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An assessment of Bitcoins capabilities as a diversifier, hedge and safe haven

En evaluering av Bitcoins evner som diversifier, hedge og safe haven

MASTEROPPGAVE - Økonomi og administrasjon/siviløkonom
Trondheim, Mai 2018

Hovedprofil: Finansiering og investering

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Abstract

In this article, we use a Dynamic Conditional Correlation (DCC) model to assess whether Bitcoin acts as a diversifier, hedge or a safe haven against movements in major developed and developing markets, as well as different types of regional indices and commodities. The dataset consists of thirteen equity markets, five regional indices and ten commodities with daily data ranging from 13.09.2011 to 25.01.2018. Results show that Bitcoin acts as a hedge for most of the developing countries such as Brazil, Russia, India and South Korea, but only as an effective diversifier for developed markets, regional indices and commodities. There is no clear distinction in regard of how investors from developed and developing markets react to extreme shocks. However, results indicate that Bitcoin is a suitable safe haven asset in times of specific crisis periods.

Sammendrag

I denne artikkelen benytter vi en Dynamic Conditional Correlation (DCC) modell for å undersøke om Bitcoin kan benyttes til diversifiserings, hedging eller safe haven formål, mot bevegelser i store utviklede og utviklende land, samt ulike typer regionale indekser og råvarer. Datasettet består av tretten aksjeindekser, fem regionale indekser og ti råvarer med daglige data fra 13.09.2011 til 25.01.2018. Resultatene viser at Bitcoin fungerer som en hedge for de fleste utviklingsland som Brasil, Russland, India og Sør Korea, men at den kun fungerer til diversifiserings formål for utviklete land, regionale indekser og råvarer. Det er ingen klare forskjeller når det gjelder hvordan investorer fra utviklede og utviklende land reagerer på ekstreme sjokk. Resultatene indikerer imidlertid at Bitcoin er en egnet safe haven i spesifikke kriseperioder.

Acknowledgements

This master thesis is completed as a final part of our Master of Science in Business Administration with major in finance, at NTNU Business School.

The subject of this thesis is to assess whether Bitcoin acts as a diversifier, hedge or a safe haven against movements in major developed and developing markets, as well as different types of regional indices and commodities. It has been a rewarding and challenging process to learn about Bitcoins capabilities, and to get a deeper understanding of its applicability.

We would like to express our sincere gratitude to our supervisor, Associate Professor Khine Kyaw at NTNU Business School, for valuable discussions, constructive feedback and for her availability. We also appreciate the input from Associate Professor Peter Molnár at University of Stavanger.

The content of this master thesis reflects our own personal views and are not necessarily endorsed by NTNU Business School.

Trondheim, Mai 2018

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1 Introduction

The purpose of this article is to investigate Bitcoins capabilities as a diversifier, hedge and safe haven against stocks and commodity assets. The aim is to examine the role of Bitcoin in the financial markets, and whether this role changes through regions. Moreover, we aim to explore Bitcoins capabilities in certain periods.

Bitcoin is a peer-to-peer electronic cash system first proposed by Nakamoto in 2008. It is the first decentralized digital currency; that is, Bitcoin is not issued by a central bank or government. Bitcoin is dependent on an underlying cryptographic protocol, which is a set of rules created to be a usable standard (Segendorf, 2014). This protocol certifies that the supply of Bitcoin is fixed at 21 million units and created at a fixed rate.[1]

Bitcoins story is both unique and controversial in terms volatility and interest. From its inception in 2009, the price has increased from \$0 to approximately \$20.000 at the end of 2017. In the beginning of 2018 Bitcoin faced a major drawback and dropped to \$11.000.[3.1] Bitcoin has shown itself to be highly volatile (Bouoiyour and Selmi, 2017, Katsiampa, 2017, Blundell-Wignall, 2014, Gronwald, 2014, Collins, 2017), which may imply that it is a poor store of value. However, this could change over time. As the user base gets larger and more money goes into Bitcoin it is likely to become more stable (Hobson, 2013). An increasing number of studies have found evidence that inclusion of Bitcoin in an investor's portfolio, enhances its performance by improving the risk-return (Eisl, Gasser and Weinmayer, 2015, Bouoiyour and Selmi, 2017, Marie, Kim and Ariane, 2015). They argue that including Bitcoin in a portfolio increases the risk; however, the additional risk is overcompensated by high returns leading to better risk-return ratios.[2]

[1] For more information, see bitcoin.org and Dwyer (2015).

[2] Marie, Kim and Ariane (2015), Eisl, Gasser, and Weinmayer (2015) and Bouoiyour and Selmi (2017) include a sample period from: 2010-2013, 2010-2015 and 2015-2017, respectively.

Globally, Bitcoin has caught the attention of legislators and investors, especially since the financial crisis led to a widespread loss of trust in financial intermediates of all kinds, leading the way for an acceptance of alternative technologies (Blundell-Wignall, 2014). During the Cypriot financial crisis in 2013 the Bitcoin price surged, indicating a clear sign of people looking for an alternative way to get their money out of the country (Farrell, 2013, Cox, 2013). The same behavior repeated itself during the 2017 Zimbabwean coup d'état, leading the way for speculations of Bitcoin being a safe haven (Urban, 2017, Titcomb, 2017). Hence, we can't stress enough the importance of understanding Bitcoins capabilities as a financial asset, and how it relates to other assets. This would be of great interest and importance for financial actors worldwide that seek protection against market turmoil and downward movements, and not to say legislators. Therefore, we seek to examine the following research question: "Is Bitcoin a diversifier, hedge or a safe haven against stocks or commodity assets in developed and developing markets?". Dyhrberg (2016*b*) states that Bitcoin is different from any other asset on the financial market and thereby creates new possibilities for stakeholders with regard to risk management.

In this study we will follow the testable definitions of a diversifier, hedge and safe haven made by Baur and Lucey (2010) and Baur and McDermott (2010), who applied this framework on gold. Gold is widely regarded as a safe haven asset, as its value tends to rise when negative shocks affect the markets. In 2013 Ratner and Chiu examined the capabilities of credit default swaps (CDS) as a hedge and safe haven using the same framework. This study builds on the mentioned work as well as (Bouri et al., 2017a,b), which were the first to apply this framework on Bitcoin.

As far as we know, earlier studies on Bitcoin have failed to properly distinguish between developed and developing markets. Developing markets are often characterized by lack of regulation, political instabilities and an undeveloped financial system, unlike the developed markets (Lunn, 2014, Krause, 2016). Taking the decentralized and transparent nature of Bitcoin into account, this might have an impact on its capabilities and how it varies through regions. Another limitation is that no other studies, to the best of our knowledge, have examined Bitcoins capabilities as a diversifier, hedge or safe haven with respect to different investor perspectives. If all

prices were computed in US dollar, the study would only examine whether Bitcoin is a hedge or a safe haven from a US investor's perspective. An exchange-rate analysis done by Baur and McDermott in 2010 shows that a common currency denomination in US dollar eliminates or greatly reduces the hedge and safe haven properties of gold. By denominating the national stock indices, as well as Bitcoin in local currencies, we get a deeper understanding of how these properties varies across borders.

This article addresses the mentioned literature gaps by including a broader set of countries, clearly distinguishing between developed and developing countries, as well as examining Bitcoins capabilities as a diversifier, hedge or safe haven against different types of commodities. The research is further broadened by a subsample analysis, that investigates Bitcoins role in certain periods explicitly.

For this study we will apply a GARCH Dynamic Conditional Correlation (DCC) model (Engle, 2002), with daily data ranging from September 2011 to January 2018. The study includes thirteen countries, five regional indices and ten commodity indices. We find evidence of Bitcoin being a hedge for a few cases and an effective diversifier for the rest. Furthermore, Bitcoin is found to have safe haven capabilities, especially in times of crisis.

The reminder of this article is organized as follows. Section 2 summarizes previous literature, section 3 describes the data, section 4 explains the empirical methodology, section 5 presents the empirical findings. Finally, section 6 provides conclusions.

2 Literature review

2.1 The role of Bitcoin

Due to Bitcoins complexity, legislators and economists have been eager to define whether Bitcoin is a currency or a commodity. Bitcoin strives to prove its position as a currency in the global market. Dyhrberg (2016*a*) states that Bitcoin has many similarities to the dollar and that it can be classified as something in between a currency and a commodity. However, Yermack (2013) and Baek and Elbeck (2015) argue that Bitcoin appears to behave more like a speculative investment rather than a currency. In 2015, the U.S Commodity Futures Trading Commission classified Bitcoin as a commodity.

With anonymity, decentralization and success comes scrutiny. Yelowitz and Wilson (2015) performs an analysis of Google search data in order to discover the characteristics of Bitcoin users, where they find robust evidence that illegal activity drives interest in Bitcoin. According to Ciaian, Rajcaniova and Kancs (2016) Bitcoin is more vulnerable to cyber-attacks than traditional currencies. Several attacks have occurred over the recent years. Moore and Christin (2013) examined the track record of 40 Bitcoin exchanges, where they found that 18 closed due to cyber-attacks. These cyber-attacks may play a destabilizing role in the Bitcoin system (Bouoiyour and Selmi, 2015).

