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Financial Economics

Bitcoin – is it worth our dime?

Bitcoin's effect on portfolio returns and its properties in a Swedish setting

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Abstract

Bitcoin made its way into the consciousness of investors and the general public around 2015. Growing in popularity from there and inspiring the creation of many other crypto currencies along the way, it has been subject to several hypes and sharp declines since. Previous research has shown that despite its extreme volatility, it is wise to include Bitcoin in most investor portfolios. Since much of this research was carried out before the major hypes post 2017, this paper examines if this is still true by optimizing portfolios of Swedish assets under four different constraints, with the objective to maximize a risk-return ratio which builds on Conditional Value-at-Risk as risk measure, using historical data from March 2012 until March 2022. We also investigate whether it could act as a hedge and safe haven against other assets in the asset pool. We find that Bitcoin is still worthwhile to include in our portfolios, albeit somewhat less convincingly which is likely due to even more extreme volatility over the last few years. We further conclude that Bitcoin could be used as a hedge against real-estate, gold and USD and possibly as safe haven in times of market distress against, again, real-estate, USD and also against bonds with 5+ years maturity.

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Table of contents

1. Background

On 31 October 2008 a paper titled *Bitcoin: A Peer-to-Peer Electronic Cash System* was published on a cryptography mailing list by author Satoshi Nakamoto (Nakamoto, 2008). It is still to this day unknown whether this 'Nakamoto' is a single person or a group of persons; their identity remains unknown but is surrounded by speculation and viewed by many as almost a mythological figure. Nakamoto, in their paper, describes an electronic cash system where a peer-to-peer network is used to send online payments from user to user without having to go through a financial institution or other third party, thus free from the influence and control of states and institutions. All Bitcoin transactions are stored in a public ledger, a so-called block-chain, and can be traced back to the very first Bitcoin that was created. New Bitcoin are created through a process called 'mining' where computers are used to solve a series of mathematical problems to complete a block of transactions, for which new Bitcoin are given as a reward to whoever completed the block. Unlike many other crypto currencies, when designing Bitcoin Nakamoto set a limit to the amount of coins that can enter circulation at 21 million. At the time of this thesis, approximately 19 million Bitcoin have been mined since 2008. The last coin is however expected to enter circulation in 2140, due to the way the reward for each completed block in the chain is halved for every 210,000 blocks produced. Currently, the block reward is 6,25 Bitcoins and a new block is completed approximately every ten minutes (Hayes, 2022).

Although some transactions had previously occurred between various individuals within the early cryptocurrency community, the first known commercial transaction of Bitcoin took place on May 22, 2010, when a Florida computer programmer traded 10,000 Bitcoin for some pizza (CBS News, 2019). Bitcoin, then, had still some ways to go before it gained traction and fame among the public and was not traded at any noteworthy volumes until the very end of 2013 when its trading jumped in volume, at a price just over $700. It was still traded at incredibly varying volumes however, with 2014 seeing as low daily volumes as $4.34M and peaking at $96.06M, greatly fluctuating between these highs and lows during the year, with prices ranging from approximately $300 to $600 per Bitcoin. While a fair amount of investors was evidently attracted to the Bitcoin at this stage it was still a very niche investment, and it was not until the latter half of 2017 when Bitcoin really started to catch the attention of the broader public. The daily trading volume for Bitcoin surpassed $1B for the first time on May 9, 2017, at a price of $1,755 per Bitcoin and just grew in popularity from there, still exhibiting the same notable volatility both in price and trading volume, however. It eventually peaked in December 2017 at

$17,776, after which the price again declined and varied between about $5,000 to $10,000 per Bitcoin until the next hype took place in late 2020. At the end of September, one Bitcoin traded for $10,784 and when October had passed it went for $13,780. On New Year's Eve, Bitcoin traded for $29,000 and on April 15 2021 it set an all-time high of $63,314. By then Bitcoin had gone from an obscure currency traded by a selected few in a narrow niche of people, to becoming popular among the more tech savvy investors to gaining the attention of the broad public in a very true sense. Although still met with some skepticism from traditional investors, many people jumped over the opportunity to make some quick money in a seldom seen fashion. Bitcoin has continued to exhibit a large volatility since, however, both in terms of price level and trading volume. By mid-2021 it had again dipped down to roughly $30,000 before gaining momentum again and peaking at a new all-time high of about $70,000 in November. 2022 has so far seen Bitcoin being traded between approximately $35,000 and $45,000 per Bitcoin.

While the hype over Bitcoin somewhat dying down, with other crypto currencies such as Ether and Dogecoin stealing more of the spotlight, one can still argue that it has earned its status as a legitimate electronic cash system as well as investment alternative. This development has certainly been aided by government efforts to regulate and legitimize cryptocurrency trading, such as BitLicense, a business license for virtual currency activities, issued by the New York State Department of Financial Services (DFSNY, 2022). Elon Musk famously first gave his public endorsement to crypto currencies and then much to the surprise of the public retracted it, which had some effect on the trading and led to heavy criticism against him (Molla, 2021). His company Tesla briefly accepted Bitcoin as a means of payment, before removing the option with reference to rapidly increasing use of fossil fuels used for Bitcoin mining and transactions. Other examples of cryptocurrency grabbing the limelight include crypto currency platform Crypto.com's purchase of the naming rights to the infamous L.A. arena previously known as Staples Center, home to teams of the NHL, NFL, and NBA. At the time of writing, they have also been presented as an official partner of the 2022 FIFA World Cup in Qatar (Munjal, 2022).

It should be noted that all is not gold regarding Bitcoin or cryptocurrencies in general, issues being such things as uncertainties regarding its legal and tax status concerns, as well as ethical issues surrounding the fact that one core aspect of Bitcoin - its anonymity - has led to misuse for criminal purposes, with Bitcoin and other crypto currencies being used for illicit activities such as scamming, terrorism financing, darknet transactions of illegal goods and for the sale and purchase of child abuse materials (Chainalysis, 2022). Furthermore, the way that crypto

currencies are stored in digital wallets to which there is only one digital key brings with it the risk of cryptocurrency platforms being targets of cyberattacks aiming to steal those wallets, potentially losing investors millions of dollars. Additionally, warnings have been raised suggesting that a large amount of shady crypto currency platforms are faking their transaction volumes in order to attract customers, meaning that there is a great threat to unaware investors that only a few trading platforms are fully legitimate (Forbes, 2019).

However, that being said, it still seems that cryptocurrencies and Bitcoin in particular are here to stay and that they have become a more serious alternative for investors looking to make a hefty profit, which is supported by the fact that 99% of all Bitcoin transactions involve sums over $100,000, which suggests large institutional involvement (BeInCrypto, 2022).

2. Article review

While there are some earlier studies that examine whether Bitcoin should be regarded as a currency or an investment asset, such as by Wu & Pandey (2014), it seems to be generally accepted as an investment asset alongside more traditional options such as stocks, bonds and various other indexes. The studies reviewed in this thesis all follow a largely similar process of creating a diversified pool of assets with some difference in regional focus, such as primarily global studies published by Wu & Pandey (2014), Brière et al. (2015), Eisl et al. (2015) and Kajtazi & Moro (2018) and those who have a narrower range of assets such as the U.S.-centric assets of Bakry et al. (2021) or those by Ahnhem & Lindberg (2017) and Hernvall & Härnestav (2018) who both focus on assets on the Swedish market. Common for all is that the base portfolios, those without Bitcoin included, consist of more or less traditional assets such as stocks, bonds, real estate, commodities, currencies, and gold. Major, broad indexes are used as a proxy for these assets.

Wu & Pandey (2014) made a discovery that has since been confirmed by, and influenced the methods of, subsequent studies on Bitcoin returns, namely that its returns does not follow a normal distribution, but instead exhibited high kurtosis values, which indicates that it has fat tails and thus deviates from a normal distribution. The presence of high kurtosis in the Bitcoin return distribution was later confirmed in several studies, such as those by Brière et al. (2015), Eisl et al. (2015) and Bakry et al. (2021). While Wu and Pandey did not find any signs of any skewness in the distribution, it was shown to exhibit a rather high positive skewness in later studies (Brière et al., Eisl et al. (2015)). These findings combined have led to later published papers assuming a non-normal distribution in the Bitcoin returns, which affects the model choices in order to calculate accurate and fair risk measurements.

The ways in which the various papers deal with this distribution issue differs quite a lot. Wu and Pandey (2014) as well as Brière et al. (2015) bases their approach in traditional mean-variance optimization. The former optimized their portfolios by simulating 1,000 trials in which random weights for each asset class were drawn in each trial, after which they selected the portfolio that optimized each of the examined measures. Brière et al. employs the mean-variance spanning test in their optimization process.

Later papers take a different approach from these two papers in order to mitigate the issues. Eisl et al. (2015) and Kajtazi and Moro (2018) use Conditional Value-at-Risk (CVaR), which measures the expected loss beyond a certain threshold, usually at the 95% confidence interval. Klabbers (2017) as well as Hernvall and Härnestav (2018) tackles the distribution challenge by employing bootstrapped Monte Carlo simulations.

