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The Impact of Regulatory Initiatives on Bitcoin

A study on the first regulated exchange in the United States

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Abstract

This paper examines how the bitcoin market reacted to the opening of Coinbase, the first regulated bitcoin exchange in the United States. Despite existing controversies towards regulating cryptocurrencies, we conclude that the market reacts positively to the announcement, with statistically significant abnormal returns. Controlling for market wide stock spikes, we can exclude that the abnormal returns were due to market wide increases and limited to the bitcoin market. Further, we investigate if the Coinbase opening imposed any difference in abnormal returns for USD/bitcoin exchanges versus other bitcoin exchanges but do not find any evidence for this. Following up on the positive market reactions to the Coinbase opening, we investigate if this has imposed any immediate change in volatility, which would show sign of a stabilizing market. We find a minimal, yet statistically significant, decrease in volatility. Last, we set out to explain bitcoin abnormal returns and find that daily change in bitcoin trading volume has a significant, negative, impact on bitcoin abnormal returns. This paper offers initial evidence of semi-strong market efficiency and validation of the law of one price on the bitcoin market and opens up for further research on regulatory initiatives effects on the bitcoin market.

Keywords: Bitcoin, BTC, Cryptocurrency, Event Study, Regulations

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Table of Contents

1. Introduction ... 3
   - 1.1 Motivation ... 4
   - 1.2 Research focus ... 6
   - 1.3 Bitcoin in brief ... 7
   - 1.4 Regulatory environment ... 8
2. Previous Literature ... 9
   - 2.1 Bitcoin ... 9
   - 2.2 Literature on the event study framework ... 11
3. Data ... 11
   - 3.1 Bitcoin data ... 12
   - 3.2 Foreign exchange data ... 12
   - 3.3 Stock exchange data ... 12
4. Methodology and Theory ... 13
   - 4.1 Event Study ... 13
   - 4.2 Event date ... 18
   - 4.3 Variance-ratio test ... 18
   - 4.4 Missing values correction ... 19
   - 4.5 Biases ... 19
   - 4.6 Logarithmic returns ... 20
   - 4.7 Efficient market hypothesis ... 20
   - 4.8 Law of one price ... 20
5. Results ... 21
   - 5.1 Abnormal returns in conjunction with the Coinbase opening ... 21
   - 5.2 Robustness test with the simple nonparametric rank test ... 26
   - 5.3 Event study on the opening of Coinbase regulated exchange (USD vs Others) ... 27
   - 5.4 Bitcoin volatility before and after the Coinbase opening ... 31
   - 5.6 Robust regression of volatility on abnormal returns ... 31
6. Conclusion ... 33
7. Limitations and Suggestions for Future Research ... 34
8. References ... 35

A. Appendix ... 38

1. Introduction

Bitcoin emerged as a cyber-libertarian dream; global, decentralized and seemingly free from any government intervention. At inception, its users were a limited number of tech enthusiasts, far from the mainstream public or any regulatory body. In the last years, however, the cryptocurrency has gained traction on a wider scale and its potential impact on the way we conduct financial transactions can no longer be neglected by governments and traditional financial institutions. Bitcoin has catalyzed innovation in the field for payment solutions businesses on several vertical levels and the peer-to-peer platform on which Bitcoin is founded has even been tested in large-scale on traditional stock exchanges. Though many perceive benefits with the cryptocurrency, great risk follow the legal grey zone that lie in the wake of the fast-paced development. This calls for legal and regulatory response, which until now has been ambiguous.

In this paper we examine how the bitcoin market reacted to the opening of Coinbase, the first regulated bitcoin exchange in the United States, which was announced and launched on January 25 and 26, 2015 respectively. The test if the event was perceived as positive by the bitcoin market and if it has contributed to any persisting effects in bringing stability to the bitcoin price by lowering volatility. As this is the first bitcoin exchange that imposes a national regulation, we also investigate if the opening of Coinbase incurred any specific effects for bitcoin exchanges trading in USD compared to exchanges trading in other currencies. A priori, one would expect the impact of the Coinbase opening to be insignificant in the difference between bitcoin exchanges in USD compared to the others if the law of one price holds for bitcoin.

Our main finding is that the cumulative abnormal returns for bitcoin exchanges experienced a significant increase in conjunction with the opening of Coinbase. Meanwhile, the control portfolio did not experience an increase. On the event date, the abnormal returns for the bitcoin portfolio increased by 9 percentage points whereas the control group portfolio did not experience any abnormal returns. We conclude that the bitcoin market perceived the opening of the first regulated bitcoin exchange in the United States as valuable. This result is interesting as it indicates that the bitcoin market is primarily driven by proponents of a further regulated cryptocurrency.

We find that the abnormal returns of bitcoin exchanges traded in USD do not deviate from those of bitcoin exchanges denoted in other currencies. This suggests that the bitcoin market does not value the Coinbase opening differently depending on what currency bitcoin is traded against. This result is in line with the law of one price but contradicts the argument of Yermack (2013) that the bitcoin market shows signs of violating the law of one price.

The high volatility in bitcoin has been found to impede its viability as a currency, making retail usage less attractive (Niblaeus & Nylund, 2014). For this reason, volatility has to decrease in order to gain more traction among merchants and consumers. If bitcoin investors rightfully predict that regulatory initiatives stabilize the market, then volatility should decrease after such an event. We examine this hypothesis by comparing daily volatility over 60 days for prices on 72 bitcoin exchanges before and after the Coinbase opened its regulated exchange. We find a minimal, yet significant, drop of 0.3 percentage points in the volatility for the period following the event window. This gives us an indication that the Coinbase opening indeed has contributed to lowering risk on the market. To fully evaluate the effects, however, time and more regulated exchanges will have to be added.

We try to explain the daily abnormal returns during the estimation period and the event period with the daily bitcoin trading volume and find again a significant but small negative relationship. For every percentage point increase in daily bitcoin trading volume the abnormal returns decrease with 0.003 percentage points. This suggest that higher trading volume slightly decreases the abnormal returns of bitcoin, at least for this specific event.

Our study contributes to the Bitcoin research with new insights on several points. We conduct our research in the greenfield of Bitcoin economics and are unprecedented in showing: (a) that the bitcoin market reacts positively to a major regulatory initiative; (b) that a regulatory initiative decreases volatility in bitcoin prices; (c) that potential arbitrage opportunities between bitcoin traded in different currencies were non-existent in conjunction to the country-specific improvement in consumer protection that the Coinbase opening exhibits; and (d) that bitcoin trading volume significantly lowers the abnormal return.

This paper is organized as follows. Section 1 presents a brief overview of Bitcoin, the key features of the Coinbase exchange and the trend of regulating initiatives in Bitcoin. In section 2 we present previous literature on the Bitcoin and event study topics. In section 3 we present our data set consisting of bitcoin prices and volume, foreign exchange rates and stock prices for the control group. In section 4 we present the underlying methodology and theory used for analyzing data. In section 5 we present our results. In section 6 we discuss the implications of our findings and in section 7 we scrutinize the limitations of this paper and make suggestions for further research.

1.1 Motivation

The uninformed reader wants to know why we use the Coinbase opening as an example of how a regulatory initiative is received by the bitcoin market. In the following section we give the background to why regulations on the bitcoin market is interesting and in particular why the Coinbase opening is a good vehicle for studying this.

"Mainstream adoption is not going to happen if you circumvent the financial system, you're going to have to be a participant in it. That doesn't mean bitcoin isn't disruptive. It is in important and very valuable ways, but that disruption will never be able to reach its full potential unless you're able to interface with the system."

Charles Cascarilla, itBit CEO

Coinbase's launch of a regulated bitcoin exchange is unprecedented and of special interest as the notion of a further regulated cryptocurrency divides Bitcoin users in two camps: on one hand the group of early adopters which has been described as tech geeks with a libertarian dream of an economy completely detached from government intervention, and on the other hand, the wide group of mainstream investors who view Bitcoin as an innovative platform for payment services in a global economy. The latter regard regulations as a necessary mean to attract a broader spectra of investors by inducing confidence and stability to a currently risky market.

We focus on the opening of the first regulated United States exchange Coinbase for four main reasons:

First, the value of the Coinbase exchange lies in its enhanced consumer protection, not only by insuring customers towards cyber-attacks, but also by abandoning the legal grey zone of cryptocurrencies and entering the well-established legal framework surrounding money transmitters. This shapeshift gives Coinbase a clear advantage against its competitors, whose future is yet for legislators to decide upon. It is the first bitcoin exchange that has been legally admitted to money transmitter licenses, and is thus operating in a comparable way to PayPal. Coinbase is being backed by the NYSE, which also helps bring credibility to the bitcoin market. With the imminent threat of Bitcoin-related wire fraud, as was seen in the cyber-attack against Mt Gox[1] where $450 million worth of bitcoin was allegedly stolen (Meredith & Tu), there is a quantifiable benefit of having a default-secure platform like Coinbase. We believe that this partnership may contribute to making previously hesitant non-users consider the possibility of acquiring bitcoin.