A number of studies have addressed the main drivers of the Bitcoin price. Kristoufek (2015) finds that the price of Bitcoin is determined by standard fundamental factors of supply and demand, even if it's regarded as a speculative asset. Further, he finds a strong relationship between investors' interest in the crypto-currency and the Bitcoin price. This is in line with the research done by Ciaian, Rajcaniova and Kancs in 2016. In addition, they find that global macro-financial development factors have a significant impact on the Bitcoin price in the short run.

Both media and economists have in the past years compared Bitcoin to gold, as they have similarities.[3] Popper (2015) argues that Bitcoin may be referred to as the digital gold. Gold is widely regarded as a safe haven asset, as its value tends to rise when negative shocks affect the markets. Previously studies have examined the correlation between gold and other financial assets. Sherman (1986), McCown and Zimmerman (2006), Hillier, Draper and Faff (2006) and Miyazaki and Hamori (2016) find evidence that the correlation is low or negative. Furthermore, the role of gold as a hedge against the dollar was analysed by Capie, Mills and Wood in 2005, where they found evidence of exchange-rate hedging potential.

2.2 Diversifier, hedge and safe haven

Baur and Lucey (2010, pp. 5-6) were the first to define testable definitions of a diversifier, hedge and safe haven, making it possible to explore and identify the capabilities of gold. The definitions are as follows:

> A diversifier is defined as an asset that is positively (but not perfectly correlated) with another asset or portfolio on average.
>
> A hedge is an asset that is uncorrelated or negatively correlated with another asset or portfolio on average. A strict hedge is (strictly) negatively correlated with another asset or a portfolio on average.
>
> A safe haven is defined as an asset that is uncorrelated or negatively correlated with another asset or portfolio in times of market stress or turmoil.

Baur and McDermott (2010, p. 1889) expanded on these definitions in an important way, making them even more precise by differentiating between weak and strong form.

> A strong (weak) hedge is defined as an asset that is negatively correlated (uncorrelated) with another asset or portfolio on average.

[3]For instance, see the article "Bitcoin Is The New 'Gold'" (Mourdoukoutas, 2017)

> A strong (weak) safe haven is defined as an asset that is negatively correlated (uncorrelated) with another asset or portfolio in certain periods only, e.g. in times of falling stock markets.

It is vital to notice that a hedge holds on average, while a safe haven only needs to hold in specific periods. Baur and Lucey (2010) explain this thoroughly. Since a hedge could exhibit a positive correlation in times of market stress or turmoil, it doesn't have the property of reducing losses in these specific periods. The property of a safe haven asset is the non-positive correlation with a portfolio in extreme market conditions, meaning the correlation can be either positive or negative on average.

Baur and Lucey (2010) analyses whether gold can perform as a hedge, a diversifier and a safe haven for stock and bonds in US, UK and Germany. They found the first empirical evidence of gold being a hedge against stocks on average, and a safe haven in extreme stock market conditions. However, they did not find any results in regard of bonds. Hillier, Draper and Faff (2006) discovered that precious metals, such as gold, silver and platinum exhibit hedging capability, particularly during periods of abnormal stock market volatility. Baur and McDermott (2010) extend the analysis done by Baur and Lucey (2010) in several important ways. By performing a multi-country analysis, separating between developed and major emerging countries they are able to test the safe haven effect across a broad cross-section of world stock markets.[4] Evidence shows that gold is both a hedge and a strong safe haven for developed markets, but not for large emerging markets as the BRIC countries.

However, similar studies relevant to this issue are relatively scarce when it comes to Bitcoin. Dyhrberg (2016*a*) argues that Bitcoin has many similarities as both gold and the dollar, in terms of hedging capabilities and symmetrical reaction to good and bad news. An additional study, 2016*b*, displayed that Bitcoin can be used as a hedge against the FTSE 100 index[5], and as a hedge against the US dollar in the short term.

[4]Developed countries consists of the G7 countries, emerging markets consists of the BRIC countries, as well as Australia and Switzerland.

[5]FTSE 100 is based on the market capitalization of the 100 largest companies listed on the London Stock Exchange

Bouri et al. (2017a) are the first to clearly distinguish between the diversification, hedging and safe haven properties of Bitcoin by looking at daily and weekly data. They extend previous literature by assessing to what extent Bitcoin can act as a diversifier, hedge and safe haven against movements in the price return of various assets.[6] Their empirical results indicate that Bitcoin can serve as an effective diversifier, and as a hedge in just a few cases. Furthermore, Bitcoin can only serve as a strong safe haven against weekly extreme down movements in Asian stocks. Interestingly, they found that Bitcoins hedging and safe haven properties vary between regions.

More recent literature (Bouri et al., 2017b) study the relationship between Bitcoin and commodities. The article focuses on energy commodities, in the form of electricity, since it is an essential input in the Bitcoin production. They take the Bitcoin crash in December 2013 into account, by looking at three panels.[7] Evidence shows that Bitcoin exhibits hedge and safe haven properties for the general commodity index and for the energy commodity index, for the entire period and the pre-crash period. After the crash, Bitcoin acts only as a diversifier. Bouri, Azzi and Dyhrberg (2017) investigated the return-volatility relationship in the Bitcoin market around the price crash.

[6] They include stock indices from US, UK, Germany, Japan and China as well as regional indices that proxies the World, Europe and the Pacific. They also include a Bond index, US dollar index, oil, gold and a general commodity index.

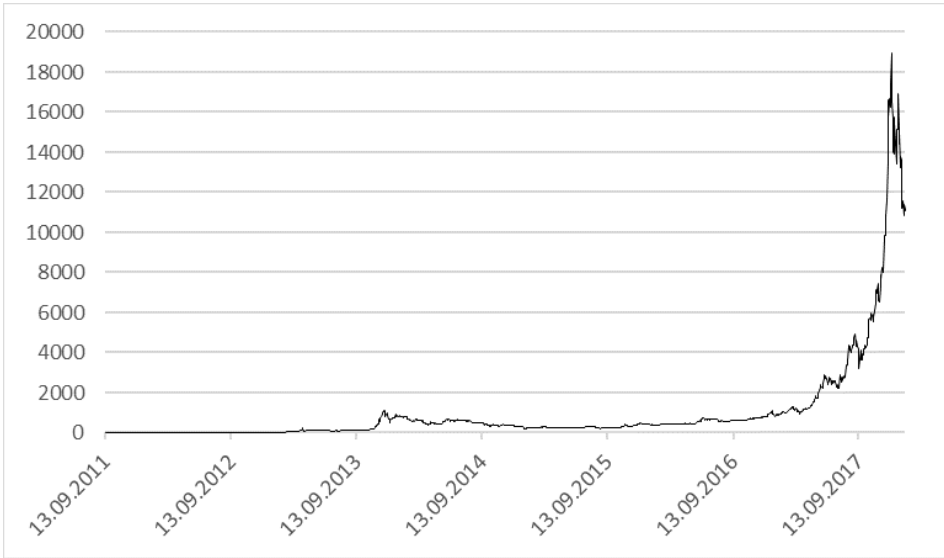
[7] Panel A: Entire period (July 19, 2010 – December 28, 2015). Panel B: Before the Bitcoin crash. Panel C: After the Bitcoin crash.

3 Data

Our study consists of 1651 daily observations, for each time series, ranging from 13.09.2011 to 25.01.2018. The dataset includes the Bitcoin price as well as a number of financial assets, such as stock indices and commodities. Daily data is chosen to obtain a sufficient amount of observations in order to get reliable GARCH estimates. Hwang and Pereira (2006) stress that at least 500 observations are needed to ensure a proper GARCH estimation.

Closing spot prices for all indices are obtained from Thomson Reuters Datastream. The Bitcoin closing price in US dollar is downloaded from Quandl using Bitstamp, which is an exchange with significantly trading volume and a strong reputation. The historical Bitcoin price is plotted in figure 3.1. The data have been filtered and made comparable, that is, only common observations through all the time series remains.

Figure 3.1: Evolution of the Bitcoin price in US dollar



The study comprises the seven largest developed countries (G7), the largest developing countries (BRIC), South Korea and Zimbabwe. South Korea is included due to its importance for the Bitcoin market, as it is currently the third-biggest market in the world for Bitcoin trades[8], and the fact that it is regarded as a developing country by Morgan Stanley Capital International (MSCI). Additionally, we include Zimbabwe because of the 2017 Zimbabwean coup d'état, where Bitcoin price nearly doubled compared to global markets.[9] The proxies for the equity markets in USA, UK, Japan, Italy, Germany, France, Canada, Brazil, Russia, India, China, South Korea and Zimbabwe are the S&P 500, FTSE 100, Nikkei 225, FTSE MIB, Dax 30, CAC 40, S&PTSX 60, IBRX, MICEX 10, NIFTY 50, Shanghai A-Share, KOSPI, MSCI Zimbabwe, respectively. The equity indices are denominated in local currencies, and the Bitcoin price is converted using daily exchange rates obtained from Thomson Reuters Datastream. Hence, we are able to capture the hedge and safe haven capabilities of Bitcoin from the investor perspective in the respective countries. With a common denomination in US dollar, we would solely have captured the perspective of an US investor.

Indices from MSCI are utilized in order to proxy the World, BRIC, Asia, Pacific and European stocks. Moreover, Standard & Poor's Goldman Sachs (SPGS) World Commodity Index, London Metal Exchange (LME), Merrill Lynch Commodity Index Extra (MLCX) Agriculture and MLCX Energy are proxies for the commodity market. Oil, Gold, Cotton, Corn, Coffee and All Wheat spot prices are also considered.[10] The regional indices and commodities are denominated in US dollar.

