# Bitcoin, Portfolio Diversification and Chinese Financial Markets

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Abstract

This research explores the effects of adding bitcoin to an optimal portfolio (naïve, long-only, unconstrained and semi-constrained) of by relying on mean-CVaR approach in Chinese market. Then backtesting to compare the performance of portfolios with and without bitcoin for each scenario is performed. Results show significant but weak correlations between various asset classes and bitcoin, implying a more mature financial profile of bitcoin in China compared to that in the west. Backtesting results show that the effect of adding bitcoin to optimal portfolios is not consistent over the entire out-of-sample period. The naïve and the long-only strategy improved the risk reward ratio up until the late 2013 price-crash with no significant advantages thereafter. Shorting strategies on the other hand, with or without leverage, fail to produce more efficient portfolios when bitcoin is added, and this is consistent over the entire out-of-sample period. The results also show that semi-annual rebalancing amplifies the advantages of adding bitcoin to most portfolios except for the semi-constrained portfolio, although the weights analysis show significant shifts in weights which might not represent a feasible strategy in realistic scenarios.

Keyword: Bitcoin, Cryptocurrencies, Portfolio diversification, Portfolio strategies

JEL classification: *G11*

## 1. Introduction

The Bardi Family from Florence used to be a very powerful and rich family in the XIV century. Their activities covered trading as well as banking and they were among those families (like the Peruzzi) that were forced out of business when in 1345 England went bankrupt. In that very same year, three members of the Bardi's family (namely Rubecchio, his uncle Aghinolfo and his cousin

Sozzo), having lost almost their entire wealth, decided to redesign their core activities: from bankers to forgers. In fact, the lack of expertise and their clumsiness compromised their new business at the very beginning: they were caught and on 15$^{th}$ October 1345, the local authority started the process against them (Cipolla 1994). Interestingly enough, the major driver for their attempt as forgers was the lack of liquidity and the re-valuation of silver and gold that characterised the years between 1333 and 1348.

Nowadays the link between metal and value of the currency (metallism) is not relevant anymore and the game attempted by the Bardi will not be possible. In fact, institutions (i.e. the central banks and commercial banks) can expand money and debase it via quantitative easing and lending activity. The result is that the largest majority of dollars, euros or pounds aren't printed but are created out of thin air by private banks when they make loans (de Soto 1995). However, the scepticism about the role of any central authority over political and economic lives of individuals is pushing the financial technology further via the launch of the cryptocurrencies. Bitcoin plays a central role in this new game as the first cryptocurrency even mined.

Cryptocurrencies are characterised by being managed and maintained via a decentralised global network of nodes operating in a globally distributed environment, where the supply is strictly controlled and fully transparent to all participants, and it also operates collaboratively without the need of financial intermediaries (Böhme et al. 2015). Thus, they do not allow central authority to control them. They are backed by the energy required to mine it through the concept of cryptographic proof-of-work (Vigna and Casey 2015). What links it to metallism is the fact that producing (mining) it requires miners to solve ever harder mathematical problems as the time goes by, all of which demand considerable computing power (i.e. electric energy), and real-money investments in specialised hardware (O'Dwyer and Malone 2014). Among cryptocurrencies, a key role is played by Bitcoin, the first cryptocurrency to be launched. Nakamoto (2008) (bitcoin founder) argues that fiat currencies do not perform properly as medium of exchange because of high transaction costs and the exclusion of a large part of the world population from the banking system. He also argues that fiat currencies do not function well as stores of value either, due to excess inflation present in them. Bitcoin aims to fix these issues by making its supply pre-determined, constant, decreasing, and ultimately finite and thus deflationary and an excellent store or value in the long run (Nakamoto 2008). Interestingly this raises a key point: if bitcoin is an excellent store of value, should it be included in a portfolio of assets?

In fact, since the seminal work by Markowitz (1952, 1976) finance stresses the important role of portfolio diversification and a lot of analysis explores the optimal mix of assets that allows for the maximisation of the return by minimising the risk (i.e. the volatility). Historically the focus was on shares (e.g. Treynor and Black 1973), bonds (e.g. Barnes and Burnie 1990), derivatives (e.g. Galai and Geske 1984). In addition, research explored the link between portfolio diversification many other aspects such as taxes (e.g. Stein et al. 2000) and leverage (e.g. Ruban and Melas 2011). Closer to our research are the works that focus the attention on the role of currencies in portfolio diversification (e.g. Makin 1978; Pojarliev and Levich 2011). Very recently the increasing role of cryptocurrencies has started to attract some interest among academics who look at bitcoin as an asset to include in portfolio diversification. Interestingly enough, to the best of our knowledge only very few works based on the US market have been published so far (Brière et al. 2015; Carrick 2016; Wu and Pandey 2014) suggesting the need for additional research in this area.

This study, by following Brière et al. (2015) approach, explores the effect of bitcoins on the overall risk-return ratio of a portfolio of well diversified assets. We look at the role of bitcoin in three different contexts (US, Europe and China) in order to explore whether bitcoin plays different roles in different settings. We construct four different portfolio frameworks, namely naïve portfolio, the long-only portfolio, the unconstrained portfolio and the semi-constrained portfolio, to which we add then bitcoin and observe any effects it might produce (Eisl et al. 2015). In the case of long-only, unconstrained and semi-constrained portfolio weights are calculated using the mean-CVaR optimisation process (Eisl et al. 2015).

Our analysis shows weak correlations between various asset classes and bitcoin, implying a more mature financial profile of bitcoin in China compared to that in the west. The back-testing results suggest that the effect of adding bitcoin to optimal portfolios is not consistent over the entire out-of-sample period. Interestingly enough the naïve (1/n) and the long-only strategy improved the risk reward ratio up until the late 2013, when there was the price-crash with. We do not find significant advantages thereafter. As far as the shorting strategies with or without leverage, bitcoin fails to produce more efficient portfolios. The results are consistent over the entire out-of-sample period.

Our analysis also provides evidence that semi-annual rebalancing amplifies the advantages of adding bitcoin to most portfolios except for the semi-constrained portfolio, although the weights analysis suggests to attach to different asset classes might not represent a feasible strategy in realistic scenarios.

## 2. Literature Review

To most ordinary people bitcoin remains a mystery: an intangible, and difficult-to-understand currency with little or no use in the real economy (Garcia et al. 2014). Nakamoto (2008) in his whitepaper describes Bitcoin as a peer-to-peer cash system. Bitcoin's system main concern lies with verifying the sender owns the funds they intend to spend, as well as preventing double-spending, which has for years been the main obstacle to the development of a viable peer-to-peer payment system (Böhme et al. 2015; Nakamoto 2008). Anyone wishing to spend, signs the request to send bitcoins to another address using the private key of the address they wish to send from, which is then broadcast to the network of nodes for processing. Nodes can confirm ownership by using the public key of the sending address to check whether the request is genuine. Genuine requests are collected into blocks and added to the blockchain a public ledger consisting in a distributed database maintained by a network of nodes where every node holds an exact copy of the database containing all historical transactions, which can only be updated with mutual consensus (Böhme et al. 2015; Nakamoto 2008). Once a record of transaction is added to it, it becomes nearly impossible to change or compromise (Böhme et al. 2015).

The idea behind the decentralisation of verification is to remove the 'middle man' from equation, thus not only eliminating the risk of any one party tampering with the proof of agreement but also making the overall economy more efficient overall (Timmerman and Thomas 2017). The lack of a governance structure other than its underlying software has several implications for the functioning of the system: there is no obligation to verify a user's identity; there is no prohibition on sales of particular items; payments are irreversible (Böhme et al. 2015). In fact, this aspect raise issues linked to the use of bitcoin as a payment tool for illicit transactions and money laundering (Hope 2017; McLannahan 2017). However, the role that cryptocurrencies are taking is so relevant that governments are starting to investigate ways to deal with them (Seddon 2017; Terazono 2017).

Unlike the fiat currencies where the money supply can be expanded to meet the increasing demand via the fractional reserve system or by direct monetary policies such as quantitative easing (de Soto 1995), bitcoin's total supply and the rate of supply is pre-determined, non-elastic and fully transparent (Nakamoto 2008). By design, the supply is capped to 21 million units of bitcoin divisible down to eight decimal places and smallest unit ("satoshi") represents the base unit of all arithmetic calculations. New bitcoins are created via an activity called mining, and nodes that engage in mining are called miners (Nakamoto, 2008). Since the rate of supply is pre-determined and continually decreasing - a process governed by an internal algorithm - bitcoin is inherently deflationary and the laws of supply and demand and the market consensus among its adopters play significant part its price formation (Ciaian et al. 2015; Kristoufek 2015). As of January 2017, around 16.1 million bitcoins have been mined, roughly 80% of all the coins. The remainder will be mined at a much slower rate. This slowdown in the money supply adds to deflationary pressures and will eventually shift the miner's incentives from block-rewards to transaction fees. Additional deflationary pressure is exerted by 'destruction': the system records the transfer of bitcoin from one wallet to another, but it does not manage or keep records of wallets: if bitcoins are sent to non-existing wallets, effectively making them un-spendable, bitcoins are destroyed (Böhme et al. 2015; Nakamoto 2008). Once the money supply is completely exhausted and all the bitcoins have been mined, the demand would have to be met by further deflation, or further subdivisions of the currency. Kristoufek (2015) find that the supply side does affect the price, although the relationship is not significant. Polasik et al. (2015) using a variety of methodologies, show that the demand factors affect the price formation significantly more than the supply side.

In Keynesian economics, the demand for money is driven by three determinants: transaction demand, speculative demand and the precautionary demand. These in turn are driven by motives such as holding money for daily transactions, the need for taking advantage of investment opportunities, and the need to save for a rainy day (Keynes 1936).

Bitcoin's 60 day average volatility over the six-year period shows a steady decline but it remains much higher than gold's, averaging about 1.5% and the traditional G10 currencies between 0.5% and 1%. Furthermore, bitcoin return distribution exhibits stronger non-normal characteristics and heavier tails, suggesting that it's not reached the investment-grade maturity just yet (Osterrieder and Lorenz 2017). Bouri et al. (2016) suggest that bitcoin's distinctive volatility is due to the small size of the market and the trading volume even if Harvey (2017) has found no correlation between volatility and the market capitalisation prior to 2014, however since January 2015, the price dynamics do appear to enter a new period of steady decline in volatility as a result of increasing market capitalisation. Academic consensus is that the price dynamics are still evolving, and many earlier proposed models break down over different time periods (Bouri et al. 2016). However, given the highly volatile nature of bitcoin that makes it unsuitable to store of value, its demand cannot be driven the result of the precautionary demand. This evidence leaves two alternative determinants of bitcoin demand and price volatility: transaction demand (derived from trade transactions); speculative demand (derived partly from exchange transactions).

