Charles University in Prague

Faculty of Social Sciences
Institute of Economic Studies

MASTER THESIS

Virtual currencies in real economy: Bitcoin

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Academic Year: **2013/2014**

Declaration of Authorship

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Prague, May 13, 2014

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Signature

Acknowledgments

I am grateful especially to PhDr. Pavel Vacek, Ph.D. for his guidance and precious comments.

I would also like to thank my family and all the precious people around me who supported me in the course of my studies.

My last thanks goes to Satoshi Nakamoto for creating something as amazing as Bitcoin.

Abstract

This paper examines the relationship between virtual currency, the Bitcoin, and the real economy. In the first part the description of the term virtual currency is provided with special focus on Bitcoin. Also the legal and taxation issues are discussed. In the main part the volatility of Bitcoin is inspected using various models from Autoregressive heteroskedasticity models family. We found that the volatility of Bitcoin differs significantly through time and that this relation is captured best by T-GARCH (1,1) model. Finally the relationship between Bitcoin and real economy indicators is observed to be inconsistent and mostly insignificant in time. Thus we conclude that the independency of Bitcoin cannot be rejected.

JEL Classification	C22, E42, K34, L17
Keywords	Bitcoin, virtual currencies, structural breaks, ARCH models

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Abstrakt

Práce zkoumá vztah mezi virtuální měnou zvanou Bitcoin a reálnou ekonomikou. V první části je uveden popis termínu virtuální měna se speciálním důrazem na Bitcoin. V této části je také diskutována hlavní právní a daňová problematika spojená s virtuálními měnami. V hlavní části práce zkoumáme volatilitu Bitcoinu s použitím rozličných modelů z rodiny modelů zkoumajících autoregresivní heteroskedasticitu. Zjistili jsme, že volatilita Bitcoinu se významně mění v čase a že tento vztah nejlépe zachycuje model T-GARCH (1,1). V poslední části zjišťujeme, že vztah mezi Bitcoinem a indikátory reálné ekonomiky je v čase nekonzistentní a převážně statisticky nevýznamný. Vyvozujeme z toho tedy, že nezávislost Bitcoinu nemůžu být zamítnuta.

Klasifikace	C22, E42, K34, L17
Klíčová slova	Bitcoin, virtuální měny, strukturální změny, ARCH modely

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Proposed Topic:

Virtual currencies in real economy: Bitcoin

Topic Characteristics:

Virtual currencies are a hot topic of today. They have evolved from their first appearance in enclosed worlds of online gaming and tentative appearances in real economy into actively used alternative global currencies. The by far most important of them is Bitcoin with total value of more than 1 billion dollars circulating and increasing. It has a sophisticated scheme of creation, exchange and encryption and is appealing to many individuals as it bypasses some of the limitations of current fiat currencies. As it differs by nature from the real currencies many political, legal, economic and monetary questions arise:

1) Can Bitcoin be considered a legal currency?
2) Can the profit realized in Bitcoins be taxed by legal authorities?
3) Will possible widespread use of Bitcoin lead to deflationary spiral?
4) Is the value of 1 bitcoin dependent solely on supply and demand, or is there another underlying factor?
5) Can Bitcoin threaten position and function of central banking?
6) Can mining of Bitcoins be in hands of monopoly/oligopoly?

I do not plan on answering all these questions, yet my goal is to assess the economic and financial risks and benefits which arise from these questions.

Hypotheses:

1. Deflationary nature of Bitcoin might eventually lead to its hoarding
2. Bitcoin is a legal currency and profits realized in Bitcoins can be taxed.
3. The market price of Bitcoin is subjected to speculation bubbles.
4. The market price of Bitcoin is linked to real economies

Methodology:

As the Bitcoin is a new financial instrument on the market, I deem it important to explain the origin and the way of creation of Bitcoin. As bitcoin is from its nature deflationary, the danger of its hoarding arises. I want to assess this question from theoretical point of view.
The question of Bitcoin's status as a legal tender depends on people's honesty and traceability of revenues realized in Bitcoin. I will study the nature of Bitcoin and the way it can be taxed. Also the precedents, which are being introduced into the world of law, will help me to assess its position as possible legal tender for world's economies. I will try to employ the results on legislative of Czech Republic.
To test the connection between real economies and price of Bitcoin I plan on employing OLS regression of Bitcoin price on a representing index of a country's economy. I will not use price of

Bitcoin denominated in one country’s currency, if its index will be tested to avoid correlation between e.g. price of Bitcoin in USD and an American index. Also dummies for important global events will be included in this regression.
To assess the volatility of Bitcoin, I plan on employing ARCH based models.

Outline:

1. Legal and political issues of Bitcoin
    a. Legislative precedents
    b. Taxation issues
    c. Example of Czech Republic
2. Relationship between Bitcoin and real economy
    a. Ties to industry – current use of Bitcoin
    b. Possible regulations
    c. Regression of Bitcoin market price on real economy assets
3. Volatility patterns of Bitcoin
    a. Description of data
    b. Volatility inspection – ARCH family models

Core Bibliography:

1. Nakamoto, S. (2009): “Bitcoin: A Peer-to-Peer Electronic Cash System." Available at www.bitcoin.org
2. Reid F. & M. Harrigan (2011): “An Analysis of Anonymity in the Bitcoin System." *Security and Privacy in Social Networks (2013):* pp 197-223
3. Plassaras, N. (2013): “Regulating Digital Currencies: Bringing Bitcoin within the Reach of the IMF.” *Chicago Journal of International Law, 14 Chi J Intl L (2013) Forthcoming.* Available at SSRN: http://ssrn.com/abstract=2248419
4. Barber, S., Boyen, X., Shi, E., Uzun, E. (2012): “Bitter to Better—How to Make Bitcoin a Better Currency." *Stanford University research paper*. Available at http://crypto.stanford.edu/~xb/fc12/bitcoin.pdf
5. Moore, T. & N. Christin (2013): „Beware the Middleman: Empirical Analysis of Bitcoin-Exchange Risk.“ *Financial Cryptography and Data Security 2013.* Available at http://fc13.ifca.ai/proc/1-2.pdf
6. The Economist (2013): „Mining digital gold.“ Available at http://www.economist.com/news/finance-and-economics/21576149-even-if-it-crashes-bitcoin-may-make-dent-financial-world-mining-digital
7. Soltas, E. (2013): “Bitcoin Really Is an Existential Threat to the Modern Liberal State." *Bloomberg*. Available at http://www.bloomberg.com/news/2013-04-05/bitcoin-really-is-an-existential-threat-to-the-modern-liberal-state.html
8. Brito, J. & Castillo, A. (2013): „Bitcoin: A Primer for Policymakers“. Available at http://mercatus.org/sites/default/files/Brito_BitcoinPrimer.pdf
9. Graf Konrad S. (2013): „On the origins of Bitcoin.“ Available at http://konradsgraf.com/storage/On%20the%20Origins%20of%20Bitcoin%20Graf%2003.11.13.pdf
10. European Central Bank (2012): „Virtual Currency Schemes.“ ISBN: 978-92-899-0862-7

Author **Supervisor**

1 The world of virtual currencies and the Bitcoin in particular

Bitcoin and other so called virtual currencies are phenomena of the present. The popularity they are receiving in the media is enormous and their use is spreading around the world. The market capitalization of Bitcoin alone has reached almost 14 billion USD in December 2013[1] and yet the countries around the world cannot agree on its specification. Bitcoin is considered to be a currency in some countries, an asset or a commodity in others. In the first part of this paper the focus is put on the description of the term “virtual currency” and of Bitcoin in particular as the most important representative. We outline the basics of Bitcoin mining and the payment system as whole with all its advantages and disadvantages.