We calculate Bitcoin, stock and commodity returns by taking the first difference of the natural logarithm of each series, to ensure stationarity. An Augmented Dickey Fuller test confirms that all return series are stationary. Table 3.1 provides descriptive statistics of the return series analysed in the study.

It emerges from the table that all commodity assets have a negative average return,

[8] Japan is the biggest market in the world for Bitcoin trades, followed by USA and South Korea. See: https://www.coinhills.com/market/currency

[9] See the article, "Zimbabweans turn to bitcoin as cryptocurrency value soars to $13,500" (Musaddique, 2017)

[10] See Appendix (A) for graphs displaying the price development and Appendix (B) for description of the variables

while the national and regional stock indices, as well as Bitcoin, exhibit a positive average return. Bitcoin has by far the highest volatility in terms of standard deviation, as well as the highest maximum and minimum values. This is interesting in regard of Bitcoins potential role as a safe haven. Most of the return series have a negative skewness and all are found to be leptokurtic, meaning the kurtosis exceeds three.

Table 3.1: Descriptive Statistics

	Mean	Max	Min	P25	P50	P75	Std. Dev	Skewness	Kurtosis	ADF
Bitcoin (in USD)	0.0046	0.4848	-0.6639	-0.0128	0.0033	0.0247	0.0611	-1.022	24.058	-42.426***
Developed markets										
Usa	0.0005	0.0424	-0.0542	-0.0028	0.0003	0.0046	0.0082	-0.375	7.083	-42.062***
UK	0.0002	0.0394	-0.0478	-0.0043	0.0002	0.0046	0.0089	-0.138	5.803	-40.618***
Japan	0.0006	0.0743	-0.0825	-0.0051	0	0.0073	0.0130	-0.304	7.613	-43.997***
Italy	0.0003	0.0639	-0.1333	-0.0075	0.0001	0.0085	0.0156	-0.470	7.557	-43.003***
Germany	0.0006	0.0534	-0.0707	-0.0049	0.0006	0.0064	0.0119	-0.181	5.795	-40.042***
France	0.0004	0.0558	-0.0838	-0.0054	0.0003	0.0063	0.0120	-0.215	6.657	-41.339***
Canada	0.0002	0.0424	-0.0381	-0.0036	0.0004	0.0043	0.0077	-0.295	5.773	-39.024***
Developing markets										
Brazil	0.0004	0.0598	-0.0921	-0.0068	0	0.0073	0.0129	-0.130	5.519	-41.312***
Russia	0.0001	0.0691	-0.0990	-0.0066	0	0.0069	0.0128	-0.581	9.076	-39.389***
India	0.0005	0.0374	-0.0610	-0.0039	0	0.0054	0.0094	-0.259	5.778	-38.314***
China	0.0002	0.0560	-0.0887	-0.0047	0.0001	0.0058	0.0138	-1.134	10.870	-38.738***
South Korea	0.0002	0.0490	-0.0590	-0.0036	0	0.0043	0.0084	-0.303	7.953	-41.123***
Zimbabwe	0.0005	0.1445	-0.2222	-0.0026	0	0.0041	0.0193	-2.791	48.436	-25.238***
Regional Indices										
World	0.0004	0.0438	-0.0503	-0.0028	0.0006	0.0042	0.0076	-0.5322	8.9613	-36.426***
BRIC	0.0002	0.0587	-0.0722	-0.0057	0.0003	0.0063	0.0110	-0.323	7.146	-33.990***
Asia	0.0003	0.0435	-0.0413	-0.0038	0.0005	0.0049	0.0088	-0.253	6.169	-41.827***
Pacific	0.0003	0.0509	-0.0476	-0.0046	0.0005	0.0054	0.0096	-0.230	6.125	-44.894***
Europe	0.0003	0.0585	-0.0918	-0.0046	0.0004	0.0057	0.0112	-0.446	9.286	-40.807***
Commodities										
Oil	-0.0002	0.1129	-0.1113	-0.0105	0	0.0099	0.0209	0.154	6.396	-43.322***
Gold	-0.0002	0.0543	-0.1016	-0.0048	0	0.0051	0.0101	-0.808	11.960	-41.123***
LME	-0.0001	0.0572	-0.0858	-0.0063	0	0.0061	0.0114	-0.114	7.060	-44.063***
Agriculture	-0.0003	0.0453	-0.0538	-0.0059	-0.0002	0.0053	0.0094	0.085	5.301	-39.250***
World Commodities	-0.0002	0.0548	-0.0659	-0.0063	0	0.0059	0.0115	-0.013	5.536	-42.649***
Energy	-0.0002	0.1837	-0.1743	-0.0078	0	0.0075	0.0173	0.173	18.865	-44.337***
Cotton	-0.0002	0.0556	-0.0713	-0.0072	0	0.0068	0.0132	-0.130	5.120	-38.224***
Corn	-0.0004	0.0738	-0.0793	-0.0086	0	0.0077	0.0151	0.035	6.039	-39.567***
Coffee	-0.0005	0.1085	-0.0642	-0.0118	0	0.0098	0.0198	0.286	4.878	-42.010***
All Wheat	-0.0003	0.0743	-0.0678	-0.0100	-0.0002	0.0089	0.0162	0.228	4.577	-39.873***

Notes: The descriptive statistics are based on daily logged returns from 13.09.2011 to 25.01.2018. P25, P50 and P75 denotes the 25^{th}, 50^{th} and 75^{th} percentile of the return distribution. ADF denotes the Augmented Dickey Fuller test statistic. *** indicates the rejection of the null hypothesis at 1% level.

4 Methodology

This section explains the research methodology used to explore the diversification, hedge and safe haven capabilities of Bitcoin. Firstly, we employ the multivariate DCC-GARCH model proposed by Engle (2002) in order to estimate the dynamic correlation structure between the variables. Secondly, we explain the regression model used to explore the diversification, hedge and safe haven capabilities of Bitcoin.

4.1 DCC-GARCH

This econometric model is widely adopted in the hedge and safe haven literature[11], but there are other applicable models and techniques that could be employed for this purpose. Rolling regression and exponential smoothing techniques are used by some researchers in order to compensate for the dynamic correlations (Ratner and Chiu, 2013). Engle (2002) states that these methods are valuable in some cases, but that they suffer from weaknesses. Rolling regression requires an ad hoc approach to determine window width, and does not track sudden changes in volatility in a very suitable way (Martin, 1998). Fomby (2008) stresses that exponential smoothing methods suffer from not having an objective statistical identification, and thus are ad hoc models. Moreover, Martin (1998) notes that Exponentially Weighted Moving Average (EWMA) models gives inadequate volatility estimates due to the fixed weight of the parameters. Different types of multivariate GARCH models such as BEKK and the Constant Conditional Correlation (CCC) model are previously employed in the literature to assess hedge and safe haven capabilities of various assets, but as Bouri et al. (2017a) state, these models may experience convergence problems and unreasonable parameter estimates. The CCC model is limited by the assumption of constant conditional correlation, and its incapability of capturing interactions among assets (Hafner and Reznikova, 2012).

[11] For instance, see among Bouri et al. (2017a,b), Lucey and Li (2015), Ratner and Chiu (2013).

The DCC-GARCH is a generalization of Bollerslev (1990) CCC model, and allows the correlation to change over time, thus it captures the interactions among assets, and gives a superior measure for correlation (Cho and Parhizgari, 2008). Additionally, the model estimates the correlation coefficients of the standardized residuals and so accounts for heteroscedasticity directly (Chiang, Jeon and Li, 2007). According to Engle (2002), a major advantage of the DCC-GARCH is that it has the flexibility of a univariate GARCH but not the complexity of a conventional multivariate GARCH, giving the model a computational benefit. In line with (Bouri et al., 2017a,b) we estimate the pairs of return series separately, and not for all return series simultaneously, due to the large number of return series, and the purpose of the study.

The DCC model, which parameterizes the conditional correlations directly, are estimated in two steps: the first is the estimation of the univariate GARCH (1,1) model, the second is the estimation of time varying conditional correlations using the standardized residuals generated from the first step.

The model is defined as:

$$X_t = \mu + {H_t}^{1/2}\epsilon_t \tag{1}$$

$$H_t = D_t R_t D_t \tag{2}$$

where $X_t = (X_{1t}, X_{2t}, ...X_{Nt})$ is a vector of past observations, H_t is the multivariate conditional variance, $\mu_t = (\mu_{1t}, \mu_{2t}, ...\mu_{Nt})$ is the vector of conditional returns, $\epsilon_t = (\epsilon_{1t}, \epsilon_{2t}, ...\epsilon_{Nt})$ is the vector of the standardized residuals, R_t is a correlation matrix containing the conditional correlations and D_t is a diagonal matrix of conditional time-varying standardized residuals (ϵ_t) that are obtained from the univariate GARCH (1,1) model with $\sqrt{h_{ii,t}}$ on the ith diagonal, $i = 1, 2, ...N$.