In the optimization process, Wu and Pandey (2014) placed the constraints on the investment strategy that no shorting was allowed, and that the portfolio was to be fully invested. This strategy of checking the robustness of the results by adding constraints in the optimization process is used by all authors reviewed in this paper, with most of them (Brière et al. (2015), Eisl et al. (2015), Klabbers (2017), Ahnhem and Lindberg (2017), Hernvall and Härnestav (2018), Kajtazi and Moro (2018)) uses four constraints while Bakry et al. (2021) imposes 10 different constraints on their portfolios. By employing this strategy, the results will both reflect the difference in investor's risk aversions and investment strategies, as well as ensure that the results are not contingent on a certain investment strategy. An example of such a constraint is the naïve portfolio, in which all assets are allocated equal weights, which has been shown by DeMiguel et al. (2009) to report performances as good or sometimes even better than a constrained portfolio framework. Other common constraints are those that do not allow for short selling, those that cap the maximum weight of an individual asset at 25% and those that seek to minimize portfolio variance in the optimization process. In evaluating the performance of the various optimal portfolios, the reviewed papers use a wide range of performance measures. All papers use the Sharpe ratio in its traditional form (Wu and Pandey (2014), Ahnhem and Lindberg (2017), Klabbers (2017), Hernvall and Härnestav (2018)) or in some variation with an adjusted risk measure such as the CVaR in place of the standard deviation (Brière et al. (2015), Eisl et al. (2015), Kajtazi and Moro (2018), Bakry et al. (2021)). Other common performance measures are the Sortino- and Omega-ratios as well as the Black-Litterman approach.

There is a general consensus in the results and conclusions of all the reviewed papers that Bitcoin will give benefits to the investors when included in their asset pool, in the form of higher risk-adjusted returns. Moreover, all papers suggest that the proportion of Bitcoin in the portfolio should be fairly low, depending on which constraints that are placed on the portfolio. There are some discrepancies in the optimal weight allocations, but they overall stay within a few percentage points of each other with e.g. Ahnhem and Lindberg (2017) suggesting weights from

0,4-4,4%, Kajtazi and Moro (2018) found weights between 2,88-5,47% to be optimal and the portfolios of Eisl et al. (2015) consisted of between 1,65% and 7,69% Bitcoin.

As for Bitcoin's capabilities to act as a diversifier or hedge against the other assets in the pool, Wu and Pandey (2014) found low correlations with all assets which suggested that Bitcoin be a potent diversifier. Similar findings were presented by Brière et al. (2015) and Eisl et al. (2015), with the former also suggesting that the low levels of correlation with other assets could even place Bitcoin in the safe haven category but include the caveat that these findings could very well be influenced by the fact that the returns were observed during a rather bullish time period. Eisl et al. (2015) similarly show very low or insignificant correlations, but do not draw any conclusions regarding its classification as diversifier, safe haven or hedging-capabilities. Dyhrberg (2015) found that Bitcoin showed clear hedging capabilities against the Financial Times Stock Exchange Index (FTSE) as well as some uncertain but possible hedging capabilities against the U.S. dollar in the short-term.

Hernvall and Härnestav (2018) find that from a Swedish investor perspective, Bitcoin is negatively correlated to short- and long-term bonds, housing, gold, USD/SEK and JPY/SEK which by their definitions classifies Bitcoin as a hedge against those assets. They further find that Bitcoin has a low positive correlation to their stock and commodity indexes as well as the CHF/SEK exchange rate, thereby classifying it as a diversifier towards those assets. Furthermore, by identifying 2016 as a year of great uncertainty and market instability following major events such as Brexit and the U.S. elections, they isolate this period in order to test Bitcoins safe haven-properties against the other assets. They find that Bitcoin had a negative correlation against the stock, housing and commodities indexes, which makes Bitcoin a safe haven against those assets. The correlation between Bitcoin and the other assets remained very low during those distressing times, meaning that it remained suitable as a diversifier during those times.

Bakry et al. concluded that due to the low correlation with most other asset classes, Bitcoin appeared to have low to medium potential as a diversifier. Furthermore, they show that during early 2020 there was a sharp decline in the correlation between Bitcoin and other asset classes, which they suggest could be an indicator that Bitcoin has the potential to be classified between a hedge and safe haven according to the generally agreed definitions of Baur and Lucey (2010).

3. Problem Definition and Problem Analysis

As described, Bitcoin has been traded on a significant level for over 8 years now and previous research has confirmed that Bitcoin should be included in an investor's portfolio as a diversification strategy, both in a global portfolio and Swedish portfolios. However, many of these studies (especially the Swedish studies) are a few years old and therefore based on data collected from a time where Bitcoin was traded at a much lower volume at a much lower price than what we have seen during the past years. As previously described, the value of one Bitcoin exploded in value in late 2020 and has since experienced major ups and downs with the value being halved, doubled again and then once more approximately halved to the value we observe today. We believe that the data from these additional years of trading can contribute valuable insight and call for a review of the conclusions arrived at by previous authors. One statement still remains true when comparing now with the time those papers were written; although Bitcoin certainly has increased even more in popularity in general, it has yet to find its way into the more traditional portfolios. This is despite the fact that research has suggested for a good few years now that a traditional portfolio could benefit in terms of diversification from including Bitcoin.

Therefore, we want to analyze whether it would be wise for the holder of an average Swedish portfolio to include Bitcoin as one of the assets as a means of diversifying risk whilst increasing the returns. We want to analyze what such a portfolio would look like in an optimized state and what weight Bitcoin would have in the allocation of the various assets. Since not all investors have the same preferences for risk and investment strategies, we also want to incorporate this aspect into our methods and analysis.

Furthermore, we would also like to test the validity today of previous comparisons that have made between Bitcoin and gold as a hedging and safe haven tool, e.g. Dyhrberg (2015), by examining Bitcoin's correlation with the other assets in the pool to check for these properties.

4. Purpose of the Thesis

The purpose of this thesis is to analyze and evaluate the effect that an inclusion of Bitcoin in the average Swedish portfolio would have on the risk-adjusted performance of the portfolio, in order to conclude if it is a worthwhile investment asset or not. Additionally, we would like to further test the previously suggested properties that Bitcoin can have as a hedging and safe haven-asset. Consequently, our research questions are as follows:

Is Bitcoin a worthwhile asset to include in the portfolio of an average Swedish investor?

Can Bitcoin serve as a hedge and/or safe haven against other assets in an investment portfolio?

5. Theoretical Framework

5.1 Modern Portfolio Theory

The method this paper will use to evaluate whether Bitcoin is a suitable asset for portfolio diversification purposes builds on the famous Modern Portfolio Theory (Markowitz, 1952, 1976), also known as mean-variance analysis. The theory makes use of efficient frontiers, which can be summarized as the set of possible portfolios, made from a specified collection of assets, that will maximize returns at a given level of risk. By using this frontier of portfolios, it is possible to find the one portfolio that have the highest ratio of returns to risk given various constraints.

5.2 Hedge and safe haven

For our purposes, we use the definitions of hedge, diversifier and safe haven as presented by Baur and Lucey (2010) where a **diversifier** is defined as an asset that is positively (but not perfectly) correlated with another asset or portfolio *on average,* a **hedge** is defined as an asset that is uncorrelated or negatively correlated with another asset or portfolio *on average* and a **safe haven** is defined as an asset that is uncorrelated or negatively correlated with another asset or portfolio *in times of market stress or turmoil.* So if Bitcoin show a negative correlation with other assets on average, this indicates a strong hedging capability. If they have no correlation, the hedging capability is said to be weak.

6. Data collection

6.1 Data collection

The data used in this paper is collected for the time period between March 1st 2012 to March 31st 2022, the main reason behind the time frame chosen being that Bitcoin did not see any trading volume of note until the beginning of 2012. All the data is gathered from Bloomberg, except for Bitcoin which is gathered from Bitcoinity.org, which in turn gathers its transaction data directly from the software interface of 19 different trading platforms.

In order to create a representative portfolio of the average Swedish investor we are using, as the referred to authors before us have, a wide collection of asset classes. Assets such as stocks, bonds, gold, real estate and commodities represented by Swedish market indexes (except for gold and commodities). The reason why we choose to use Swedish indexes is because of proximity bias. Proximity bias is described by Lindblom et al. (2017) as a phenomenon where investors tend to invest locally because there is a lower cost of gathering information. Even when there are equal costs investors choose to invest locally. Another reason for investors' proximity bias is that they know their local firms well and because the firms they invest in act locally they feel that they can monitor the companies they have in their portfolio better. Since the investors are "close" to their companies they can quickly and easily reallocate the assets in their portfolio if bad news about their investments would occur. Due to the lack of widely used Swedish indexes for commodities and gold, we have chosen to use the S&P GSCI Commodity Spot index as a proxy for the former and Bloomberg's XAU index which tracks the price of one troy ounce of gold in U.S. Dollars.

While gold and USD might not be traditional assets held by the average Swedish investors, Dyhrberg (2015) has shown that Bitcoin has shown hedging capabilities against these two assets, why we have chosen to include them in our pool. The following assets are included in our asset pool:

1. **Stocks – OMX Stockholm 30 (OMXS30)**
    - **a.** An index containing the 30 most liquid stocks on the Swedish Stock Exchange (Nasdaq, 2022)
2. **Bonds – OMX Nordic Exhange Stockholm's Interest-rate Indexes (OMRX1-3 & OMRX5+)**

   a. OMRX is a collection of indexes showing the value growth trend for a passively managed portfolio of liquid interest-bearing Swedish securities. Our portfolio includes two different OMRX indexes; the index for bonds with 1-3 year maturities as well as the index for bonds with 5+ years maturities (Nasdaq, 2022)

3. **Commodities – S&P GSCI Commodity Spot (S&PGSCI)**
   a. A leading measure and benchmark for investment performance in the global commodity markets (Bloomberg, 2022)
4. **Real Estate – Valueguard-KTH Housing Index (VG-KTH)**
   a. An index constructed to be a consistent and reliable benchmark for the traded private real estate house and apartment markets in Sweden (Valueguard, 2022)
5. **Gold against the USD Index (XAU)**
   a. An index of the spot exchange rate for one troy ounce of gold against the US Dollar (Bloomberg, 2022)
6. **US Dollar Exchange rate** (**USD)**
   a. The exchange rate between the US Dollar and the Swedish Krona.
7. **Bitcoin – Bitcoinity.org (BTC)**
   a. An index tracking the price of 1 Bitcoin traded against US Dollars on 19 different trading platforms (Bitcoinity.org, 2022).
8. **Risk free rate (CTSEK10Y)**
   a. CTSEK10Y Index is an index of a 10 year Swedish government bond investment (Bloomberg, 2022).