Second, the total amount invested in Bitcoin-related ventures to date is $762 million whereof $75 million was raised by Coinbase for the regulated exchange (Coindesk, 2015). We believe that the relative magnitude of the investment in developing a single regulated exchange amidst a plethora of non-regulated exchanges in the world tells an important tale of how investors view the future of bitcoin. The large amount invested in Coinbase should also enhance the effects on the

[1] Before shutting down in February 2014, Mt Gox was the largest Bitcoin exchange globally, serving up to 80% of all Bitcoin transactions.

bitcoin market in terms of potential abnormal returns, making it a good example of a regulatory initiative to study.

Third, information was released in conjunction to the opening which makes a perfect setting for an event study to assess investors' reactions to a regulated Bitcoin initiative.

1.2 Research focus

The focus of our study lies in the regulative framework that faces Bitcoin in the United States.

In the last year, several initiatives have been launched to explore the green field of financial products related to Bitcoin. Examples of this include the Crypto Facilities and TeraExhange platforms for trading bitcoin forwards and the BitMEX range of novel instruments including a bitcoin fear index. Financial innovations have historically been viewed as conductors for stability (Merton, 1995), and we believe bitcoin to be no exception. Before bitcoin derivatives gain sufficient traction, however, we believe that the largest effect on stability in the near time will come from higher investor protection provided by insured and regulated exchanges.

Hypothesis 1: The opening of Coinbase will generate abnormal returns on the global bitcoin market.

The market's reaction on this event will give implications for future reactions as the bitcoin market matures and experiences more regulated exchanges opening up.

Hypothesis 2: The opening of Coinbase will generate abnormal returns for the USD/BTC-exchanges that deviate from all other BTC-exchanges.

While the opposite would be the correct assumption given arbitrage-free pricing on the bitcoin market, Yermack (2013) argues that bitcoin markets show signs of violations of the law of one price.

Hypothesis 3: The opening of Coinbase will inject legitimacy to bitcoin markets and as a consequence decrease the high level of volatility.

One reason for why bitcoin is not seen as a fully viable currency is due to its high level of volatility. The Coinbase opening is marketed as an enhancement of consumer protection and scrutiny towards intermediaries in bitcoin transactions.

Hypothesis 4: The abnormal returns in bitcoin markets are explained by an increase in daily bitcoin trading volume.

Increased stability in the Bitcoin platform would increase the attractiveness of purchasing bitcoin for both new and existing users. Thus, one might expect an increased level of daily trading volume in conjunction to the event date.

1.3 Bitcoin in brief

Bitcoin has been named the first decentralized digital currency in the world and was introduced to the Internet in October 2008 by an unknown person writing under the pseudonym Satoshi Nakamoto. In early 2009 Satoshi Nakamoto's invention, an electronic payment system where each transaction is openly validated through a peer-to-peer system, were put to reality as the open source code was released and implemented (Nakamoto, 2008).

Bitcoin transactions are validated, and new bitcoins are obtained, by a process called mining. Mining is carried out by Bitcoin user-owned computers, connected to the peer-to-peer network, as they gather blocks of pending transactions, convert them into a mathematical puzzle and compete to solve the equation. The first node to break the puzzle for a block of transactions proposes the solution to the network, which subsequently votes if or not to add the solved block into the blockchain. The blockchain is a public distributed ledger containing all previously accepted transactions. Any participant's voting power is weighted by the computing power it adds to the network, making it impossible to double-spend bitcoin by altering the blockchain unless a single actor reaches more than 50% of the computing power. The first node to break the puzzle is awarded a specified number of bitcoins, which will decrease over time until the total supply of bitcoins reaches 21 million. The complexity of the puzzle increases if more computer capacity is added to the network and vice versa if capacity is lowered.

By constructing the digital currency using peer-to-peer validation and mathematical problems to constrain supply, bitcoin differs from fiat currencies in two important ways; value can be transferred without the need of an intermediary, thus decreasing the transaction costs, and no central authority can affect supply and demand, which in some states in the world may be viewed upon as giving higher predictability in the development of the currency value.

Bitcoins are stored in digital wallets either at a user's own hard drive or with a third party wallet provider. A wallet can be described as the storage place for the private key that together with a matching public key validates one person as the owner of the bitcoins used in a transaction. The public key is much like a bank account number and the private key the password to this account. Since all transactions are openly stored in the blockchain, the balances of all bitcoin accounts are public. The identity behind an account, however, is not public and anyone wishing to operate secretively can do so. Bitcoins are traded to fiat currencies, or other digital currencies, through certain bitcoin exchanges available around the world. In this thesis we are using data from 72 exchanges from 26 countries, which is the full set of exchanges available through Bitcoincharts.

The advantages of bitcoin as a mean for payment differ somewhat between the payer and the payee. For a payer, the advantages lie in a relatively short verification time, the anonymity in transactions and the fact that no details from previous transactions can be stolen and used for fraud, as is the case with traditional bank account details. Furthermore, payers will generally not be exposed to currency-related costs when making purchases in a foreign country. The largest benefits from using Bitcoin, however, lie with the payee. A payee can take advantage of a fast and inexpensive verification process since there are no intermediary payment service providers. The global Bitcoin platform is also favorable for payees wishing to offer products on an international market without having to take the direct risks of currency fluctuations (European Central Bank, 2012).

A notable drawback for retailers accepting bitcoin payments is the fact that no chargebacks are possible. Once a transaction is proposed to the blockchain, it cannot automatically be reversed which has been solved by retailers offering in-store credits instead of bitcoin when customers return goods purchased with the virtual currency (Lo & Wang, 2014). The issues with lack of consumer protection related to transactions in cryptocurrencies are further pointed out by Hughes & Middlebrook (2014), who also argue that increased regulation would be of benefit for Bitcoin.

1.4 Regulatory environment

Historically, increased regulation has been viewed positively by Bitcoin users as a way to bring comfort to new users who previously deemed the digital currency to be too risky (Tiwari, 2013).

Regulatory activity focusing on cryptocurrencies in the US gained momentum in 2013 following the increased media attention surrounding virtual currencies (Middlebrook & Hughes, 2014).

In March 2013, the Financial Crimes Enforcement Network (FinCEN) issued guidance on how to apply the Bank Secrecy Act (BSA) to virtual currencies. The probable practical implications of this guidance is that bitcoin exchanges and "mining" businesses are to be treated as money transmitters and thus have to file reports and maintain records as money services businesses (MSBs). Licenses for money transmissions are obtained within each state for which a bitcoin exchange wish to operate. Retail purchases with bitcoin, however, do not qualify as money transmission and as a result of that do not need to comply with the requirements on registration.

It is unclear from the guidance, however, how a person selling bitcoins, i.e. trading the virtual currency to a fiat currency, is to be treated.

After FinCEN's early move to recognize virtual currencies, several other authorities followed suit. To the benefit of the Senate Committee of Finance, The Government Accountability Office initiated an investigation on how the use of virtual currencies could be subject to taxation and suggested the Internal Revenue Service (IRS) to give further guidelines on what the tax consequences from using virtual currencies are. In late 2013 the Homeland Security and Governmental Affairs Committee held a hearing with participants from industry and law enforcement on the potential dangers and benefits residing in virtual currencies. This was followed by another hearing by the Senate Banking Committee focusing on present and future impacts of virtual currencies. Both hearings were viewed with optimism by Bitcoin followers as several government officials described legitimacy and purpose in virtual currencies going forward (Middlebrook & Hughes, 2014).

The United States has yet to provide a clear legal framework for cryptocurrencies, and as a result, Bitcoin innovators has started to take own action in order to increase the safety of its customers (Tu and Meredith, 2015). On this notion, and for the strategic purpose of position itself well ahead of any regulations to come, Coinbase has become the first example of a bitcoin exchange to seek compliance with existing guidelines by obtaining state money licenses for 24 states[2]. Coinbase is insured towards breaches in cyber and physical security as well as any employee theft.

In May 2015, itBit obtained a trust company charter from the New York State Department of Financial Services (NYDFS) making it the second regulated bitcoin exchange and the first with license to operate in all US states (Higgins, 2015).

2. Previous Literature

2.1 Bitcoin

Previous academic research on Bitcoin can be divided into financial and non-financial studies. For non-financial studies, regulative and technological aspects dominate the field. Though Bitcoin has gained traction the last few years, research on the topic is limited and economic studies on the effect of regulations are unprecedented.

Böhme et al. (2015) give a comprehensive overview of the recent developments in how the Bitcoin platform is used and provide arguments for when regulations on the decentralized cryptocurrency are indeed justified. One of the key areas in which regulations have yet to play an

[2] A list of states and the respective licenses can be found in the appendix.

important role is consumer protection. Further, Böhme et al. (2015) argue that in the way Bitcoin is currently used, it has more resemblance to a payment platform than a traditional currency in the economic sense. They argue that the bitcoin market has concentrated around a few large exchanges and that these large exchanges are running an increasing risk of being targeted by hackers. They further point towards the irreversible nature of bitcoin transactions and the legal grey zone in which cryptocurrencies currently reside as an imminent risk for consumers. In the light of this, adequate consumer protection in terms of regulatory initiatives are highly justified.