The DCC specification is defined as follows:

$$Q_t = (1 - \phi - \gamma)\overline{Q} + \gamma Q_{t-1} + \phi\sigma_{i,t-1}\sigma_{j,t-1} \tag{3}$$

where Q_t is the $N \times N$ time-varying covariance matrix of standardized residuals ($\sigma_{it} = (\epsilon_{it}/\sqrt{h_{it}})$) and $\overline{Q}$ is the unconditional correlations of $\sigma_{i,t}\sigma_{j,t}$ and ϕ and γ are non-negative scalar parameters that satisfies $\phi + \gamma < 1$.

Thus, the DCC between asset i and j is calculated by:

$$\rho_{ij,t} = \frac{(1-\phi-\gamma)\overline{q}_{ij}+\phi\sigma_{i,t-1}\sigma_{j,t-1}+\gamma q_{ij,t-1}}{[(1-\phi-\gamma)\overline{q}_{ii}+\phi\sigma^2_{i,t-1}+\gamma q_{ii,t-1}]^{1/2}[(1-\phi-\gamma)\overline{q}_{jj}+\phi\sigma^2_{j,t-1}+\gamma q_{jj,t-1}]^{1/2}} \quad (4)$$

The purpose of the article is not to derive estimates of the equations, neither to elaborate on the modeling, only to extract the pairwise DCC between Bitcoin and the financial assets, which are used in order to examine the diversification, hedge and safe haven capabilities of Bitcoin. Diagnostic tests will be carried out to verify that the model is well fitted.

4.2 Diversifier, hedge and safe haven

To examine Bitcoins capabilities as a diversifier, hedge and safe haven against movements in equity markets, regional indices and commodities we follow the method used by Ratner and Chiu (2013) and Bouri et al. (2017a). Following the DCC-GARCH estimation, the pairwise dynamic conditional correlations between Bitcoin and each of the assets are extracted from equation (3) into separate time series. DCC_t are regressed on dummy variables (D).

$$DCC_t = c_0 + c_1 D(r_{asset} q_1) + c_2 D(r_{asset} q_5) + c_3 D(r_{asset} q_{10}) \quad (5)$$

where D represent extreme movements and are equal to one if the assets return exceeds a certain threshold given by the lower 1^{st}, 5^{th} and 10^{th} percentile of the return distribution. Bitcoin is a diversifier against the other asset if c_0 is significantly positive. Bitcoin is a weak hedge against the other asset if c_0 is zero or a strong hedge if c_0 is significantly negative. Bitcoin is a weak safe haven if the parameters c_1,c_2 or c_3 are insignificantly different from zero, or a strong safe haven if they are significantly negative.

4.3 Subsample analysis

To examine Bitcoins capabilities as a safe haven against equity markets during times of crisis, we are inspired by the dummy variable regression employed by Baur and McDermott (2010) and Ratner and Chiu (2013). We predefine three specific periods and use dummies which are equal to one if the returns overlap with the predefined period and zero otherwise.

$$DCC_t = c_0 + c_1 D(TrumpElection) + c_2 D(Brexit) + c_3 D(ChinaTurbulence) \quad (6)$$

Bitcoin is a diversifier against the other asset if c_0 is significantly positive. Bitcoin is a weak hedge against the other asset if c_0 is zero or a strong hedge if c_0 is significantly negative. Bitcoin is a weak safe haven if the parameters c_1,c_2 or c_3 are insignificantly different from zero, or a strong safe haven if they are significantly negative.

5 Empirical results

5.1 DCC-GARCH

To determine the most suitable model we obtain maximum likelihood values, and we rely on the Akaike information criteria (AIC) as well as the Bayesian information criterion (BIC). Results show that maximized log likelihood values under t-distribution are larger than those obtained under the Gaussian distribution. The AIC and BIC give coinciding results, as the DCC-model estimated with t-distribution produces the lowest values. This indicates that a model estimated with t-distribution is more suitable to capture the fat-tailed behavior of the return distributions under consideration. A comparison of different lag specifications based on the same criteria's show that the data is best captured by a DCC (1,1), with each conditional variance in a univariate GARCH (1,1) model.

As mentioned, we do not intend to elaborate on the DCC-GARCH results. However, the results are as expected and in line with previous literature.[12] The sum of the estimated ARCH(1) and GARCH(1) parameters, α and β respectively, were all close to one, indicating a high degree of persistence in the GARCH processes. Furthermore, most of the coefficients in the estimation were significant at the 1% significance level.

5.2 Diversifier, hedge and safe haven capabilities of Bitcoin

Table 5.1 shows the regression results from equation 5. The DCC_t coefficients, which are extracted from equation 3, are regressed on a constant (c_0) and three dummy variables (c_1,c_2,c_3) representing extreme movements in the lower 1^{st}, 5^{th} and 10^{th} percentile of the return distribution. In the following we report the results for the equity markets, regional indices and commodities.

[12] See among , Bouri et al. (2017a,b), Ciner, Gurdgiev and Lucey (2013), Joy (2011).

Table 5.1: Estimation results

This table presents the estimation results on the diversification, hedge and safe haven capabilities of Bitcoin from equation (5). Negative coefficients in the hedge column indicate that Bitcoin is a hedge against stocks or commodities. Zero (negative) coefficients in extreme market conditions (quantile columns (0.01, 0.05 or 0.10)) indicate that Bitcoin is a weak (strong) safe haven.

	Hedge(c_0)	1% quantile(c_1)	5% quantile(c_2)	10% quantile(c_3)
Developed Markets(local currencies)				
Usa	0.01060***	-0.02655***	-0.00555	0.00331
UK	0.02989***	-0.00146	0.00140	-0.00049
Japan	0.05298***	0.00745	-0.00514	0.00030
Italy	0.01590***	0.00264	0.00220	0.00210
Germany	0.02933***	0.00394	0.00777	-0.00687
France	0.03475***	0.02247	0.00155	-0.00510
Canada	0.03928***	0.00505	-0.00012	-0.00187
Developing markets(local currencies)				
Brazil	-0.00078	-0.00479	-0.00234	0.00429
Russia	-0.02361***	0.00822	-0.00071	0.00026
India	-0.03971***	0.01328	-0.01297**	0.00895**
China	0.03762***	-0.00185	0.00292	-0.00220
South Korea	-0.03357***	-0.00662	0.00457	0.00191
Zimbabwe	0.01463***	-0.02792**	0.00470	-0.00181
Regional Indices(in USD)				
World	0.03036***	-0.02076***	-0.00063	0.00266
BRIC	0.05891***	-0.01540***	0.00150	-0.00304***
Asia	0.02877***	-0.00131	0.00029	-0.00018
Pacific	0.03089***	-0.00581***	-0.00058	-0.00116**
Europe	0.03868***	0.00653	0.00634**	-0.00466**
Commodities(in USD)				
Oil	0.01074***	0.00160	-0.00551*	0.00436**
Gold	0.07261***	0.00154	-0.00318**	0.00175**
LME	0.07392***	-0.01916	0.01037	0.00216
Agriculture	0.02877***	-0.00112	-0.00085	0.00169***
World Commodities	0.02106***	-0.00289**	-0.00010	0.00074
Energy	0.02601***	-0.00057	0.00050	0.00017
Cotton	0.03303***	-0.00085	0.00293	-0.00140
Corn	0.02002***	-0.00394	0.00128	0.00151
Coffee	0.00189***	-0.00086	0.00353	-0.00134
All Wheat	0.01399***	-0.00669**	0.00084	-0.00091

***, **, * indicate statistical significance at the 1%, 5% and 10% level, respectively.

5.2.1 Equity markets

The results for the developed countries reveal that Bitcoin cannot be regarded as a hedge, as all the coefficients (c_0) are significantly positive. Thus, Bitcoin is no more than an effective diversifier. Interestingly, we find evidence of Bitcoin being a strong hedge for stock movements in Russia, India and South Korea, and a weak hedge for Brazil. This indicates that it is beneficial for investors with exposure to developing countries to include Bitcoin in their equity portfolios for hedging

purposes. These findings confirm that the hedging capabilities of Bitcoin varies through regions. One explanation for this might be that the trust in financial systems and governments in developing countries are less compared to developed countries, taking the decentralized and independent nature of Bitcoin into account (Lunn, 2014, Krause, 2016). Golam and Monowar (2015) state that BRIC countries are facing numerous challenges and uncertainties in the social, political, military and security sectors.

The analysis did not show any signs of Bitcoin being a strong safe haven for most of the countries regardless of region. However, there is substantial evidence of Bitcoin being a strong safe haven within the 1% stock quantile in USA and Zimbabwe, and furthermore within the 5% stock quantile in India. These findings suggest that investors react quite similarly to shocks in developed countries as in developing countries. This implies that in times of extreme market turmoil and uncertainty, investors with exposure to USA, Zimbabwe and India sell stocks and buy Bitcoin. The most striking result that emerges is Bitcoins safe haven capabilities in Zimbabwe. During the 2017 Zimbabwean coup d'état where the political uncertainty was extraordinary, investors sought refuge in Bitcoin from the faltering economy (Monks, 2017, Brand, Latham and Marawanyika, 2017, Titcomb, 2017).

Insignificant coefficients (c_1,c_2,c_3) for the equity markets under study indicate that Bitcoin can act as a weak safe haven in all quantiles except for India at the 10% quantile.