6.2 Data issues

An issue with compiling the data is the difference in trading hours. One unique aspect of Bitcoin compared to the other assets is that Bitcoin is traded around the clock, which means that the Bitcoin data for a ten-year period will result in many more data points than the data for assets that are only traded when the exchanges are open and a transformation of the data into a uniform timeline is thus needed. Furthermore, as Bakry et al. (2021) points out, there is a risk with using raw daily data that it will pick up too much noise, why a longer interval is recommended. Considering this, we have chosen to retrieve the daily closing price data for all assets, except for the VG-KTH housing index which only provides monthly data, from which we then calculate monthly averages which will be used in our optimization process.

7 Method application

7.1 Model choice

Employing the classic mean-variance model assumes that standard deviation is an adequate measure of risk, which is based on the further assumption that the returns of the assets follow a normal distribution. When returns do not follow a normal distribution, however, other measures of risk are recommended (Bodie et al., 2021). Bitcoin returns has been shown to be positively skewed and exhibit large excess kurtosis (Eisl et al., 2015). Positive skewness means that the distribution does not follow the symmetrical, bell shaped, curve of the normal distribution but rather that the curve is skewed to the right which indicates that extreme positive outcomes dominates. Excess kurtosis means that there is more probability mass in the tails of the distribution compared to what is predicted by the normal distribution, with less probability mass near the center of the distribution. Visually, this is represented by "fatter" tails and a pointier center (Bodie et al., 2021).

One often used model to meet the challenges of a non-normal distribution is the Value-at-Risk (VaR) model, which measures the loss corresponding to a low percentile of the entire return distribution. In other words, it could be seen as a measure of worst-case-scenarios. Employing VaR at a certain confidence level, e.g. 95%, will provide a value which the losses will not exceed over a given time period (Eisl et al., 2015). However, as shown by Rockafellar and Uryasev (2002) VaR is burdened with some rather serious disadvantages in cases where the distribution is non-normal. Such disadvantages is that the model is unstable and numerically difficult, as well as that it does not give any hint of the severity of the losses beyond the cut-off point as indicated by its confidence level. This means that in cases with a non-normal distribution with the possibility of a wide range of losses beyond the cut-off point, VaR tends to underestimate the risk.

Another recommended model to use in cases is of non-normal distributions is a variation of VaR, namely the Conditional Value-at-Risk (CVaR) model which as the name indicates builds on the former model. The difference between the two models is that instead of only providing a threshold level of losses as VaR will do, CVaR calculates the expected value of the losses given that the worst-case-scenario becomes a reality (Bodie et al., 2021).

This paper follows in the steps of Eisl et al. (2015), Kajtazi and Moro (2018) and Bakry et al. (2021) in using historical CVaR as risk measure, due to the advantages and disadvantages described above. This paper further is further convinced by the arguments made by Kajtazi and Moro (2018) that the CVaR approach uses more realistic assumptions regarding investor's risk preferences. The mean-variance approach makes use of variance, which includes both the upside and downside volatility. However, assuming that the investors are rational, they will only be concerned about the downside risk, which is something that is reflected by instead employing CVaR as risk measure.

7.2 Calculating portfolio risk using CVaR

In order to arrive at the CVaR of all individual assets included in our asset pool we follow the model presented by Kajtazi and Moro (2018), which uses the historical/empirical approach. This approach fits well with the observations of the skewness and kurtosis of the Bitcoin returns as previously mentioned, since as they point out it does not make any assumptions of normality because the distribution is gathered from the historical data. This model does come with a disadvantage, which is that it is assumed that the distribution will continue to follow the same non-normal distribution in the future.

Again, using daily data for each asset, we calculate monthly averages of the daily returns. In addition to address the issues mentioned in section 6.2, we choose monthly data as our basis due to the fact that all but one of our referenced articles uses monthly data, which makes our data more suitable for comparison with those.

Thereafter, CVaR is rather straightforwardly calculated as the mean of all observations in the 5^{th} percentile of the monthly averages, or in other words as all observations that fall on or below the VaR threshold at the confidence interval level of α = 5%:

$$CVaR = \frac{1}{N}\sum_{i=1}^{N} \quad MA : MA \leq V \tag{1}$$

To calculate the expected return and the CVaR of the portfolio, the following formulas will be used:

$$CVaR_p^2 = \sum_{i}^{n} \quad \sum_{j}^{n} \quad w_i w_j CVaR_i CVaR_j \rho_{ij}$$

where (2)

w_{ij} = asset weight

$CVaR_{ij}$ = asset CVaR

$\rho_{ij} = asset\ correlation$

Portfolio risk can then be derived as:

$$CVaR_p = \sqrt{CVaR_p^2} \tag{3}$$

The expected returns of the portfolios are calculated as:

$$E(r_p) = \sum_{i=1}^{n} w_i E(r_i) \tag{4}$$

7.3 Portfolio optimization

Given our risk measure, $CVaR_p$ and our monthly return measure, $E(r_p)$, we can combine these to arrive at the formula for the measure which we use to optimize our portfolios – the Risk-Return ratio:

$$RR_p = \frac{E(r_p) - R_f}{CVaR_p} \tag{5}$$

As the risk-return ratio in the numerator uses monthly excess returns we subtract the corresponding risk-free rate, as reported by the Swedish central bank, from our observations and the data presented in our results section is thus referring to excess returns. We then compile the monthly excess return data, covering the whole sample period, for all assets in the asset pool in an excel spreadsheet and arrange it in such a way that we are able to calculate from a portfolio consisting of all assets values for excess returns, VaR, CVaR, standard deviation and the risk-return ratio. For the first portfolio, we input the weight allocation of the portfolio manually and for the remaining scenarios – as described below – we use the Solver function in Excel to

calculate the portfolio weight allocation that will maximize the risk-return ratio given certain constraints that we input in the function. We can thereafter compare these portfolios in terms of risk-return ratio, risk measures and returns and draw conclusions on whether adding Bitcoin to the asset pool will be beneficial to the investor or not.

In order to test the strength of the results, we repeat the optimization under four different constraints, or scenarios, in order to reflect various preferences and limitations of the investor. This method is adopted from those papers we reviewed under the article review section of this paper, with the four chosen scenarios being the most commonly occurring ones, used by for example Eisl et al. (2015), Kajtazi & Moro (2018) and Bakry et al. (2021). We will thus in total have optimized eight different portfolios under these different constraints; four including Bitcoin and four excluding it.

Scenario 1: **the Naïve portfolio (**$w_i = \frac{1}{N} \forall\ i$)

In the first scenario, which does not require use of Solver since the weights are predetermined, the constraint is that the portfolio must be made up of all available assets in the pool with an equal weight distribution of the total portfolio budget. This follows from the findings of DeMiguel et al. (2009) who in their paper show that equally weighted portfolios tends to perform as well or even better than portfolios that use various optimization techniques, in terms of Sharpe ratios. They attribute their results to the lackluster predictive ability of many common risk-return measures. Since the weights of this portfolio is pre-determined, it will not undergo the same optimization procedure as the other three portfolios.

Scenario 2: the Conservative Portfolio ($w_i \leq 0.25; \sum w_i = 1$)

In this scenario, we set the restrictions so that no asset can claim more than 25% of the total portfolio budget. This restriction follows from the findings from Conover et al. (2009) that portfolio managers are unlikely to allocate more than 25% of the portfolio budget to one single asset.

Scenario 3: the No Shorting Portfolio ($w_i \geq 0; \sum w_i = 1$)

This portfolio sets the constraint that no shorting is allowed. While shorting Bitcoin has developed into a relatively easy procedure over the years, it remains a rather advanced investment strategy. This paper believes that including a scenario which disallows shorting is suitable to reflect the many investors who are novice or intermediate and refrain from utilizing shorting strategies.

Scenario 4: the Unconstrained Portfolio

This first portfolio will set not constraints on the optimization process and should therefore in theory give us the truly optimal allocations of assets in terms of risk-return ratio. There is however a risk that such a portfolio will have both very large asset weights as well as unrealistic short positions.

7.4 Hedging and safe haven evaluation

To be able to determine whether Bitcoin exhibits hedging and/or safe haven attributes, we construct correlation matrixes from the assets' monthly average returns. One of the constructed matrixes includes data from the whole period of interest and will be used to examine the hedging capabilities of Bitcoin against the other assets in the pool.

The other correlation matrix that is constructed uses data from February 2020 until the end of the same year. This is in order to test the safe haven-properties of Bitcoin, which is best done when looking at the correlation between it and the other assets during extraordinary times. Covid-19 hit worldwide in the spring of 2020, which lead to a massive fall in the markets. After the initial shock, the markets recovered remarkably towards the end of the year, however with continued turbulence and more sharp drops throughout the year as worrying forecasts about the pandemic were announced. Therefore, this paper believe that it would be interesting to examine the movements of Bitcoin during that time period, along with the movements of the other assets included in the pool.

