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Published on: 01 Jan 2015 - Social Science Research Network

Topics: Alternative investment, Virtual currency, Diversification (finance), Portfolio and Hedge fund

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To cite this article:

Brière M., K. Oosterlinck, and A. Szafarz (2015). "Virtual Currency, Tangible Return: Portfolio Diversification with Bitcoin." ***Journal of Asset Management*** **16(6), pp. 365–373.**

This is a post-peer-review, pre-copyedit version of an article published in the *Journal of Asset Management*. The definitive publisher-authenticated version **doi:10.1057/jam.2015.5** is available online at: **http://link.springer.com/article/10.1057/jam.2015.5**

Keywords: Bitcoin, risk, return, diversification, virtual currency.

JEL codes: G11, G15, O16, F39, G01, E44

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Virtual Currency, Tangible Return: Portfolio Diversification with Bitcoin

Abstract

Bitcoin is a major virtual currency. Using weekly data over the 2010-2013 period, we analyze a Bitcoin investment from the standpoint of a U.S. investor with a diversified portfolio including both traditional assets (worldwide stocks, bonds, hard currencies) and alternative investments (commodities, hedge funds, real estate). Over the period under consideration, Bitcoin investment had highly distinctive features, including exceptionally high average return and volatility. Its correlation with other assets was remarkably low. Spanning tests confirm that Bitcoin investment offers significant diversification benefits. We show that the inclusion of even a small proportion of Bitcoins may dramatically improve the risk-return trade-off of well-diversified portfolios. Results should however be taken with caution as the data may reflect early-stage behavior which may not last in the medium or long run.

1. Introduction

The recent crisis has prompted investors to explore innovative investment opportunities.[1] Bitcoin, a virtual currency, has recently attracted substantial media attention and has now become a standard means of payment over the internet (ECB, 2012). More and more providers of goods and services—legal and illegal—trade in Bitcoins. Importantly, the projected launch of a Bitcoin exchange-traded fund, Winklevoss Bitcoin Trust, shows that Bitcoin is now a credible investment vehicle (Baluchnas, 2013; Arash and Alloway, 2013; Arthur, 2013). Even though currencies are commonly used to diversify financial portfolios, the literature has so far overlooked the investment characteristics of Bitcoin.[2] Our paper fills that gap.

Bitcoin was invented in 2009 by a programmer known as Satoshi Nakamoto (Grinberg, 2011). The creation of Bitcoin follows precise rules derived from the gold market. So-called "miners" competitively use computer resources to solve cryptographic problems and verify the validity of transactions (Velde, 2013). Success is rewarded by newly issued Bitcoin. The subsequent money creation evolves according to a fixed scheme pre-established by the inventor. Since supply is perfectly predictable,[3] Bitcoin is free from any central-bank-like intervention (ECB, 2012). The value of Bitcoin solely depends on supply and demand. Currently, Bitcoins are actively traded against 32 hard currencies on well-organized virtual exchange markets. These markets remain accessible during week-ends, which is valuable to investors, especially in hectic times (Michie, 1999). As of December 2013, the Bitcoin market capitalization was approximately USD 10 billion.

The ECB (2012, p. 13) defines Bitcoin as "a type of unregulated, digital money, which is issued and controlled by its developers, and used and accepted among the members of a specific virtual community". Obviously, Bitcoin is not legal tender.[4] Bitcoins are typically stored in virtual

[1] Yet, alternative investment goods, such as artworks, deliver mixed financial results (David et al., 2013; Renneboog and Spaenjers, 2013).
[2] In contrast to hard currencies, Bitcoins pay no interest.
[3] http://bitcoin.org/en/how-it-works
[4] Arguably, this could imply that Bitcoin has no intrinsic value. Things are changing fast, however. According to the regulation issued by the U.S. Financial Crimes Enforcement Network on 18 March 2013, Bitcoin exchanges and miners are required to register as Money Services Businesses and comply with anti-money laundering regulations

wallets, which attract hackers.[5] As a result, Bitcoin tends to be more volatile than hard currencies, and more prone to speculative bubbles (Grinberg, 2011). On the other hand, virtual transactions are nearly anonymous and have low or inexistent transaction fees.