5.2.2 Regional stock indices and commodities

Bitcoin acts only as an effective diversifier for the regional stock indices and commodities, as the coefficients (c_0) are significantly positive. Interestingly, there is no clear distinction of the hedging capability of Bitcoin between developed and developing countries. An explanation for Bitcoin not being a hedge for any of the indices or commodities under study might be due to the common currency denomination in US dollar. Baur and McDermott (2010) states that a common currency denomination yields a greater co-movement compared to a case in which local currencies are used, causing the currency effect to dominate the hedging effect. Bouri et al. (2017a) refer

to the results reported by Ciaian, Rajcaniova and Kancs (2016) when explaining the diversification benefits of using Bitcoin. Their findings show that Bitcoin price formation is unrelated to global macroeconomic factors in the long run and can instead be explained by Bitcoin supply and demand, as well as other digital currency-specific factors, e.g., Bitcoin attractiveness for investors.

We find statistical evidence of Bitcoin being a strong safe haven for World, BRIC and Pacific countries in the 1% quantile. Additionally, Bitcoin is a strong safe haven in the 10% quantile for BRIC, Pacific and European countries. Moreover, Bitcoin cannot be regarded as a strong safe haven for most of the commodities, with exception from the World commodity index (in the 1% quantile), All Wheat (in the 1% quantile) and gold (in the 5% quantile). Insignificant coefficients (c_1,c_2,c_3) indicate that Bitcoin can act as a weak safe haven within the 1% and 5% quantile for all of the regional indices and commodities except for Europe at the 5% quantile. This implies that investors faced with heavy losses and uncertainty could buy Bitcoin to seek shelter from the downward movements in the mentioned indices and commodities. Surprisingly, and in contradiction to earlier findings (Bouri et al., 2017a), we find that Bitcoin is a strong safe haven for gold within 5% quantile at a 5% significance level. This is interesting since it is well established in the literature that gold is a safe haven asset. One reason for this result could be the fact that the value of gold has decreased since 2012, and the value of Bitcoin has risen in the same period. Another reason might be the mentioned currency effect which is triggered by a common currency denomination in US dollar.

5.3 Safe haven capabilities of Bitcoin in times of crisis

Table 5.2, 5.3 and 5.4 shows the regression results from equation (6). This model analyses three predefined crisis periods explicitly and is a more arbitrary approach than the model specified in equation (5). Firstly, the crisis periods need to be selected, secondly, the start and end date need to be defined. Due to the limited timespan under investigation, 13.09.2011 to 25.01.2018, the number of crises to choose between are rather scarce. We have defined the following crisis periods: (I) United States presidential election 2016, (II) Brexit 2016 and (III) the Chinese stock

market turbulence in 2015. All these events led to uncertainty and market turmoil, causing huge losses in the global financial markets[13], e.g., the Shanghai A-Share lost about a third of its value after the stock market bubble popped on June 12, 2015 (Riley and Yan, 2015). Hence, it is valuable to get a deeper insight of Bitcoins capabilities during these periods. As previous literature shows (Forbes and Rigobon, 2002, Dungey et al., 2005, Baur and McDermott, 2010), it is not straightforward to define the start of a crisis, and its end. We define the starting dates as November 8, 2016 (I), June 23, 2016 (II) and June 12, 2015 (III). Moreover, we include an effect window of 20 trading days (approximately one month) before and after the start date, where the dummy variables are equal to one within the effect window, and zero otherwise. Forbes and Rigobon (2002), Baur and McDermott (2010) and Ratner and Chiu (2013) include only the 20 trading days subsequent to their start date when defining the crisis periods. However, we extend this by including the 20 trading days leading up to the start date, this to capture the political uncertainty that comes with referendums. We do not elaborate on the parameter c_0, as the interpretation is qualitatively the same as in section 5.2.1. In the following we report the safe haven results for the subsample analysis from equation (6).

[13]See among: (I) Mullen and Egan (2016), (II) Wearden and Fletcher (2016), (III) Allen (2015).

Table 5.2: Subsample results - Entire period

This table presents the estimation results on the safe haven capability of Bitcoin in the whole crisis period. Zero (negative) coefficients in extreme market conditions (quantile columns (0.01, 0.05 or 0.10)) indicate that Bitcoin is a weak (strong) safe haven.

	Hedge(c_0)	Trump(c_1)	Brexit(c_2)	China(c_3)
Developed markets				
Usa	0.01204***	-0.03495***	-0.04217***	0.01010*
UK	0.03030***	-0.00160	-0.00992**	-0.00456
Japan	0.05462***	0.00218	-0.04248***	-0.03183***
Italy	0.01553***	-0.00199	-0.00084	0.03165***
Germany	0.03093***	-0.01438**	-0.03754***	-0.02305***
France	0.03709***	-0.02392***	-0.05003***	-0.02934***
Canada	0.03960***	-0.00447*	-0.00395	-0.01002***
Developing markets				
Brazil	-0.00022	-0.00659	0.00009	-0.00500
Russia	-0.02345***	-0.00100*	-0.00107**	-0.00100*
India	-0.03919***	-0.00439	-0.00076	-0.00043
China	0.03890***	-0.00368	-0.03311***	-0.01855***
South Korea	-0.02930***	-0.04271***	-0.08096***	-0.03398***
Zimbabwe	0.01430***	0.00819	-0.01313*	0.00883

***, **, * indicate statistical significance at the 1%, 5% and 10% level, respectively.

Table 5.3: Subsample results - Pre-period

This table presents the estimation results on the safe haven capability of Bitcoin in the 20 trading days leading up to the defined start date. Zero (negative) coefficients in extreme market conditions (quantile columns (0.01, 0.05 or 0.10)) indicate that Bitcoin is a weak (strong) safe haven.

	Hedge(c_0)	Trump(c_1)	Brexit(c_2)	China(c_3)
Developed markets				
Usa	0.01091***	-0.03665***	-0.03284***	0.02734***
UK	0.03006***	-0.00347	-0.01083**	0.00136
Japan	0.05324***	0.01400**	-0.02515***	-0.02142***
Italy	0.01548***	-0.00013	0.01567***	0.04474***
Germany	0.02980***	-0.01523	-0.04260***	0.00025
France	0.03556***	-0.02587**	-0.05900***	0.00348
Canada	0.03932***	-0.00636*	-0.00471	-0.00292
Developing markets				
Brazil	-0.00043	-0.00358	0.00326	-0.00617
Russia	-0.02349***	-0.00098	-0.00099	-0.00099
India	-0.03928***	-0.00377	0.00019	-0.00066
China	0.03829***	0.00550	-0.04765***	-0.01813***
South Korea	-0.03165***	-0.06094***	-0.09194***	0.02987**
Zimbabwe	0.01465***	0.01331	-0.02039*	-0.01280

***, **, * indicate statistical significance at the 1%, 5% and 10% level, respectively.

Table 5.4: Subsample results - Post-period

This table presents the estimation results on the safe haven capability of Bitcoin in the 20 trading days after the defined start date. Zero (negative) coefficients in extreme market conditions (quantile columns (0.01, 0.05 or 0.10)) indicate that Bitcoin is a weak (strong) safe haven.

	Hedge(c_0)	Trump(c_1)	Brexit(c_2)	China(c_3)
Developed markets				
Usa	0.01148***	-0.03150***	-0.05011***	-0.00522
UK	0.03011***	0.00087	-0.00778	-0.00941*
Japan	0.05420***	-0.00797	-0.06061***	-0.03894***
Italy	0.01630***	-0.00460	-0.01830***	0.01821***
Germany	0.03017***	-0.01132	-0.03109***	-0.04394***
France	0.03600***	-0.01909	-0.03797***	-0.05838***
Canada	0.03941***	-0.00226	-0.00252	-0.01650***
Developing markets				
Brazil	-0.00034	-0.00912	-0.00153	-0.00285
Russia	-0.02349***	-0.00094	-0.00107	-0.00093
India	-0.03927***	-0.00444	-0.00065	0.00003
China	0.03813***	-0.01215**	-0.01844***	-0.01723***
South Korea	-0.03093***	-0.02072*	-0.06788***	-0.09112***
Zimbabwe	0.01408***	0.00233	-0.00733	0.02996***

***, **, * indicate statistical significance at the 1%, 5% and 10% level, respectively.

5.3.1 United States presidential election

For the entire period, results show that Bitcoin acts as a strong safe haven for USA, Germany, France and South Korea during the US presidential election. Bitcoin is a weak safe haven for all remaining countries. Interestingly, we find that the results are less statistical significant in the days subsequent from the outbreak of the crisis compared to the days leading up to it. This imply the fact that it was a lot of uncertainty tied to the outcome of the election, and that it was dampened in the post-period when the results were announced.

5.3.2 Brexit

Bitcoin is a strong safe haven for USA, UK, Japan, Germany, France, Russia, China and South Korea, and a weak safe haven for all other countries in the entire period. The results are qualitatively the same for both the pre -and post period. High levels of uncertainty and turmoil related to the referendum serves as an explanation for this. In the pre-period it was tied to the outcome of the referendum, while the post-period

is still characterized by uncertainty, as it is difficult to anticipate the consequences of Brexit.

5.3.3 Chinese stock market turbulence

The stock market bubble popped June 12, 2015 and led to major repercussions in the aftermath. This crisis is of a different nature compared to the other two, which was of a political essence. Thus, as expected, we do not find much results of significance in the pre-period. However, in the post-period, we find statistical evidence of Bitcoin being a strong safe haven for Japan, Germany, France, Canada, China and South Korea. Moreover, for the same period, Bitcoin acts only as a weak safe haven for USA, UK, Brazil, Russia and India.