8. Results

8.1 Descriptive statistics

Table 1 presents average monthly statistics for all assets in the asset pool for the period March 2012 until March 2022. Bitcoin had a considerably higher mean return over the sample period compared to all other assets. Averaging 9,83% excess returns monthly, Bitcoin's excess returns were 11,3 times higher than the second highest, OMXS30 stock index, and 492 times higher than the worst performing asset in terms of returns, OMRX1-3. Meanwhile, it also exhibits a much greater volatility in terms of standard deviation, VaR and CVaR as well as delivering a very wide range of returns as is shown by its minimum and maximum returns during the sample period, soaring to 187,32% excess returns in November 2013 and falling as low as -39,18% in May 2021. Bitcoin furthermore exhibits a clear positive skewness and considerable excess kurtosis, which indicates that its return distribution does not follow a normal distribution, but rather that it has a longer and fatter tail on the right-hand side of the distribution. The extremes that are present in the distribution of Bitcoin can be exemplified when sorting the data by lowest to highest excess returns, where 8 months of 120 have seen negative returns at or below 25%, 30 months have seen excess returns greater than 25% and 7 months with 50% or more excess returns from the previous month.

Looking at CVaR, Bitcoin is approximately 1,6 times as volatile as the next most volatile asset, S&P GSCI commodity index, and 3,1 times as volatile when comparing their standard deviations. Compared to the least volatile asset, the OMRX1-3 bond index, Bitcoin is 93,4 times more volatile in terms of standard deviation and 44,6 times as volatile when comparing CVaR. This can be contrasted with the already stated fact that Bitcoin delivered 492 times higher average returns than the OMRX1-3 bond index, suggesting that while it is much more volatile the increase in excess returns is far greater than the increase in volatility, relatively speaking. Furthermore, compared to the OMXS30 stock index, Bitcoin had 11,3 times higher average excess returns, but was only 2,9 times more volatile in terms of CVaR and 4,9 times more volatile when considering their standard deviations. Against the S&P GSCI commodity index, Bitcoin had 33,1 times higher average returns while being 1,6 times as volatile when comparing CVaR and 3,1 times as volatile in terms of standard deviation.

Our data furthermore indicates that when looking at the risk-return ratio, Bitcoin is only comparable to one asset, the Vanguard-KTH real estate index which with a risk-return ratio of 0,24 is just about lower than Bitcoin's risk-return ratio of 0,28. The distance to the third ranking

asset in terms of risk-return ratio, however, is relatively large as the OMXS30 stock index has the third highest ratio at 0,07 – only slightly more than a quarter of Bitcoin's ratio.

Table 1
Descriptive statistics of monthly returns

	OMXS30	OMRX1-3	OMRX5+	S&PGSCI	VG-KTH	XAU	USD	BTC
Min	-14,67%	-1,79%	-7,49%	-43,17%	-3,07%	-17,21%	-7,76%	-40,16%
Max	15,93%	0,77%	6,22%	27,38%	6,37%	14,85%	10,11%	187,32%
Mean	0,87%	0,02%	0,19%	0,30%	0,55%	0,19%	0,38%	9,83%
Median	1,37%	-0,05%	0,18%	1,43%	0,41%	-0,05%	0,54%	8,23%
Skewness	-0,34	-1,68	-0,21	-0,87	0,58	0,06	0,10	2,28
Kurtosis	0,18	9,24	1,11	3,48	1,89	-0,01	-0,42	11,63
St.Dev.	5,89%	0,31%	2,17%	9,32%	1,41%	5,88%	3,61%	28,91%
VaR	10,04%	0,50%	3,70%	16,36%	1,69%	9,36%	5,33%	31,61%
CVaR	12,14%	0,80%	4,67%	22,59%	2,27%	11,33%	6,51%	35,63%
Risk-return ratio	0,07	0,02	0,04	0,01	0,24	0,02	0,06	0,28

8.2 Correlation matrixes

When considering the full sample period, Bitcoin is showing low but positive correlation with most of the asset classes, while three are negatively correlated. Bitcoin has the strongest correlation with the OMXS30 stock index, although with relatively weak strength at 0,141. It has the lowest correlation with the Valueguard-KTH housing index with a coefficient of -0,109.

When only comparing the period between February and December 2020, which was the beginning of the Covid-19 crisis, and in this thesis considered times of unusual distress, most of the correlation coefficients change considerably. Both OMXS30 stock index and S&P GSCI commodity index went from showing a low correlation to exhibiting moderate correlation with Bitcoin at 0,444 and 0,591 respectively. The largest change, however, can be seen in the correlation between Bitcoin and the U.S. Dollar where the correlation shows a large decrease, going from negative, but weak, -0,082 to a very clear negative correlation at -0,721. It is also clearly negatively correlated with VG-KTH real estate index at -0,454. Moreover, a significant change can be seen in the gold index which goes from practically uncorrelated at -0,041 to clearly correlated at 0,349. Meanwhile, the data indicates that the OMRX5+ bond index goes from being positively, but weakly, correlated to showing a weak negative correlation with Bitcoin. Overall, no clear trend can be shown as three out of seven assets increases in correlation with Bitcoin while the other four decreases its correlation.

Table 2

Correlation matrix February 2012-February 2022

	OMXS30	*OMRX1-3*	*OMRX5+*	*S&PGSCI*	*VG-KTH*	*XAU*	*USD*	*BTC*
OMXS30	1,000							
OMRX1-3	0,132	1,000						
OMRX5+	-0,052	0,710	1,000					
S&PGSCI	0,343	-0,250	-0,324	1,000				
VG-KTH	0,000	-0,010	-0,023	0,013	1,000			
XAU	-0,007	0,055	0,174	0,125	-0,186	1,000		
USD	-0,048	0,184	0,366	-0,385	0,155	-0,323	1,000	
BTC	0,141	0,101	0,068	0,112	-0,109	-0,041	-0,082	1,000

Table 3

Correlation matrix February-December 2020 (Covid-19 crisis)

	OMXS30	*OMRX1-3*	*OMRX5+*	*S&PGSCI*	*VG-KTH*	*XAU*	*USD*	*BTC*
OMXS30	1,000							
OMRX1-3	0,155	1,000						
OMRX5+	-0,091	0,844	1,000					
S&PGSCI	0,764	0,223	0,057	1,000				
VG-KTH	-0,280	0,394	0,485	-0,437	1,000			
XAU	-0,052	0,038	-0,137	0,134	-0,480	1,000		
USD	-0,447	-0,047	0,135	-0,724	0,458	-0,531	1,000	
BTC	0,444	-0,005	-0,139	0,591	-0,454	0,349	-0,721	1,000

8.3 Portfolio optimization

As is shown in table 4, when optimizing the portfolio with the target of finding the maximum risk-return ratio given the four different scenarios that were previously outlined, the naïve portfolios were first optimized without and with Bitcoin in the asset pool, with every asset being allocated 14,29% and 12,5% of the total portfolio budget, respectively.

When continuing the optimization process under the other three scenarios, Bitcoin was consistently allocated a relatively low share of the total portfolio budget, ranging from 2,92% in the no-shorting portfolio to 4,40% in the unconstrained portfolio and 6,66% in the conservative portfolio.

Table 4

Portfolio	Naïve without Bitcoin								
Asset	OMXS30	OMRX1-3	OMRX5+	S&PGSCI	VG-KTH	XAU	USD		Total
Weights	14,29%	14,29%	14,29%	14,29%	14,29%	14,29%	14,29%		100%

Portfolio	Naïve with Bitcoin								
Asset	OMXS30	OMRX1-3	OMRX5+	S&PGSCI	VG-KTH	XAU	USD	BTC	Total
Weights	12,50%	12,50%	12,50%	12,50%	12,50%	12,50%	12,50%	12,50%	100%

Portfolio	Conservative without Bitcoin								
Asset	OMXS30	OMRX1-3	OMRX5+	S&PGSCI	VG-KTH	XAU	USD		Total
Weights	4,68%	25,00%	6,46%	3,31%	25,00%	10,55%	25,00%		100%

Portfolio	Conservative with Bitcoin								
Asset	OMXS30	OMRX1-3	OMRX5+	S&PGSCI	VG-KTH	XAU	USD	BTC	Total
Weights	11,87%	25,00%	14,29%	0,12%	25,00%	1,76%	15,30%	6,66%	1

Portfolio	No-shorting without Bitcoin								
Asset	OMXS30	OMRX1-3	OMRX5+	S&PGSCI	VG-KTH	XAU	USD		Total
Weights	3,37%	27,46%	0,00%	1,80%	63,17%	4,18%	0,03%		100%

Portfolio	No-shorting with Bitcoin								
Asset	OMXS30	OMRX1-3	OMRX5+	S&PGSCI	VG-KTH	XAU	USD	BTC	Total
Weights	1,85%	30,83%	0,00%	0,22%	64,17%	0,00%	0,00%	2,92%	100%

Portfolio	Unconstrained without Bitcoin								
Asset	OMXS30	OMRX1-3	OMRX5+	S&PGSCI	VG-KTH	XAU	USD		Total
Weights	17,24%	-163,75%	27,61%	4,47%	187,08%	12,32%	-9,62%		75,35%

Portfolio	Unconstrained with Bitcoin								
Asset	OMXS30	OMRX1-3	OMRX5+	S&PGSCI	VG-KTH	XAU	USD	BTC	Total
Weights	7,18%	-6,40%	-0,87%	0,54%	117,48%	1,58%	-7,51%	4,40%	116%

In terms of performance, adding Bitcoin to the asset pool did in all four scenarios result in Bitcoin being included in the optimal portfolio when optimizing with the objective of maximizing the portfolio risk-return ratio. The naïve portfolio was affected the most by the inclusion of Bitcoin, achieving both the highest average return in terms of excess monthly returns at 1,54%, and the largest increase with 331,07% greater returns when including Bitcoin compared to when excluding it. The naïve portfolio also saw the greatest improvement of the risk-return ratio when adding Bitcoin to the portfolio, with a 183,83% increase from 0,09 to 0,24.