Computer science aside, the scarce academic literature on Bitcoin is mostly dedicated to legal issues such as trading safety, money laundering, and income tax. To our knowledge, investment aspects remain unaddressed. Here, we put Bitcoin investment into a portfolio perspective. Our results confirm that Bitcoin investment *per se* is extremely risky (ECB, 2012, Harper, 2013). More surprisingly, we show that the Bitcoin rate of return presents statistical characteristics that differ markedly from those of other assets, including gold, oil, and hedge funds. In addition, Bitcoin investment is attractive because it delivers exceptionally high diversification benefits. This is due to low correlations not only with traditional financial assets but also with alternative investments. Results should however be taken with caution as Bitcoin is still in its infancy and data may be subject to an early-stage behavior which may not continue in the future.

2. **Data and Results**

Since 2009, 40 Bitcoin (BTC) exchanges have been created, 20 of which are still active today (Moore and Christin, 2013). BTC liquidity has improved dramatically since the currency was created (see Fig. A1 in Appendix A). Currently, more than 50,000 transactions are handled daily on BTC exchanges.[6] We use weekly BTC closing exchange rates against the USD retrieved from the *Bitcoincharts* website for the period from 23 July 2010 to 27 December 2013. BTC has already experienced two major speculative crises in its short history (see Fig. A2 in Appendix A). The first started in June 2011 and ended in a crash after the first major BTC theft in July 2011.[7] The second coincided with the Cyprus crisis (Rushe, 2013). A period of price inflation started in March 2013

(http://fincen.gov/statutes_regs/guidance/html/FIN-2013-G001.html). Furthermore, Germany recognized Bitcoin for legal and tax purposes in August 2013 (Gotthold and Eckert, 2013).

[5]Stolen Bitcoins are never recoverable. A recent cyber-attack against a Bitcoin exchange resulted in the theft of the equivalent of USD 9 million (ECB, 2012).

[6] Daily number of transactions and daily traded volumes can be retrieved from http://bitcoincharts.com

[7] http://www.forbes.com/sites/timworstall/2011/06/17/bitcoin-the-first-500000-theft/

just after the U.S. published legislative guidance on virtual currencies, and ended in April 2013 when BTC lost nearly half of its value in a couple of hours. Our sample period covers both crises.

We consider the situation of a U.S. investor holding a diversified portfolio comprising both traditional assets (worldwide stocks, bonds, hard currencies) and alternative investments (commodities, hedge funds, real estate). Each asset class is represented by several liquid financial indices.[8] The weekly returns of these indices are retrieved from Datastream (total return indices in USD).

Fig. 1 draws cumulative performances for the 13 assets under study, and Table 1 provides descriptive statistics. BTC returns are exceptional in many regards. The average return is skyrocketing (404% annually), but so is volatility (176% annually). These exceptionally high figures reflect the risks in BTC investment, including non-survival risk.[9] Financial innovations are hard to value and assets linked to these financial innovations are likely to exhibit bubble-like features (Frehen et al., 2013). The returns observed on our sample may thus be linked to novelty and may not be reached again in subsequent periods. In other words, BTC past returns should be used with care when assessing future expected returns.[10] The presence of significant extreme risks is reflected in kurtosis values of up to 9.10, comparable with those of emerging government bonds (108.96). Even more striking is the extremely high skewness (1.85), a real curiosity for financial analysts. Positive skewness levels of this magnitude are known to be reachable only by sophisticated strategies such as volatility investments meant to hedge financial portfolios against

[8] We use the following indices. (1) Equities: developed and emerging (MSCI World, MSCI Emerging); (2) Bonds: developed and emerging government bonds (JPMorgan GBI Broad, JPM EMBI+), World inflation linked bonds (Barclays Global Inflation World) and World corporate bonds (Merrill Lynch Global Broad Market Corporate and High Yield); (3) Commodities: gold and oil (gold bullion and WTI); (4) Hard currencies: money market investments in Euro and Yen; and (5) Alternatives: hedge funds (HFRX Hedge Fund Index) and listed World real estate (FTSE Global NAREIT). Data come from Datastream. Working with weekly returns, we are unable to account for art investments, where indices are computed on an annual basis.