1.1 Virtual currencies

The money is subjected to a continuous evolution. From the time when animal tusks and salt lumps were used as the first media of exchange through the first minted coins, commodity backed banknotes till the use of fiat money the shape of the money has changed more than once and all these changes were for the sake of convenience. Animal hides were lighter and easier to manipulate with than mammoth tusks, golden coins were smaller than animal hides and eventually even those had to make space for light and foldable paper.

However, the question is where should the evolution of money proceed then? What can be lighter and easier to manipulate with than paper? How heavy are twenty bites, which are needed to write 1 000 000 in a binary number? The intangible money, which can eventually be represented by nothing more than a matchbox size piece of plastic, is the current step in the evolution of the money. And yet, even though the electronic money exists for roughly 50 years and its widespread use is even shorter, new

[1] http://blockchain.info/charts/market-cap

form of money is entering the market. These are so called virtual or digital currencies - currencies, because their sole purpose is to serve as money, and virtual as the natural environment of their use is "virtual" community, e.g. "…a place within cyberspace where individuals interact and follow mutual interests or goals" (European Central Bank, 2012).

Even though the terms virtual currency and digital currency are often considered synonymous, this is not strictly speaking true. Virtual currency is a type of currency used in any sort of virtual space, such as trading communities (e-gold), social networks (Facebook credits) or massive multiplayer games (World of Warcraft, Diablo). However only those that overlap the original virtual space they have been created for or have never been intended for one particular virtual space can be considered as digital currencies. These are not linked to any specific virtual community and can be used for various purposes. However, in the following text we will be using both terms as synonymous.

1.2 Cryptocurrencies and Bitcoin

Various virtual currencies have been created in past 20 years (with e-gold in 1996 being the first significant with its 5 million users) yet not all were able to survive till today. Before Bitcoin there was none which would have broken through the limits of the virtual community for which it was created and become a digital currency. Amongst many other reasons this was also caused by technical imperfections. It was actually Bitcoin that became the first digital cryptocurrency.

The name cryptocurrency stems from the use of cryptography for securitization of the digital currency. This is not the specialty of digital currencies, as cryptography is the cornerstone of every payment system used for the transfers of electronic money. However, in the case of cryptocurrencies the cryptography is also used for the creation of the currency itself.

The currency is created, or "mined", by spending computing power and as a consequence electrical energy to perform transactions of the currency between each set of two parties. All new transactions between a payer and a payee are broadcasted via peer-to-peer network to every connected mining “node” (= computer connected to the network of the cryptocurrency with mining software installed and running). Every single node then collects all the transactions available at a given point of time and puts them into a transaction block with two loose cryptographic keys attached (the amount of transactions in one particular block can vary from node to node). Each node is then trying to find a solution to a cryptographic problem of how to connect its new block’s loose key to an existing chain of blocks of transactions faster than the rest of the nodes. When a solution is found, the node publishes the solution to the whole peer-to-peer network to find out whether it was the fastest solution. If this is confirmed by majority of the nodes in the network, the block is attached to the chain, its other loose key becomes loose key of the block (to which new block has to be attached) and all the nodes start again with all the transactions that have not been yet connected to the chain. Also, the miner is awarded a fixed sum of currency for the effort plus a transaction fee from every transaction which has been performed in this block. This principle of how the cryptocurrency is being mined and transferred was first introduced by Satoshi Nakamoto on the case of Bitcoin. (Nakamoto, 2012)

There are four main advantages in this way of functionality of Bitcoin compared to the fiat currencies. Firstly, there is no central authority needed for the transaction or securitization of Bitcoins as the network of Bitcoin miners and users is based on the “peer-to-peer” basis mentioned before. In this setup every node connected to the network has access to information about all the transactions that are being performed using the currency. However this information contains only public keys, which in their substance are usable only for the transaction itself. This means that the physical payer or payee (a person) concerned in any of the transactions cannot be identified, unless she decides to do so by publishing her private key of the transaction.

This also means that the cryptocurrency network cannot be brought down simply by shutting down some main server or by a hacker attack. Even if all the nodes would be shut down except for one, the functionality of the currency would not be compromised and could be restored.

The second advantage is that there is no need for a central authority to regulate or mint the currency. As all the nodes are connected to the same network, they have access to the same amount of information. This set of information consists of the “block chain” which is an array of all the blocks containing all past transactions which have been previously successfully connected by solving the cryptographic problem; and of all transactions waiting to be executed. When a solution of connecting a new block of transactions is found, the majority of the network has to evaluate the verity of this solution, otherwise the block will not be added to the block chain and the network will be awaiting another solution from a different node. Thus the whole network functions as a controlling entity of authenticity of every single Bitcoin transferred.

The third advantage is impossibility of unexpected increase of the supply of Bitcoins in the market. As previously mentioned, Bitcoins are created by executing the transactions by finding a solution for a block connection problem. The fixed amount of Bitcoins awarded for this is given by the total amount of 21 000 000 Bitcoins that can ever be mined, 6 blocks connected in an hour and the half-life of the mining, which is 4 years. In the first four years, 2009 - 2012, 10 500 000 Bitcoins have been mined with 50 Bitcoins being the reward for each block. In the period of 2013 – 2016 the reward is 25 Bitcoins with total number of Bitcoins in circulation at the end of this period being 15 750 000.[2] These parameters are hard-coded into the mining clients of every node and cannot be changed. This also means that at every single point of time the current amount of Bitcoins in circulation is predetermined.