The conservative portfolio had the second-best transformation when including Bitcoin, as its excess returns improved by 208,82% and its risk-return ratio by 88,03%. The unconstrained portfolio had a noteworthy change in that the performance of the optimal portfolio under the scenario decreased by 7,17% when Bitcoin was added to the asset pool. Its risk-return ratio did however at the same time increase by 46,30%, as the portfolio CVaR also decreased when adding Bitcoin, by 36,55%. As for the no-shorting portfolio, it delivered the lowest numbers for both performance and the risk factors; standard deviation and CVaR. It also saw the smallest change in those numbers when Bitcoin was included among the assets.

In terms of the CVaR risk-return ratio, it is a close call between the no-shorting and the unconstrained portfolios for the highest ratio, where the latter slightly edges the former out with a ratio of 0,47 compared to 0,45.

	Naïve		
	Base	BTC	Change
Performance	0,36%	1,54%	331,07%
Std.Dev.	1,91%	4,12%	115,68%
CVaR	4,14%	6,34%	52,96%
Risk-return (CVaR)	0,09	0,24	181,83%

	Conservative		
	Base	BTC	Change
Performance	0,32%	0,99%	208,82%
Std.Dev.	1,08%	2,23%	107,28%
CVaR	1,81%	2,98%	64,24%
Risk-return (CVaR)	0,18	0,33	88,03%

	No-Shorting		
	Base	BTC	Change
Performance	0,39%	0,66%	68,04%
Std.Dev.	0,93%	1,19%	27,72%
CVaR	1,28%	1,47%	14,73%
Risk-return (CVaR)	0,31	0,45	46,46%

	Unconstrained		
	Base	BTC	Change
Performance	1,20%	1,11%	-7,17%
Std.Dev.	1,91%	2,05%	7,23%
CVaR	3,75%	2,38%	-36,55%
Risk-return (CVaR)	0,32	0,47	46,30%

9. Discussion

9.1 Bitcoin's price trend and future

Unsurprisingly, considering the findings of previous studies as well as the visual impression when inspecting the Bitcoin price graphs, our data show that while Bitcoin does offer the prospect of far greater average monthly returns than the other assets included in the pool, it does so at a price. As table 1 presents, Bitcoin have shown a volatility that is several times higher than the next most volatile asset in the pool throughout our sample period, and as much as 93,4 times more volatile in terms of standard deviation and 44,6 times more volatile according to CVaR than the safest asset, the OMRX1-3 bond index. Earlier studies, in particular those published prior to the hype around 2017 such as those by Wu and Pandey (2014), Eisl et al. (2015) and Kajtazi & Moro (2018), have more or less agreed that while Bitcoin was a very volatile asset, that fact was well compensated by very generous returns. While, as shown, Bitcoin according to our findings still provides the investor with monthly excess returns that are far above those of the other assets in the pool, it does seem to do so less convincingly since the returns we have found for Bitcoin are lower than those reported in the mentioned articles. Kajtazi and Moro, for example, employed a technique very similar to ours and reported average monthly excess returns for Bitcoin at 12,76% in their European portfolio, which is 2,8 percentage points higher than our average. They furthermore reported a CVaR of 32,93% which is 2,7 percentage points lower than the CVaR that we have calculated from our data, at 35,63%. As a consequence of these differences, they also presented a risk-return ratio – calculated in the same manner as in this thesis – of 0,39 while the risk-return ratio we found for Bitcoin was 0,27. This pattern of lower average returns in combination with a higher volatility repeats itself when comparing our results with all reviewed studies that was carried out using data prior to the beginning of 2017. This could likely be attributed to the fact that Bitcoin can be said to have entered the broader public's consciousness in early 2017, resulting in a major hype which included a sharp rise during almost the whole of 2017 before it saw a great decline in early-to-mid 2018, after which it entered a period of relative stability again. This pattern has since repeated, with brief periods of extreme returns in mid-2019, late 2020 to early 2021 and again in mid to late 2021 – all followed by a decline almost as steep as its rise. When examining the distribution of Bitcoin's returns, our findings have confirmed those by previous authors in that Bitcoin is showing a positive skewness and large excess kurtosis. In fact, our data shows that when including the period between 2017-2022 the skewness is generally on approximately the

same level as that presented by for example Wu & Pandey, Brière et al. and Kajtazi & Moro, but with a notable increase in kurtosis. Only Eisl et al. had more extreme indications of skewness and kurtosis at 3,19 and 14,95, respectively, during the period July 2010 to April 2015.

Overall, the impression that Bitcoin is an unusual asset that promises great but uncertain returns is confirmed by our data. Our findings do thus not offer any more clues as to the future of Bitcoin in terms of whether or not it will stabilize around a certain price level. One reason for this continued uncertainty could be, as Bakry et al. (2021) suggests, that institutional investors lack interest in Bitcoin, since they see it as nothing but a bubble that is fueled by young, inexperienced investors, in addition to some lingering concerns about legal, taxation and accounting problems surrounding cryptocurrencies.

This may very well be one major reason behind the very high volatility that can be seen in Bitcoin's returns. Unlike assets which are taken more seriously by institutional investors and financial scholars, there does not seem to exist any established and sophisticated models for calculating and forecasting the value of Bitcoin. Instead, it is very much driven by pure speculation and highly influenced by the general consensus at the time, which evidently can shift very quickly, for example with the tweet of an influential person such as Elon Musk. Since Bitcoin lacks intrinsic value and has price movements that are much harder to foresee compared to a regular stock, for example, which to a much greater extent can be predicted by things such as company news and financial reports, it might also be the case that what drives at least part of the volatility in Bitcoin is people reacting to the actions of other people rather than any other indicators of Bitcoin's value. This may especially be true in the wake of the extreme ups and downs of the last five years, which can be observed in the Bitcoin price chart in Appendix A, where people are quick to act as they know that the value might either double or be cut in half within a short period of time.

9.2 Bitcoin's place in an optimized portfolio

Despite the issues stated above, our results show that previous findings that Bitcoin can contribute significant value to a well-diversified portfolio in terms of risk-adjusted returns still hold true. In line with previous studies, our data suggests that a portfolio optimized in accordance with various assumed investor preferences will include a significant, but relatively small, proportion of Bitcoin in the range of 2,92-6,66% when excluding the naïve portfolio. This is in the same region as the suggested allocation that was suggested by authors such as

Ahnhem and Lindberg (2017) who suggests weights between 0,4-4,4%, Kajtazi and Moro (2018) who found weights between 2,88-5,47% to be optimal and Eisl et al. (2015) whose portfolios consisted of between 1,65% and 7,69% Bitcoin.

Interestingly, the simplest portfolio composition – the naïve portfolio – show the highest performance increase in terms of pure average excess monthly returns as well as improved risk-return ratio when including Bitcoin in the asset pool and portfolio. This further supports the findings of De Miguel et al. (2009) that a portfolio where the weights are allocated evenly among the assets on average will perform as well or even better than a constrained portfolio framework. However, the naïve portfolio is also the portfolio with the highest volatility in terms of standard deviation and CVaR, so the higher returns unsurprisingly come at the cost of higher volatility.

The portfolios that delivered the highest overall risk-return ratios was the unconstrained portfolio, narrowly followed by the no-shorting portfolio. Common for these portfolios is that they only include a small amount of Bitcoin and other risky assets, such as the OMXS30 stock index, and instead have an emphasis on low-risk assets in the portfolio, in particular the Vanguard-KTH housing index – which has the second lowest volatility of all assets. This would, as one could expect, suggest that the best approach to achieving the highest risk-return ratio when trading with Bitcoin is if it is combined with a few low risk, traditional assets, thus diversifying away some of the inherent risk in Bitcoin as it is today while simultaneously reaping some of its benefits in the form of very high returns.

The naïve and the conservative portfolios are the ones where the effect of adding Bitcoin, compared with the base portfolio under the same constraints, is strongest in terms of percentage change in both pure performance as well as risk-return ratio. This coincides with the fact that the proportion of Bitcoin is highest in these portfolios. The naïve portfolio has the highest increase in performance and risk-return ratio, 331,07% and 181,83%, while also having the highest allocation of Bitcoin, 12,5%. For the conservative portfolio, the corresponding numbers are 208,82% performance increase and 88,03% risk-return improvement while consisting of 6,66% Bitcoin. This is a logical consequence of the fact that Bitcoin as an individual asset delivers by far the highest average returns as well as the highest volatility. Again, this shows that when adding Bitcoin to a portfolio one makes a trade between portfolio returns and portfolio risk. Bitcoin could thus be a very worthwhile addition to the portfolio, but the investor must be aware of the consequences of including it and thoughtful of what level of risk they are willing to bear as it quickly rises as the amount of Bitcoin rises.