Bitcoin transaction data is used by Kristoufek (2015) to show that an increase in trade volume is correlated with bitcoin price, consistent with the theoretical expectations of the quantity theory of money, further supported by Ciaian et al. (2015) and Wang et al. (2016). Thus, bitcoin appreciates in the long run if it is used more for transacting, challenging the earlier studies that have argued that bitcoin's price is driven purely by the expectations of future exchange rate, or pure speculation (Cheah and Fry 2015). In fact, the comparison of exchange-traded volume of bitcoins to total transaction volume within the Bitcoin network suggests that most users (by volume) treat their bitcoin investments as speculative assets rather than as means of payment (Glaser et al. 2014). Bouri et al. (2016) and Kristoufek (2015) find bitcoin is not so effective as a safe haven since its hedging properties vary between time horizons. More importantly, since 2013 neither is it a good hedge nor a safe haven for major world stock indices, bonds, and currency indices. More specifically, even if some research suggests that Bitcoin has not reached the investment grade status (Cheah and Fry 2015; Urquhart 2016) in fact more recent research and testing suggest that it is mature (Nadarajah and Chu 2017) and thus can be included in a portfolio of well differentiated assets. Thus, bitcoin might offer diversification benefits and thus, a related question emerges: is bitcoin an asset to include in an optimal portfolio? Interesting enough, there is very reduced research that try to answer to this question.

The effects of adding bitcoin to optimal portfolios have been studied by Brière et al. (2015). They show that adding bitcoin to an already diversified portfolio of US assets improves its Sharpe Ratio (Sharpe 1963). In addition, an optimal mix of bitcoin and US equities can reduce the overall risk of a portfolio (Bouri et al. 2016). Similarly, Eisl et al. (2015) show that including bitcoin in an already diversified portfolio of US assets increases both the expected return and the risk of the portfolios. They go on suggesting a possible allocation of bitcoin in such portfolio to maximise the

Sharpe Ratio. Bitcoin also increases the efficiency of portfolios when tested against other measures, such as the Omega Ratio (Wu and Pandey 2014) devised by Keating and Shadwick (2002) and other variations of the Sharpe ratio where VaR and CVaR replace the standard deviation as a measure of risk (Eisl et al. 2015).

However, bitcoin's financial characteristics, such as volatility, have evolved considerably since the "crash" of 2013, when some of its earlier properties as a safe haven completely disappeared (Kristoufek 2015). This implies that Bitcoin's qualities as a diversifier might also have been affected since previous works have been published (Bouri et al. 2016). More importantly, the quoted empirical studies adopt the perspective of a US investor, where portfolio optimisations mainly incorporate US assets listed in the US financial markets, with very limited exposure to the markets outside of the US. Incidentally, in these alternative markets bitcoin trading activity and the adoption rates are the highest. In fact, historical data[1] from *data.bitcoinity.org* shows that the proportion of Bitcoin bought and sold, for instance, in China has steadily grown over the years and as of September 2017 comprises of ~99% of all bitcoin exchange transactions globally, whereas USD transactions have remained relatively stagnant in comparison and comprise less than 1% of global exchange volume. Consequently, events happening in the wider Chinese economy directly affect the CNY Bitcoin market which in turn can have a significant impact on the USD market (Kristoufek 2015). The lack of research on the role of bitcoin in portfolio diversification in Chinese and European market is too important to be dismissed.

## 3. Methodology and Data

The nature of this research is primarily explorative. It employs a variation of the established Modern Portfolio Theory (Markowitz 1952, 1976) to estimate parameters and draw conclusions from

[1] Accessed on 12/09/2017

historical data, and in this regard it adopts a positivist perspective. The analysis will focus on the effects of adding bitcoin to an already diversified portfolio, or more precisely the effects that it might have on the risk-reward ratio of such a portfolio. The analysis requires building efficient frontiers of portfolios where Bitcoin is present and comparing it to portfolios where *ceteris paribus,* bitcoin is not present. The efficient frontier comprises of all the possible portfolios which can be constructed from a given pool of assets where the return is maximised given the desired risk. We use terms 'optimal' and 'well-diversified' interchangeably throughout this work to refer to such portfolios. We follow Eisl et al. (2015) by constructing portfolios in four different optimisation contexts, described in more detail below. We then repeat the process but with an asset pool that contains the Bitcoin, yielding eight portfolios in total for each area (namely US, Europe and China), half of which include bitcoin. These are subsequently compared to see if adding bitcoin has any effect on portfolio weights and the portfolio risk-return ratio in respect of the optimisation procedure used.

*Table 1 - Matrix of portfolios created as a result of the optimisation process*

| | naive | long-only | unconstrained | semi-constrained |
|---|---|---|---|---|
| w/o bitcoin | NN | LN | UN | SN |
| with bitcoin | NB | LB | UB | SB |

***Scenario 1: Naïve (equal weights) Portfolio ($w_i = \frac{1}{N} \quad \forall\ i$)***

The naïve portfolio is constructed so that all assets are allocated equally irrespective of potential effects on the risk-return ratio. In their landmark study, DeMiguel et al. (2007) have shown that a portfolio where asset allocation is calculated using the mean-variance optimisation procedure, performs no better than an equal weight portfolio consisting of the same pool of assets in terms of Sharpe Ratio (Sharpe 1963, 1964). It would therefore be interesting to see what kind of effect Bitcoin might have in this scenario and if such an effect is any different from the one observed in other scenarios. Since no part of the sample data is used to estimate optimal weights, the out-of-sample period equals the entire 60-month sample period.

***Scenario 2: Long-Only Portfolio ($w_i \in \mathbb{R}^+ : \sum w_i = 1$ )***

This optimisation process allows no shorting and effectively limits the individual weights to 100%. This framework represents a more feasible option for investors given the context, and the asset weights should also be more stable when re-balancing. Since the first 12 months are used to determine portfolio weights, the out-of-sample period is 12 months shorter than the total sample period.

***Scenario 3: Unconstrained Portfolio ($w_i \in \mathbb{R}$ )***

Under the Unconstrained scenario, no restrictions are placed on asset weights. Shorting and leveraging are both allowed and in theory it should yield the highest risk-return ratio of all. This type of optimisation is expected to result in extreme long or short positions which might not be implementable in the real world, due to large initial weights in either direction (short or long) and subsequent shifts in weights during re-balancing. Its main purpose however is test theoretical limits of any advantages bitcoin might add to well-diversified portfolios. Similarly, the first 12 months of the sample data are used to construct the portfolio weights; hence the out-of-sample period is 12 months shorter than the total sample period.

***Scenario 4: Semi-constrained Portfolio ($w_i \in \mathbb{R} : -1 \leq w_i \leq 1 : \sum w_i = 1$)***

Here, the optimisation process seeks to maximise the risk-return ratio of a portfolio without placing any weight-related constraints on assets, but which does not allow leveraging, as such it is should yield a better risk-return ratio than other scenarios except for the Unconstrained portfolio.

Though hypothetically it is possible to short bitcoin, there is no evidence at present of how this could be implemented in practice. The results of this strategy might therefore be rendered purely theoretical should the optimisation procedure demand that bitcoin is shorted. This could potentially change in the near future as and when bitcoin-derived funds become authorised by the financial regulators. Thus, we decided to add an additional constrain to scenario 3 and 4 by excluding the possibility to shorten bitcoin.

**3.1 The Mean-CVaR approach**

For all scenarios except Naïve, we adopt a variation of Markowitz's Modern Portfolio Theory (Markowitz 1952) as basis for constructing efficient portfolios, where an efficient portfolio is defined as the one that achieves maximum expected return for a desired level of risk. Under the original model, the expected return is simply the weighted average of constituent asset returns and the risk, which is measured by the portfolio variance $\sigma_p^2$, is a function of the correlations $\rho_{ij}$of constituent assets, for all asset pairs $(i, j)$ (Markowitz 1952). The main disadvantage with the mean-variance approach is that it oversimplifies investor's risk-preferences. Variance is a symmetric measure that incorporates both, the upside and the downside volatility, where as in the real-world, assuming investors are rational, only the downside component is undesirable.

An alternative risk measure proposed in literature is the Value-at-risk (VaR). It is an asymmetric measure that is expressed as a minimum loss value (or percentage) for a given probability and time horizon. VaR's main limitation is that it only estimates the minimum potential loss, and does not quantify the amount this threshold could be exceeded by; potentially underestimating the tail risk. The Conditional Value at Risk (CVaR), or as it is also more commonly known, the Expected shortfall (ES) addresses this problem by calculating the expected return (average loss) beyond the VaR threshold (Alexander and Baptista 2004) and it has previously used to portfolio optimisation (e.g. Silvapulle and Granger 2001; Topaloglou et al. 2002). Acerbi and Tasche (2002) have shown that CVaR/ES offers a number of advantages over VaR, without giving up any of its original advantages. CVaR/ES is often described as a coherent measure of risk, because it satisfies a set of four desirable properties, namely: Monotonicity, Translation invariance, Homogeneity and Sub-additivity (Artzner et al. 1999) whereas Variance and VaR do not.

We adopt the Conditional Value at Risk (CVaR) as the measure of portfolio risk which we calculate for each asset at the $\alpha = 5\%$ confidence level.

$$CVaR_p^2 = \sum_i \sum_j w_i w_j CVaR_i CVaR_j \rho_{ik} \tag{1}$$

From which, portfolio risk is derived:

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

The optimisation procedure for non-naïve scenarios will therefore seek optimal asset weights that maximise the risk-return ratio, provided that the listed constrains for each scenario are met as prescribed.

$$\max\left(\frac{E(R_p)}{CVaR_p}\right) \tag{3}$$

Calculating portfolio risk using this approach requires that we know the CVaR of individual assets used in the optimisation process. There are various methods for calculating the CVaR, the most common being the variance-covariance, stochastic and empirical methods. Skewed distributions make the historical/empirical approach the preferred method for the purpose of our research (note that bitcoin returns exhibit a pronounced positive skew). The main advantage of this method is that it does not make assumptions of normality, since the distribution is inferred from historical data. The downside of this strategy of course assumes that future distributions maintain the same skew over time. Using the 12 month in-sample daily data and for each asset, we calculate monthly moving averages ($MA$) of daily returns, resulting in 261 data points. CVaR is then calculated as the simple mean of all the observations on and below the Value-at-Risk (VaR) threshold at the $\alpha = 5\%$ confidence interval, or the 5th percentile of the calculated monthly moving average returns:

$$CVaR = \frac{1}{N}\sum_{i=1}^{N} MA \ : \ MA \leq VaR \tag{4}$$

## 3.2 Data

### *3.2.1 The Bitcoin Price Index*

We construct the Bitcoin CNY Price Index (BCPI) using data from data.bitcoinity.org, which in turn derives its data from the publicly available raw blockchain[2] data. Since this study adopts the Chinese Investors perspective, we gather daily price and volume data from exchanges that trade in CNY/BTC only. BCPI is calculated as the volume weighted price average of all BTC/CNY exchange prices. Historical data for bitcoin starts on 18th July 2010, however, the early period of Bitcoin trading is characterised by very low trading volumes and liquidity which does not significantly improve until 2012. For this reason we choose February 2012 as the start date of the sample period ending on 31st January 2017, covering 60 months of daily returns data.

