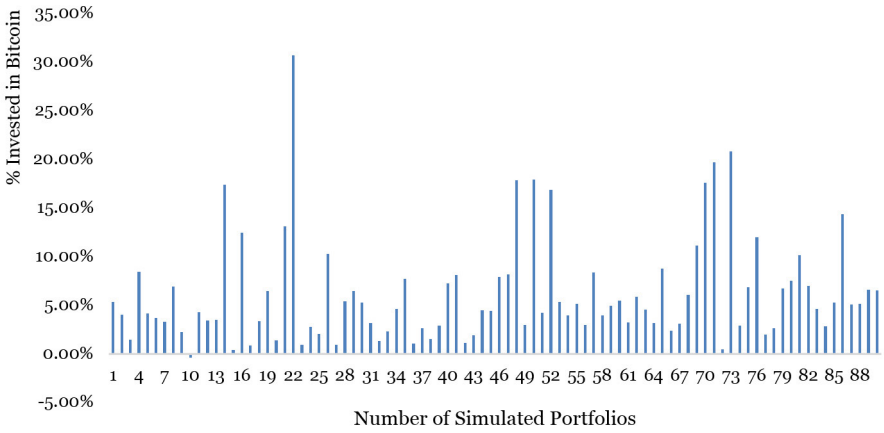



**Figure IV.2**
**Share of Bitcoin in the simulated portfolios with weight constraint**