Middlebrook & Hughes (2014) study the regulations and guidelines imposed on cryptocurrencies in the United States and provide a discussion on what future implications different regulative approaches may have. They argue that regulations on any value storage is unavoidable and that more regulations are likely to emerge in the field of cryptocurrencies.

Tu & Meredith (2014) shed light on the difficulties in creating a regulative framework for a peer-to-peer network such as Bitcoin. For one thing, there is no central Bitcoin entity to regulate and no central actor to monitor or hold responsible for illicit activities towards users. They point to the fact that bitcoins are stored digitally and that transactions are irreversible which creates a unique problem in case of theft. Examples of this legal grey zone include the security breach of the Mt. Gox exchange in 2014 and the more recent hacking of the Bitstamp exchange where over $450m and $5m respectively was allegedly stolen.

Yermack (2013) studies the characteristics of bitcoin in relation to other currencies and asset classes and finds that bitcoin has very low correlation with other currencies, gold and stocks. Further, he argues that bitcoin markets show signs of violating the law of one price because of the large dispersion between the lowest and highest bitcoin price quoted in a USD.

Kristoufek (2013) proves that there is a strong correlation between bitcoin prices and weekly search queries on Google, and also between daily bitcoin prices and daily page views on Wikipedia.

Niblaeus & Nylund (2014) extend upon the research done by Yermack (2013) and Kristoufek (2013) proving that bitcoin does not correlate with any other major stocks, assets or currencies. They distinguish between positivity and negativity in a sentiment analysis, however bitcoin does not seem to react differently between the sentiments. The drawback with their study is that they do not study any specific event for bitcoin to test for price adjustments related to positive or negative announcements.

Hayes (2014) employs a cross-sectional regression model for 66 different cryptocurrencies and finds that the three main value drivers for cryptocurrencies are computational power employed in cryptocurrency mining, the rate of production and the algorithm used for the protocol of the cryptocurrency.

2.2 Literature on the event study framework

The event study methodology has been used in different forms since 1960. The first uniformed frameworks for conducting event studies on stock returns were presented by Brown & Warner (1980) and further developed by MacKinley (1997). Campbell & Wasley (1992) further develop the work of Brown & Warner (1985) on daily NASDAQ returns and show the strength of the nonparametric rank test specified by Corrado (1989).

The event study methodology has spread from financial perspectives to applications in measuring the effect of political events on firm performance. One example of this is the event study by Abadie & Gardeazabal (2003) on the effect of the ETA truce in the Basque Country on stock performance.

Methodology wise, the closest study to ours is the event study by Guidolin & La Ferrara (2007) on the effect of the sudden death of an Angolan rebel leader on the stock prices of Angolan diamond firms. Just like our research, theirs is limited to a single event. Our research however includes a larger sample of 72 bitcoin exchanges while theirs is based on a sample of seven Angolan diamond firms.

There are no previous event studies on bitcoin, but some have been done on foreign exchange markets. Subject wise, the study that is most similar to ours is the event study on changes in foreign exchange rates by Cosset & Doutriaux de la Rianderie (1985).

Cosset and Doutriaux de la Rianderie (1985) examine the change in exchange rates caused by announcements of changes in business environment in a country. They prove that the foreign exchange market reacts more strongly to unfavorable events than to favorable ones and confirm the hypothesis that foreign exchange markets are efficient.

Kwok and Brooks (1990) present a standard framework for event studies in foreign exchange markets based on the previous work by Brown & Warner (1980) and Brown & Warner (1985).

3. Data

The data sources used in this study are Bloomberg, Compustat and Bitcoincharts from which daily bitcoin data, daily foreign exchange data and daily stock market data is retrieved.

3.1 Bitcoin data

Bitcoincharts provides price and volume data for virtually all bitcoin exchanges available in the world. From this dataset, we manually downloaded 99,659 observations for 194 bitcoin exchanges traded in 38 different currencies. The dataset is further narrowed down to exclude any exchange displaying missing values to finally include 72 bitcoin exchanges in 26 different currencies.

Daily bitcoin data is cited at midnight UTC while other foreign exchanges are cited in different time zones. We have handled this problem when choosing the length of the event window.

The bitcoin portfolio that we use in the event study is equally weighted. A more traditional volume-weighted approach would limit the analysis to a few larger exchanges. We are interested in detecting events that affect bitcoin prices over all exchanges and for this the equally weighted portfolio is more sensitive to changes in each exchange.

In the event study we first look at a portfolio of all bitcoin exchanges and secondly divide it by forming one portfolio consisting of USD-denominated bitcoin exchanges, referred to as "bitcoin portfolio (USD)", and one portfolio consisting of the other 25 currencies, referred to as "bitcoin portfolio (Others)".

3.2 Foreign exchange data

Foreign exchange data has been retrieved for six currencies in accordance with Kwok & Brook (1990) using dollar as the numeraire. The six currencies chosen are Chineese yen (CNY), Euro (EUR), British pound (GBP), Australian dollar (AUD), Canadian dollar (CAD) and Polish zloty (PLN) which are the currencies that bitcoin is traded most frequently against during the estimation window and the event window.

3.3 Stock exchange data

The control portfolio is selected using the North American Industry Classification System based on companies engaged in financial transactions processing, reserve, and clearinghouse activities (NAICS code 522320). We have manually reviewed the list of control portfolio firms in order to exclude firms with operations too distant from the payment service platform which Bitcoin can be said to provide. The market index used to compute abnormal returns for the control portfolio is daily prices of S&P500 retrieved from Bloomberg.

4. Methodology and Theory

4.1 Event Study

The standard methodology presented by MacKinlay (1997) has been used in this paper. Since MacKinlay presents a methodology for event studies based on a data set of stocks, we have turned to the framework for event studies on foreign exchanges presented by Kwok and Brooks (1990) in some regards to adjust the methodology for bitcoin.

Event window

MacKinlay (1997) suggests that the event window should at least cover the event day and the day after. Kwok & Brooks (1990) use eleven days in the event window (-5, +5). To target the event date with precision, we allow the event window to be five days (-2, +2) and three days (-1, +1). This way we cover any potential information leakage during the days prior to the event date and lagged market reactions due to that foreign exchanges open in different time zones.

Estimation window

Kwok & Brooks (1990) suggest that a longer estimation period of 60 days improves the idiosyncratic errors and thus provides better estimates of normal returns, even though 30 days is acceptable for event studies on foreign exchange markets. MacKinlay (1997) suggests that 120 days should be used for event studies based on stock markets and explains that with longer estimation window, the sampling error variance approaches zero and the abnormal return observations become independent through time. However, Guidolin and La Ferrara (1997) use 24 days for the estimation window due to the high frequency of political events in Angola during that time.

Since there are no practical restraints to our data for using 60 days, which is the longest estimation window proposed for currencies by Kwok & Brooks (1990), we allow the estimation window to be 60 days to get as good results as possible. We do not apply the full 120 days proposed by MacKinlay (1997) since there is a high frequency of events on the bitcoin market and we do not want to include too many potential events in our estimation window, just like Guidolin and La Ferrara (1997) wish to exclude interfering political events in their estimation window.

The estimation window does not overlap the event window and the time periods we study are visualised in Figure 1 and Figure 2 respectively.

Figure 1. Timeline for Longer Event Window

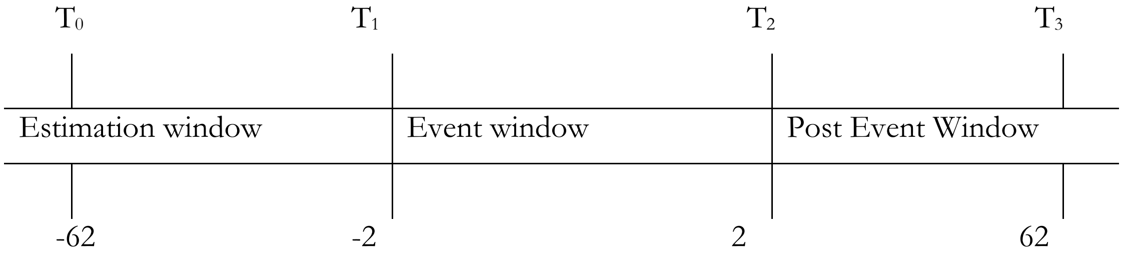
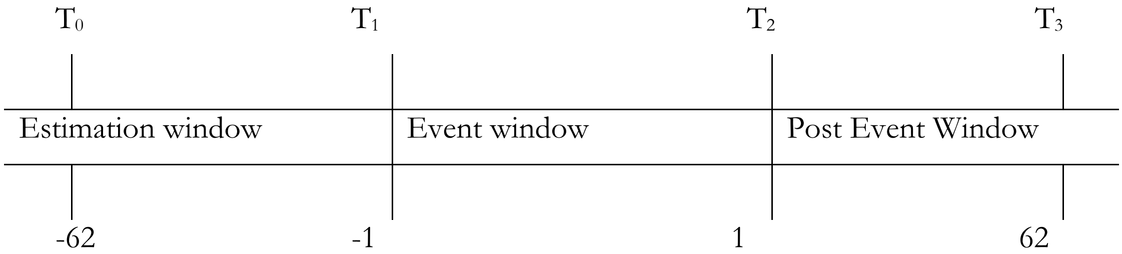


Figure 2. Timeline for Shorter Event Window



Market model for abnormal returns

To compute abnormal returns, both statistical models and economical models (CAPM) can be used. The statistical models dominate the economic models and the best model to identify event effects is the market model according to both MacKinlay (1997) and Kwok & Brooks (1990).

$$R_{it} = \alpha_i + \beta_i R_{mt} + \varepsilon_{it} \qquad (1)$$

R_{it} is the daily logarithmic return on security i, R_{mt} is the daily logarithmic return on the market portfolio, β_i is the systematic risk for security i, α_i is the performance of security i after adjusting for the systematic risk and ε_{it} is the estimation error of the market model for security i.