[2] https://en.bitcoin.it/wiki/Controlled_Currency_Supply

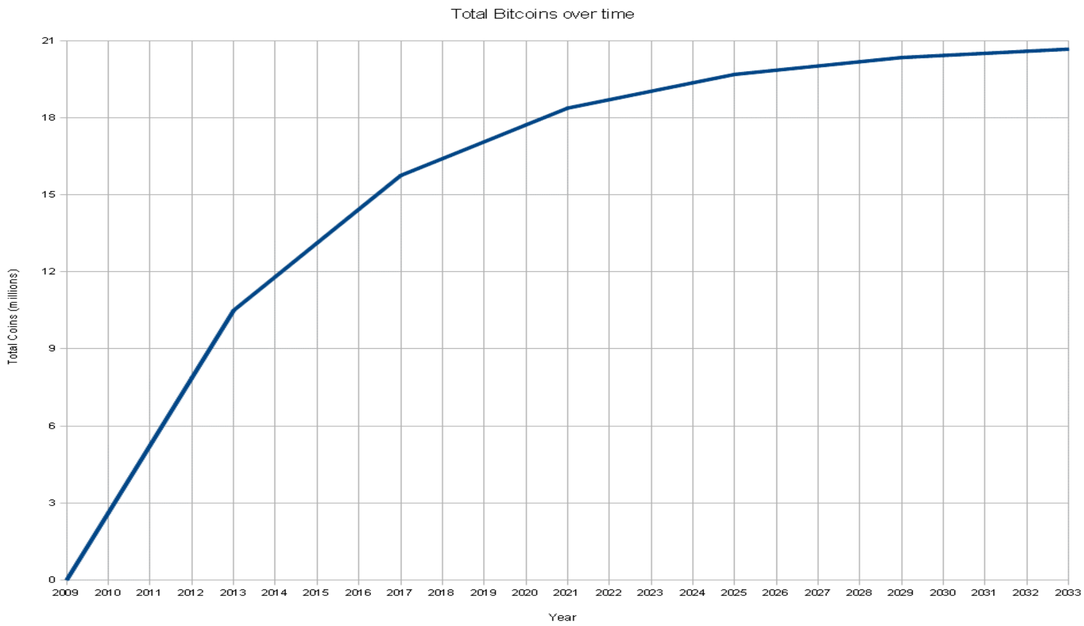


Figure 1 – Total projected amount of Bitcoins through time.

Source: www.wikipedia.org

The fourth advantage of Bitcoin is the reduction of transaction time. Nowadays, the financial institutions have a technical background to execute every money transaction in less than an hour and yet this time is generally counted in days. However, in the case of Bitcoin the time needed to perform a transaction is roughly 10 minutes; that is approximately how long it takes to find a solution to connecting a new block of transactions to the existing block chain. When the time needed for this gets substantially lower due to increased global computational power dedicated to Bitcoin mining, the peer to peer network of clients automatically increases a parameter of difficulty of the block connection problem (it sets up an artificial difficulty threshold and decides not to use some of the easier solutions offered) so that the total award for mining does not exceed the predetermined amount and the speed of executing the transactions remains roughly constant.

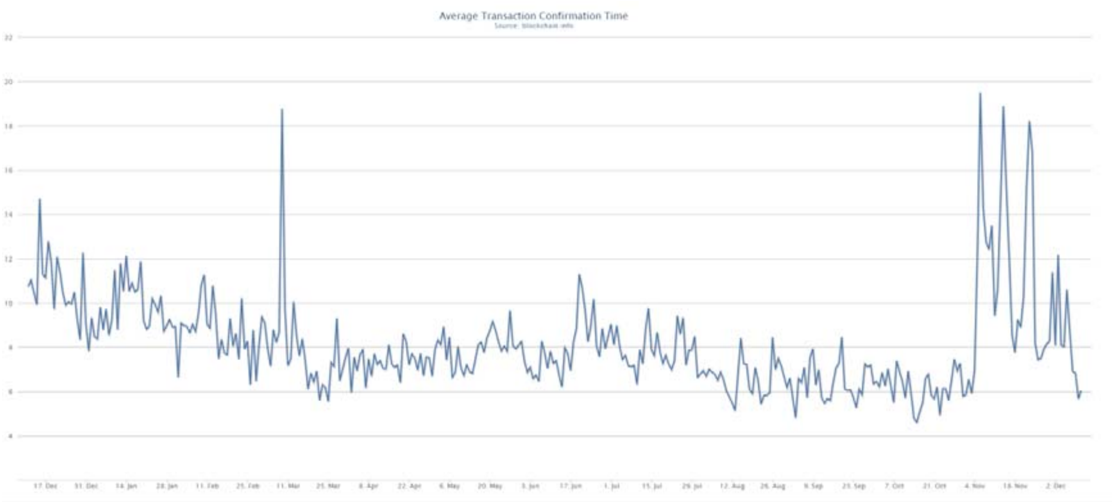


Figure 2 – Average time needed to execute a transaction. Year 2013

Source: www.blockchain.info

1.3 The security and double-spending of Bitcoin

The lack of central emitting and regulatory authority has twofold effect on the nature of Bitcoin. As it was mentioned before, the amount of Bitcoins in the world is precisely known at any point of time which brings stability to its system. However, concerns have been raised about quality of securitization of the Bitcoin network. Any computer network can be a subject of a digital attack of hackers, who might be able to duplicate or double-spend the currency.

This is not strictly speaking true, as any network which is to be attacked by hackers has to have central servers which would be attacked. In the case of peer to peer network, where no central authority/server exists, a successful attack would mean that more than a half of nodes currently connected to the network would have to be attacked simultaneously. In other words Bitcoins can be double-spent or duplicated only if a majority of the nodes approve a block where Bitcoins are double-spent. Yet with rapidly growing amount of connected nodes this is more than improbable.

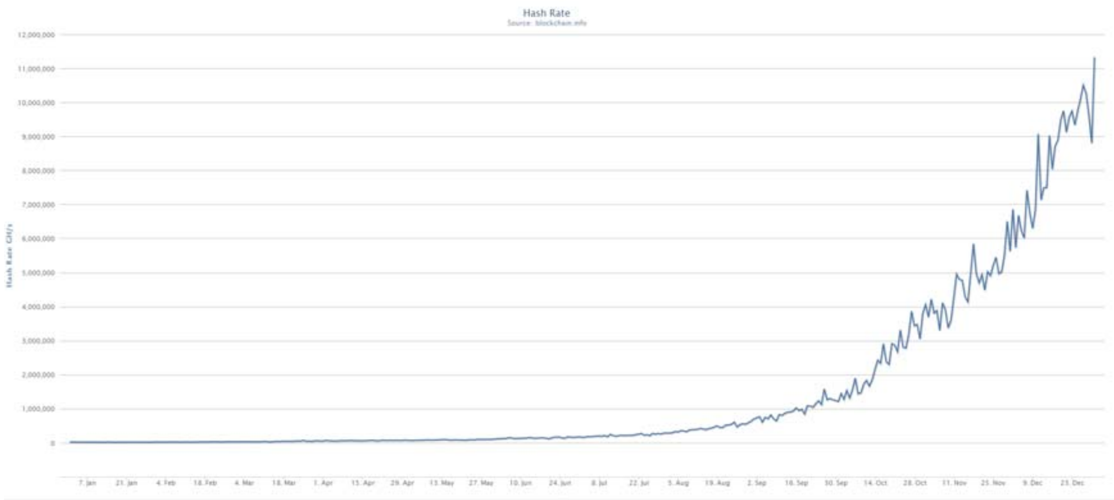


Figure 3 – Computational power of Bitcoin network as a proxy to the number of Bitcoin miners. Year 2013

Source: www.blockchain.info

1.4 Economic definition of Bitcoin

Bitcoin was originally created as a substitute for national currencies. This implies that it should be considered to fulfill the definition of money despite its very special nature. Mankiw (2008) specifies three purposes of money: a store of value, a unit of account and a medium of exchange. Bitcoin satisfies all three of them. It can serve as a store of value, even though currently a very imperfect one - the value of one Bitcoin is extremely volatile to be an effective value repository; despite the fact that in the time of crisis it can prove to be trusted more than national or supranational currencies, such as Euro in Cyprus. Bitcoin has no expiration date as it does not lose quality over time, so it might easily serve as a reliable store of value when the variation of its price decreases.