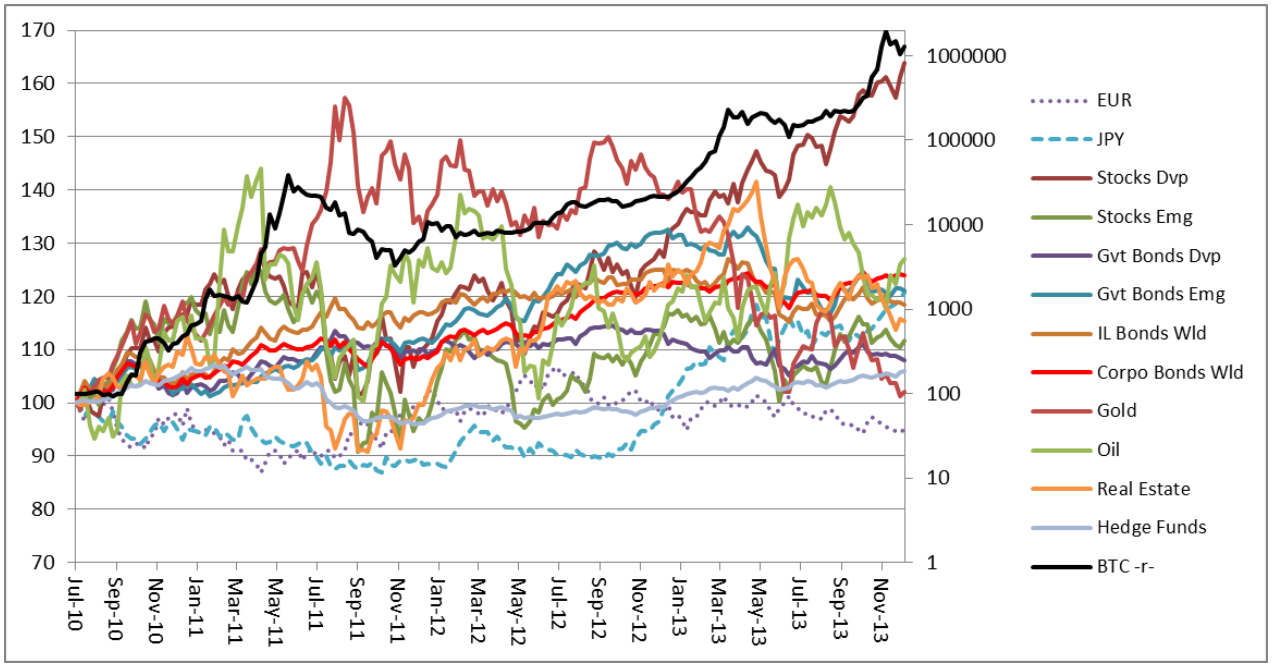
[9] Other important risks are liquidity risk, legal risk, and the risk of security breaches in electronic portfolios. Moreover, like cash transactions, BTC settlements are irreversible.

[10] The use of realized returns for studying expected returns is debatable. There are, however, few alternatives. As pointed out by Elton (1999), "Almost all of the testing (…) involves using realized returns as a proxy for expected returns." Therefore, this paper follows the traditional approach.

crises (Brière et al., 2010).[11] This evidence, though still frail, suggests that BTC could act as a partial hedge against crises. Overall, it looks like something new in the investment universe.[12]

Figure 1: Performances of bitcoin and traditional investment

This figure shows the performance in USD of BTC investment (logarithmic right scale-) compared with those of traditional and alternative assets (left scale) over the time period 23 July 2010 - 27 December 2013. Traditional assets are money market investments (one-week interbank interest rates) in hard currencies, EUR and JPY, developed and emerging equities (Stocks Dvp and Stocks Emg), developed and emerging government bonds (Gvt Bonds Dvp and Gvt Bonds Emg), World inflation-linked bonds (IL Bonds Wld), World corporate bonds (Corpo Bonds Wld), gold, oil, hedge funds and listed World real estate.



[11] The asymmetry to the left of a return distribution means that prices tend to fall sharply during crashes. Besides volatility derivatives, there are few assets exhibiting such characteristics.

[12] In addition, BTC investment achieves a Sharpe ratio of 2.12, which is particularly attractive compared with asset classes.