9.3 Bitcoin's properties as diversifier, hedge and safe haven

As Baur and Lucy (2010) defined safe haven, diversifier and hedge, Bitcoin could in this this pool of assets function very well as a diversifier given that there is no asset that Bitcoin is more than weakly correlated with. Our data suggests that Bitcoin could have hedging capabilities against real estate (VG-KTH), gold (XAU) and U.S. Dollars (USD), since it is negatively correlated with those assets, the clearest of them being towards real estate. It is however not as clear when it comes to the 5+ year maturity bonds in OMRX5+ index, since it does have a positive correlation with Bitcoin, but with a rather low coefficient which could mean that Bitcoin could still act as a weak hedge towards it. Bitcoin have the highest positive correlation with the OMXS30 stock index, the S&PGSCI commodity index and the OMRX1-3 bond index, with relatively low but not insignificant coefficients, which would suggest that its hedging capabilities against those assets are doubtful. This stands in contrast with the findings of Dyhrberg (2015) who found that Bitcoin had clear hedging capabilities against the Financial Times Stock Exchange Index. On the other hand, Dyhrberg also found that their results could not support any claims of Bitcoin being a hedge against the U.S. Dollar, so the positions seem to have switched when it comes to our results. These differences could be attributed to several factors, such as the differing sample period (2010-2015 compared to 2012-2022), their use of a rather different model (GARCH) or the fact that they used indexes tracking the London stock exchange as well as the USD against the Sterling Pound and Euro, while this thesis uses an index tracking the Stockholm stock exchange and the USD/SEK exchange rate.

Furthermore, our findings are mostly in line with those of Bakry et al. (2021), as they found similar correlation coefficient to ours, except for gold where they had a relatively clear positive correlation between it and Bitcoin whereas we found the coefficient to be negative, but barely so. This discrepancy casts some doubt over the suggestion by some authors, such as Dyhrberg, that Bitcoin could be placed in the same asset class as gold when it comes to minimizing specific market risks. At the very least, it indicates that any such signs have become less pronounced as Bitcoin has developed as an asset.

The period between February 2020 and December 2020 was chosen for our second correlation matrix in order to reflect a turbulent market during the Covid-19 crisis. Looking at the matrix during this time period, the changes in correlations were relatively large and there are still only three assets that show a negative correlation. The assets that Bitcoin is negatively correlated with during times of extreme market conditions are OMRX5+, VG-KTH and USD. The correlations are rather clearly negative, especially so for VG-KTH and the USD index, which

suggest that Bitcoin could potentially be used as a safe haven asset against these three assets during times of extreme market conditions. As for OMXS30, S&PGSCI and XAU, our data shows that Bitcoin exhibits a moderate positive correlation with these assets which would indicate that they are not very suitable to hold in combination with Bitcoin during extreme market conditions.

One interesting relationship that can be observed in the correlation matrixes is that between Bitcoin and gold (XAU). This is particularly interesting due to the fact that Bitcoin has often been called the "digital gold", with similarities being that both lack intrinsic value and instead derive their value from things such as their scarcity of supply. However, as shown the correlation between Bitcoin and gold over the complete sample period is weakly negative, which does not seem to correspond to the claim that Bitcoin is the digital gold, since their correlation in that case should be positive. Baur and Hoang (2021) provide possible explanations as to why this discrepancy exists; either that it is just a narrative that is not accepted by investors, or that there are other factors that affect the correlation, such as a substitution effect or what they call a catching-up effect. The substitution effect means that investors are simply substituting their gold holding for Bitcoin and the catching-up effect that they are complementing their gold holdings with Bitcoin. Their reasoning is that while these assets might both be driven by factors that should make their correlation positive, a consequence of them selling one asset to buy the other, or if they buy for example Bitcoin instead of increasing their holdings of gold, the correlation between the assets would be significantly reduced.

This may however not just be the case for the correlation between Bitcoin and gold, but between Bitcoin and the other assets in the asset pool as well. As previously mentioned, many institutional investors still shy away from investing in Bitcoin while a lot of the investments instead come from younger individuals who are not building traditional diversified portfolios. These 'alternative', if you will, investors seem to rather have a very clear focus on Bitcoin and other crypto currencies as well as other digital assets such as non-fungible tokens (NFT). This means that they are to a high degree abandoning traditional assets such as stocks and bonds for these digital assets, thus lowering the correlations in a similar way to the substitution effect as described above. Even if they do not sell their traditional assets, but instead just complement them with investments in Bitcoin and similar assets, this could also affect their correlations like the described catching-up effect.

10. Conclusion

Bitcoin has certainly entered the global financial markets with an air of something different and innovative, seducing some – perhaps mainly the young and daring – and causing some to brush it off as something naïve, speculative and doomed to fail. Regardless of such opinions, our results seem to confirm what has been suggested for a long time; Bitcoin is an asset that is worth taking seriously as a means of diversifying an investment portfolio. As the portfolio optimization have shown, investors with different kinds of preferences and strategies are able to enhance their risk-reward ratio if they include a small portion of Bitcoin among their assets. The key term, as previously stressed, is however *risk* as the overall portfolio risk quickly increases even with small incremental increase of the Bitcoin weights. It is therefore of utmost importance that the investor who wishes to include Bitcoin in their portfolio do their due diligence as to how it will affect their risk profile, and whether it is worth it. We do however wish that we would have had the time to include more measures of risk and performance as well as additional constraints in our optimization, in order to enhance the strength and comparability of our results.

Furthermore, our results also suggest that Bitcoin does seem to have some of the hedging and safe haven properties as have been suggested, although the correlations do not show a clear trend of movements against all other assets and the examined timeframe might be a bit too short and unique (hoping that we will not see such a paralyzing and terrible pandemic again) to provide a completely satisfying strength of results. These correlations do however give further support to the impression that Bitcoin is still an asset that is very different from most traditional assets that we are used to and that they exist somewhere on the outskirts of the investment community, not yet fully accepted as a legitimate investment option. This despite the clear advantages it brings in terms of a being a powerful boost to the risk-return ratios of portfolios.

It is worth reminding that Bitcoin is a, comparatively, new asset on the financial markets and it will be very interesting to see its price development as it matures as an asset, both in terms of establishing itself further in investor portfolios as well as possible regulatory development addressing some legal and accounting issues. We are wishing for many more research on Bitcoin and other crypto currencies place in and effect on investment portfolios and are looking forward to seeing what the future might hold for it as both a currency and investment alternative.