To allow for creation of a well-diversified portfolio, we sample a broad range of assets available to Chinese investors consisting of equities, fixed income, commodities, real estate, cash equivalents, currencies, and alternative investments. Each of these asset-classes is represented by a liquid investible index, most of which are denominated in the local RMB currency except for the S&P WCI ASIA, the Global hedge fund index and the S&P WCI Gold index. These are quoted in USD, however, both are available to Chinese investors and consist of futures contracts traded on the international exchanges outside of the United States. The latter is highly correlated with historical gold prices quoted in CNY; hence it represents a good approximation to Gold.

We also include the US Dollar to the pool of assets, because it has appreciated significantly in value against the CNY since the beginning of 2014, and as such it might potentially be of interest in portfolio diversification. Table 2, shows a detailed overview of assets which will be used in the optimisation process.

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[2] The blockchain is the distributed public ledger of all the historical Bitcoin transactions.

*Table 2: A comprehensive list of assets used in the portfolio optimisation process*

| Name | Mnemonic | Asset Class |
|---|---|---|
| BTC-CNY-Index | btccny | Cryptocurrency |
| S&P CHINA GOVERNMENT BILL INDEX | billcn | Money Market |
| S&P CHINA SOVEREIGN BOND INDEX | condcn | Fixed-income |
| S&P CHINA CORPORATE BOND INDEX | corpcn | Fixed-income |
| S&P WCI GOLD (ER) | gold | Gold ETF |
| S&P CHINA A 100 INDEX (RMB) | spc100 | Equity (large cap) |
| S&P CHINA A 200 INDEX (RMB) | spc200 | Equity (mid cap) |
| S&P CHINA A SMALLCAP INDEX (RMB) | spcsml | Equity (small cap) |
| S&P WCI ASIA | wcia | Commodities |
| Guggenheim China Real Estate ETF (TAO) | tao | Real Estate |
| Global hedge fund index | hfrx | Alternative |
| USDCNY Exchange rate (holding USD as investment) | usdcny | Currency |

### 3.3 Evaluating robustness

We divide back-testing in two parts. The first part will assess whether the initial weights $w_i$ calculated during the optimisation process are robust over the entire out-of sample investment period without any rebalancing. The second part examines the performance of portfolios over the entire out-of-sample period but with semi-annual weight rebalancing. For non-naïve scenarios where the initial 12-month sample period is used to calculate the initial weights, the investment period is 48-months long, whereas for the equally-weighted scenario, the full 60 month sample is used for backtesting. We calculate the monthly rolling excess portfolio returns and monthly rolling CVaR, and then apply

3-month smoothing. Using this data we derive and observe monthly risk-reward (RR) performance of all eight portfolios over the investment period using a simple risk-reward ratio formula:

$$\mathrm{RR}_m = \frac{R_m}{CVaR_m} \quad (5)$$

Finally, we take the average Risk-reward ratios of all portfolios without bitcoin and compare them to their respective equivalents with bitcoin. We repeat the entire process again but with six-monthly rebalancing using the same methods used to calculate the initial weights. The results will be deemed robust if the mean of the estimated Bitcoin weights over the investment period is not significantly different from the initial weights, with regard to the optimisation procedure used.

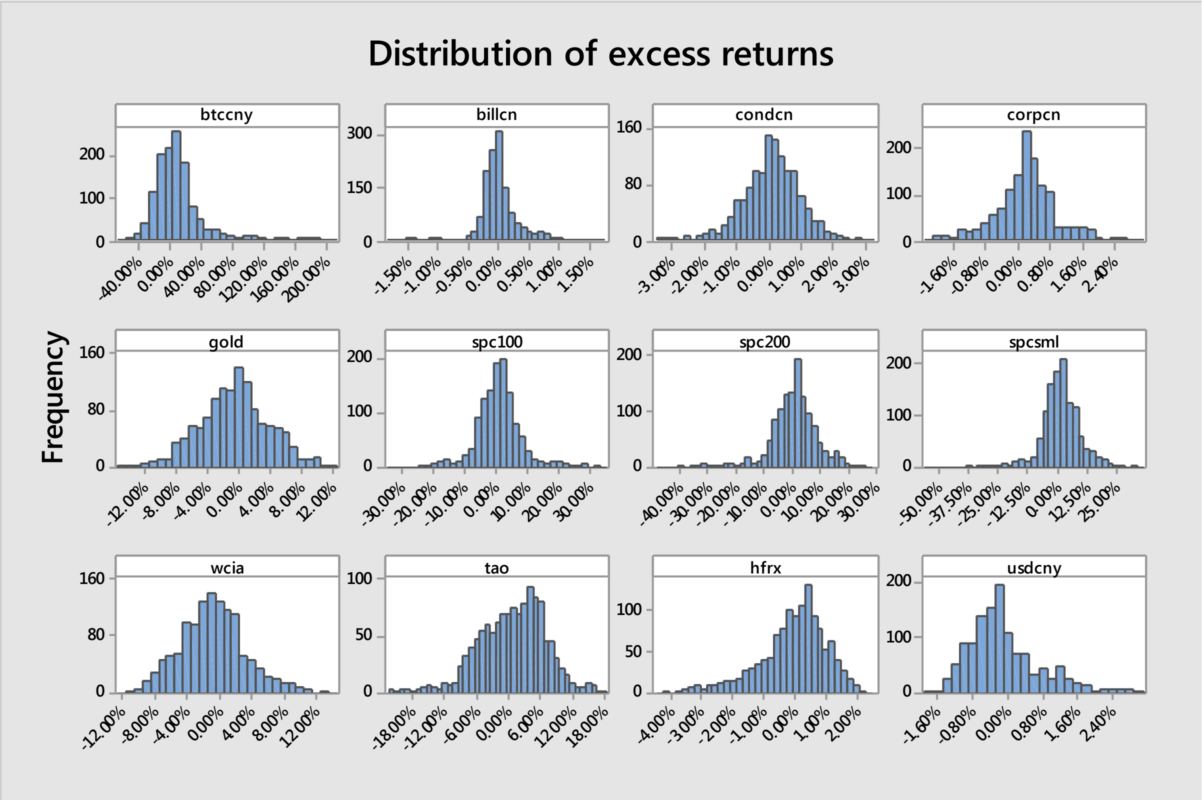
## 4 – Analysis and Findings

The table 3 below shows the descriptive statistics of the excess monthly returns of assets included in the portfolios used in the optimisation process. In line with the previous studies by Eisl et al. (2015) and Wu and Pandey (2014), Bitcoin exhibits large kurtosis (7.99) and is positively skewed (2.38), albeit to a much lesser extent than previously reported.

*Table 3- Descriptive statistics of the excess monthly returns*

| Descriptive Statistics | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | btccny | billcn | condcn | corpcn | gold | spc100 | spc200 | spcsml | wcia | tao | hfrx | usdcny |
| Min | -56.21% | -1.79% | -3.47% | -2.13% | -14.70% | -33.33% | -47.12% | -53.94% | -11.89% | -22.39% | -4.39% | -1.84% |
| Max | 208.10% | 1.74% | 3.19% | 2.95% | 11.97% | 33.12% | 28.94% | 35.67% | 13.65% | 18.02% | 2.50% | 3.02% |
| Mean | 12.63% | 0.00% | 0.09% | 0.20% | -0.57% | 0.61% | 0.61% | 1.01% | -0.73% | 0.61% | -0.08% | -0.07% |
| Median | 6.29% | -0.03% | 0.12% | 0.22% | -0.44% | 0.57% | 1.25% | 1.32% | -0.91% | 1.22% | 0.10% | -0.23% |
| Skewness | 2.38 | -0.17 | -0.32 | -0.06 | -0.06 | 0.31 | -0.97 | -0.93 | 0.31 | -0.46 | -0.84 | 1.01 |
| Kurtosis | 7.99 | 6.26 | 1.01 | 1.24 | 0.05 | 2.86 | 3.54 | 4.50 | 0.25 | 0.54 | 0.91 | 1.08 |
| St.Dev. | 34.90% | 0.32% | 0.88% | 0.73% | 4.54% | 7.77% | 9.00% | 9.90% | 4.07% | 6.44% | 1.12% | 0.83% |
| VaR | 24.85% | 0.34% | 1.40% | 1.15% | 8.03% | 11.59% | 15.40% | 15.52% | 7.36% | 9.67% | 2.25% | 1.18% |
| C-VaR | 33.11% | 0.73% | 1.99% | 1.52% | 10.13% | 17.59% | 24.61% | 26.72% | 8.50% | 14.75% | 2.97% | 1.34% |
| Sharpe (C-VaR) | 0.38 | 0.00 | 0.04 | 0.13 | -0.06 | 0.03 | 0.02 | 0.04 | -0.09 | 0.04 | -0.03 | -0.05 |

*Figure 1- Visual representation of the distribution of excess returns for each asset*




Correlation analysis in

*Table* 4 report overall small but statistically significant correlations between bitcoin and a number of Chinese indices used in this study, except for the China Mid-Cap, Small-Cap equity indices and the Guggenheim China Real Estate ETF (TAO), in sharp contrast to earlier similar studies by Eisl et al. (2015) and Wu and Pandey (2014), where no significant correlations are reported with any of the US indices. A significant negative correlation exists between bitcoin and the Chinese government bill index (billcn), and a somewhat weaker but still significant negative correlation with the China Sovereign bond (condcn) and corporate bond (corpcn) indices, suggesting that bitcoin could be used by some investors in China as safe haven during certain events that affect the prices of these assets.