Table 1: Descriptive statistics

This table shows descriptive statistics (mean, median, maximum, and minimum returns, standard deviation, volatility, skewness, kurtosis and Sharpe ratio) of weekly returns in USD of BTC, traditional and alternative assets over the time period between 23 July 2010 and 27 December 2013. Traditional assets are money market investments (one-week interbank interest rates) in hard currencies, EUR and JPY, developed and emerging equities (Stocks Dvp and Stocks Emg), developed and emerging government bonds (Gvt Bonds Dvp and Gvt Bonds Emg), World inflation-linked bonds (IL Bonds Wld), World corporate bonds (Corpo Bonds Wld), gold, oil, hedge funds and listed World real estate.

	BTC	EUR	JPY	Stocks Dvp	Stocks Emg	Gvt Bonds Dvp	Gvt Bonds Emg	IL Bonds Wld	Corpo Bonds Wld	Gold	Oil	Real Estate	Hedge Funds
Mean	7.79%	-0.02%	0.11%	0.30%	0.09%	0.05%	0.11%	0.10%	0.12%	0.04%	0.20%	0.10%	0.03%
Ann. Mean	404.89%	-1.20%	5.93%	15.64%	4.91%	2.45%	5.88%	5.16%	6.38%	2.20%	10.24%	5.19%	1.75%
Median	3.32%	-0.01%	0.00%	0.43%	0.10%	0.07%	0.20%	0.05%	0.14%	0.19%	0.25%	0.22%	0.12%
Maximum	137.62%	4.17%	3.97%	8.27%	9.46%	2.25%	3.23%	2.28%	1.83%	7.14%	13.51%	5.91%	0.90%
Minimum	-41.78%	-3.19%	-3.55%	-8.81%	-11.62%	-2.85%	-5.90%	-3.51%	-2.55%	-7.11%	-14.57%	-9.04%	-2.49%
Std. Dev.	24.43%	1.39%	1.31%	2.20%	2.58%	0.84%	1.04%	0.96%	0.70%	2.47%	3.56%	2.03%	0.46%
Volatility	176.15%	10.03%	9.43%	15.89%	18.61%	6.05%	7.53%	6.89%	5.06%	17.82%	25.68%	14.61%	3.33%
Skewness	1.85	0.31	0.14	-0.44	-0.28	-0.24	-1.07	-0.22	-0.29	-0.21	-0.17	-0.64	-1.35
Kurtosis	9.10	2.95	2.96	5.34	6.35	3.31	8.96	3.42	3.69	3.61	5.13	5.48	7.36
Sharpe Ratio	2.30	-0.14	0.61	0.97	0.25	0.37	0.75	0.72	1.22	0.11	0.39	0.34	0.47
Observations	179	179	179	179	179	179	179	179	179	179	179	179	179

Table 2 shows that BTC benefits from low correlations with the other assets. Only two assets exhibit a significant correlation with BTC, gold (14%) and inflation-linked bonds (14%). This is hardly surprising as the fully predictable BTC supply is often presented as an inflation hedge (ECB, 2012; Harper, 2013), which is attractive to investors (Bodie, 1976).

The low correlations between BTC and other investment vehicles should be interpreted with caution since they were computed on a bullish period. Correlations are known to be unstable and can change dramatically during crises (Goetzmann et al., 2005, Brière et al., 2012). Unfortunately, the limited period of observation does not allow us to test whether BTC correlations with other assets remain low when markets are bearish.

Table 2: Correlations

This table displays the correlation matrix between the weekly returns in USD of the 13 asset classes under study (BTC and traditional investments) over the time period between 23 July 2010 and 27 December 2013. Traditional and alternative assets are money market investments (one-week interbank interest rates) in hard currencies, EUR and JPY, developed and emerging equities (Stocks Dvp and Stocks Emg), developed and emerging government bonds (Gvt Bonds Dvp and Gvt Bonds Emg), World inflation-linked bonds (IL Bonds Wld), World corporate bonds (Corpo Bonds Wld), gold, oil, hedge funds and listed World real estate. ***/**/* indicate that the coefficient estimates are significantly different from zero at the 1%/5%/10% level.