MacKinlay (1997) proposes that the market return should be the S&P500 Index, the CRSP Value Weighted Index or the CRSP Equal Weighted Index but according to Kwok & Brooks (1990) the variance of currencies has very low correlation with the world market index and an equally weighted index of six currencies should be used instead.

The market return in the model is an index of six foreign equally weighted currencies. The six currencies included in the index are CNY, EUR, GBP, AUD, CAD, PLN because they are the six currencies that most bitcoins trade against.

Calculating abnormal returns for bitcoin portfolios

$$AR_{it} = R_{it} - \hat{\alpha}_i - \hat{\beta}_i R_{mt} \qquad (2)$$

Where AR_{it} is the daily abnormal return for bitcoin exchange i, R_{it} is the daily logarithmic return for bitcoin exchange i, R_{mt} is the market return of the equally weighted currency index. $\hat{\alpha}_i$ and $\hat{\beta}_i$ are parameters estimated from the estimation window using an OLS regression.

The OLS regression assumes that there are no correlation between abnormal returns of different bitcoin exchanges. Since we cannot fully assume this, we cluster our regressions in two clusters, bitcoin portfolio and control portfolio respectively. This way we indicate that the observations within the bitcoin portfolio and the control portfolio may be correlated but each return between the portfolios are independent.

Now we calculate the daily cumulative abnormal returns for each bitcoin exchange in the event window.

$$CAR_i(T_1, t) = \sum_{t=T_1}^{t} AR_{it} \qquad (3)$$

We calculate the daily average cumulative abnormal returns for all bitcoin exchanges in the event window to test if it is equal to zero on the last day of the event window.

$$\overline{CAR_i}(T_1, t) = \frac{1}{N}\sum_{i=1}^{N} CAR_i(T_1, t) \qquad (4)$$

Calculating abnormal returns for the control portfolio

Guidolin & La Ferrara (2007) use a control group of diamond firms listed on the same exchanges though not present on the same regional market to isolate the effect of the specific conflict ending on the firms in the region they study.

In our case, we want to have a control group that controls for positive shocks in the general economy that might have influenced the bitcoin price during the event window. We are not using a control group consisting of other cryptocurrencies because other cryptocurrencies might be influenced by bitcoin activities, i.e. positive news for bitcoin could be positive news for all cryptocurrencies. Instead we use a group of payment solutions providers. The reason behind this is that these firms will control for any potential daily market boom during the event window. Online payments is what bitcoin was created for, so the firms are partly in the same business as bitcoin. If the economy would experience an unexpected increase in the event window, the price of the control group would increase and the price increase of bitcoin could also be explained by a general market increase in the specific time period.

We calculate abnormal returns the same way for the control portfolio, but instead of using an equally weighted index of six currencies for the market return, we use S&P500 as suggested by MacKinlay (1997).

Parametric tests

Parametric tests assume that daily returns are normally distributed. Since we use logarithmic daily returns, this assumption is valid. According to Brown & Warner (1985) daily stock returns show signs of non-normality but the cross-section of mean abnormal return converges to normality as the portfolio sample size increases.

In order to test if the daily average cumulative abnormal returns for all bitcoin exchanges in the event window is equal to zero on the last day of the event window, we calculate the test statistic

$$\frac{\overline{CAR_i}(T_1,T_2)}{SD\left(\overline{CAR_i}(T_1,T_2)\right)} = t \qquad (5)$$

where $$SD\left(\overline{CAR_i}(T_1,T_2)\right) = \sqrt{\frac{T_2-T_1-1}{N^2}\sum_{i=1}^{N}\hat{\sigma}_{\varepsilon,i}^2} \qquad (6)$$

where $$\hat{\sigma}_{\varepsilon,i}^2 = \frac{1}{T_1-T_0}\sum_{t=T_0}^{T_1} AR_{it}^2 \qquad (7)$$

Test statistic t is according to Brown & Warner (1985) well specified for portfolios down to a size of 5 securities. Under the null hypothesis of no abnormal returns, the statistic (5) is tested using a simple Student's t-test with T_1-T_0-2 degrees of freedom in accordance with the methodology by Campbell, Lo and MacKinlay (1997).

Crude Dependence Adjustment

To account for the fact that the event date is clustered, i.e. takes place on the same date for all bitcoin exchanges and for all control firms, and thus the average residuals are dependent in time, we compute the adjusted standard deviation called crude dependence adjustment by Brown & Warner (1980). This adjustment was originally specified for monthly returns and according to Brown & Warner (1985) there should be no larger problem with event date clustering for daily returns. We do however include it as daily bitcoin returns might exhibit slightly different characteristics than daily stock returns. P-values for the adjusted t-statistics t^{adj} are reported to ensure robust results in this study.

$$\frac{\overline{CAR_i}(T_1,T_2)}{SD^{adj}\left(\overline{CAR_i}(T_1,T_2)\right)} = t^{adj} \qquad (8)$$

$$\text{where } SD^{adj}\left(\overline{CAR_i}(T_1,T_2)\right) = \sqrt{\sum_{t=T_1}^{T_2} \hat{\sigma}_{\overline{AR}}^2} \qquad (9)$$

$$\text{where } \hat{\sigma}_{\overline{AR}} = \sqrt{\frac{\sum_{t=T_0}^{T_1}\left(\frac{\sum_{i=1}^{N} AR_{it}}{N} - \overline{AR}\right)^2}{T_1 - T_0}} \qquad (10)$$

$$\text{where } \overline{AR} = \frac{\sum_{i=1}^{N}\left(\frac{\sum_{t=1}^{T} AR_{it}}{T}\right)}{N} \qquad (11)$$

Under the null hypothesis of no abnormal returns, the statistic (8) is tested using a simple Student's t-test with T_1-T_0-2 degrees of freedom in accordance with the methodology by Campbell, Lo and MacKinlay (1997).

Nonparametric test

Including a nonparametric test complements the results from parametric tests as a robustness check (MacKinlay, 1997).

To account for non-normality and skewness in cross-sectional distributions of abnormal returns and any variance increase in the event-date abnormal returns we apply the nonparametric simple rank test specified by Corrado (1988). This test is robust to multi-day event periods and clustered event dates (Campbell & Wasley, 1993). This test is well specified for portfolios down to ten securities and does not require abnormal returns to be distributed symmetrically which gives higher power under the alternative hypothesis of abnormal returns. Corrado (1988) shows that the nonparametric rank test has an approximate normal distribution while classical parametric tests show leptokurtic and positive skewness.

First we rank each daily abnormal return during both the estimation window and the event window. The lowest daily abnormal return during the period is assigned 1 and the highest is assigned 65:

$$K_{it} = rank(A_{it}), \qquad t = -62, \dots, +2 \qquad (12)$$

By construction, the average rank is one-half plus the number of observed returns, or in this test 33. The rank statistic at day t is

$$\frac{\frac{1}{N}\sum_{i=1}^{N}(K_{it}-33)}{S(K)} = t^{rank} \qquad (13)$$

The standard deviation $s(K)$ is calculated from the entire period of both the estimation window and the event window

$$s(K) = \sqrt{\frac{1}{65}\sum_{t=-65}^{2}\left(\frac{1}{N}\sum_{i=1}^{N}(K_{it}-33)\right)^2} \qquad (14)$$

Under the null hypothesis of no abnormal returns, the statistic (13) is tested using a simple Student's t-test with T_1-T_0-2 degrees of freedom in accordance with the methodology by Campbell, Lo and MacKinlay (1997).

4.2 Event date

The first news about the opening of the exchange was released around 23:00 UTC January 25, 2015 why the event date is set to January 25, 2015. The opening of the exchange was January 26, 2015 so the largest effect is expected to take place for closing prices between January 25 to January 26, 2015, i.e. on day 1.

4.3 Variance-ratio test

In order to compare the variance of the bitcoin portfolios before and after the event window, we assume that the samples are normally distributed given the large daily sample size and logarithmic daily returns and compute

$$F = \frac{S_A^2}{S_B^2} \qquad (15)$$

where $S_A^2 > S_B^2$ and S_A^2 and S_B^2 are the sample standard deviations before and after the event date (Snedecor, 1936). The test statistic in (15) is distributed under an F-distribution with N_A -1 and N_B

-1 degrees of freedom where N_A is the sample size of the numerator and N_B sample size of the denominator.