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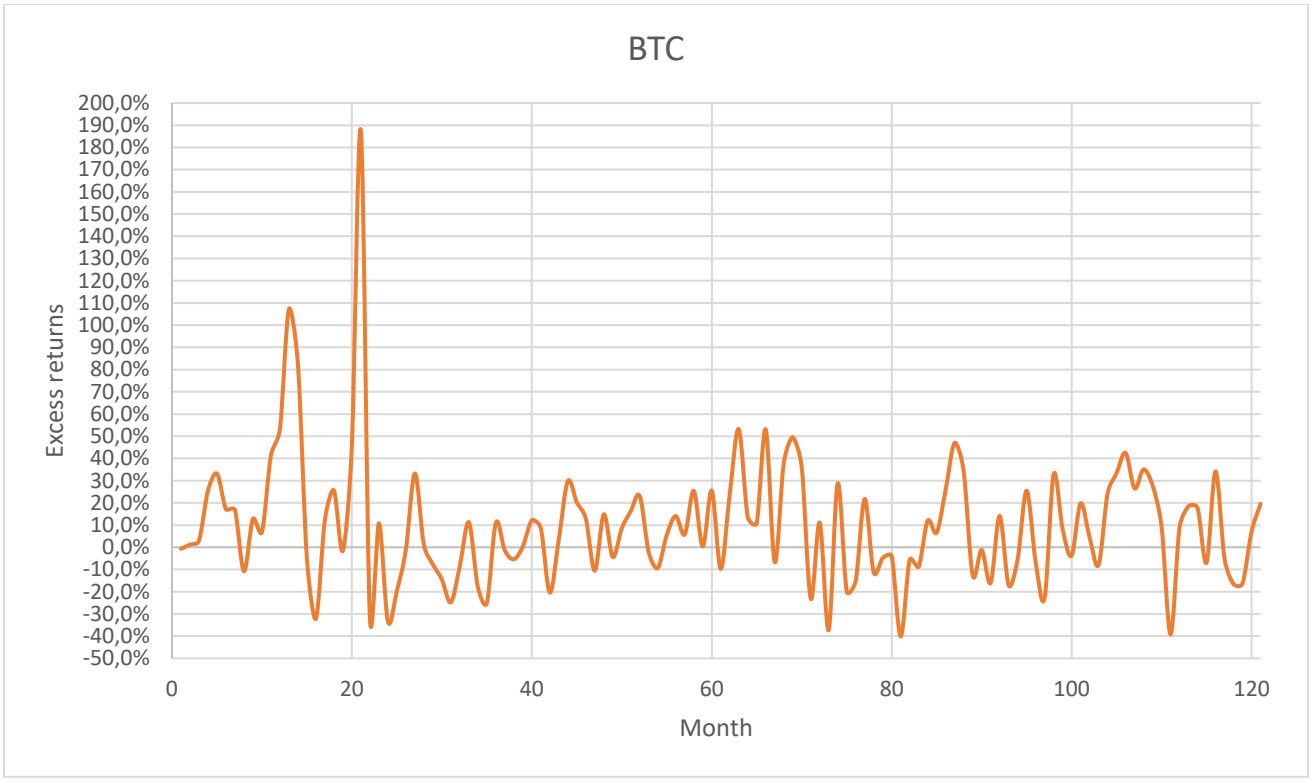
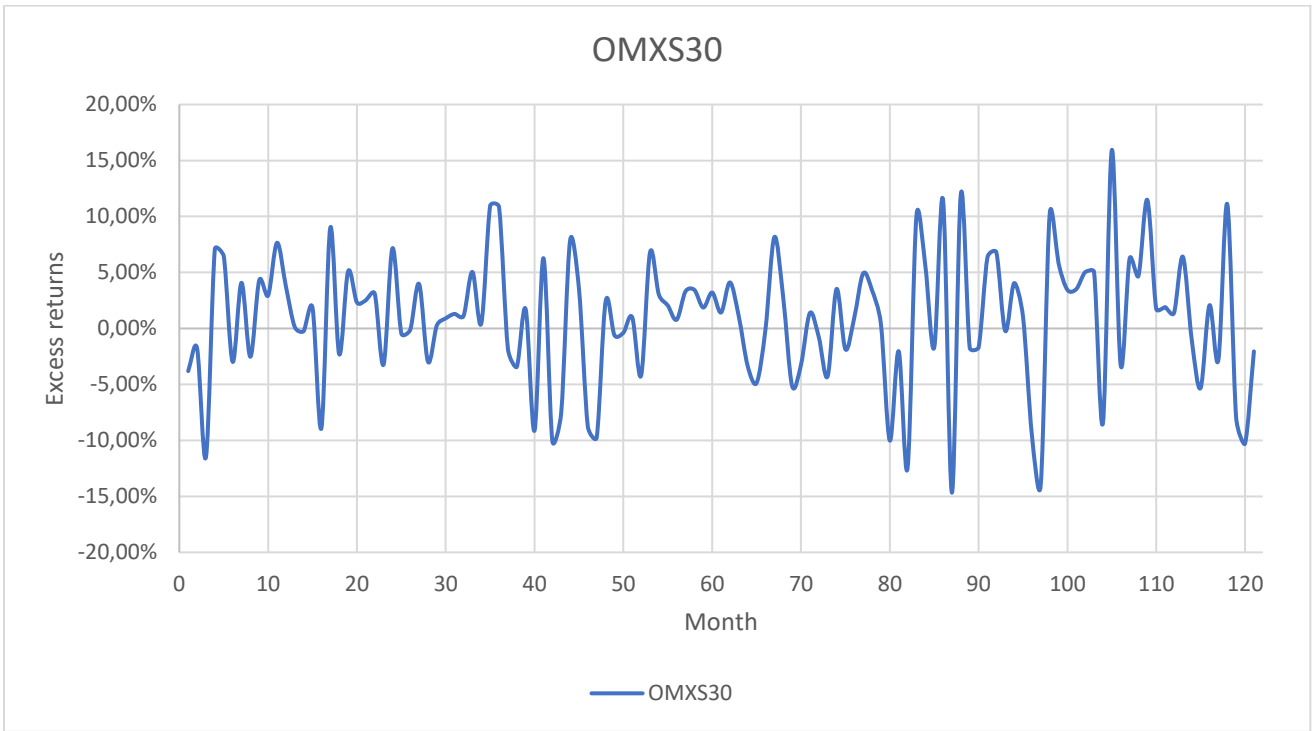
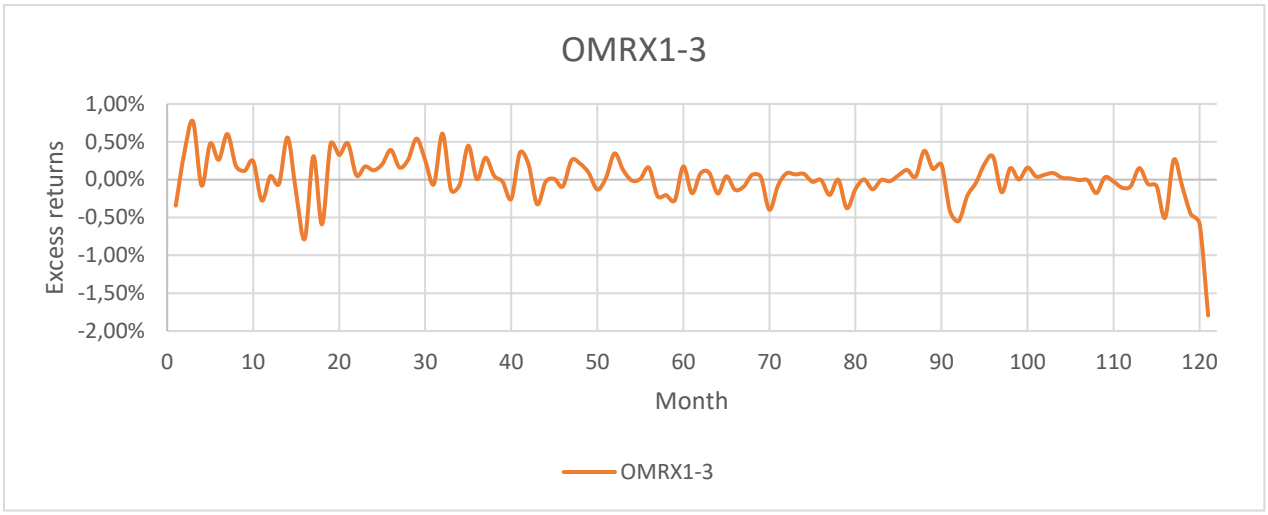
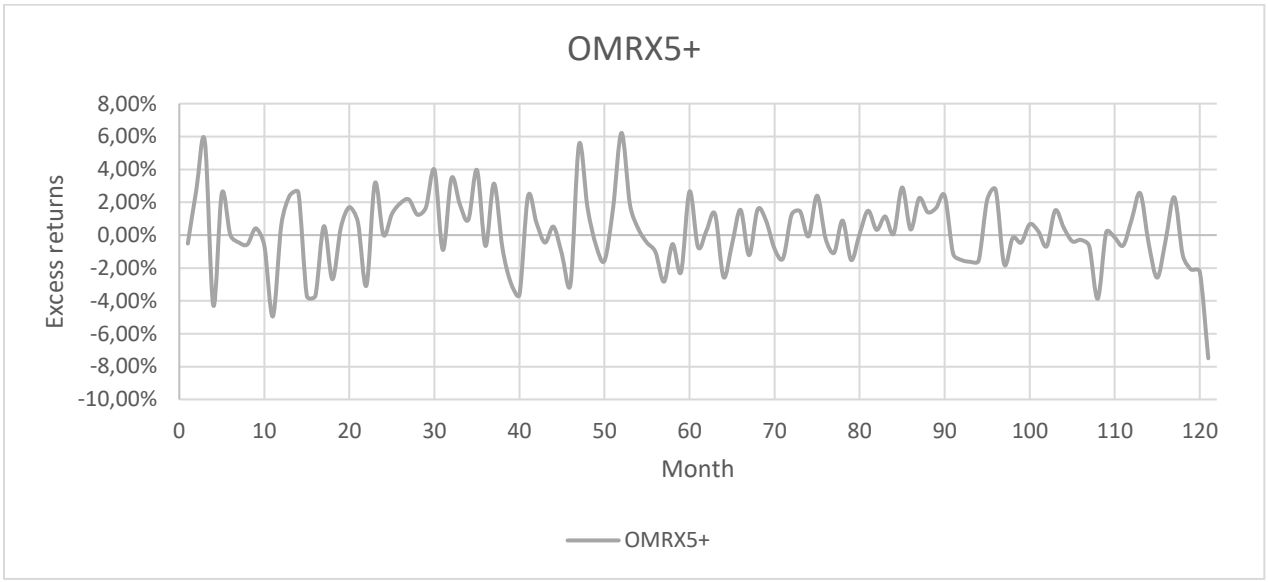
Appendix A

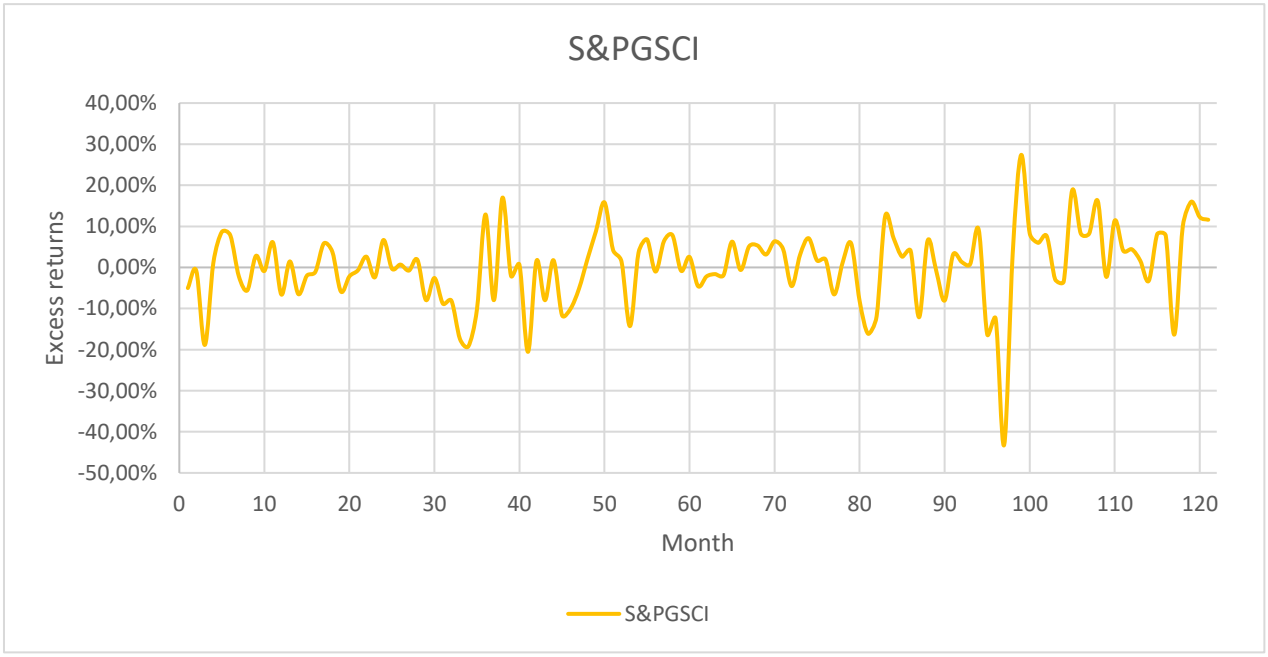
This appendix includes charts over the excess returns of each asset in the asset pool, ranging from March 2012 (Month 1) to March 2022 (Month 121).