	Bitcoins	Euro	Yen	Stocks Dvp	Stocks Emg	Gvt Bonds Dvp	Gvt Bonds Emg	IL Bonds Wld	Corpo Bonds Wld	Gold	Oil	Real Estate	Hedge Funds
Bitcoins													
Euro	-4												
Yen	-6	21***											
Stocks Dvp	5	-53***	4										
Stocks Emg	4	-45***	6	80***									
Gvt Bonds Dvp	8	-64***	-74***	16**	20***								
Gvt Bonds Emg	3	-27***	-5	34***	53***	39***							
IL Bonds Wld	14*	-60***	-44***	23***	30***	84***	48***						
Corpo Bonds Wld	10	-70***	-38***	38***	49***	81***	61***	81***					
Gold	14*	-38***	-36***	21***	31***	49***	31***	50***	48***				
Oil	-1	-34***	-6	50***	47***	14*	20***	23***	21***	30***			
Real Estate	0	13*	15**	63***	66***	-11	46***	2	14*	0	28***		
Hedge Funds	9	-34***	15**	77***	71***	7	32***	23***	37***	17**	49***	60***	

To gauge the interest of BTC from an investment perspective, we conduct spanning tests, which check whether adding a given asset (here BTC) to a predetermined universe improves investment opportunities. We use the mean-variance spanning test proposed by Huberman and Kandel (1987) and Ferson et al. (1993). First, the test developed by Huberman and Kandel (1987) involves running OLS regressions of BTC return R_E on the returns of K benchmark assets, $R_B^k, k = 1,\ldots,K$.

$$R_{E,t} = \alpha + \sum_{k=1}^{K} \beta_k R_{B,t}^k + \varepsilon_t \qquad t = 1,2 \ldots T$$

The necessary and sufficient condition for spanning is:

$$H_0: \alpha = 0 \text{ and } \sum_{k=1}^{K} \beta_k = 1$$

Under the null of spanning, there exists a portfolio comprising K benchmark assets, which has the same expected return but a lower variance than the test asset since the K benchmark assets are uncorrelated with ε_t. We run a Wald test to assess spanning under the assumption of independent

and identically distributed disturbances ε_t with a multivariate centered normal distribution and covariance matrix Σ. The Wald test statistic has the following asymptotic distribution (Berndt and Savin, 1977):

$$W = T(\lambda_1 + \lambda_2) \sim \chi_2^2,$$

where:

$$\lambda_1 = \max_r \frac{1+\hat{\theta}_2^2(r)}{1+\hat{\theta}_1^2(r)} - 1, \qquad \lambda_2 = \min_r \frac{1+\hat{\theta}_2^2(r)}{1+\hat{\theta}_1^2(r)} - 1,$$

and $\hat{\theta}_1^2(r)$ and $\hat{\theta}_2^2(r)$ are the Sharpe ratios obtained for the risk-free rate r and the tangency portfolios comprising the K benchmark assets and the $K + 1$ assets including BTC, respectively.

Second, Ferson et al. (1993) extend the same testing approach to Hansen's (1982) Generalized Method of Moments (GMM) estimation, which allows them to assume away homoscedasticity and normality. Both test statistics have asymptotic Chi-square distributions with two degrees of freedom. Kan and Zhou (2012) compare the sizes and powers of the two tests under several return distributions. In particular, when the returns under study have a joint multivariate elliptical distribution with excess kurtosis, which is a common characteristic of financial returns, the regular Wald test tends to over-reject the null, and the problem persists when the sample size increases. In this respect, the GMM-based test proposed by Ferson et al. (1993) performs better, but lifting away the normality assumption entails a significant loss in statistical power. Kan and Zhou (2012) show that the amplitude of the power loss depends on the characteristics of the test asset; it is especially high when the test asset affects the global minimum-variance portfolio.

Table 3 provides the results of the mean-variance spanning tests. We add BTC to portfolios made of 1) traditional assets (currencies, stocks and bonds), 2) alternative assets (commodities, real estate, and hedge funds), and 3) all assets together. We find that BTC significantly spans all asset categories. The results imply that BTC-inclusive portfolios deliver superior mean-variance trade-offs than do similar BTC-free portfolios.

Table 3: Spanning tests

This table reports the results of the spanning tests checking whether BTC investment spans a traditional investment universe made from traditional assets (currencies, stocks, bonds), alternative assets (commodities, hedge funds, real estate) or both (all assets). Weekly returns are used over the time period between 23 July 2010 and 27 December 2013. The first, respectively second, column reports Wald statistics for the mean-variance spanning tests of Huberman and Kandel (HK) (1987), resp. Ferson, Foerster and Keim (FFK) (1993). ***/**/* indicate that the coefficient estimates are significantly different from zero at the 1%/5%/10% level.