*Table 4 - Correlation coefficients and their respective P-values of the assets used in optimisations*

| Correlation Matrix - Coefficients | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | btccny | billcn | condcn | corpcn | gold | spc100 | spc200 | spcsml | wcia | tao | hfrx |
| billcn | -0.357 | | | | | | | | | | |
| condcn | -0.254 | 0.619 | | | | | | | | | |
| corpcn | -0.250 | 0.683 | 0.863 | | | | | | | | |
| gold | -0.183 | 0.085 | 0.049 | 0.009 | | | | | | | |
| spc100 | -0.080 | 0.051 | -0.060 | -0.121 | 0.038 | | | | | | |
| spc200 | -0.057 | 0.193 | -0.045 | -0.028 | -0.015 | 0.845 | | | | | |
| spcsml | -0.051 | 0.241 | -0.030 | 0.023 | -0.009 | 0.736 | 0.974 | | | | |
| wcia | -0.100 | 0.017 | 0.012 | -0.038 | 0.635 | 0.124 | 0.050 | 0.059 | | | |
| tao | -0.046 | 0.018 | 0.042 | 0.042 | 0.165 | 0.496 | 0.446 | 0.403 | 0.221 | | |
| hfrx | 0.187 | -0.050 | -0.160 | -0.089 | -0.092 | 0.309 | 0.361 | 0.342 | 0.089 | 0.486 | |
| usdcny | -0.094 | -0.019 | 0.058 | 0.071 | -0.055 | -0.157 | -0.213 | -0.202 | -0.075 | -0.403 | -0.283 |

| Correlation Matrix - P - Values | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | btccny | billcn | condcn | corpcn | gold | spc100 | spc200 | spcsml | wcia | tao | hfrx |
| billcn | 0.000 | | | | | | | | | | |
| condcn | 0.000 | 0.000 | | | | | | | | | |
| corpcn | 0.000 | 0.000 | 0.000 | | | | | | | | |
| gold | 0.000 | 0.002 | 0.080 | 0.757 | | | | | | | |
| spc100 | 0.004 | 0.069 | 0.031 | 0.000 | 0.171 | | | | | | |
| spc200 | 0.041 | 0.000 | 0.110 | 0.312 | 0.584 | 0.000 | | | | | |
| spcsml | 0.071 | 0.000 | 0.279 | 0.417 | 0.741 | 0.000 | 0.000 | | | | |
| wcia | 0.000 | 0.552 | 0.659 | 0.171 | 0.000 | 0.000 | 0.074 | 0.035 | | | |
| tao | 0.102 | 0.510 | 0.134 | 0.135 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | |
| hfrx | 0.000 | 0.075 | 0.000 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | |
| usdcny | 0.001 | 0.495 | 0.037 | 0.011 | 0.047 | 0.000 | 0.000 | 0.000 | 0.007 | 0.000 | 0.000 |

## 4.1 Optimal portfolio weights analysis

In this section we discuss the findings about the effect of adding bitcoin in the composition of a well-diversified portfolio of Chinese assets. The initial weights of the optimisation process are shown in

*Table* . Portfolios containing bitcoin are highlighted in red. Out of the three optimised groups, only the 'Long-only' portfolio results in significant amounts of bitcoin (34.89%). Where shorting is allowed, namely in the 'Unconstrained' and the 'Semi-Constrained', the weight of bitcoin relative to other assets is relatively small, and remains small with semi-annual rebalancing.

*Table 5 - Results from initial optimisation process. Portfolios with bitcoin are shown in red.*

| Portfolio Weights | btccny | billcn | condcn | corpcn | gold | spc100 | spc200 | spcsml | wcia | tao | hfrx | usdcny |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Naive no BTC | 0.00% | 9.09% | 9.09% | 9.09% | 9.09% | 9.09% | 9.09% | 9.09% | 9.09% | 9.09% | 9.09% | 9.09% |
| | 8.33% | 8.33% | 8.33% | 8.33% | 8.33% | 8.33% | 8.33% | 8.33% | 8.33% | 8.33% | 8.33% | 8.33% |
| Long-only | 0.00% | 0.00% | 0.00% | 65.05% | 0.09% | 0.00% | 0.00% | 0.00% | 0.00% | 4.63% | 30.23% | 0.00% |
| | 34.89% | 6.02% | 0.00% | 0.00% | 7.16% | 2.96% | 0.00% | 12.49% | 0.00% | 36.47% | 0.00% | 0.00% |
| Unconstrained | 0.00% | -788.04% | 1628.73% | -288.89% | 53.93% | 536.26% | -1622.52% | 1029.12% | -48.44% | -54.89% | 722.27% | -1204.38% |
| | -3.04% | -1.33% | 263.48% | -15.39% | 14.34% | 64.68% | -202.79% | 123.96% | -12.93% | -13.13% | 130.10% | -93.82% |
| Semi-Constrained | 0.00% | -100.00% | 99.92% | -22.22% | 7.61% | 32.32% | -99.18% | 58.19% | -9.62% | -4.09% | 82.97% | -48.39% |
| | 0.74% | 55.14% | 71.02% | -71.93% | 2.03% | 30.21% | -93.94% | 57.57% | -1.63% | -3.56% | 46.99% | -82.19% |

| Portfolio optimisation stats | SUM | RETURN | RISK | SHARPE |
|---|---|---|---|---|
| Naive no BTC | 1.00 | 0.01% | 3.13% | 0 |
| | 1.00 | 2.80% | 2.61% | 1.07 |
| Long-only | 1.00 | 0.39% | 0.70% | 0.56 |
| | 1.00 | 12.54% | 4.96% | 2.53 |
| Unconstrained | -0.37 | 11.28% | 0.00% | 4590.26 |
| | 2.54 | 0.19% | 0.00% | 4092.92 |
| Semi-Constrained | -0.03 | 0.71% | 0.00% | 7478.39 |
| | 0.10 | 0.82% | 0.00% | 7415.48 |

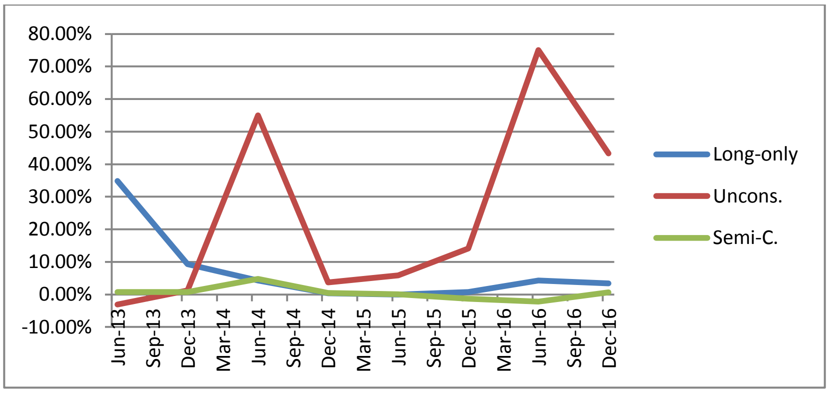
When applying semi-annual rebalancing to a ‘Long-only’ portfolio, the weight of bitcoin is progressively reduced from a very significant proportion to a relatively minor proportion of the total portfolio over time, averaging out at 7.17% for the duration of the investment period (out-of-sample data). For comparison, in an equally weighted portfolio this share would amount to 8.33% of the total portfolio (1/12 assets = 8.33%). The Semi-Constrained framework which allows shorting but no leveraging suggests an overall minor yet stable role of bitcoin.

*Table 6 - Proportion of bitcoin for each portfolio after semi-annual rebalancing.*

| Semi-annual BTC weights | | | |
|---|---|---|---|
| Portfolio | Long-only | Uncons. | Semi-C. |
| Jun-13 | 34.89% | -3.04% | 0.74% |
| Dec-13 | 9.31% | 1.25% | 0.79% |
| Jun-14 | 4.33% | 55.02% | 4.78% |
| Dec-14 | 0.31% | 3.69% | 0.44% |
| Jun-15 | 0.00% | 5.83% | 0.10% |
| Dec-15 | 0.75% | 14.13% | -1.35% |
| Jun-16 | 4.32% | 75.05% | -2.22% |
| Dec-16 | 3.42% | 43.28% | 0.69% |
| Mean | 7.17% | 24.40% | 0.50% |

The role of bitcoin in an 'Unconstrained' portfolio is harder to interpret due to the effects of shorting and leverage, resulting in drastic changes in weight over the investment period for bitcoin as well as the other assets during periodic re-optimisation.

*Figure 2- Bitcoin weights in each portfolio over the investment period.*

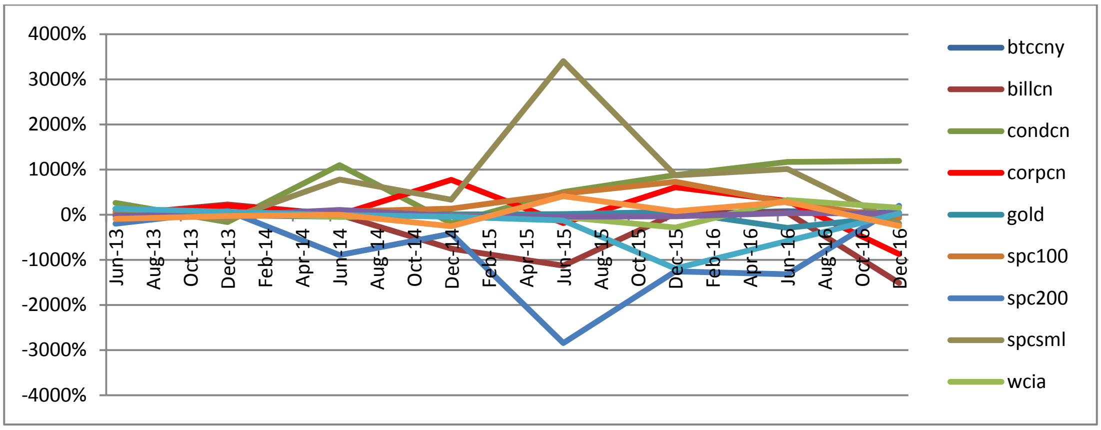



This indicates that such portfolio might require more frequent rebalancing (as opposed to semi-annual used here) and from the liquidity perspective it is probably a strategy that is beyond reach to all but dedicated institutional investors. Table  shows the evolution of weights for an 'Unconstrained' portfolio over the investment period, where the role of bitcoin is relatively minor relative to other assets.