5.3.4 Implications

These findings are remarkable since the safe haven capabilities of Bitcoin are nearly non-existing when looking at the whole timespan, 13.09.2011 to 25.01.2018. This suggests that Bitcoin is highly suitable as a safe haven asset in certain periods when facing short-lived and extreme shocks. An explanation for these results might be due to the fact that investors have started to realize the advantages of Bitcoin, in terms of decentralization, transparency and cryptographic security. The findings imply that the safe haven capabilities of Bitcoin are effective for certain periods, and not only limited to days of extreme market turmoil, e.g., the thresholds given by the lower 1^{st}, 5^{th} and 10^{th} percentile in the return distribution.

6 Conclusion

This article analyses the diversification, hedging and safe haven capabilities of Bitcoin in the financial markets, and whether it changes through regions. We extend previous literature by clearly distinguishing between developed and developing markets, as well as capturing the local investor perspectives. Additionally, we fill a void in the literature by assessing Bitcoins capabilities in certain periods, thus, allowing us to get a better understanding of its time-varying nature.

In answer to our research question and on the basis of a DCC-GARCH model (Engle, 2002) with daily frequencies we have found intriguing results, that can be summarized as follows. We find evidence of a qualitative difference between developed and developing markets, in regard of Bitcoins suitability as a hedge. Bitcoin acts as a strong hedge for most of the developing markets, but only as an effective diversifier for the developed markets, regional indices and commodities. Bitcoin is a strong safe haven for only a few national equity indices, regional indices and commodities. However, in most cases we don't find any evidence of Bitcoin being a strong safe haven, neither do we find a difference in how investors from developed and developing markets react to shocks. Looking at the three crisis periods, the results show that Bitcoin is either a strong or weak safe haven for most of the countries during the whole effect window.

Overall, our findings have implications for investors who seek protection from downward movements in equity -and commodity markets. The results presented suggests that investors with exposure to the financial assets under study is benefited by having a position in Bitcoin in times of uncertainty and turmoil. Furthermore, these results provide useful insight for legislators, in terms of Bitcoins applicability.

Although the results are interesting, caution must be taken in regard of Bitcoins volatility and liquidity. Bitcoin is by far the most volatile asset under study, and thus

it might be less appealing to investors as a haven asset due to its lack of reliability and stability. The absence of sufficient liquidity makes it challenging for investors to move their money away from stocks and commodities, and into Bitcoin. Another limitation is tied to the use of daily observations, which yields more noise, than the use of weekly or monthly observations. As pointed out in the data section, daily data is chosen due to the limited timespan of Bitcoin. Further research should address the independence and interaction between Bitcoin and the other assets under study, in order to get a better understanding of how the variances affect each other.

References

Allen, K. (2015) Why is china's stock market in crisis?, *The Guardian*. Available at: https://www.theguardian.com/business/2015/jul/08/china-stock-market-crisis-explained (Accessed: 04.04.2018).

Baek, C. and Elbeck, M. (2015) Bitcoins as an investment or speculative vehicle? a first look, *Applied Economics Letters*, 22(1), pp. 30–34.

Baur, D. and Lucey, B. (2010) Is gold a hedge or a safe haven? an analysis of stocks, bonds and gold, *The Financial Review*, 45(2), pp. 217. doi: 10.1111/j.1540-6288.2010.00244.x.

Baur, D. and McDermott, T. (2010) Is gold a safe haven? international evidence, *Journal of Banking Finance*, 34(8), pp. 1886. doi: 10.1016/j.jbankfin.2009.12.008.

Blundell-Wignall, A. (2014) The bitcoin question: Currency versus trust-less transfer technology, *OECD Working Papers on Finance, Insurance and Private Pensions*, (37), pp. 1.

Bollerslev, T. (1990) Modelling the coherence in short-run nominal exchange rates: a multivariate generalized arch model, *The review of economics and statistics*, pp. 498–505.

Bouoiyour, J. and Selmi, R. (2015) What does bitcoin look like?, *Annals of Economics and Finance*, 16(2), pp. 449.

Bouoiyour, J. and Selmi, R. (2017) Ether: Bitcoin's competitor or ally? Available at: https://arxiv.org/pdf/1707.07977.pdf.

Bouri, E., Azzi, G. and Dyhrberg, A. (2017) On the return-volatility relationship in the bitcoin market around the price crash of 2013, *Economics*, 11(2), pp. 1–17. doi: 10.5018/economics-ejournal.ja.2017-2.

Bouri, E., Jalkh, N., Molnár, P. and Roubaud, D. (2017b) Bitcoin for energy commodities before and after the december 2013 crash: diversifier, hedge or safe haven?, *Applied Economics*, 49(50), pp. 5063–5073.

Bouri, E., Molnár, P., Azzi, G., Roubaud, D. and Hagfors, L. I. (2017a) On the hedge and safe haven properties of bitcoin: Is it really more than a diversifier?, *Finance Research Letters*, 20, pp. 192–198.

Brand, R., Latham, B. and Marawanyika, G. (2017) *Bloomberg*. Available at: https://www.bloomberg.com/news/articles/2017-11-15/bitcoin-surges-in-zimbabwe-after-military-moves-to-seize-power (Accessed: 06.02.2018).

Capie, F., Mills, T. and Wood, G. (2005) Gold as a hedge against the dollar, *Journal of international financial markets, institutions and money*, 15(4), pp. 343–352. doi: 10.1016/j.intfin.2004.07.002.

Chiang, T. C., Jeon, B. N. and Li, H. (2007) Dynamic correlation analysis of financial contagion: Evidence from asian markets, *Journal of International Money and finance*, 26, pp. 1206–1228.

Cho, J. and Parhizgari, A. (2008) East asian financial contagion under dcc-garch, *International Journal of Banking and Finance*, 6(1), pp. 17–30.

Ciaian, P., Rajcaniova, M. and Kancs, D. (2016) The economics of bitcoin price formation, *Applied Economics*, 48(19), pp. 1799–1815. doi: 10.1080/00036846.2015.1109038.

Ciner, C., Gurdgiev, C. and Lucey, B. M. (2013) Hedges and safe havens: An examination of stocks, bonds, gold, oil and exchange rates, *International Review of Financial Analysis*, 29, pp. 202–211.

Collins, D. (2017) Bitcoin volatility, *Modern Trader*, (537), pp. 59–59.

Cox, J. (2013) Bitcoin bonanza: Cyprus crisis boosts digital dollars, *CNBC*. Available at: https://www.cnbc.com/id/100597242 (Accessed: 28.02.2018).

Dungey, M., Fry, R., González-Hermosillo, B. and Martin, V. L. (2005) Empirical modelling of contagion: a review of methodologies, *Quantitative Finance*,

5(1), pp. 9–24. Available at: https://doi.org/10.1080/14697680500142045. doi: 10.1080/14697680500142045.

Dwyer, G. P. (2015) The economics of bitcoin and similar private digital currencies, *Journal of Financial Stability*, 17, pp. 81–91.

Dyhrberg, A. (2016*a*) Bitcoin, gold and the dollar - a garch volatility analysis, *Finance Research Letters*, 16, pp. 85–92. doi: 10.1016/j.frl.2015.10.008.

Dyhrberg, A. (2016*b*) Hedging capabilities of bitcoin. is it the virtual gold?, *Finance Research Letters*, 16, pp. 139–144. doi: 10.1016/j.frl.2015.10.025.

Eisl, A., Gasser, S. M. and Weinmayer, K. (2015) Caveat emptor: Does bitcoin improve portfolio diversification? Available at: https://dx.doi.org/10.2139/ssrn.2408997.

Engle, R. (2002) Dynamic conditional correlation: A simple class of multivariate generalized autoregressive conditional heteroskedasticity models, *Journal of Business Economic Statistics*, 20(3), pp. 339–350. doi: 10.1198/073500102288618487.

Farrell, M. (2013) Bitcoin prices surge post-cyprus bailout, *CNN*. Available at: http://money.cnn.com/2013/03/28/investing/bitcoin-cyprus/index.html (Accessed: 13.02.2018).

Fomby, T. B. (2008) Exponential smoothing models, *Mannual SAS/ETS Software: Time Series Forecasting System. Version*, 6, pp. 225–235.

Forbes, K. J. and Rigobon, R. (2002) No contagion, only interdependence: measuring stock market comovements, *The journal of Finance*, 57(5), pp. 2223–2261.

Golam, M. and Monowar, M. (2015) The rise of the brics and their challenge to the g7, *International Journal of Emerging Markets*, 10(1), pp. 156–170. Available at: https://www.emeraldinsight.com/doi/abs/10.1108/IJOEM-07-2012-0063. doi: 10.1108/IJOEM-07-2012-0063.

Gronwald, M. (2014) The economics of bitcoins–market characteristics and price jumps. Available at: https://ideas.repec.org/p/ces/ceswps/$_5$121.*html*.

Hafner, C. M. and Reznikova, O. (2012) On the estimation of dynamic conditional correlation models, *Computational Statistics Data Analysis*, 56(11), pp. 3533–3545. doi: 10.1016/j.csda.2010.09.022.