	HK Spanning test	FFK Spanning test
Traditional assets	6.87***	4.64**
Alternative assets	10.45***	8.28***
All assets	6.93***	5.22***

Next, we investigate the importance of the risk-return benefits gained by including BTC in a well-diversified portfolio. We exclude short positions in order to stick to realistic investment possibilities. First, we build and compare the equally-weighted portfolios without and with BTC, respectively. Although the relevance of equally-weighted portfolios is debatable in the context of such diverse asset classes, the exercice is simple and intuitive. It appears that BTC improves performances dramatically, with the Sharpe ratio increaseing from 0.78 (annualized return of 5.38%) to 2.36 (annualized return of 36.11%), while annual volatility more than doubles (from 6.38% to 15.15%). In addition, including BTC creates positive asymmetry in returns. One might however object that the BTC-inclusive portfolio has 7.7% of BTC, which may seem too high for the vast majority of reasonably risk-averse investors.

Second, we make a more refined analysis involving portfolio optimization. Fig. 2 draws the mean-variance efficient frontiers without and with BTC. It shows that the BTC-inclusive frontier is much steeper than its BTC-free counterpart. As expected, the minimal-variance portfolio excludes BTC. Despite its high diversification potential, BTC remains too volatile to be included in the lowest-risk portfolio. However, a slight increase in the investor's risk tolerance is associated with a sharp increase in the average returns obtained for a given level of risk.

Table 4 compares performance indicators of same-volatility efficient portfolios without and with BTC. At the 6% volatility level, including BTC in the portfolio makes the average annual

return jump from 8.8% to 17.6%. Meanwhile, the annualized semi-variance decreases from 4.2% to 2.8% when a scant 3% of BTC is included. The decrease in semi-variance reflects the low level of downside risk of BTC investment, which exhibits heavy but positively skewed tails of the distribution. The Sharpe and Sortino ratios[13] increase considerably with the inclusion of BTC, from 1.39 to 2.83 and from 2 to 6.1, respectively. However, the adjusted Sharpe ratio[14] taking extreme risks into account decreases sharply, from 0.8 to -1.45, demonstrating that a small share of BTC can seriously harm the investor's position in terms of extreme risk (fatter tails of the distribution).

At the 12% volatility level, Table 4 shows that including 6% of BTC in the investor's portfolio would yield a 19% jump in average return (from 13.1% to 32.5%) and a 3.5% decline in annualized semi-variance (from 8.8% to 5.4%). At the same time, the Sharpe and Sortino ratios increase and the adjusted Sharpe ratio decreases strongly (from 0.7 to -1.1). In sum, even for moderately risk-averse investors, BTC may lead to substantial financial gains, but simultaneously to a significant increase in extreme risk.

[13] Whereas the Sharpe ratio performance indicator divides the portfolio excess return over the risk-free rate by its volatility, the Sortino ratio replaces the volatility by the standard deviation of negative asset returns.
[14] The adjusted Sharpe ratio is an alternative to the standard Sharpe ratio when returns are not normally distributed. The measure is derived from a Taylor series expansion of an exponential utility function.

Figure 2: Mean-variance efficient frontiers without and with BTC

This figure presents two efficient frontiers. The dotted line, labelled "without BTC," is derived from an investment universe including traditional and alternative investments only (currencies, stocks, bonds, commodities, hedge funds and real estate). The plain line, labelled "with BTC," is derived from the same investment universe plus BTC. We use weekly returns from 23 July 2010 to 27 December 2013.