*Table 7- Optimal weights for the Unconstrained portfolio with semi-annual rebalancing.*

| Evolution of optimal portfolio weights for an 'Unconstrained' portfolio | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Portfolio | btccny | billcn | condcn | corpcn | gold | spc100 | spc200 | spcsml | wcia | tao | hfrx | usdcny |
| Jun-13 | -3% | -1% | 263% | -15% | 14% | 65% | -203% | 124% | -13% | -13% | 130% | -94% |
| Dec-13 | 1% | 229% | -166% | 198% | -18% | 2% | 84% | -99% | 36% | -12% | 61% | -32% |
| Jun-14 | 55% | 0% | 1097% | -1% | -46% | 72% | -896% | 775% | -52% | 102% | -6% | -4% |
| Dec-14 | 4% | -756% | -184% | 773% | -2% | 132% | -420% | 330% | -19% | -28% | -43% | -253% |
| Jun-15 | 6% | -1130% | 504% | -188% | 13% | 466% | -2846% | 3399% | -49% | -44% | -131% | 408% |
| Dec-15 | 14% | 26% | 880% | 609% | 64% | 729% | -1256% | 869% | -287% | -37% | -1192% | 76% |
| Jun-16 | 75% | 42% | 1169% | 306% | -292% | 270% | -1321% | 1014% | 327% | 35% | -583% | 283% |
| Dec-16 | 43% | -1511% | 1188% | -873% | -31% | -73% | 201% | -189% | 156% | 26% | 27% | -246% |
| Mean | 24% | -388% | 594% | 101% | -37% | 208% | -832% | 778% | 12% | 4% | -217% | 17% |

*Figure 3- Graphical representation of all asset weights for an 'Unconstrained' portfolio*




## 4.2 Risk-return ratio analysis

In this section we explore the findings about whether bitcoin improve the risk-return ratio of optimal portfolios and whether our results are robust. We run back-testing twice, first without any rebalancing, where the weights calculated using the 12-month in-sample data are held constant throughout the out-of-sample investment period. Then, we run the test again but with semi-annual rebalancing using the same optimisation technique used to calculate the initial weights. Without rebalancing the results indicate that adding bitcoin to a Naïve and Long-Only portfolios is beneficial mainly due to strong performance up to 2013. After this year the effect fade away. When shorting is allowed, portfolios containing bitcoin are less efficient than the bitcoin-less counterparts throughout the backtesting period. This is partly down to the continuous evolution of bitcoin's financial characteristics as shown by Bouri et al. (2016), where volatility, correlations with other asset indices and overall returns are significantly different between the in-sample period and the out-of-sample period. When semi-annual rebalancing is applied to counter this aspect, the positive effect of adding bitcoin to portfolios is amplified, except for the semi-constrained scenario where rebalancing shows 12-fold increase in the risk-reward ratio but with no significant advantages over the bitcoin-less portfolio which also sees the mean monthly risk-reward ratio increase from 0.04 to 0.51. This could be due to re-optimisations phases. Six month re-balancing used here appears to react to periodic downturns, due to high volatility, but fails to capture the long-term upward trend in bitcoin prices, resulting in low or negative bitcoin weights, and as a result negatively affecting portfolio returns.

The results summarised in
*Table* show mean monthly returns, CVaRs, and risk-reward ratios of the naïve portfolio and all the other optimal portfolios constructed in this study.

*Table 8- Performance test results*

**Portfolio backtesting statistics for portfolios without rebalancing**

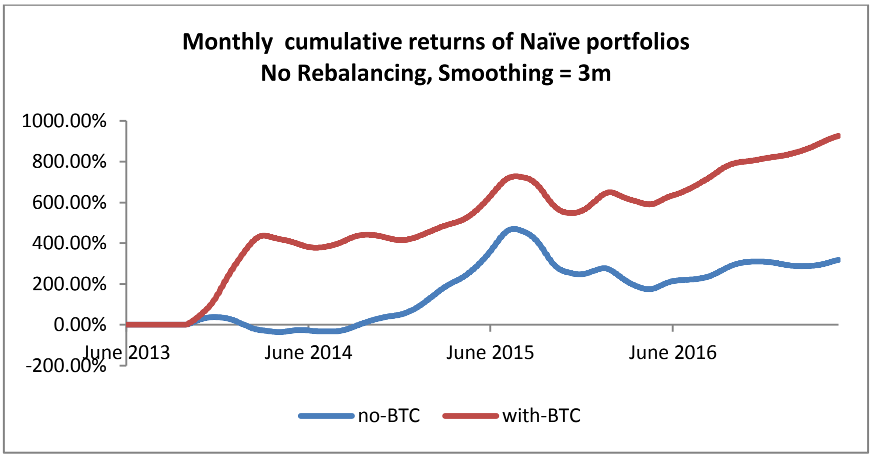
| | **Naïve** | | **Long-only** | | **Unconstrained** | | **Semi-constrained** | |
|---|---|---|---|---|---|---|---|---|
| | No BTC | with BTC | No BTC | with BTC | No BTC | with BTC | No BTC | with BTC |
| Mean monthly return | 0.22% | 0.81% | 0.13% | 2.76% | 3.01% | 0.19% | 0.07% | 0.05% |
| Mean monthly C-VaR | 2.31% | 2.44% | 0.61% | 4.73% | 21.58% | 3.46% | 1.73% | 1.43% |
| Mean monthly Risk/Rewa | 0.09 | 0.33 | 0.21 | 0.58 | 0.14 | 0.06 | 0.04 | 0.04 |

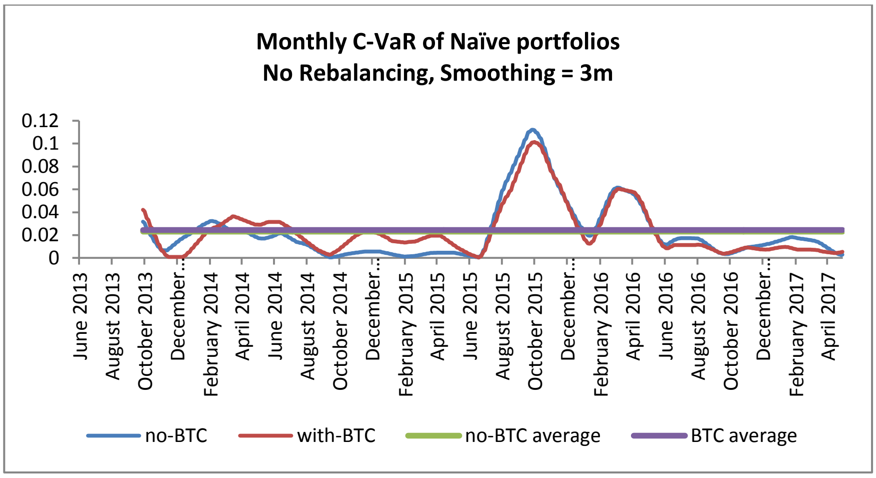
**Portfolio backtesting statistics for portfolios with semi-annual rebalancing**

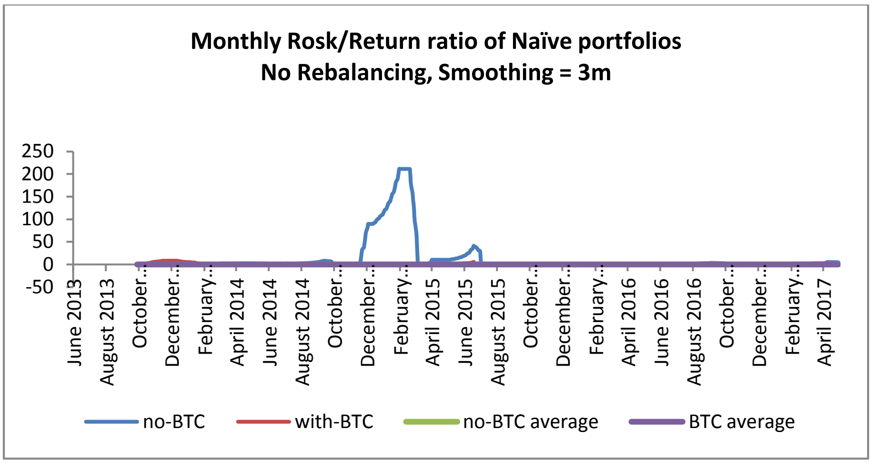
| | **Naïve** | | **Long-only** | | **Unconstrained** | | **Semi-constrained** | |
|---|---|---|---|---|---|---|---|---|
| | No BTC | with BTC | No BTC | with BTC | No BTC | with BTC | No BTC | with BTC |
| Mean monthly return | 0.22% | 0.81% | 0.09% | 1.58% | 5.48% | 9.41% | 0.67% | 0.66% |
| Mean monthly C-VaR | 2.31% | 2.44% | 2.20% | 2.34% | 28.99% | 36.95% | 1.31% | 1.30% |
| Mean monthly Risk/Rewa | 0.09 | 0.33 | 0.04 | 0.67 | 0.19 | 0.25 | 0.51 | 0.51 |

The following panels graphically outline the backtesting results of portfolios that include bitcoin, represented in dark red, and portfolios that exclude bitcoin, represented in blue. In each panel, we first plot the rolling monthly cumulative excess returns for both portfolios, followed by the monthly CVaR time series and finally we plot the time series of the risk-return ratios; resulting in three plots per panel, and one panel for each scenario. Where possible, we only show the backtesting results with semi-annual rebalancing, as this represents a more realistic scenario for an investor, except for naïve portfolios which are equally weighted and where the weights remain constant throughout the investment period. We apply three-month smoothing to cancel out the noise and to cover the gaps left by periods of "zero risk", where the expected shortfall is negative and cannot be used to calculate the risk-reward ratio.