Second part of money definition is function as a unit of account. There are no difficulties here as the information about current value of one Bitcoin is public and easily available. The only difficulty here is again the variation of its price due to the menu costs. For the sake of the case when price of one Bitcoin would climb too high and it couldn't be lowered by emitting more Bitcoins (which is impossible due to the basic principle of Bitcoin), all the Bitcoin-related systems are working with 8 decimal numbers. With upper limit of 21 million Bitcoins this means that there will be 2.1×10^{15} units in the Bitcoin system. That is roughly 30times more than gross world product in 2012 in US dollars.[3] Strictly theoretically speaking, if Bitcoins were to completely replace American dollars of which there are 1.23 trillion in circulation at the end of December 2013[4] and keep the same value of total currency, one Bitcoin would be worth roughly 58 thousand dollars.

Concerning the third function of money, a medium of exchange, there is no doubt that Bitcoins have this function. According to spend.bitcoins.com there are 1610 physical places as of the end of December 2013 where Bitcoin is accepted as a form of payment.[5] Coinmap.org, interactive map of the Bitcoin accepting venues shows at the same time 2044 physical locations where Bitcoin is accepted; 27 of them are located in Czech Republic.

By fulfilling these three definitions Bitcoin can be considered to be money. Even though it is not yet being used as much as fiat currencies, the number of places where Bitcoins can be spent is growing every day strengthening the position of Bitcoin as money.

However, it has also been argued that Bitcoin could better be defined as a commodity (Trading Titan Blog, 2012). According to Ballentine's law dictionary commodity is: "*A useful thing; an article of commerce; a movable and tangible thing produced or used as the subject of barter or sale*." (Anderson, 1969) The core of the argument whether or not Bitcoin is commodity is its tangibility. There is no common physical form of Bitcoin, even though anyone can mint a coin with a private key which represents value in Bitcoins on it.[6] So the discussion shrinks to the polemics whether a magnetic record created on a HDD of a computer where Bitcoins are recorded is tangible enough to be considered a commodity.

[3] https://www.cia.gov/library/publications/the-world-factbook/geos/xx.html
[4] http://www.federalreserve.gov/faqs/currency_12773.htm
[5] https://www.spendbitcoins.com/places/
[6] https://www.casascius.com/

Grinberg (2011) explains what Bitcoin has in common with commodities and its similarity to securities and argues that similarly to securities Bitcoin is intangible defying the definition of commodity:

"Owning a Bitcoin gives one only rights to use the Bitcoin in any way one sees fit and to sell or make contracts involving that Bitcoin. Similarly, one who owns, say, corn, has only the right to use the corn (by, e.g., making corn-on-the-cob or processing it into biofuel) or to sell the corn or make contracts involving that corn. Securities, on the other hand, have a feature that commodities do not have: they confer a claim on some other entity. In these ways, Bitcoin is like corn and any other commodity. However, decisions explaining why commodities are not securities have also noted that commodities are "tangible" and have "inherent value," unlike securities. Bitcoins are not "tangible," and one may argue that by design they have no inherent value because there is no government or commodity backing them. Furthermore, just as one generally cannot "use" a security — except by buying, selling, or pledging it—one cannot "use" a Bitcoin except by buying, selling, or pledging." (Grinberg, 2011)

The author's opinion is that the physical records of Bitcoins cannot be considered as basis of commodity. If it was to be considered a commodity, there would have to be a physical way of dividing the Bitcoins amount. E.g. if we would have 10 Bitcoins in our wallet stored on a flash disk, we would expect to have a chance to physically break the flash disk in half making it effectively two disks with 5 Bitcoins on them. More generally we think that Bitcoin cannot be clearly defined in terms of present asset types. Even though it arguably does fulfill the necessary attributes of money its acceptance is still not widespread enough. However, it cannot be considered to be a commodity either as its only function is to represent some value and apart from that it has no other use. The standpoint of Finland, which will be described in further sections, seems to capture the best the nature of Bitcoin as of now, however, it might change in the future if Bitcoin becomes more widespread and its value will become less volatile.

2 Literature review

There is generally a small amount of economic papers written on the subject of Bitcoin, with most of them being written in late 2013. Graf (2013) inspects history of monetary evolution resulting into the genesis of Bitcoin. He describes how the value of a Bitcoin was first determined and the progression of its use. This work follows series of articles concerning monetary aspects of Bitcoin written previously.

Šurda (2012) argues whether Bitcoin can evolve into form of money which could be alternative to the fiat currencies or gold. Viewing from Austrian school point of view he points out Bitcoin's superiority to fiat currency and gold in low transaction costs and inelastic supply. Šurda (2012) empirically inspects the price data of Bitcoin from January 2009 to November 2012 to find connection between liquidity and volatility of Bitcoin. The negative correlation he finds reinforces his view of Bitcoin as medium of exchange.

The relationship between price of Bitcoin and search queries on Google and Wikipedia has been reviewed and econometrically tested by Krištoufek (2013). He points out the fact that there is no underlying asset behind Bitcoin and no connection to any sovereign. His econometric models show very strong bidirectional relationship between searches and price of Bitcoin, concluding that this shows that the price of a Bitcoin is subject to nothing else but speculation and trend chasing. (Kristoufek, 2013)

Roio (2013) identifies two important political and sociological events determining the price of Bitcoin. First was the financial blockade of Wikileaks on the 7th of December 2010, which effectively made donations using Visa or MasterCard impossible. This was followed by sharp increase of Bitcoin price from \$0.22 at this time and peaking at \$1.06 on the 12th of February, crossing the 1 dollar threshold for the first time.

The second event presumably started the first Bitcoin bubble. It was a publishing of a first article on Bitcoin in Forbes on the 9th May 2011. On this day MtGox was closing at \$3.80 per one Bitcoin; the price doubled in next five days, when it closed at

$7.86. The bubble peaked on the 9th of June of the same year, closing at $29.58 per one Bitcoin (Roio, 2013).