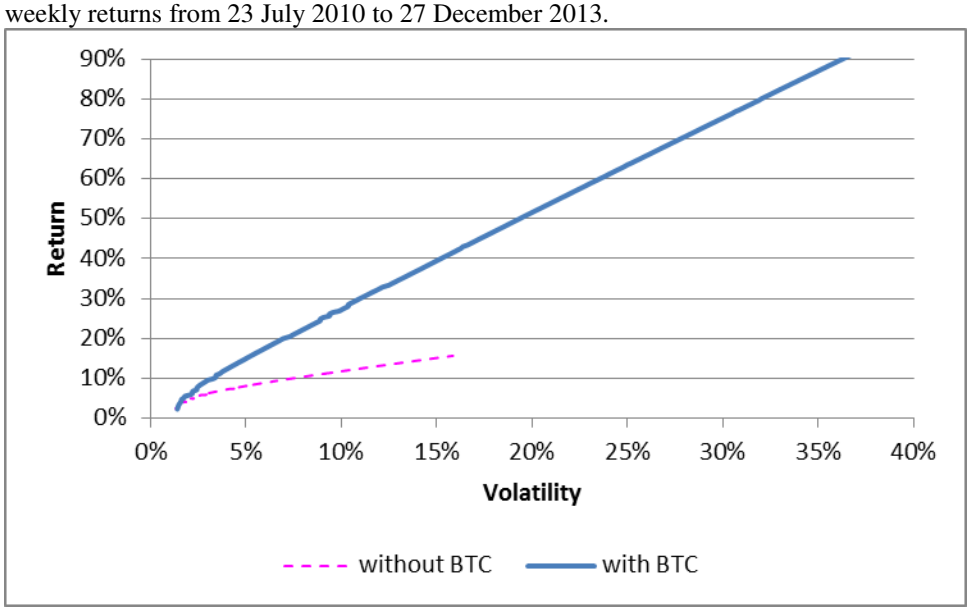


Table 4: Portfolio performances without and with BTC

This table compares the annualized mean return, semi-variance, Sharpe and Sortino ratios (and adjusted Sharpe ratio) of same-volatility efficient portfolios without and with BTC. The first two portfolios (columns 1 and 2) achieve 6% volatility over the sample period while the last two portfolios have 12% volatility over the same period. We use weekly returns from 23 July 2010 to 27 December 2013.

	Efficient portfolio			
	6% volatility		12% volatility	
	without BTC	with BTC	without BTC	with BTC
Ann. Mean	8.84%	17.59%	13.10%	32.51%
Ann. Semi-Variance	4.19%	2.82%	8.85%	5.38%
Sharpe Ratio	1.39	2.83	1.05	2.66
Sortino Ratio	2.00	6.07	1.43	5.96
Adjusted Sharpe Ratio	0.80	-1.45	0.73	-1.14
% BTC	0%	3%	0%	6%
Observations	179	179	179	179

3. Concluding Remarks

BTC is a recent concept and subsequently a still rather unexplored financial asset with a short history. Some might even argue that BTC is just a bubble. Figuring out the fundamental value of BTC is a difficult task, and history has shown that assets linked to innovations (financial or real) are more bubble-prone (Frehen et al., 2013). Furthermore, our data is contaminated by early-stage behavior that might compromise the analysis of future performance. Past performance is obviously no forecast for future asset prices, particularly for young and highly risky assets such as BTC. The fact that BTC has low correlations with other assets over the timeframe of this study (2010-2013) does not necessarily imply that BTC will remain this low in times of crises, as correlations are known to increase during crises. As such, it is hard to say how BTC will be perceived in future time of crises. The correlations observed would tend to place BTC in the safe-haven category, but history is replete with examples of assets initially presented as safe havens and not fulfilling that promise. Keeping this caveat in mind, we carefully exploit the most recent, most robust spanning testing methodology to explore the diversification potential of BTC.

As internet-based transaction systems, virtual currencies fulfill a useful economic function. From the investor's standpoint, the distinctive features of the Bitcoin make it a unique asset. Bitcoins are currently traded on several exchanges, and the launch of exchange-traded funds is now being planned.[15] This paper shows that Bitcoin investment exhibits very high volatility but also very high returns. In addition, for holders of well diversified portfolios, high risk is compensated by low correlations with other assets. Including even a small proportion of Bitcoins in a well-diversified portfolio may dramatically improve risk-return characteristics. Overall, our key message is that virtual currencies deserve to be taken seriously by financial analysts.

[15] The current development of virtual currencies is impressive. More than 50 new ones have been created recently following Bitcoin and its little brother, Litecoin (https://www.cryptsy.com/)

Appendix A

Fig. A1 gives the daily number of BTC transactions over the sample period: January 2009-December 2013. Fig. A2 draws the BTC/USD weekly exchange rate on a logarithmic scale.

Figure A1: Daily Number of BTC Transactions, January 2009 – December 2013

Data are sourced from https://blockchain.info.