4.4 Missing values correction

Bitcoin prices

We only include bitcoin exchanges that do not present missing values on the event date. For the ones that still remain, we allow the bitcoin exchanges to have missing values equivalent to two non-trading days per week, as is normal for regular stocks and foreign exchanges that are closed during weekends.

The period of interest for the event is 60 days prior and 60 days after the event for comparison of standard deviation. 72 exchanges are left after the screening process. The remaining missing daily prices are carried forward as this is the preferred adjustment by Kwok & Brooks (1990).

Foreign currency exchange

For weekends and holidays when values are missing for the dollar-denominated FX rates (EUR, GBP, CNY, JPY, CHF and PLN) we carry forward values from the last close.

Stock exchange data

For weekends and holidays when values are missing for control firms and S&P500 we carry forward values from the last close.

Imputation choice

Carry forward is applied to returns missing on trading days to have continuous time series data which is necessary for time-series regressions. This is done to have continuous time-series during the estimation window. We find the carry-forward option to be most realistic since this till give returns equal to zero.

4.5 Biases

For many of the smaller bitcoin exchanges used in our data set, observations may be missing for different periods of time. The missing values may be the result of technical difficulties or lack of liquidity on that market. This lack of complete data may result in thin-trading induced biases to our event study. The risks of thin trading, as is pointed out by Heinkel & Kraus (1988), is that the perceived lower standard deviation of returns may work in favour for rejecting a null hypothesis that the event has no impact. Guidolin & La Ferrara (2007) argues that in the worst case, thin trading affects the studied firm, or set of bitcoin exchanges in our case, to a larger extent than it affects the control portfolio. As is the case for Guidolin & La Ferrara, the percentage of missing observations is on average significantly lower among bitcoin exchanges than in the control group of currencies. Over the estimation period, the incidence of days with no raw returns is lower for the set of bitcoin exchanges than for the basket of currencies. The implications of this is that our data set is rather biased towards accepting the null hypothesis that no difference between returns exists over the event days.

4.6 Logarithmic returns

We compute daily logarithmic returns for all bitcoin exchanges and control firms in this study to reasonably assume that daily returns are normally distributed.

4.7 Efficient market hypothesis

Fama (1970) presents that an efficient market is a market in which prices fully reflect available information. Efficient markets come in three different forms: weak, semi-strong and strong. Weak forms of efficient markets has no other information available than historical prices. Semi-strong forms of efficient markets adjust prices for both historical prices as well as all other publicly available information (e.g. acquisitions, earnings announcements, events etc.).

Strong forms of efficient markets include all information in the weaker forms and additionally also private information that has not been publically announced yet. The strong form of efficient markets is generally considered to be a theoretical form.

Kwok & Brooks (1990) argue that the foreign exchange market is efficient in interpreting and reacting to events like announcements of changes in the business environment of a country. Since Bitcoin is not a mature established foreign exchange market, this might not be 100% valid. We have however chosen an event that announced just one day before opening and the event window covers this whole period. Thus, there should not have been any information available except for private information prior to the announcement date. This event study could be seen as a test of semi-strong market efficiency in the bitcoin market.

4.8 Law of one price

The law of one price is based on the notion of arbitrage-free pricing, meaning that equal assets will be priced the same over the whole market or as Lamont & Thaler (2003) describe it *"[…]an ounce of gold should have the same price (expressed in U.S. dollars) in London as it does in Zurich[…]"*.

For bitcoin this means that the daily return should be the same for each bitcoin exchange no matter what currency it is traded against. However, Yermack (2013) shows signs of violation of the law of one price in the bitcoin market where bitcoin prices for five different exchanges had a difference in 7% between the highest and the lowest price.

5. Results

Under the results section our main results are presented. First, we present the results for our study on abnormal returns in the event window for the bitcoin portfolio versus the control portfolio. Second, we present the results for our study on abnormal returns in the event window for the bitcoin portfolio (USD) versus the bitcoin portfolio (Others). Third, we present the results for our test of the hypothesis that the volatility decreased after the event window. Last, we present the results for the regression of daily bitcoin trading volume on daily bitcoin abnormal returns.

5.1Abnormal returns in conjunction with the Coinbase opening

The natural starting point in this study is the opening of Coinbase, the first regulated bitcoin exchange in the United States. Coinbase is the first bitcoin exchange in the United States backed by a traditional stock exchange, the NYSE, and the first bitcoin exchange only accessed from the United States.

Table 1 displays the descriptive statistics for the bitcoin portfolio and the control portfolio during the estimation window, the longer event window and the post event window.

Table 1: Descriptive Statistics for the Bitcoin Portfolio and the Control Portfolio

This table shows the mean daily logarithmic return, standard deviation, number of days and number of exchanges (firms) for the bitcoin portfolio (control portfolio) during the estimation window, the event window and the post event window.

	Bitcoin portfolio				Control portfolio			
	Mean daily return	Sd.	Days	Exchanges	Mean daily return	Sd.	Days	Firms
Estimation window	-.0064	.0825	60	72	-.0007	.0294	60	21
Event window	.0246	.0731	5	72	-.0035	.0295	5	21
Post event window	-.0004	.0795	60	72	-.0000	.0688	60	21

Figure 1 displays the daily cumulative abnormal returns during the event window and shows that there is a clear increase in cumulative abnormal returns for the bitcoin portfolio during this period. Meanwhile, it is clear that the control portfolio does not experience an increase in the cumulative abnormal returns.

Figure 1: Cumulative Abnormal Returns for the Bitcoin and Control Portfolios

This figure shows the average cumulative abnormal returns for the bitcoin portfolio and the control portfolio respectively for each day during the event window. The bitcoin portfolios consists of 72 bitcoin exchanges and the control portfolio consists of 21 control firms.

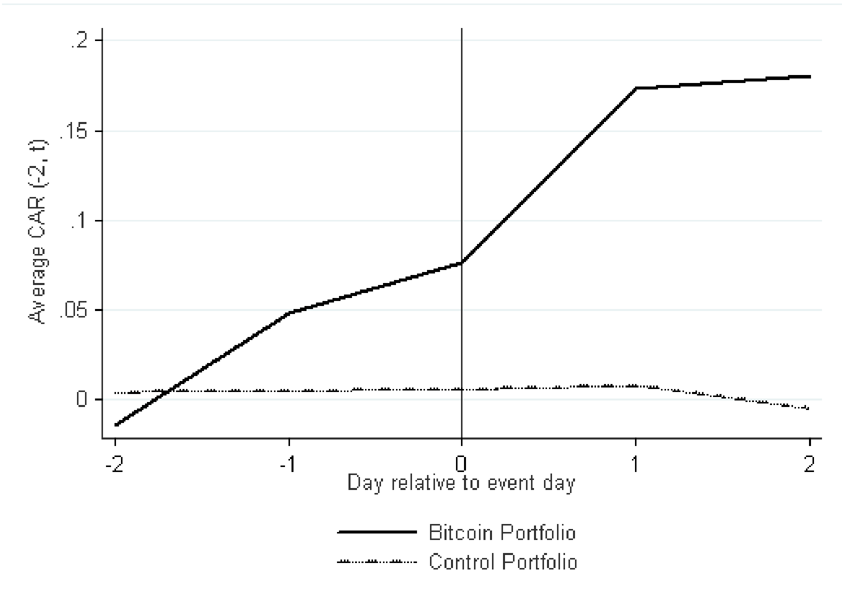


Table 2 shows that the equally weighted daily abnormal returns for the bitcoin portfolio increases with 9 percentage points on day 1 and that cumulative abnormal returns for the bitcoin portfolio aggregates to 18% on day 2. Meanwhile, abnormal returns for the control portfolio increases with barely 1 percentage point on day 1 and cumulative abnormal returns for the control portfolio is -2% on day 2. This suggests that the bitcoin market reacted positively to the opening of Coinbase, while firms involved in transactions similar to bitcoin did not.

Table 2: Cumulative Abnormal Returns and Abnormal Returns for the Bitcoin and Control Portfolios

This table shows the average cumulative abnormal returns and the average abnormal return for the bitcoin portfolio and the control portfolio respectively for each day during the event window. The bitcoin portfolios consists of 72 bitcoin exchanges and the control portfolio consists of 21 control firms.

Day relative to event day	Bitcoin portfolio		Control portfolio	
	CAR	AR	CAR	AR
-2	-.01	-.01	.00	.00
-1	.05	.06	.00	.00
0	.08	.03	.01	.01
1	.17	.09	.01	.0
2	.18	.01	-.01	-.02

In Table 3 we formally test if the effects that are visible in Figure 1 are statistically significant. We show that the cumulative abnormal returns are significantly positive for the bitcoin portfolio using the test statistic from MacKinlay (1997). When accounting for the fact that the event date is the same for all bitcoin exchanges and control firms by using the Crude Dependence Adjustment (Brown & Warner, 1980) the significance drops slightly. The cumulative abnormal return is still highly significant for the 3 day event window. We cannot reject the null hypothesis that cumulative abnormal returns is equal to zero for the control portfolio, which means that the control portfolio did not experience any cumulative abnormal returns during the event window.