The taxation issues of Bitcoin are explored by Marian (2013). He argues that cryptocurrencies, such as Bitcoin, could be used as a different approach to tax-evasion and replace tax-havens eventually. He further states that governments are not seeing the true graveness of this issue. They might prove to be too inflexible to accommodate to the approach of the digital currencies in terms of their legislative.

Brito & Castillo (2013) explore the general benefits and caveats of Bitcoin. They argue that high volatility of Bitcoin is not a problem as long as the main usage of Bitcoin is not storage of value or unit of account. Low transaction costs accompanied with usage of Bitcoin overcome the inconvenience with following of current price on the exchanges. This inconvenience can be bypassed completely by quoting the value of goods in fiat currency and then paying in Bitcoins according to current exchange rates. As transactions are executed almost immediately, exchange rate risk diminishes rapidly. They also suggest that volatility of Bitcoin is most likely to decrease in future as Bitcoin and its schemes will become more familiar to public and more realistic expectations will be developed by public. (Brito & Castillo, 2013)

In the same paper (Brito & Castillo, 2013) the authors also approach regulatory issues noting that emergence of Bitcoin was as unexpected for policymakers as was VoIP (Voice over Internet Protocol) in the near past. They expect unequal treatment of Bitcoin in legislatives of different countries as Bitcoin generally complies with definitions of commodity, electronic payment system and currency. Specifically they point out legality of Bitcoin as currency in the USA. Finally they introduce a few recommendations to policymakers on how to approach regulation and future development of Bitcoin. (Brito & Castillo, 2013)

Kaplanov (2012) approaches the problems of regulations a year before Brito & Castillo (2013), in the times when Bitcoin was not a hot topic yet. He describes the nature of Bitcoin and strongly encourages judges and policymakers to become familiar with the Bitcoin technology. He proposes the same for law enforcers as an answer to money laundering issues. He points out that when correctly understood the Bitcoin scheme (more specifically the block chain) can help to discover the illegal activities Bitcoin is being used for. Kaplanov (2012) also stresses that understanding Bitcoin and flexibly adapt the legislative could avoid problems which could arise by its prohibition.

Eyal & Sirer (2013) from Cornell University are inspecting the game theory aspects of Bitcoin mining. They show how the incentive-compatibility condition that supports honest mining can be broken by colluding miners to obtain bigger than fair share of the revenue. Eventually majority of the miners would join this collusion and Bitcoin would cease to be decentralized. They also propose a solution to how to overcome this issue. (Eyal & Sirer, 2013)

3 Legal status of Bitcoin around the world

The following part revolves around the recognition of Bitcoin by governments and its legal status in countries around the world. We are introducing countries which have banned the use of Bitcoin, recognized it as a form of money and even some which have labeled it as “profit from property rights”.

Since the beginning of 2013 there have been many discussions around the world about the legal status of Bitcoin and about legality of operations of the Bitcoin exchanges. These include most importantly discussions about whether or not can Bitcoin be classified as a currency and what approach should be used for the taxation of earnings made in Bitcoins.

We will address the Bitcoin related decisions according to the size of the Bitcoin market in the given country and also by the gravity of the decisions and the stemming consequences. At the end of year 2013 the biggest Bitcoin market share constitutes of USD exchanges, Mt. Gox and Bitstamp. They represent 50% of the world’s Bitcoin trade volume. The Chinese exchange BTC China (BTC is an acronym for Bitcoin) represents 43% of the market, with its share decreasing in last days of 2013. This attributes to legal difficulties in China. The rest 7% represents all other Bitcoin exchanges around the world.

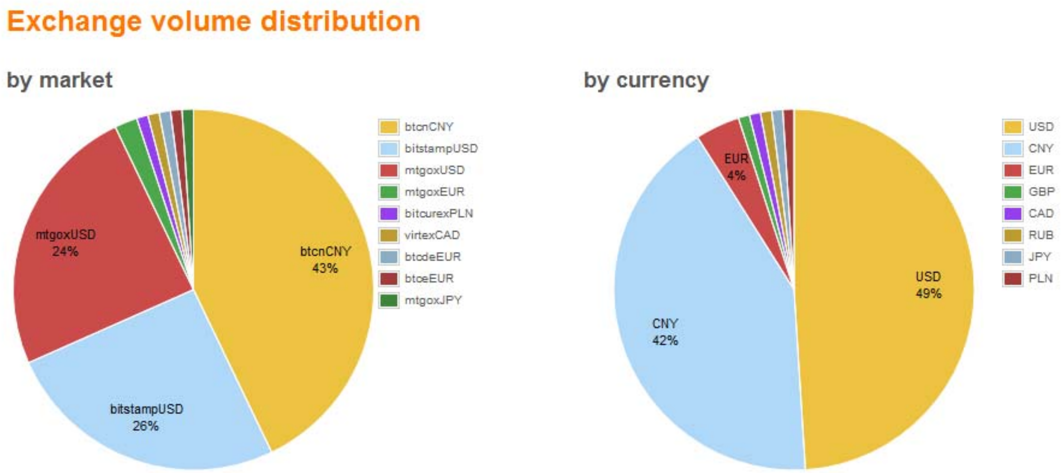


Figure 4 – Global exchange volume distribution on 30.12.2013.

Source: bitcoincharts.com

The distribution of volume according to currencies generally follows the same pattern. USD represents 49% of the traded volume and CNY 42%. EUR has 4% share with other relevant currencies being GBP, CAD, RUB, JPY and PLN, all under 1% of global trade volume. The average volume of the total Bitcoin market in December 2013 was 120 000 traded Bitcoins per day.[7]

3.1 USA

The first legal statement concerning Bitcoin was made by Financial Crimes Enforcement Network (FinCEN) of United States' Department of the Treasury on the 18th of March 2013. It approaches the question whether the digital currencies users can be classified as money transmitting businesses. Firstly the term "convertible virtual currency" is defined, quoting:

„In contrast to real currency, "virtual" currency is a medium of exchange that operates like a currency in some environments, but does not have all the attributes of real currency. In particular, virtual currency does not have legal tender status in any

[7] Blockchain.info

jurisdiction. This guidance addresses "convertible" virtual currency. This type of virtual currency either has an equivalent value in real currency, or acts as a substitute for real currency." (Financial Crimes Enforcement Network of United States department of the Treasury, 2013)

Bitcoin clearly satisfies this definition as its purpose is to function as money. It functions as a currency in an environment consisting of any individual holding Bitcoins in his virtual wallet, companies accepting Bitcoin, the decentralized peer to peer network of nodes and the Bitcoin exchanges. The equivalent value in real currency is specified as well as for any other currency on any foreign exchange. The exchanges for Bitcoin are opened 24 hours a day and the ticks are being made roughly every second. The second quote approaches the money transmission problem:

"A person that creates units of this convertible virtual currency and uses it to purchase real or virtual goods and services is a user of the convertible virtual currency and not subject to regulation as a money transmitter. By contrast, a person that creates units of convertible virtual currency and sells those units to another person for real currency or its equivalent is engaged in transmission to another location and is a money transmitter. In addition, a person is an exchanger and a money transmitter if the person accepts such de-centralized convertible virtual currency from one person and transmits it to another person as part of the acceptance and transfer of currency, funds, or other value that substitutes for currency." (Financial Crimes Enforcement Network of United States department of the Treasury, 2013)

This has very important consequences as the money transmitting business must obey two key measures, "Anti-Money Laundering" and "Know Your Customer." These are enforced by USA Patriot Act and require recordkeeping of certain information related to all sides in any business transaction, specifically:

"(i) the identity and address of the participants in a transaction or relationship, including the identity of the originator of any funds transfer;

(iii) the identity of the beneficial owner of the funds involved in any transaction, in accordance with such procedures as the Secretary determines to be reasonable and practicable to obtain and retain the information;" (Public Law, 2001)

This would imply loss of anonymity for all the Bitcoin using money transmitters defined in the quotation above.

One of the results of this legal guidance was shown in June 2013 when the U.S. Department of Homeland Security seized 2.9 million USD from Dwolla (US payment network that allows any business or person to send, request and accept money[8]) account belonging to MtGox and 2.1 million USD from MtGox's Wells Fargo bank account. (Seizure warrant, 2013) Both of these were result of failure of MtGox exchange to register as money transmitting company in United States of America. (Dillet, 2013)

Second important decision was made on the 6th of August 2013 by a Federal judge in case of Securities and Exchange Commission versus Trendon T. Shavers, founder and operator of Bitcoin Savings and Trust. This trust was uncovered to be actually a Ponzi scheme which in August 2012 defrauded 263 104 Bitcoins, and the accused defended himself that he cannot be prosecuted in a matter of financial crime as "*Bitcoin is not money, and is not part of anything regulated by the United States*." (United States Magistrate Judge Mazzant, 2013)

However the Federal judge, Amos L. Mazzant, was of a different opinion:

"It is clear that Bitcoin can be used as money. It can be used to purchase goods or services, and as Shavers stated, used to pay for individual living expenses. The only limitation of Bitcoin is that it is limited to those places that accept it as currency. However, it can also be exchanged for conventional currencies, such as the U.S. dollar, Euro, Yen, and Yuan. Therefore, Bitcoin is a currency or form of money…" (United States Magistrate Judge Mazzant, 2013)

This was the first legal recognition of Bitcoin as a currency in the world.

[8] www.dwolla.com

The question of taxation of Bitcoin and virtual currencies has only been answered by Internal Revenue Service (IRS) in March 2014. It defines Bitcoin as a convertible virtual currency based on the existence of an equivalent value in the real currency. For tax purposes it is considered to be property with capital gain tax and all the taxation principles applicable. Also a fair value of any Bitcoins mined has to be considered as part of gross income of an individual. (Internal Revenue Service, 2014)

3.2 Germany and the European Union

German Ministry of finance announced its first decision on Bitcoin in less than two weeks after the U.S. Federal judge, on the 17th August 2013. The Ministry confirmed a 2011 definition from BaFin, German financial supervisory authority, that Bitcoin is a form of private money and that their mining is money creation. As such Bitcoins are subjected to capital gains tax of 25%. The tax must not be paid if Bitcoins are held for more than 1 year. (Nestler, 2013) (Gotthold & Eckert, 2013)

There is one advantage for promotion of Bitcoin in Europe compared to United States. As Karl-Friedrich Lenz, German professor of German, European and International trade law points out:

"…if someone gets a "regulated market" licensed under the EU MIFID Directive, they need to deal only with the regulator of their own Member State. You don't need to run around all the 27 Member States applying for licenses." (Lenz, 2013)

Thus any Bitcoin exchange can ask for the license to serve as a "regulated market" in one EU country and provide their services in any other member state.

On the 13th of December 2013 Reuters reported the only statement on the matter of Bitcoin from European Union officials so far. The European Banking Authority warned the public that Bitcoins have no protection or compensation in the case of their theft. There are no laws in European law to protect users of virtual currencies. EBA also warned about potential tax liabilities of Bitcoin users towards any of the EU members. (Jones, 2013)

3.3 China

Chinese Bitcoin market is second most important, very closely following the American one. Its 30 days trade volume (at the end of December 2013) was roughly 2 million Bitcoins compared to 2.1 million in USD.[9] There have been huge expectations connected to Bitcoin on Chinese market stemming from its private and cryptographic nature. In China, where any export of currency is strictly restricted to very small amounts, Bitcoin usage could undermine this regulated environment.

The official statement form People's Bank of China (PBC), the Chinese central bank on the 5th of December was dismissive. It also showed how the Chinese expectations have increased the price of Bitcoin in weeks preceding this statement. On the 4th of December, MtGox was closing at $1 235 per Bitcoin. During the next 24 hours the price plummeted to $1 021 per Bitcoin and was closing at $697 on the 7th of December.[10]

In the official statement (unofficially translated as PBC did not provide English version of this statement) is PBC stating the following:

"Clearly defining the nature of Bitcoin, which is not issued by a central monetary authority, it does not possess characteristics of legal tender, and does not have real meaning as a currency. On the nature of Bitcoin, Bitcoin is a specially-designated virtual commodity or good, and does not have the same legal status as currency, and cannot be used as circulating currency in the market. However, Bitcoin trading constitutes a method of buying and selling commodities online, and ordinary people are free to participate, so long as they are willing to assume the risk.

It is required that, at this stage, financial and payment institutions may not use Bitcoin pricing for products or services, may not buy or sell Bitcoins, may not act as a central counterparty in Bitcoin trading, may not offer insurance products associated with Bitcoin, may not provide direct or indirect Bitcoin-related services to customers,

[9] http://bitcoincharts.com/markets/ on 23rd of December 2013
[10] www.mtgox.com

including: registering, trading, settling, clearing or other services; accepting Bitcoin or use of Bitcoin as a clearing tool; trading Bitcoin with CNY or foreign currencies; storing, escrowing, and mortgaging in Bitcoin; issuing Bitcoin-related financial products; and using Bitcoin as a means of investment for trusts and funds."(The People's Bank of China, 2013)

The impact of this decision is much graver than in case of Germany due to the volume of the Chinese Bitcoin market. Even though individuals can still trade Bitcoin on their own, the companies are effectively banned from using it.