Hillier, D., Draper, P. and Faff, R. (2006) Do precious metals shine? an investment perspective, *Financial Analysts Journal*, 62(2), pp. 98–106. doi: 10.2469/faj.v62.n2.4085.

Hobson, D. (2013) What is bitcoin?, *XRDS*, 20(1), pp. 0–44. doi: 10.1145/2510124.

Hwang, S. and Pereira, P. L. (2006) Small sample properties of garch estimates and persistence, *The European Journal of Finance*, 12(6-7), pp. 473–494.

Joy, M. (2011) Gold and the us dollar: Hedge or haven?, *Finance Research Letters*, 8(3), pp. 120–131.

Katsiampa, P. (2017) Volatility estimation for bitcoin: A comparison of garch models, *Economics Letters*, 158, pp. 3–6.

Krause, M. (2016), Bitcoin: Implications for the developing world, Open access senior thesis. Available at: http://scholarship.claremont.edu/cmc$_t$*heses*/1261.

Kristoufek, L. (2015) What are the main drivers of the bitcoin price? evidence from wavelet coherence analysis, *PLoS ONE*, 10(4). doi: 10.1371/journal.pone.0123923.

Lucey, B. and Li, S. (2015) What precious metals act as safe havens, and when? some us evidence, *Applied Economics Letters*, 22(1), pp. 35. doi: 10.1080/13504851.2014.920471.

Lunn, E. (2014) What is an emerging market?, *Telegraph*. Available at: https://www.telegraph.co.uk/sponsored/finance/investment-library/overseas-investment/10844574/emerging-markets-investment-strategy.html (Accessed: 15.04.2018).

Marie, B., Kim, O. and Ariane, S. (2015) Virtual currency, tangible return: Portfolio diversification with bitcoin, *Journal of Asset Management*, 16(6), pp. 365. doi: 10.1057/jam.2015.5.

Martin, R. (1998) Garch modeling of time-varying volatilities and correlations, *Financial Engineering News*, (May, No 4).

McCown, J. R. and Zimmerman, J. R. (2006) Is gold a zero-beta asset? analysis of the investment potential of precious metals. Available at: http://dx.doi.org/10.2139/ssrn.920496.

Miyazaki, T. and Hamori, S. (2016) Asymmetric correlations in gold and other financial markets, *Applied Economics*, 48(46), pp. 4419–4425. doi: 10.1080/00036846.2016.1158919.

Monks, K. (2017) What is fueling zimbabwe's record-breaking bitcoin binge?, *CNN*. Available at: https://edition.cnn.com/2017/10/31/africa/zimbabwe-bitcoin-surge/index.html (Accessed: 23.03.2018).

Moore, T. and Christin, N. (2013) *Beware the middleman: Empirical analysis of Bitcoin-exchange risk*, Springer.

Mourdoukoutas, P. (2017) Bitcoin is the new 'gold', *CNN*. Available at: https://www.forbes.com/sites/panosmourdoukoutas/2017/08/30/bitcoin-is-the-new-gold/1421eb633b36 (Accessed: 15.02.2018).

Mullen, J. and Egan, M. (2016) Global markets drop as u.s. election results shock investors, *CNN*. Available at: http://money.cnn.com/2016/11/08/investing/global-markets-stocks-trump-clinton-us-presidential-election/index.html (Accessed: 12.02.2018).

Musaddique, S. (2017) Zimbabweans turn to bitcoin as cryptocurrency value soars to $13,500, *Independent*. Available at: https://www.independent.co.uk/news/business/news/zimbabwe-bitcoin-coup-us-dollar-currency-robert-mugabe-exchange-rate-money-a8056286.html (Accessed: 26.03.2018).

Nakamoto, S. (2008) Bitcoin: A peer-to-peer electronic cash system. Available at: https://bitcoin.org/bitcoin.pdf.

Popper, N. (2015) *Digital gold: The untold story of Bitcoin*, Penguin UK.

Ratner, M. and Chiu, C. (2013) Hedging stock sector risk with credit default swaps, *International Review of Financial Analysis*, 30, pp. 18–25. doi: 10.1016/j.irfa.2013.05.001.

Riley, C. and Yan, S. (2015) China's stock market crash...in 2 minutes, *CNN*. Available at: http://money.cnn.com/2015/07/09/investing/china-crash-in-two-minutes (Accessed: 04.04.2018).

Segendorf, B. (2014) What is bitcoin, *Sveriges Riksbank Economic Review*, 2, pp. 71–87.

Sherman, E. J. (1986) *Gold investment: Theory and application*, Prentice Hall, New York.

Titcomb, J. (2017) How bitcoin has become zimbabwe's crisis currency, *Telegraph*. Available at: https://www.telegraph.co.uk/technology/2017/11/20/bitcoin-has-become-zimbabwes-crisis-currency (Accessed: 03.02.2018).

Urban, R. (2017) Bitcoin is the new crisis currency, *Bloomberg*. Available at: https://www.bloomberg.com/news/articles/2017-11-17/bitcoin-emerges-as-crisis-currency-in-hotspots-such-as-zimbabwe (Accessed: 18.03.2018).

Wearden, G. and Fletcher, N. (2016) Brexit panic wipes $2 trillion off world markets - as it happened, *The Guardian*. Available at: https://www.theguardian.com/business/live/2016/jun/24/global-markets-ftse-pound-uk-leave-eu-brexit-live-updates (Accessed: 13.04.2018).

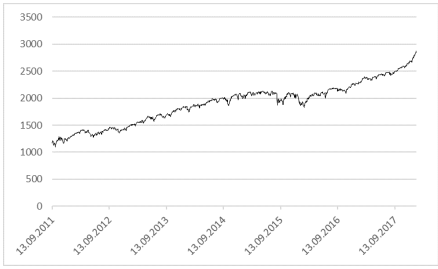
Yelowitz, A. and Wilson, M. (2015) Characteristics of bitcoin users: an analysis of google search data, *Applied Economics Letters*, 22(13), pp. 1030–1036.

Yermack, D. (2013) Is bitcoin a real currency? an economic appraisal, *NBER Working Paper Series*, pp. 31 – 44. doi: 10.3386/w19747.