*Figure 4 - Naive portfolio results*

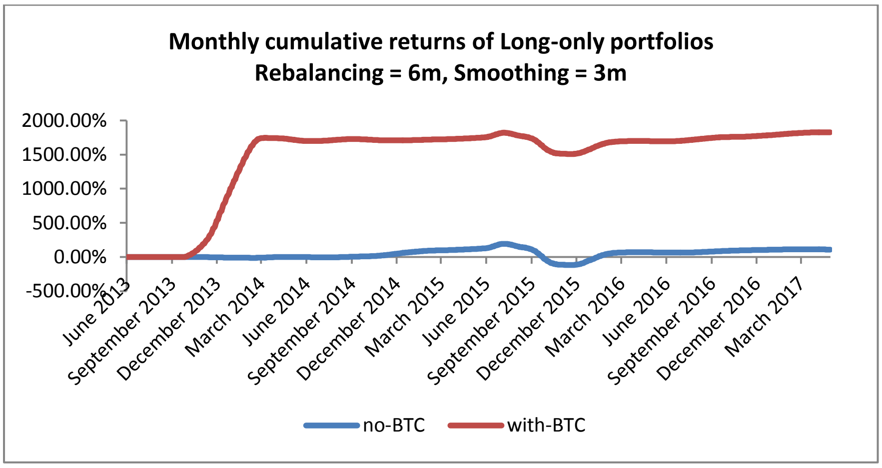


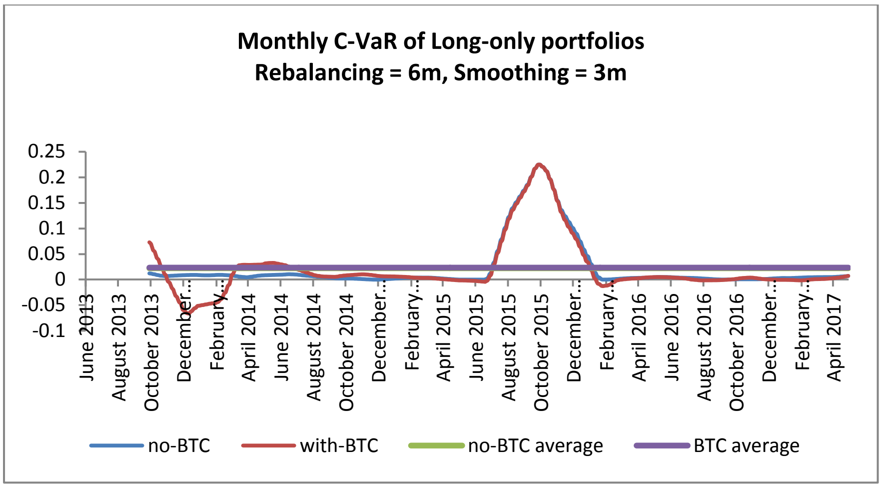



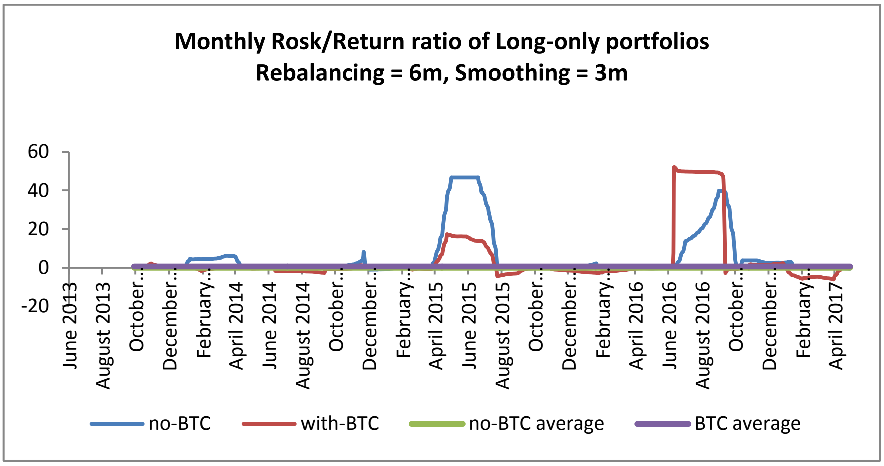



Equally weighted portfolio with bitcoin appears to outperform an equally-weighted portfolio where bitcoin is not present. This is primarily due to much higher returns over the early months of the investment period, especially during 2013, almost 3.73 times higher overall (824.35%/221.11); whereas the risk for both portfolios over time remained largely similar, with no significant differences.

*Figure 5 - Long-only portfolio results*

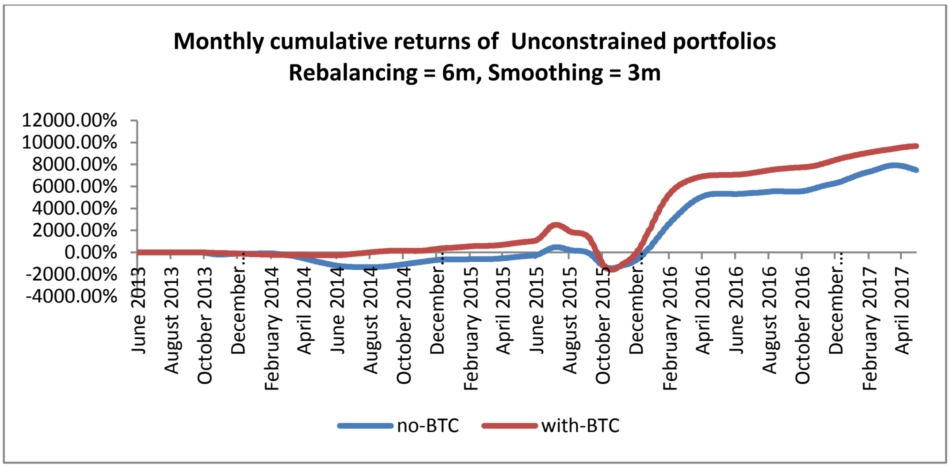


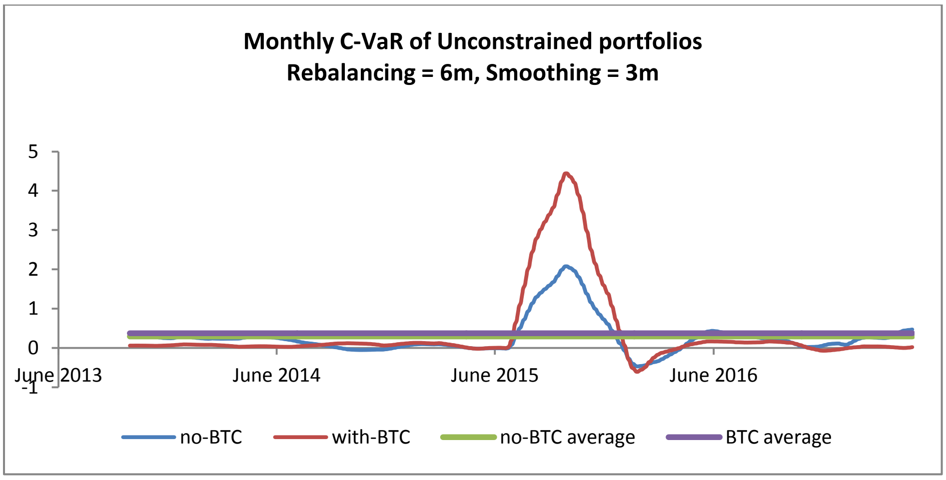


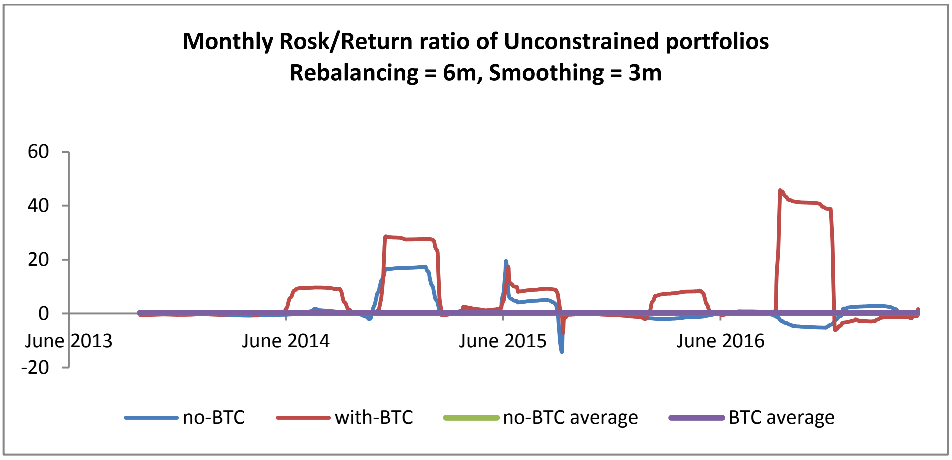




For portfolios with no shorting, the effect of adding bitcoin appears to be even more pronounced, again, mostly due to a major bitcoin price surge of the last quarter of 2013. From that point onwards, the effects of adding bitcoin to a long-only portfolio are less clear-cut and appear to be insignificant, in line with the earlier study carried out by Bouri et al. (2016). The second graph shows a significant drop in CVaR during the same period, but with no subsequent evidence of bitcoin's ability to reduce portfolio risk after that.

*Figure 6 - Unconstrained portfolio results*

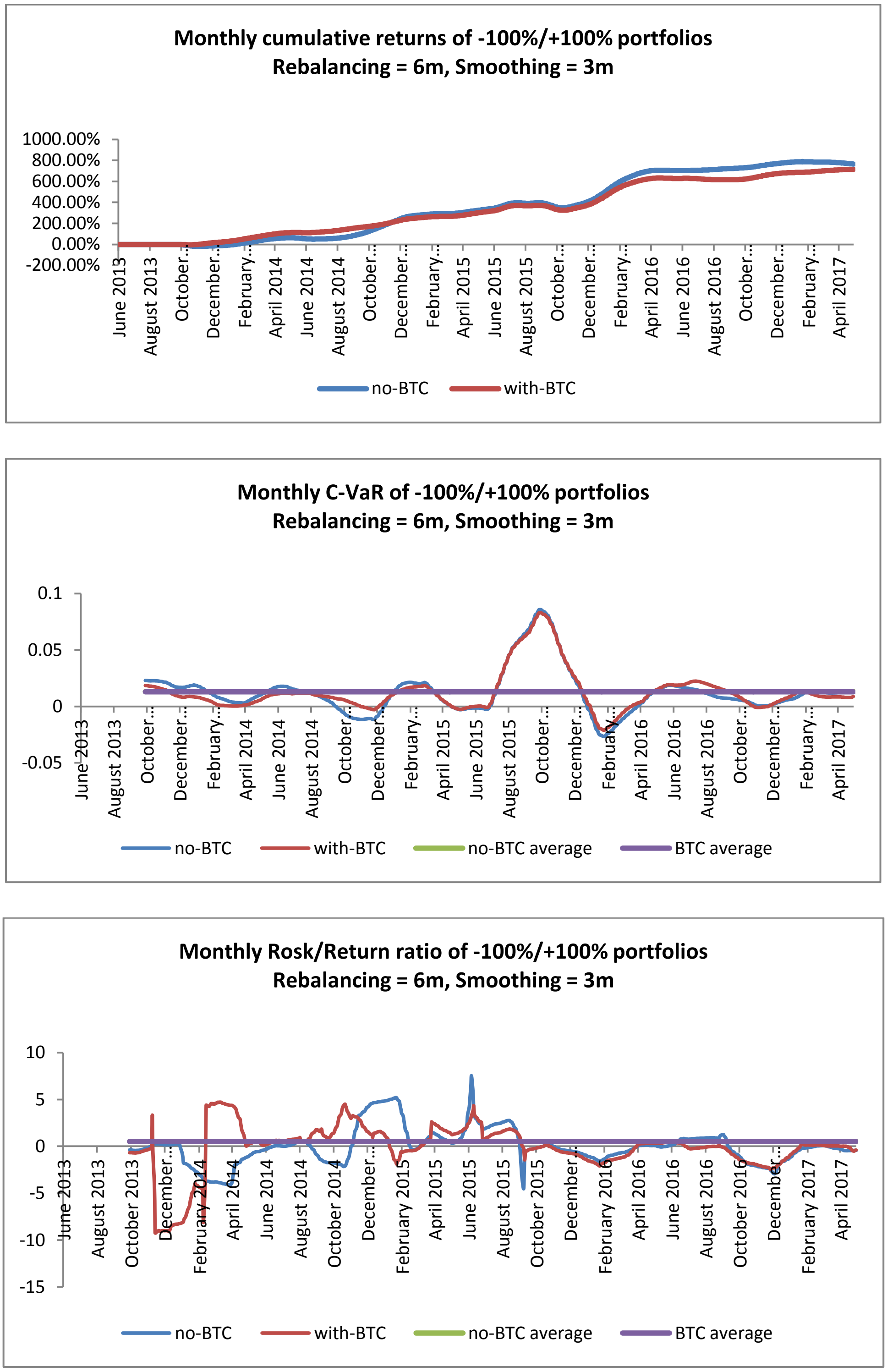



In a theoretical unconstrained scenario where shorting and leverage are allowed on each asset, the optimal portfolio comprising bitcoin only performs better when rebalancing is applied. The initial weights calculated during the initial optimisation process do not hold well over the investment period and a bitcoin portfolio underperforms if left with initial weights. When semi-annual re-optimisation is applied, the portfolio containing bitcoin becomes more efficient and performs better, though significantly less so than in the long-only scenario.