The position of Bitcoin in China was shaken even more on the 18th of December, when chief executive of BTC China, by far the biggest Bitcoin exchange in China with 99% of Yuan volume traded,[11] announced that BTC China can no longer accept deposits in CNY (Hern, 2013). This was due to the fact that PBC "*…extended that ban to payment companies like YeePay, and gave them until Chinese New Year, which begins on 31 January, to comply*" (Lee, 2013). This decision also made trading of Bitcoins almost impossible for individuals as they have no possibility to buy Bitcoins without third party payment companies (Hern, 2013). The effect of this decision was immediately projected in the price of Bitcoin which fell from $723 per Bitcoin at 11:00 p.m. on 17th of December to $457 per Bitcoin only 13 hours later even on non-Chinese exchange MtGox.[12]

[11] www.bitcoincharts.com
[12] www.mtgox.com

3.4 The rest of the world

3.4.1 Canada

Canada is a very open minded and progressive country, at least as far as digital currencies are concerned. It was the first country where Bitcoin ATM could be found. (Cieslak, 2013) This ATM can exchange Bitcoins for fiat currency and vice versa. The Canadian government has also made a statement concerning taxation of digital currencies. In its short memo on their webpage an explanation of what digital currencies are and how they should be approached concerning taxation can be found. The most important part of this memo tells that Canadian government does not consider digital currencies, including Bitcoin, to be real currency.

"Where digital currency is used to pay for goods or services, the rules for barter transactions apply. A barter transaction occurs when any two persons agree to exchange goods or services and carry out that exchange without using legal currency." (Government of Canada, 2013)

Thus according to Canadian law the value of Bitcoins earned from a barter trade should be converted to the value in Canadian dollars and this amount used for taxation purposes. However, if Bitcoin is used for speculative purposes only, this is considered to be commodity trading according to the Canadian government memo. The gains or losses stemming from speculative trading have to be taxed as well.

3.4.2 Finland

The Finnish Tax Administration (2013) has issued a specialized document considering the taxation issues of digital currencies. It states that virtual currencies are neither money nor securities but that they are considered as an unspecified agreement and the proceeds from the selling of Bitcoins are "monetary benefits". As such they are subjected to tax act and should be taxed as a capital income. However, any contractual liabilities associated with Bitcoin loss are not tax-deductible.

It also defines taxability of Bitcoin mining. It defines Bitcoin mining as earned income and the proceeds from mining are to be taxed as such in the value of national currency (Euro) using the effective exchange rate from the day when the miner received newly mined Bitcoins.

Companies accepting payments in Bitcoins are supposed to, according to the same document, use the exchange rate of the day when Bitcoins were received as a payment to translate the amount into Euro for tax purposes.

3.4.3 Norway

According to the Norwegian Tax Administration Bitcoins are an asset and as such are supposed to be taxed on the gain on sale. Also any proceeds from sale of Bitcoins made by businesses are subjected to Value added tax. They also stated that Bitcoins are not regarded as legal tender. (Lorentzen, 2013)

3.4.4 United Kingdom

Her Majesty's Revenue & Customs, the United Kingdom's tax authority, issued a brief on the taxation of Bitcoins. It states that no value added tax is to be paid from proceeds of Bitcoin mining nor exchange of Bitcoin for Sterling or other foreign currencies. However VAT is to be paid in a usual way from suppliers of goods and services sold for Bitcoin. In relation to businesses operation Bitcoin is treated as any other currency meaning that corporation tax, income tax and capital gains tax are to be paid on Bitcoin. (HM Revenue and Customs, 2014)

3.4.5 Denmark

The same decision was made by tax authorities in Denmark. Individuals who are earning Bitcoins by mining do not have to tax the proceeds of the mining. The only exception are legal entities who sell goods for Bitcoins and both legal entities and individuals who are using Bitcoins for speculative purposes. This is already third denial in Denmark of Bitcoin being a currency. Before the tax authorities it was Central bank and Financial Services Authority of Denmark who made the same decision. (Hannestad, 2014)

3.4.6 Poland

Poland is amongst the 10 biggest miner of Bitcoins amongst the countries around the world and thus Bitcoins are closely regarded in Poland. An official from Polish Ministry of Finance announced that Bitcoins are not illegal in Poland; however, they are not considered to be legal tender. Bitcoins are to be taxed as profits from property rights. However, any regulations are not to be proposed until there will be an official statement from the European Union. (Wierciszewski, 2013)

3.4.7 Thailand

The status of Bitcoin in Thailand is definitely not stable. It was the first country in the world to effectively ban usage of Bitcoins. Bitcoin Co. Ltd., Thai company specialized in mining, trading and promoting Bitcoin in Thailand, reported their struggles with Thai authorities when trying to register to serve as a legal financial operator. After the official money exchange license was received and subsequently canceled by the Bank of Thailand, the company was invited in July 2013 to participate on a conference on Bitcoin with following result:

"At the conclusion of the meeting senior members of the Foreign Exchange Administration and Policy Department advised that due to lack of existing applicable laws, capital controls and the fact that Bitcoin straddles multiple financial facets the following Bitcoin activities are illegal in Thailand:

- *Buying Bitcoins*
- *Selling Bitcoins*
- *Buying any goods or services in exchange for Bitcoins*
- *Selling any goods or services for Bitcoins*
- *Sending Bitcoins to anyone located outside of Thailand*
- *Receiving Bitcoins from anyone located outside of Thailand"* (Bitcoin Co. Ltd., 2013)

Thus Thailand was the first country in the world to officially prohibit the usage of Bitcoins. However, in mid-February 2014 the same company, Bitcoin Co. Ltd. started to trade Bitcoins again based on a second letter from the Bank of Thailand (Sakawee, 2014). On the 18th of March the same authority issued a press release with a set of information about Bitcoin aimed for the public (The Bank of Thailand, 2014). It states that Bitcoin is not a legal tender in Thailand and any Bitcoin payment can be rejected by a merchant. Also it warns the Bitcoin users of its volatility and possibility of theft.

3.4.8 Russia

Before any official statement was made, both critics and promoters of virtual currencies appeared in Russia. Former economy minister and current CEO of largest Russian state-owned bank Sberbank, Herman Gref, referred to a potential ban of Bitcoin in Russia as to a "colossal step backwards" (Pronina & Kravchenko, 2014). Current economy minister, Alexei Ulyukayev, was more reluctant to give his opinion on status of virtual currencies.

On the 27th of January 2014 the central bank of Russia, Bank of Russia, has issued a statement on the legality of Virtual currencies, particularly Bitcoin, in Russia. In this statement it warned the Russian citizens and legal entities that *"…using the 'Virtual currencies' for exchange for goods or cash will be regarded as a potential involvement in the implementation of suspicious transactions in accordance with the legislation on counteraction to legalization (laundering) proceeds of crime and financing of terrorism."* (The Bank of Russia, 2014)

It was also pointed out in this statement that issuance of monetary surrogates is prohibited by Article 27 of Federal law On the Central Bank of the Russian Federation (Bank of Russia). Here it is clearly stated that *"…the issue of any other monetary units (than roubles) or quasi-money shall be prohibited in the Russian Federation."* (State Duma, 2002)

Thus Bitcoin mining is forbidden in Russia and any trading of Bitcoin will be regarded suspicious. This does not legally stop Bitcoin trade in Russia; however, it is expected to cripple the trade significantly.