Table 3: Tests for Significant Cumulative Abnormal Returns (CAR)

This table shows the test statistics and the two-tailed p-values from a Student's t-test for positive cumulative abnormal returns in the bitcoin portfolio and the control portfolio respectively. The t-test has been performed once according to the standard methodology by MacKinlay (1997) and once with the Crude Dependence Adjustment by Brown & Warner (1980).

	Bitcoin portfolio				Control portfolio			
Event window	T-statistic[a]	P-value two-tailed[a]	T-statistic[b]	P-value two-tailed[b]	T-statistic[a]	P-value two-tailed[a]	T-statistic[b]	P-value two-tailed[b]
CAR								
(-1, +1)	11.1305	.0001	2.4081	.0192	.3639	.7198	.3848	.7018
(-2, +2)	8.2869	.0001	1.7929	.0782	-.6823	.5029	-.7214	.4736

[a] Regular test statistics for a Student's t-distribution with $T_1 - T_0 - 2$ degrees of freedom.

[b] Crude dependence adjusted test statistics for a Student's t-distribution with $T_1 - T_0 - 2$ degrees of freedom.

In Table 4 we formally test the difference between the average cumulative abnormal returns for the bitcoin portfolio and the control portfolio under a Student's t-distribution. We can successfully reject the null hypothesis that the difference between the portfolios is zero, both with the test statistic from MacKinlay (1997) and when accounting for the fact that the event date is the same for all bitcoin exchanges and control firms by using the Crude Dependence Adjustment (Brown & Warner, 1980). This suggests that the bitcoin portfolio actually did generate abnormal returns during the event window, not because of general industry effects[3], but specifically on the bitcoin market. These abnormal returns are most likely generated by the opening of Coinbase.

[3] The industry is defined as companies engaged in financial transactions processing, reserve, and clearinghouse activities.

Table 4: Tests for Significant Difference in Cumulative Abnormal Returns (CAR) Between the Bitcoin Portfolio and the Control Portfolio

This table shows the test statistics and the two-tailed p-values from a Student's t-test for the difference in cumulative abnormal returns between the bitcoin portfolio and the control portfolio. The t-test has been performed once according to the standard methodology by MacKinlay (1997) and once with the Crude Dependence Adjustment by Brown & Warner (1980).

CAR (Bitcoin-Control)	T-statistic[a]	P-value two-tailed[a]	T-statistic[b]	P-value two-tailed[b]
(-1, +1)	8.7957	.0001	2.3255	.0236
(-2, +2)	7.1084	.0001	1.8794	.0652

[a] Regular test statistics for a Student's t-distribution with $T_1 - T_0 - 2$ degrees of freedom.

[b] Crude dependence adjusted test statistics for a Student's t-distribution with $T_1 - T_0 - 2$ degrees of freedom.

5.2 Robustness test with the simple nonparametric rank test

To account for non-normality and provide robust test results we use the simple nonparametric rank test by Corrado (1989). This test is used as a complement to parametric tests in event studies (MacKinlay, 1997).

In Table 5 we test the abnormal returns for each day in the event window for the bitcoin portfolio and the control portfolio respectively. The test shows that the bitcoin portfolio has significant abnormal returns on day 1 for the bitcoin portfolio but not for the control portfolio for any day in the event window. This confirms our results from the previous tests and validates that the bitcoin portfolio generates robust significant abnormal returns on day 1 in the event window while the control portfolio does not.

Table 5: Nonparametric Rank Tests for Significant Abnormal Returns

This table shows the test statistics and the two-tailed p-values from a Student's t-test for positive abnormal returns in the bitcoin portfolio and the control portfolio respectively.

	Bitcoin portfolio			Control portfolio		
Day relative to event day	AR	T-statistic	P-value two-tailed	AR	T-statistic	P-value two-tailed
-2	-.01	-.7310	.4677	.00	-1.3459	.1836
-1	.06	1.6790	.0985	.00	-1.2481	.2170
0	.04	1.0587	.2941	.01	-1.2481	.2170
1	.10	2.0417	.0457	.0	-.8015	.4261
2	.00	-.0844	.9330	-.02	-.0428	.9660

5.3 Event study on the opening of Coinbase regulated exchange (USD vs Others)

Since the Coinbase exchange is regulated to allow trade from the United States only, we want to study if the Coinbase opening affects the bitcoin exchanges that trade in BTC/USD differently than it affects the other exchanges.

Table 6 displays the descriptive statistics for the bitcoin portfolio (USD) and the control portfolio (Others) during the estimation window, the longer event window and the post event window.

Table 6: Descriptive Statistics for the Bitcoin Portfolio (USD) and the Bitcoin Portfolio (Others)

This table shows the mean daily logarithmic return, standard deviation, number of days and number of exchanges for the bitcoin portfolio (USD) and for the bitcoin portfolio (Others) during the estimation window, the event window and the post event window.

	Bitcoin portfolio (USD)				Bitcoin portfolio (Others)			
	Mean daily return	Sd.	Days	Exchanges	Mean daily return	Sd.	Days	Exchanges
Estimation window	-.0072	.0770	60	15	-.0062	.0839	60	57
Event window	.0246	..0572	5	15	.0246	.0769	5	57
Post event window	-.0004	.0852	60	15	-.0003	.0779	60	57

Figure 2 shows that both the bitcoin portfolio (USD) and the bitcoin portfolio (Others) experience the same development during the event window. However, between the period of day (-1, +1) the bitcoin portfolio (USD) seems to generate slightly higher abnormal returns.

Figure 2: Cumulative Abnormal Returns and Abnormal Returns for Bitcoin Portfolio (USD) and Bitcoin Portfolio (Others)

This table shows the average cumulative abnormal returns and the average abnormal return for the bitcoin portfolio (USD) and bitcoin portfolio (Others) respectively for each day during the event window. The bitcoin portfolio (USD) consists of 15 bitcoin exchanges that trade against USD and the bitcoin portfolio (Others) consists of 57 bitcoin exchanges that are traded in 26 different currencies.

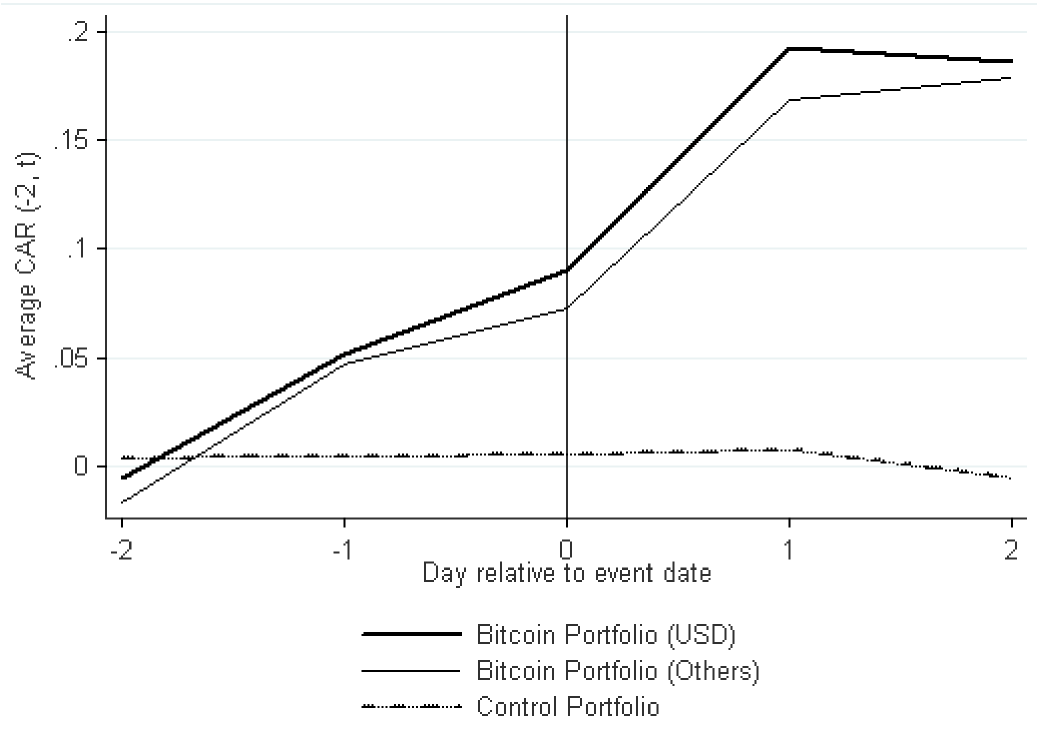


Table 7 shows that the equally weighted daily abnormal returns of the bitcoin portfolio (USD) increases with 9 percentage points on day 1 and that cumulative abnormal returns for the bitcoin portfolio aggregates to 19% on day 2. Meanwhile, abnormal returns for the bitcoin portfolio (Others) increases with 9 percentage points on day 1 and cumulative abnormal returns for the bitcoin portfolio (Others) is 18% on day 2. This suggests that the bitcoin market reacted the same for bitcoin portfolio (USD) as for bitcoin portfolio (Others). This result may be intuitive at a first glance, however given the difference in price that prevails on the different exchanges, it was by no means a matter of course.