*Figure 7 - Semi-constrained portfolio results*



In a more realistic setting where shorting is allowed but without leverage, the presence of bitcoin appears to reduce portfolio risk (CVaR) somewhat, but the returns are also lower. This results in an overall equal performance of both portfolios regardless of whether re-balancing is applied. In other words, bitcoin has no significant effect on the risk-return ratio of a portfolio of assets where shorting is allowed without leverage.

In summary, the findings show quite a marked difference between the role of bitcoin prior to December 2013 and the subsequent period until the end of 2016: During this early period, the effects of inclusion are significantly positive in naïve and long-only scenarios, whereas where shorting is allowed, the effects are weak or insignificant. This partially supports the earlier findings by Eisl et al. (2015) where bitcoin improves the risk-reward ratio in all scenarios if added to an optimal portfolio of western assets. A sharp divergence can be observed in the period after December 2013 where the inclusion reveals no significant effect in terms of the risk-reward ratio in any scenario. Hence, when the Chinese perspective is assumed, the effects of adding bitcoin to optimal portfolios are neither negative nor positive in this regard. However, since the hypothetical investment period in this study started in early 2013 the long-only optimisation procedure proved the most effective of all strategies. Its effect is further augmented with semi-annual rebalancing where the risk-reward ratio jumps from 0.58 to 0.67, although during backtesting portfolio weights show significant fluctuations ranging from 0% to 34.89%, which is not ideal from the liquidity point of view of a private investor who would have to carry out frequent rebalancing. Institutional investors on the other hand might find rebalancing a more feasible option should they wish to maximise the returns. There’s also a practical limit to how much bitcoin can be bought considering the market cap of 62bn USD (as of September 2017). These strategies could fall apart if large sums of bitcoin are bought or sold at any one time. With bitcoin, such information would travel instantly and inevitably result in price signalling effects.

## 5. Conclusions

Bitcoin is arguably one of the most important financial innovations in recent times. It has drawn an increasing number of critics and supporters in equal measure, yet its rise has been exceptional since its inception in the early 2009 when one bitcoin sold for less than a 0.01USD and continued to climb the highs of 4,470USD in the third quarter of 2017. There is now a rising body of academic literature attempting to explain various value drivers that have contributed to this, such as the genuine transaction demand, speculation, and the in-build deflationary characteristics of bitcoin. There's also a growing body of literature attempting to analyse its other financial characteristics, such as the particularly high volatility, correlations with other more traditional assets and any potential roles that it could play in the financial and investment markets given such information. The meteoric rise in value, as well as very low correlations between bitcoin and the majority of western assets inevitably led to economically-motivated research on its suitability for inclusion in diversified portfolios in these countries. This particular area of research is almost non-existent and draws conclusions from the western perspective; home of only about 1% of the total trading in bitcoin globally.

To expand the analysis of bitcoin as an asset, we have adopted the Chinese perspective, where the bulk of the trading occurs. Results show small but significant correlations between bitcoin and several Indices of Chinese asset classes, in contrast to earlier studies which have not shown any correlations between bitcoin and the western assets. Given the fact that around 99% of all trading occurs in China this might not come as a surprise and insinuates that to a degree, the bitcoin market is not fully insulated from various economic events in that country. The portfolio results are mixed depending on the timeframe and the optimisation framework used: for the long-only scenario, adding bitcoin to a portfolio is beneficial in terms of the risk-reward ratio, but only up until late 2013, with no tangible benefits thereafter. Similarly, for naïve portfolios, the results show that adding bitcoin to an equal weights portfolio would have achieved over three times the risk reward ratio of a portfolio without bitcoin over the entire out-of-sample period. As with the long-only portfolio, the positive effects of adding bitcoin to a naïve portfolio bitcoin are pronounced and positive up until the end of 2013 with no significant effect observed during the remainder of this period. Where unleveraged shorting is allowed, effects on the risk-reward ratio are insignificant throughout the out-of-sample period, even with semi-annual rebalancing. In the scenario where in addition to shorting, leveraging is also possible, bitcoin's effect is generally negative, unless periodic rebalancing is applied. Such rebalancing requires significant shifts in weights which might not be possible in practice, both in terms of practicality and the potential transaction costs, and the results indicate that the risk return ratio would be lower than the in the cases of long-only and naïve portfolios. Since the beginning of 2014, optimised portfolios consisting of a mix of Chinese assets with bitcoin in general do not perform better than bitcoin-less counterparts due to the constantly evolving financial characteristics of bitcoin. Given the total share of trading and the correlations documented in this paper, the overall results suggest a more mature financial profile of bitcoin in China.

A more surprising outcome of this research relates to the (under)performance of the portfolios where shorting is present compared to the long-only portfolios and especially the naïve portfolio. DeMiguel et al. (2007) show that naïve portfolios often perform better than optimised portfolios in general, yet this does not entirely explain why the optimised long-only portfolio performed well. We suggest that this might be due to infrequent semi-annual re-balancing used. Optimisations with shorting react to bitcoin's high volatility, producing negative weights during short-to-medium-term downturns but fail to capture the long-term upward trend. This could have been tested for with an additional strategy such as allowing shorting on all other assets except bitcoin. Semi-annual re-balancing was chosen to reflect a more realistic scenario; however, this represents a theoretical limitation of this study, which is best addressed with continual daily rebalancing.

Between in January 2017 bitcoin represented the bulk of the total market capitalisation of all tradeable cryptocurrencies. By September 2017, this proportion has fallen[3] to under 50% (60bn/130bn), mainly due to the more rapid expansion of alternative cryptocurrencies compared to bitcoin. This has given rise to a variety of theoretical crypto-indices such as the CRIX[4] and the WorldCoinIndex[5] being the most popular. Future research should seek to explore the effects of such indices on optimal portfolios for a more comprehensive analysis.

## References


Acerbi, C., & Tasche, D. (2002). Expected Shortfall: A Natural Coherent Alternative to Value at Risk. *Economic Notes by Banca Monte dei Paschi di Siena SpA*, *31*(2), 379–388.

Alexander, G. J., & Baptista, A. M. (2004). A Comparison of VaR and CVaR Constraints on Portfolio Selection with the Mean-Variance Model. *Management Science*, *50*(9), 1261–1273.

Artzner, P., Delbaen, F., Eber, J., & Heath, D. (1999). Coherent Measures of Risk. *Mathematical Finance*, *9*(3), 203–228.

Barnes, T., & Burnie, D. (1990). Corporate Bonds, Term Structure Expecation and Optimal Portolios: The Canadian Experience. *Journal of Business Finance & Accounting*, *17*(3), 411–420.

Böhme, R., Nicolas, C., Edelman, B., & Moore, T. (2015). Bitcoin: Economics, Technology, and Governance. *Journal of Economic Perspectives*, *9*(2), 213–238.

Bouri, E., Molnár, P., Azzi, G., Roubaud, D., & Hagfors, L. (2016). On the hedge and safe haven properties of Bitcoin: Is it really more than a diversifier? *Finance Research Letters*, *20*, 192–198.

Brière, M., Oosterlinck, K., & Szafarz, A. (2015). Virtual Currency, Tangible Return: Portfolio


[3] Source: https://coinmarketcap.com/ (accessed 23 September 2017)
[4] http://crix.hu-berlin.de/
[5] https://www.worldcoinindex.com/

Diversification with Bitcoin. *Journal of Asset Management*, *16*(6), 365–373.

Carrick, J. (2016). Bitcoin as a Complement to Emerging Market Currencies. *Emerging Markets Finance & Trade*, *52*(10), 2321–2334.

Cheah, E., & Fry, J. (2015). Speculative bubbles in Bitcoin markets? An empirical investigation into the fundamental value of Bitcoin. *Economics Letters*, *130*, 32–36.

Ciaian, P., Rajcaniova, M., & Kancs, D. (2015). The economics of BitCoin price formation. *Applied Economics*, *48*(19), 1799–1815.

Cipolla, C. M. (1994). Uomini Duri. In C. M. Cipolla (Ed.), *Tre Storie Extravaganti*. Bologna: Il Mulino.

de Soto, J. (1995). A critical analysis of central banks and fractional-reserve free banking from the Austrian school perspective. *The Review of Austrian Economics*, *8*(2), 25–38.

DeMiguel, V., Garlappi, L., & Uppal, R. (2007). (2007). Optimal Versus Naive Diversification: How Inefficient is the 1/N Portfolio Strategy? *Review of Financial Studies*, *22*(5), 1915–1953.

Eisl, A., Gasser, S. M., & Weinmayer, K. (2015). *Caveat Emptor: Does Bitcoin Improve Portfolio Diversification?*

Galai, D., & Geske, R. (1984). Option performance measurement. *Journal of Portfolio Management*, *10*(3), 42–46.

Garcia, D., Tessone, C., Mavrodiev, P., & Perony, N. (2014). The digital traces of bubbles: feedback cycles between socio-economic signals in the Bitcoin economy. *Journal of The Royal Society Interface*, *11*(99), 623–623.

Glaser, F., Zimmermann, K., Haferkorn, M., Christian Weber, M., & Siering, M. (2014). Bitcoin—Asset or Currency? Revealing Users' Hidden Intentions. In *Proceedings of the 22nd European Conference on Information Systems*. Tel Aviv.