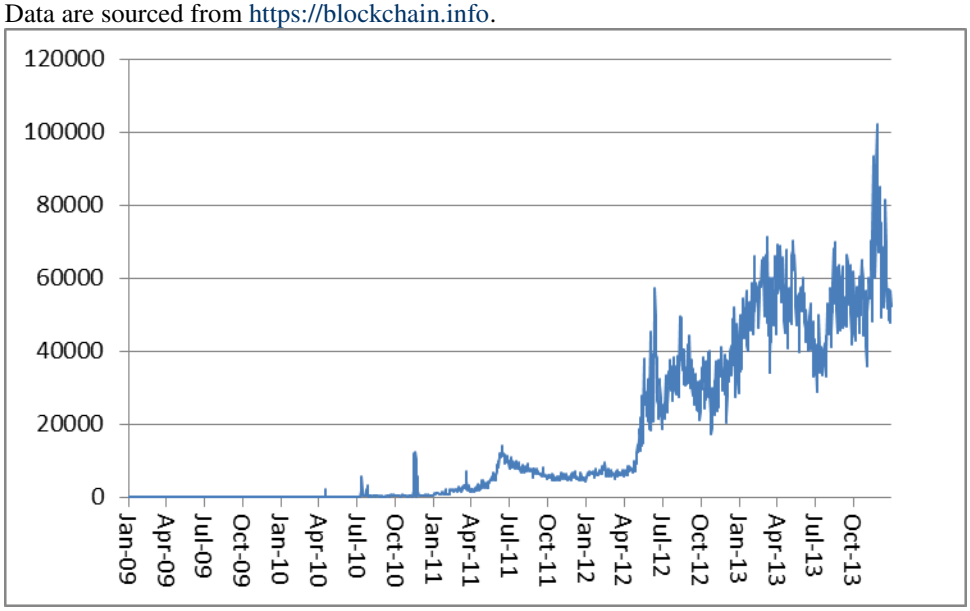
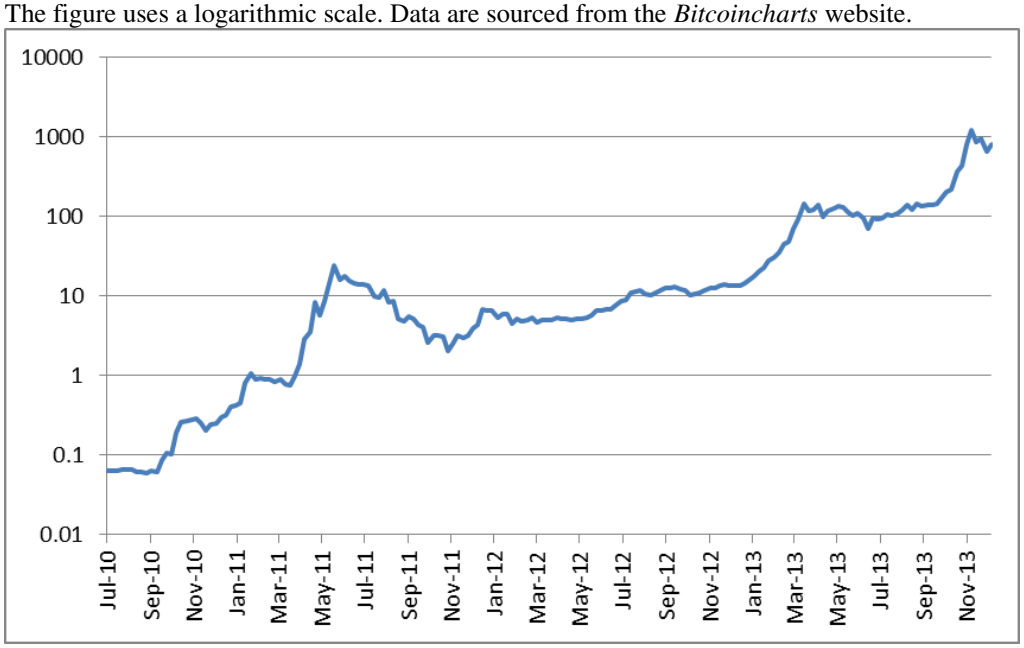


Figure A2: Weekly BTC/USD Exchange Rate, January 2009 – December 2013

The figure uses a logarithmic scale. Data are sourced from the *Bitcoincharts* website.



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