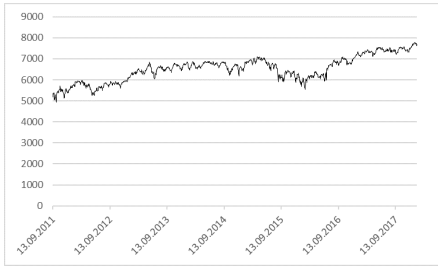
A Appendix

Graphs displaying the price development

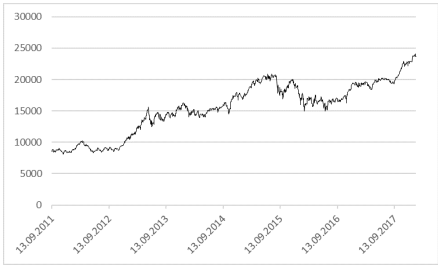
USA



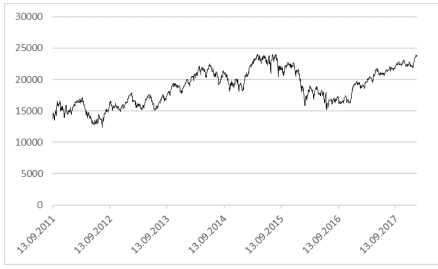
UK



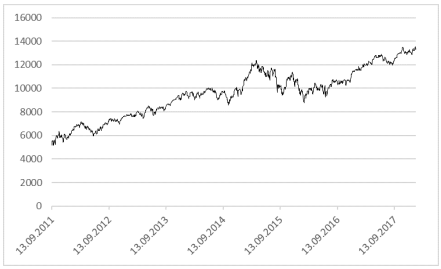
Japan



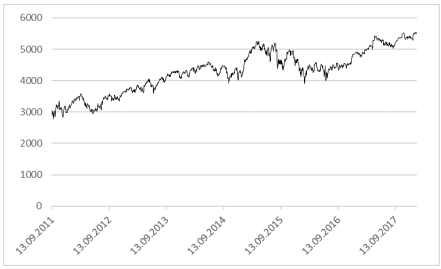
Italy



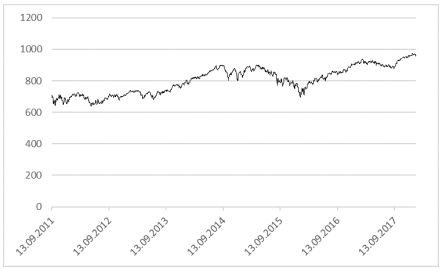
Germany



France



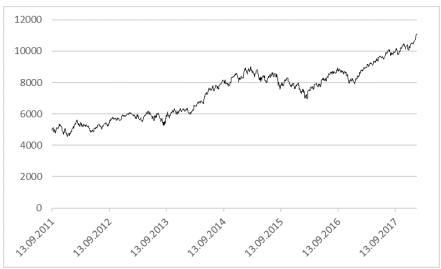
Canada



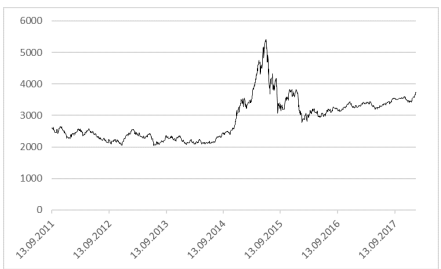
Brazil

Russia

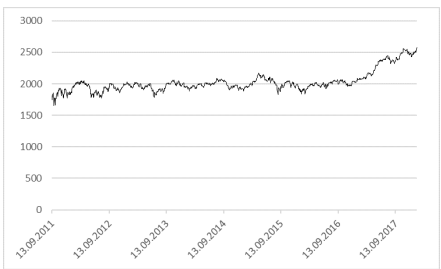
India



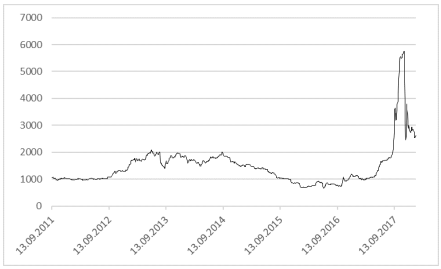
China



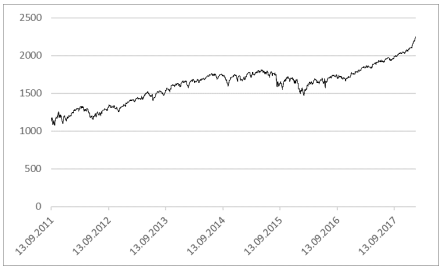
South Korea



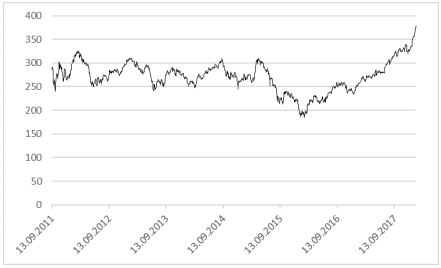
Zimbabwe



World

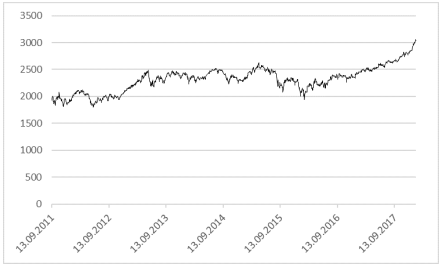


BRIC

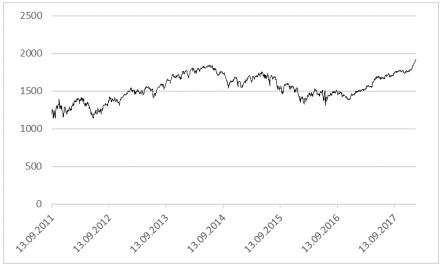


Asia

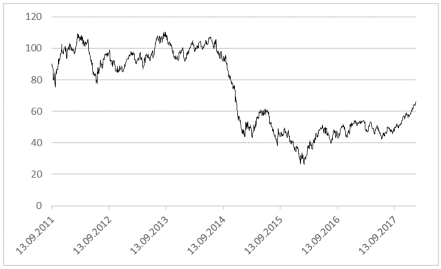
Pacific



Europe



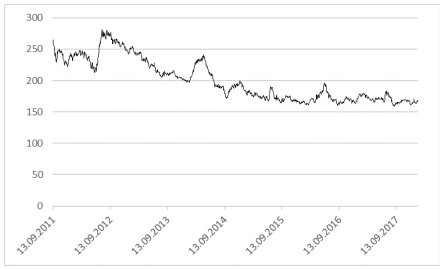
Oil



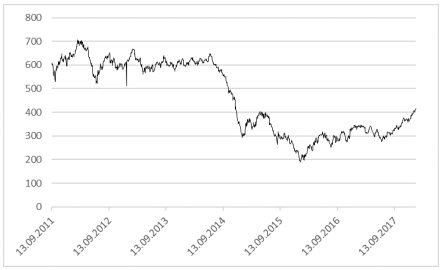
Gold

LME - Metals

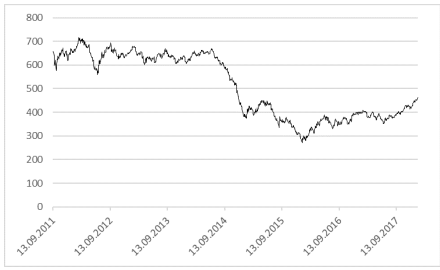
Agriculture



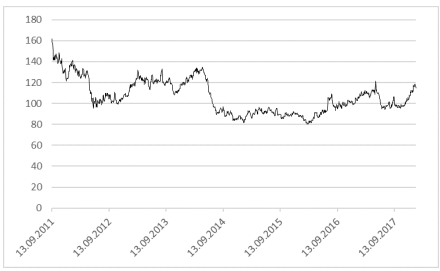
Energy



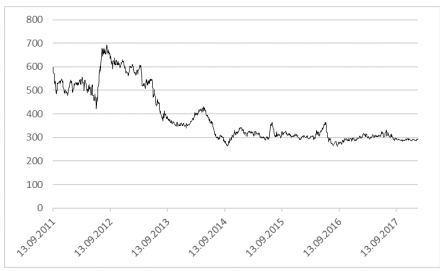
World Commodity



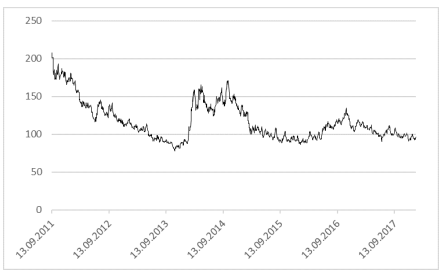
Cotton



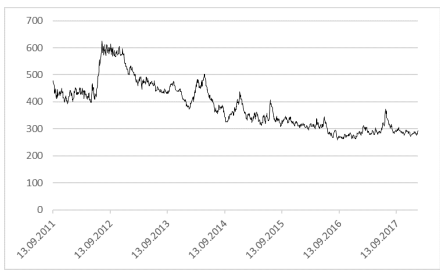
Corn



Coffee



All Wheat



B Appendix

Description of data

A description of the indices used to proxy developed markets

Country	Stock Index	Description
USA	S&P 500	Based on the market capitalization of 500 large companies listed on NYSE or NASDAQ
UK	FTSE 100	Based on the market capitalization of the 100 largest companies listed on the London Stock Exchange
Japan	Nikkei 225	Price weighted index comprised of 225 blue-chip companies listed on Tokyo Stock Exchange
Italy	FTSE MIB	Benchmark stock market index comprised of the 40 most traded companies listed on Borsa Italiana
Germany	DAX 30	Blue chip stock market index consisting of 30 major German companies listed on the Frankfurt Stock Exchange
France	CAC 40	Benchmark stock market index consisting of the 40 most significant companies among the 100 highest markets caps listed on the Euronext Paris
Canada	S&PTSX 60	Stock market index consisting of 60 large companies listed on the Toronto Stock Exchange

A description of the indices used to proxy developing markets

Country	Stock Index	Description
Brazil	IBRX	Weighted index comprised of the 100 most actively traded and best representative stocks of the Brazilian stock market
Russia	MICEX 10	Equally weighted index comprised of the 10 most liquid shares traded on Moscow Exchange
India	NIFTY 50	Benchmark stock market index comprised of 50 blue-chip companies listed of the National Stock Exchange of India
China	Shanghai A-share	Stock market index that consists of A-shares listed on the Shanghai Stock Exchange and the Shenzhen Stock Exchange
South Korea	KOSPI	Weighted index comprised of all common shares listed on the Korean Stock Exchange
Zimbabwe	MSCI Zimbabwe	Index designed to measure the performance of the large and mid- cap segments of the Zimbabwe market

A description of the indices used to proxy regions

Region	Index	Description
World	MSCI World Index	Countries included: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Hong Kong, Ireland, Israel, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, the UK and the US
BRIC	MSCI BRIC	Countries included: Brazil, Russia, India and China
Asia	MSCI AC Asia Index	Countries included: Hong Kong, Japan, Singapore, China, India, Indonesia, Korea, Malaysia, Pakistan, the Philippines, Taiwan and Thailand
Pacific	MSCI Pacific Index	Countries included: Australia, Hong Kong, Japan, New Zealand and Singapore
Europe	MSCI Europe Index	Countries included: Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the UK

A description of the commodities and commodity indices included in the study

Commodity	Index/Source	Description
Oil	Crude Oil-WTI Spot Cushing U$/BBL - DS MID PRICE	Spot crude oil
Gold	Gold Bullion LBM U$/Troy Ounce. Spot	Spot gold price
LME- Metals	LME-LMEX Index - PRICE INDEX	A commodity exchange in London, England. The LME is one of the main metal markets in the world
Agriculture	MLCX Agriculture Spot Index - PRICE INDEX	Spot agriculture price
Energy	MLCX Energy Spot Index - PRICE INDEX	Spot energy price
World Commodity	S&P GSCI Commodity Spot - PRICE INDEX	Broad-based and production weighted index to represent the global commodity market
Cotton	S&P GSCI Cotton Spot - PRICE INDEX	Spot cotton price
Corn	S&P GSCI Corn Spot - PRICE INDEX	Spot corn price
Coffee	S&P GSCI Coffee Spot - PRICE INDEX	Spot coffee price
All Wheat	S&P GSCI All Wheat Spot - PRICE INDEX	Spot all wheat price