Harvey, C. (2017). *Cryptofinance*.

Hope, K. (2017). Greek court backs US request to extradite Russian over bitcoin laundering. *Financial Times*.

Keating, C., & Shadwick, W. (2002). A universal performance measure. *Journal of performance measurement*, *6*(3), 59–84.

Keynes, J. M. (1936). *The General Theory of Employment, Interest, and Money.* Basingstoke, Hampshire: Palgrave Macmillan.

Kristoufek, L. (2015). What Are the Main Drivers of the Bitcoin Price? Evidence from Wavelet Coherence Analysis. *PLOS ONE*, *10*(4).

Makin, J. (1978). Portfolio theory and the Problem of Foreign Exchange Risk. *Journal of Finance*, *33*(2), 517–534.

Markowitz, H. M. (1952). Portfolio Selection. *The Journal of Finance*, *7*(1), 77–91.

Markowitz, H. M. (1976). Markowitz Revisited. *Financial Analyst Journal*, *Sept. 76*(47–52).

McLannahan, B. (2017). Dimon and Fink unite on need to “crush” bitcoin. *Financial Times*.

Nadarajah, S., & Chu, J. (2017). On the inefficiency of Bitcoin. *Economics Letters*, *150*, 6–9.

Nakamoto, S. (2008). *Bitcoin: A peer-to-peer electronic cash system.* https://bitcoin.org/en/bitcoin-paper

O’Dwyer, K., & Malone, D. (2014). Bitcoin Mining and its Energy Footprint. In *25th IET Irish Signals & Systems Conference 2014 and 2014 China-Ireland International Conference on Information and Communities Technologies*.

Osterrieder, J., & Lorenz, J. (2017). A Statistical Risk Assessment of Bitcoin and Its Extreme tail Behaviour. *Annals of Financial Economics*, *12*(1), 175.

Pojarliev, M., & Levich, R. (2011). Are All Currency Managers Equal? *Journal of Portfolio Management*, *37*(4), 42–53.

Polasik, M., Piotrowska, A., Wisniewski, T. P., Kotkowski, R., & Lightfoot, G. (2015). Price Fluctuations and the Use of Bitcoin: An Empirical Inquiry. *International Journal of Electronic Commerce, 20*(1), 9–49.

Ruban, O., & Melas, D. (2011). Constructing Risk Parity Portfolios: Rebalance, Leverage, or Both? *Journal of Investing*, *20*(1), 99–107.

Seddon, M. (2017). Putin orders government to devise cryptocurrency regulations. *Financial Times*.

Sharpe, W. (1963). A Simplified Model for Portfolio Analysis. *Management Science*, *9*(2), 277–293.

Sharpe, W. (1964). Capital Asset Prices - A Theory of Market Equilibrium Under Conditions of Risk. *Journal of Finance*, *19*(3), 425–442.

Silvapulle, P., & Granger, C. W. (2001). Large returns, conditional correlation and portfolio diversification: a value-at-risk approach. *Quantitative Finance*, *1*(5), 542–551.

Stein, D. M., Siegel, A. F., Narasimhan, P., & Appeadu, C. E. (2000). Diversification in the Presence of Taxes. *Journal of Portfolio Management.*, *27*(1), 61–71.

Terazono, E. (2017). Japan experiments with cryptocurrencies. *Financil Times*.

Timmerman, K., & Thomas, M. (2017). Proctor, The - Ethereum: More than 'the new Bitcoin. *Humanities & Social Sciences Collection - Informit. [online] Search.informit.com.au.* https://search.informit.com.au/documentSummary;dn=886797444851448;res=IELHSS

Topaloglou, N., Vladimirou, H., & Zenios, S. (2002). CVaR models with selective hedging for international asset allocation. *Journal of Banking & Finance*, *26*(7), 1535–1562.

Treynor, J. L., & Black, F. (1973). How to Use Security Analysis to Improve Portfolio Selection. *Journal of Business*, *46*(1), 66–86.

Urquhart, A. (2016). The inefficiency of Bitcoin. *Economics Letters*, *148*, 80–82.

Vigna, P., & Casey, M. (2015). *Cryptocurrency*. Bodley Head.

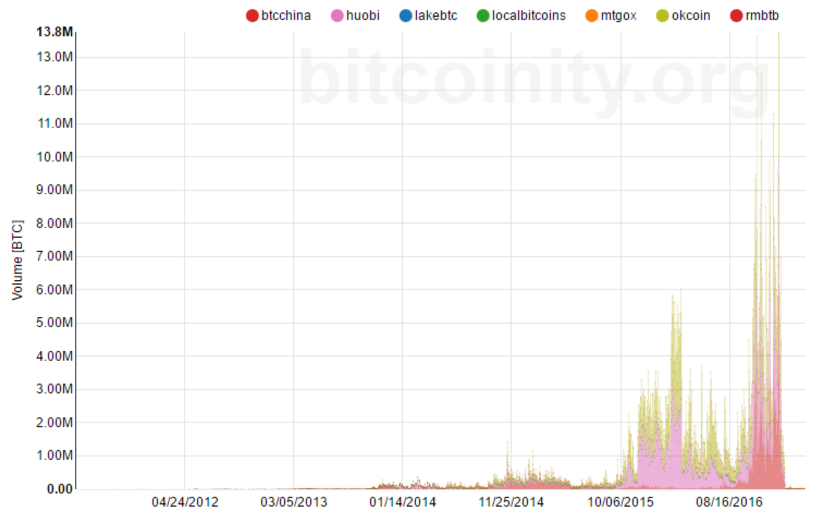
Wang, J., Xue, Y., & Liu, M. (2016). An Analysis of Bitcoin Price Based on VEC Model. In *Proceedings of the 2016 International Conference on Economics and Management Innovations*.

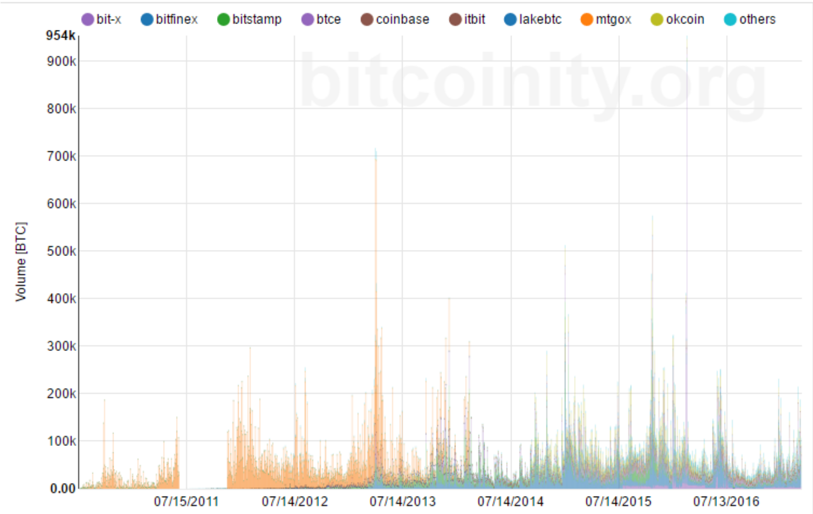
Wu, C. Y., & Pandey, V. K. (2014). The Value of Bitcoin in Enhancing the Efficiency of an Investor's Portfolio. *Journal of Financial Planning.*, *27*(9), 44–52.

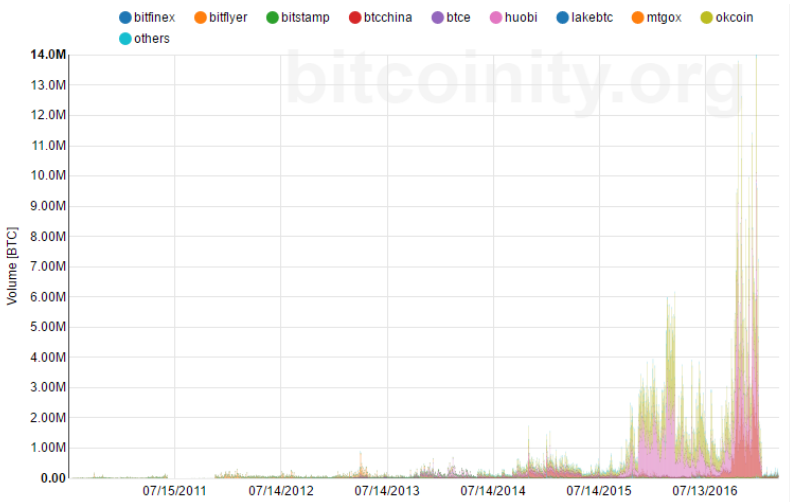
# Appendix 1 – Data sources

| Name | Source |
|---|---|
| The Bitcoin CNY Price Index | https://data.bitcoinity.org/markets/price/all/CNY?c=e&r=day&t=l |
| S&P CHINA GOVERNMENT BILL INDEX | http://us.spindices.com/indices/fixed-income/sp-china-government-bill-index |
| S&P CHINA SOVEREIGN BOND INDEX | http://us.spindices.com/indices/fixed-income/sp-china-sovereign-bond-index |
| S&P CHINA CORPORATE BOND INDEX | http://us.spindices.com/indices/fixed-income/sp-china-corporate-bond-index |
| S&P WCI GOLD (ER) | http://us.spindices.com/indices/commodities/sp-wci-gold-er |
| S&P CHINA A 100 INDEX (RMB) | http://us.spindices.com/indices/equity/sp-china-a-100-index-rmb |
| S&P CHINA A 200 INDEX (RMB) | http://us.spindices.com/indices/equity/sp-china-a-200-index-rmb |
| S&P CHINA A SMALLCAP INDEX (RMB) | http://us.spindices.com/indices/equity/sp-china-a-smallcap-index-rmb |
| TR/HKEX RXY Global CNY | https://www.hkex.com.hk/eng/prod/drprod/rmb/rxy.htm |
| S&P WCI ASIA | http://us.spindices.com/indices/commodities/sp-wci-asia |
| China Housing Index | https://www.fxstreet.com/economic-calendar/event/704fa9ee-e4c6-4599-97d3-7f3f42bf7542 |
| Eurekahedge Greater China Hedge Fund Index | http://www.eurekahedge.com/Indices/IndexView/Special/66/Eurekahedge_Greater_China_Hedge_Fund_Index |
| USDCNY Exchange rate | https://www.google.co.uk/finance?q=USDCNY |

# Appendix 2 – Bitcoin trading volume breakdown



# Appendix 3 – Bitcoin volatility

The bitcoin volatility index is represented in black, compared to USD/CNY currency pair volatility, shown in orange. (*Source: www.buybitcoinworldwide.com/volatility-index/)*