Table 7: Cumulative Abnormal Returns and Abnormal Returns for Bitcoin Portfolio (USD) and Bitcoin Portfolio (Others)

This table shows the average cumulative abnormal returns and the average abnormal returns for the bitcoin portfolio (USD) and bitcoin portfolio (Others) respectively for each day during the event window. The bitcoin portfolio (USD) consists of 15 bitcoin exchanges that trade against USD and the bitcoin portfolio (Others) consists of 57 bitcoin exchanges that are traded in 26 different currencies.

Day relative to event day	Bitcoin portfolio (USD)		Bitcoin portfolio (Others)	
	CAR	AR	CAR	AR
-2	-.01	-.01	-.02	-.02
-1	.05	.06	.05	.07
0	.09	.04	.07	.02
1	.19	.09	.17	.09
2	.19	.00	.18	.01

In Table 8 we formally test if the effects that are visible in Figure 2 are statistically significant. We show that the cumulative abnormal returns are significantly positive for both bitcoin portfolios using the test statistic from MacKinlay (1997). When accounting for the fact that the event date is the same for all bitcoin exchanges using the Crude Dependence Adjustment (Brown & Warner, 1980) the significance drops and the bitcoin portfolio (USD) is not significant in the 5 day event window any more. The cumulative abnormal return is still highly significant for the 3 day event window. We cannot tell any difference between the two portfolios from this test.

Table 8: Tests for Significant Cumulative Abnormal Returns (CAR)

This table shows the test statistics and the two-tailed p-values from a Student's t-test for positive cumulative abnormal returns in the bitcoin portfolio (USD) and the bitcoin portfolio (Others) respectively. The t-test has been performed once according to the standard methodology by MacKinlay (1997) and once with the Crude Dependence Adjustment by Brown & Warner (1980).

	Bitcoin portfolio (USD)				Bitcoin portfolio (Others)			
Event window	T-statistic[a]	P-value two-tailed[a]	T-statistic[b]	P-value two-tailed[b]		T-statistic[a]	P-value two-tailed[a]	T-statistic[b]
Abnormal returns								
(-1, +1)	5.7553	.0001	2.2653	.0272	9.5943	.0001	2.4066	.0193
(-2, +2)	4.1865	.0001	1.6478	.1048	7.1894	.0001	1.8034	.0765

[a] Regular test statistics for a Student's t-distribution with $T_1 - T_0 - 2$ degrees of freedom.

[b] Crude dependence adjusted test statistics for a Student's t-distribution with $T_1 - T_0 - 2$ degrees of freedom.

In Table 9 we formally test the difference between the average cumulative abnormal returns for the bitcoin portfolio (USD) and the bitcoin portfolio (Others) under a Student's t-distribution. We cannot reject the null hypothesis that the difference between the portfolios is zero, neither with the test statistic from MacKinlay (1997) nor when accounting for the fact that the event date is the same for all bitcoin exchanges and control firms by using the Crude Dependence Adjustment (Brown & Warner, 1980). This suggests that the bitcoin portfolio (USD) did generate the same abnormal returns during the event window as the bitcoin portfolio (Others) did. These results confirm that the law of one price holds for the bitcoin market.

Table 9: Tests for Significant Difference in Cumulative Abnormal Returns (CAR) Between the Bitcoin Portfolio (USD) and the Bitcoin Portfolio (Others)

This table shows the test statistics and the two-tailed p-values from a Student's t-test for the difference in cumulative abnormal returns between the bitcoin portfolio (USD) and the bitcoin portfolio (Others). The t-test has been performed once according to the standard methodology by MacKinlay (1997) and once with the Crude Dependence Adjustment by Brown & Warner (1980).

CAR (USD-Others)	T-statistic[a]	P-value two-tailed[a]	T-statistic[b]	P-value two-tailed[b]
(-1, +1)	.3268	.7450	.1107	.9122
(-2, +2)	.1348	.8932	.0456	.9638

[a] Regular test statistics for a Student's t-distribution with $T_1 - T_0 - 2$ degrees of freedom.

[b] Crude dependence adjusted test statistics for a Student's t-distribution with $T_1 - T_0 - 2$ degrees of freedom.

5.4 Bitcoin volatility before and after the Coinbase opening

To test our hypothesis that regulated initiatives such as the Coinbase opening will bring trust to the bitcoin market, which should lower the bitcoin price volatility, we test if the volatility decreased in the 60 days following the event compared to the 60 days preceding the event.

Table 10: Variance Ratio Test for Equal Variances

This table shows real difference between the sample standard deviation before and after the Coinbase opening calculated on a 60 days period for all 72 bitcoin exchanges. The upper-tail p-value is from an F-test for equal variance $\frac{s_A^2}{s_B^2} = 1$ where s_A^2 the bitcoin sample variance before the Coinbase opening is and s_B^2 is the sample variance after the Coinbase opening.

	N	Std. Dev.	P-value upper-tail
Pre event	4320	.0825	
Post event	4320	.0795	
Difference		.0030	.0075

5.6 Robust regression of trading volume on abnormal returns

We set out to identify why the Coinbase opening generates abnormal returns. Our hypothesis is that the opening of Coinbase increased trading volume of bitcoin because bitcoin became a more viable asset class to hold, which in turn caused the increase in abnormal returns. Table 11 displays the result from the regression of daily bitcoin trading volume on daily bitcoin abnormal returns. The regression shows that daily bitcoin trading volume significantly decreases the daily abnormal returns with 0.00298 percentage points.

Table 11: Trading Volume and Abnormal Returns

This table shows the regression of the independent variable Trading Volume that is the logarithmic daily change in bitcoin trading volume on the dependent variable Daily Abnormal Returns that is the daily bitcoin returns of all 72 bitcoin exchanges during the 65 days of the estimation window and the event window.

VARIABLES	Daily Abnormal Returns
Trading Volume	-0.00298***
	(-2.983)
Constant	0.00257**
	(2.077)
Observations	4,336
R-squared	0.003

Robust t-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

6. Conclusion

We have tested four different hypotheses related to recent regulatory initiatives on the bitcoin market.

First, we confirm our hypothesis that the opening of Coinbase would generate abnormal returns on the global bitcoin market. We prove with statistically robust results that the abnormal returns of the bitcoin portfolio following the announcement and opening of Coinbase are positive. We conclude that despite the different opinions on regulations that divide bitcoin users, the overall market finds this regulatory initiative to be of value for bitcoin. We find this to be an important indication on what trajectory the majority of bitcoin investors believe that the cryptocurrency is on; more regulatory incentives in order to further integrate bitcoin with the established financial markets. To control for the possibility that the abnormal returns were caused by a general spike in the stock market or in the overall economy, we show that the abnormal returns on the day of Coinbase opening was as high as 9% while the control portfolio generated zero abnormal returns. This suggests that the positive abnormal returns generated on the bitcoin market in conjunction to the Coinbase opening was in fact due to the Coinbase opening.

Second, we cannot confirm our hypothesis that the opening of Coinbase would generate deviating abnormal returns between the bitcoin portfolio (USD) and the bitcoin portfolio (Others). We show that the abnormal returns are positive both for the bitcoin portfolio (USD) and the bitcoin portfolio (Others). Yermack (2014) suggests that there are arbitrage opportunities between individual bitcoin exchanges, however we are unable to prove any difference in the abnormal returns between the two portfolios during the event window. This result is in line with the law of one price (Lamont and Thaler, 2003).

Third, we confirm our hypothesis that the opening of Coinbase would decrease the volatility in bitcoin prices. Decreasing the high volatility is an important issue in the bitcoin community to ensure the viability of bitcoin as a currency, as is further stressed by Niblaues and Nylund (2014). Though we are able to statistically show that a significant decrease in volatility, the decrease is so small that it is unlikely that it would yield any practical effect over the short period we study. We believe, however, that the long-run volatility will decrease as more regulated exchanges emerge.

Fourth, we are able to show that the daily trading volume has significant explanatory power for the daily abnormal returns during the estimation window and the event window. The relationship is however negative. Our results suggest that for every one percentage unit increase in trading volume there is a 0.003 percentage point decrease in abnormal returns. This result is small and will not yield any practical effect. It does, however, lay ground for future research on the relationship between bitcoin trading volume and returns.

Our results show signs of semi-strong market efficiency as bitcoin prices adjust to new, public information of a regulated exchange opening. The semi-strong form is not surprising, and has been tested by Kwok & Brooks (1990) who report that foreign exchange markets are efficient at reacting to events like announcements of important changes. The result is however an interesting addition to the bitcoin research. We also show that there were no arbitrage opportunities during the event window in conjunction to the Coinbase opening.