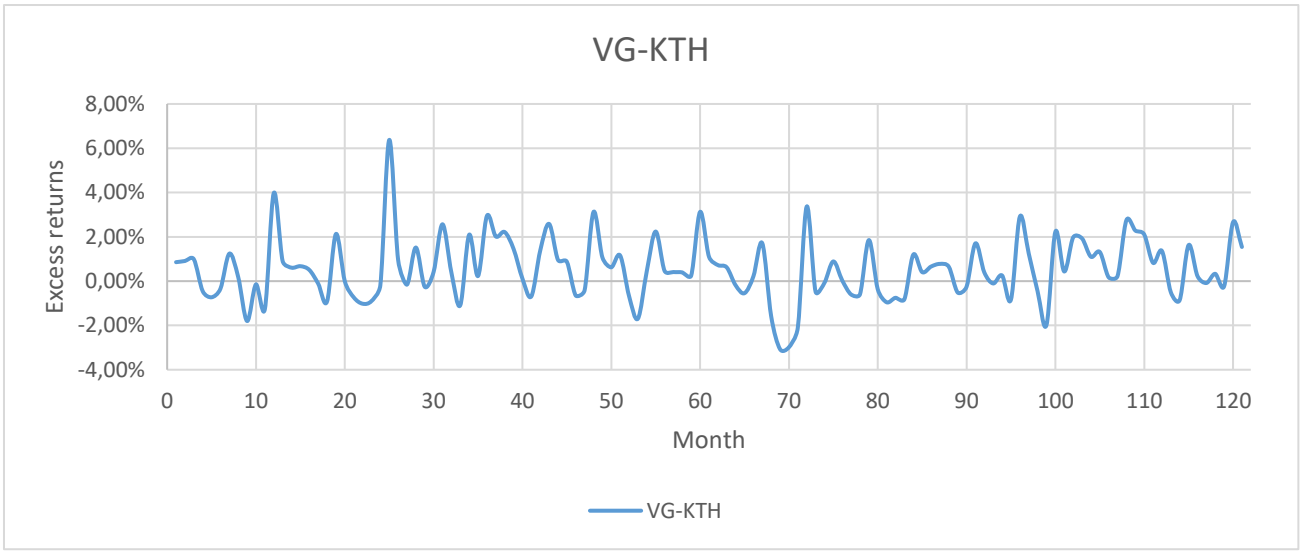


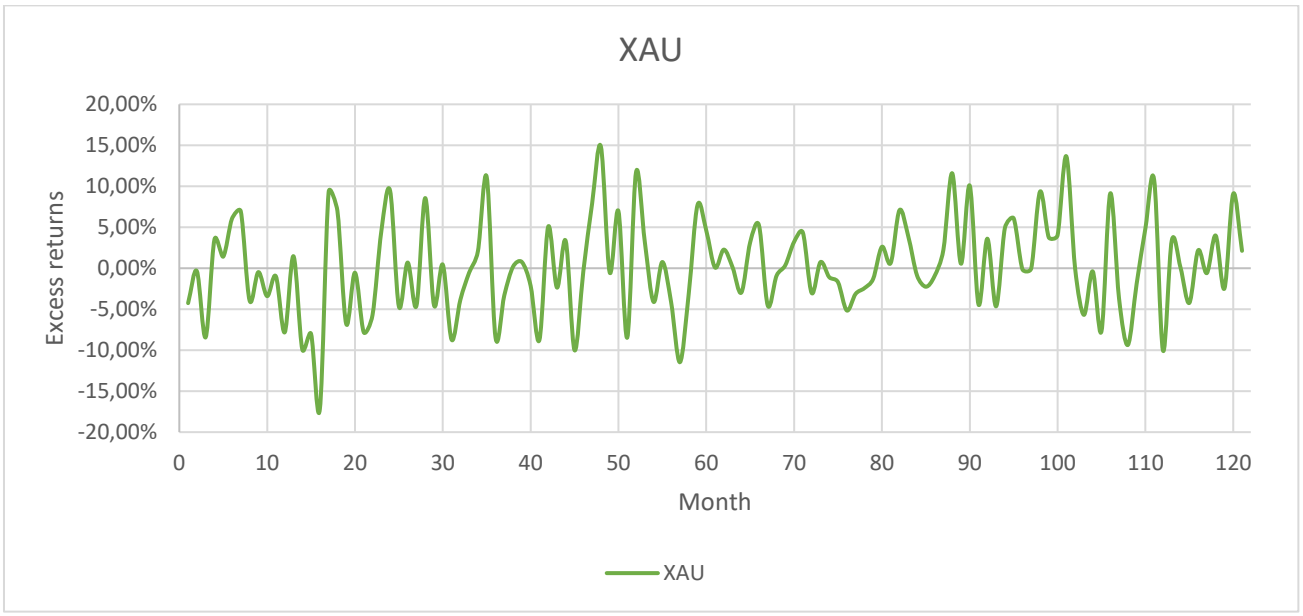


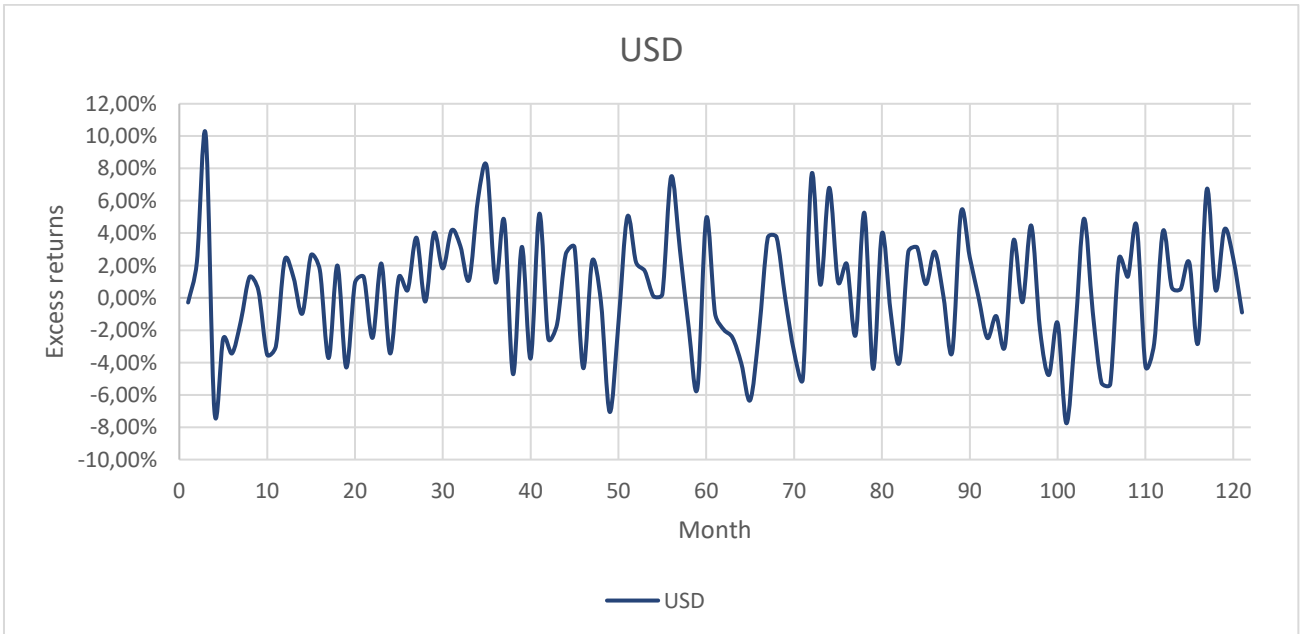

OMRX1-3
1,00%
0,50%
0,00%
-0,50%
-1,00%
-1,50%
-2,00%
Excess returns
0
10
20
30
40
50
60
70
80
90
100
110
120
Month
OMRX1-3


OMRX5+
8,00%
6,00%
4,00%
2,00%
0,00%
-2,00%
-4,00%
-6,00%
-8,00%
-10,00%
Excess returns
0
10
20
30
40
50
60
70
80
90
100
110
120
Month
OMRX5+


S&PGSCI
40,00%
30,00%
20,00%
10,00%
0,00%
-10,00%
-20,00%
-30,00%
-40,00%
-50,00%
Excess returns
0
10
20
30
40
50
60
70
80
90
100
110
120
Month
S&PGSCI


VG-KTH
8,00%
6,00%
4,00%
2,00%
0,00%
-2,00%
-4,00%
Excess returns
0
10
20
30
40
50
60
70
80
90
100
110
120
Month
VG-KTH


XAU
20,00%
15,00%
10,00%
5,00%
0,00%
-5,00%
-10,00%
-15,00%
-20,00%
Excess returns
0
10
20
30
40
50
60
70
80
90
100
110
120
Month
XAU


USD
12,00%
10,00%
8,00%
6,00%
4,00%
2,00%
0,00%
-2,00%
-4,00%
-6,00%
-8,00%
-10,00%
Excess returns
0
10
20
30
40
50
60
70
80
90
100
110
120
Month
USD