7. Limitations and Suggestions for Future Research

One obvious limitation to our study is the number of events investigated. The event study method is valid while looking at just one event, and conclusions can be made from our specific event but to examine any persistent trend, several events must be studied. As regulatory initiatives in terms of regulated bitcoin exchanges are new on the market at the time for writing this thesis, we have focused on the first regulated U.S. exchange. For future research we would like to include several regulatory initiatives to be able to draw more general conclusions from the effect of regulations in its entirety.

We find indications of lowered volatility in the period after the Coinbase event. We are aware that the short time period that we study is a limitation and we therefore view the results as indications rather than proof. To truly conclude that the volatility has decreased, it is necessary to look at the long-term trend in bitcoin volatility and study any abnormal changes following the implementation of a regulatory initiative. For instance, if the bitcoin volatility has been decreasing systematically for the past two years then that trend has to be taken into consideration when making conclusions from our findings. We look forward to see further research on the relation between regulations and volatility on the bitcoin markets, and hope that our study will spark interest in the field.

In our method there is a limitation in using the market return model for estimating abnormal returns. This is a problem because there is no obvious market return to compare bitcoin returns against, and there are no previous event studies on bitcoin to establish praxis. One way to develop event studies on bitcoin in future research is by using the constant mean return model that is described by MacKinlay (1997) and by Kwok and Brooks (1990) and does not require that a market return is estimated. These are, however, less preferred methods by the authors.

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A. Appendix

Table A1: Descriptive Statistics Bitcoin Portfolio

Table A1 reports mean return, standard deviation, number of observations and mean daily trading volume for 72 bitcoin exchanges respectively. Daily observations differ due to that bitcoin exchanges have opened up frequently along the way. The sample period starts in June 2011 and ends in April 2015, which is the full sample period for each exchange downloaded from bitcoincharts.com.

Bitcoin Exchange	Mean ln. daily return (2011-2015)	Standard deviation of ln. daily returns (2011-2015)	Daily observations (2011-2015)	Mean Daily Trading Volume
localbtcTHB	0.00	0.11	751	25
fybseSEK	0.00	0.07	639	20
kptnSEK	0.00	0.07	639	20
localbtcZAR	0.00	0.16	691	10
localbtcRUB	0.00	0.21	748	42
bitcurexEUR	0.00	0.11	1,003	40
localbtcCZK	0.00	0.11	735	3
cbxUSD	0.00	0.07	1,38	506
localbtcCHF	0.00	0.15	738	11
localbtcMXN	0.00	0.10	765	10
localbtcSEK	0.00	0.10	764	17
hitbtcEUR	0.00	0.04	463	359
fybsgSGD	0.00	0.07	828	14
localbtcINR	0.00	0.12	756	8
btcdeEUR	0.00	0.07	1,328	964
bitstockCZK	0.00	0.05	478	5
mrcdBRL	0.00	0.15	1,357	73
cotrUSD	0.00	0.04	480	58
anxhkAUD	0.00	0.04	448	833
anxhkNZD	0.00	0.04	412	926
korbitKRW	0.00	0.06	589	293
hitbtcUSD	0.00	0.04	474	555
bit2cILS	0.00	0.08	761	21
itbitUSD	0.00	0.06	598	1231
anxhkCNY	0.00	0.26	542	752
itbitEUR	0.00	0.06	514	72
anxhkCAD	0.00	0.04	370	930
anxhUSD	0.00	0.10	603	582
anxhkSGD	0.00	0.04	459	915
krakenEUR	0.00	0.04	462	1,586
localbtcNZD	0.00	0.09	763	8
anxhkJPY	0.00	0.04	403	926
okcoinCNY	0.00	0.06	672	67,394
anxhkEUR	0.00	0.04	426	870
anxhkHKD	0.00	0.07	612	719
zyadoEUR	0.00	0.04	356	352
1coinUSD	0.00	0.40	402	602
btcnCNY	0.00	0.06	1,402	24,701
itbitSGD	0.00	0.05	513	127
localbtcBRL	0.00	0.12	758	4
rockEUR	0.00	0.07	1,253	45
bitstampUSD	0.00	0.06	1,31	9443
bitfinexUSD	0.00	0.06	745	17,321
btceEUR	0.00	0.06	894	171
anxhkGBP	0.00	0.04	465	891
lakeUSD	0.00	0.04	410	4,187
btcmarketsAUD	0.00	0.06	593	60
bitkonanUSD	0.00	0.08	652	5

bitbayPLN	0.00	0.06	382	253
coinfloorGBP	0.00	0.05	382	79
bitmarketplPLN	0.00	0.04	410	231
localbtcGBP	0.00	0.09	765	406
bitcurexPLN	0.00	0.07	995	460
krakenUSD	0.00	0.05	463	17
btceUSD	0.00	0.06	1,34	7,271
btceRUB	0.00	0.05	971	417
btcoidIDR	0.00	0.04	430	79
rockUSD	0.00	0.14	1,25	10
bitbayUSD	0.00	0.06	334	28
bitnzNZD	0.00	0.11	1,311	24
localbtcNOK	0.00	0.10	764	7
localbtcARS	0.00	0.11	726	7
bitxZAR	0.00	0.07	584	17
localbtcSGD	0.00	0.09	753	3
localbtcAUD	0.00	0.10	765	124
localbtcUSD	0.00	0.21	765	818
localbtcHKD	0.00	0.08	742	9
localbtcPLN	0.00	0.09	660	5
localbtcCAD	0.00	0.14	764	29
krakenNMC	0.00	0.06	468	1
localbtcEUR	0.00	0.21	762	136
krakenLTC	0.00	0.03	463	22

Table A2: Descriptive Statistics Control Portfolio

Table A2 reports mean return, standard deviation and number of daily observations during the for 21 control firms respectively. Daily observations differ due to new bitcoin exchanges open up frequently. The sample period starts in April 2011 and ends in April 2015 to match the full time period of bitcoin, however Currency Exchange Intl. Corp. started trading in September 2012.

Control Firm	Mean ln. daily return (2011-2015)	Standard deviation of ln. daily returns (2011-2015)	Daily observations (2011-2015)
Currency Exchange Intl. Corp.	0.00	0.02	779
EFT Canada Inc.	0.00	0.06	1079
Euronet Worldwide Inc.	0.00	0.02	1079
First Global Data Ltd.	0.00	0.11	1079
Fleetcor Technologies Inc.	0.00	0.02	1079
Global Axcess Corp.	0.00	0.15	1079
Global Cash Access Holdings	0.00	0.03	1079
Green Dot Corp.	0.00	0.04	1079
Heartland Payment Systems	0.00	0.02	1079
Higher One Holdings Inc.	0.00	0.03	1079
Mastercard Inc.	0.00	0.07	1079
Money Centers of America Inc.	0.00	0.23	1079
Moneygram International Inc.	0.00	0.07	1079
MyEcheck Inc.	0.00	0.41	1079
Payment Data systems Inc.	0.00	0.11	1079
Ready Credit Corp.	0.00	0.17	1079
Total System Services Inc.	0.00	0.01	1079
Velocity Portfolio Group Inc.	0.00	0.13	1079
Visa Inc.	0.00	0.05	1079
Western Union Co.	0.00	0.02	1079
Wex Inc.	0.00	0.02	1079

Table A3: Coinbase Money Transmitter Licenses

Table A3. Displays the money transmitter licenses for each stat obtained by the regulated Coinbase bitcoin exchange. The list is available from Coinbase's website.

Jurisdiction	License	State Agency
Alabama	Sale of Checks License, SC 509	Alabama Securities Commission
Arizona	Money Transmitter, MT-0928767	Arizona Department of Financial Institutions
Arkansas	Money Transmission License, 43387	Arkansas Securities Department
Delaware	Sale of Checks and Transmission of Money, 019214	Office of the State Bank Commissioner
Georgia	Seller of Payment Instruments License, 42767	Georgia Department of Banking and Finance
Idaho	Money Transmitter License, MTL-169	Idaho Department of Finance, Securities Bureau
Iowa	Money Services License, 2014-0087	State of Iowa Division of Banking
Kansas	Kansas Money Transmitter License, MT.0000078	Kansas Office of the State Bank Commissioner
Maine	Money Transmitter License, MD1505	Department of Professional & Financial Regulation
Mississippi	Money Transmitter License, MT/002612/2014	Mississippi Department of Banking and Consumer Finance
Nebraska	Nebraska Money Transmitter License, 1163082	Nebraska Department of Banking & Finance
New Hampshire	Money Transmitter License, 1163082	New Hampshire Banking Department
New Jersey	Money Transmitter License, 1401158C22	New Jersey Department of Banking and Insurance
North Carolina	Money Transmitter License, 161420	North Carolina Commissioner of Banks
North Dakota	North Dakota Money Transmitter License, MT102790	North Dakota Department of Financial Institutions
Oklahoma	Oklahoma - DOB Money Transmission License, OKDOB001	Oklahoma Department of Banking
Puerto Rico	Money Transmitter License, TM-053	Office of the Commissioner of Financial Institutions
Washington	Money Transmitter License, 550-MT-90174	State of Washington - Department of Financial Institutions
West Virginia	Money Transmitter License, WVMT-1163082	West Virginia Division of Financial Institutions