3.5 Conclusion

From the preceding parts it can be seen that it is not easy to classify Bitcoin and that most of the countries listed were not prepared for its recognition. It is definitely not easy to define what Bitcoin is from the legal point of view, however, the governments should act more flexibly in order to protect their citizens who get in touch with Bitcoin. More importantly it can be seen from the previous section that the issue of Bitcoin taxation can be solved in various ways and the author's opinion is that it should be taxed.

4 The Fall of MtGox exchange and the future of Bitcoin

Even though the system of Bitcoin is believed to be not susceptible to hacker attacks, there are still weak spots in the system which proved to be dangerous for the whole existence of the concept of Bitcoin. One of these weak spots is the security of exchanges and intermediaries who act as custodians of their clients' Bitcoins.

The first important security failure happened in June 2011 when more than 400 000 Bitcoins (6% off all Bitcoins ever mined at the time) were stolen by a hacker from the MtGox exchange. When the hacker tried to sell the Bitcoins later on the same exchange for the current price of $17.50, the price dropped down close to zero, forcing the representatives to close MtGox exchange for 4 days. After this time the Exchange was reopened and the victims of the hacker attack were reimbursed from the MtGox's own funds. The underlying problem was however not security issue in the Bitcoin algorithm, but in the MtGox's security system:

"MtGox says access to its site was gained after a financial auditor's computer was hacked, and insists its site was not compromised.

But Amir Taaki, who runs the rival Bitcoin exchange Britcoin.co.uk, disputes this chain of events. Developers working on his site, which runs on much of the same software as MtGox, found a security hole several days before the hack was carried out. He says MtGox was notified publicly and privately of the problem. (Ball, 2011)

More important breakdown of security and also a terminal one for the MtGox exchange happened in February 2014. Mark Karpeles, representative director of MtGox Co., Ltd. stated in an announcement regarding an application for commencement of a procedure of civil rehabilitation, which is a Japan form of bankruptcy protection:

"At the start of February 2014, illegal access through the abuse of a bug in the bitcoin system resulted in an increase in incomplete bitcoin transfer transactions and we

discovered that there was a possibility that bitcoins had been illicitly moved through the abuse of this bug.

As a result of our internal investigation, we found that a large amount of bitcoins had disappeared. Although the complete extent is not yet known, we found that approximately 750,000 bitcoins deposited by users and approximately 100,000 bitcoins belonging to us had disappeared." (Karpeles, 2014)

These 850 000 represented at the moment approximately 6.8% of all Bitcoins "in circulation".[13] Coincidentally later on 200 000 Bitcoins belonging to MtGox were found:

"…on March 7, 2014, MtGox confirmed that an old-format wallet which was used prior to June 2011 held a balance of approximately 200,000 bitcoins…". (BBC, 2014)

The effect on the whole Bitcoin market and users community was devastating. The following charts are showing the exchange volume distribution two months after the bankruptcy of MtGox:

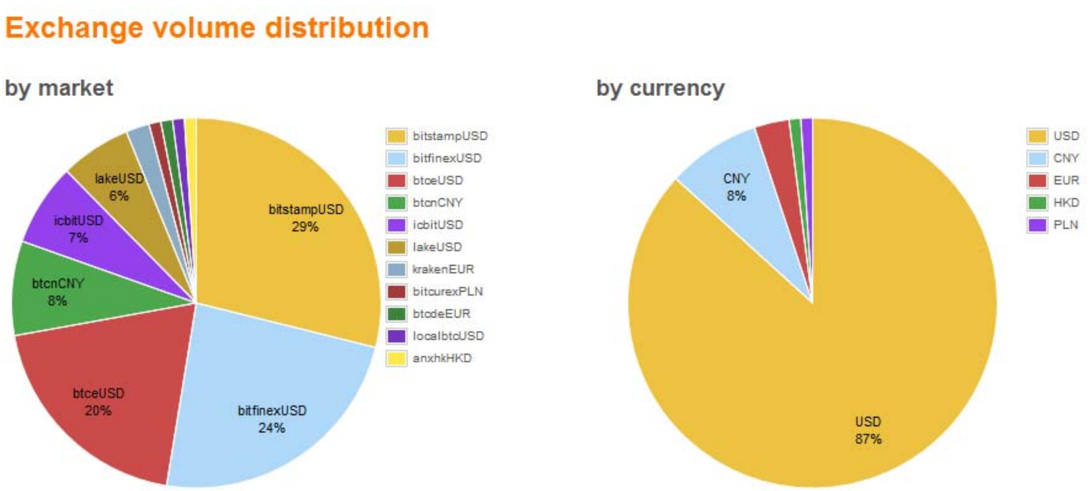


Figure 5 - Global exchange volume distribution on the 13.04.2014.

Source: bitcoincharts.com

[13] www.bitcoincharts.com

For comparison see the same chart from end of 2013 in the third chapter. The market has approximately halved in the same time period with the amount of Bitcoins traded in April 2014 being on average 60 000 per day. Very significant is the decline of Chinese Bitcoin market. The Bitcoin China represented 43% of global Bitcoin market at the end of 2013. A hundred days later the share of Chinese most important Bitcoin exchange shrunk to only 8%. The USD market represents 87% of total volume with three biggest players taking up 73% in total. The price of Bitcoin and the volume traded on BitStamp exchange is depicted on the chart below. A clear declining trend can be observed since the beginning of 2014.

Figure 6 – Price of Bitcoin and volume traded on BitStamp exchange. June 2013 – May 2014

Source: www.bitcoincharts.com

It is true that the bankruptcy of MtGox was an unexpected and painful blow to the reputation of Bitcoin. However the author’s view is that it should not endanger the existence of Bitcoin as such. It can be considered as an end of an era of wild Bitcoin trading and most probably the interest in Bitcoin will subside. It might eventually happen that Bitcoin will cease to exist in the future, however, the idea of cryptography based virtual currencies will prevail in its successors, such as Ripple or Litecoin.

5 Volatility inspection of Bitcoin price

5.1 Motivation

The volatility is an important property of any financial asset. It is the basic measure of risk to which is the investor exposed when buying an asset. For this reason it is crucial for any Bitcoin investor to assess the potential threats arising from Bitcoin volatility. The easiest way to observe the volatility of an asset is to compare its returns against returns of another asset which is being traded on global market in high volume. For this comparison I have chosen two very different assets, gold and NASDAQ composite index.

It can be observed from the following figure that the daily volatility of Bitcoin (in red) is substantially higher than volatility of either gold or NASDAQ composite index. The data shows that in the observed period even the highest daily log return of gold (-0.096) is approximately ten times lower that the highest spike in Bitcoin's log returns (-0.85018).

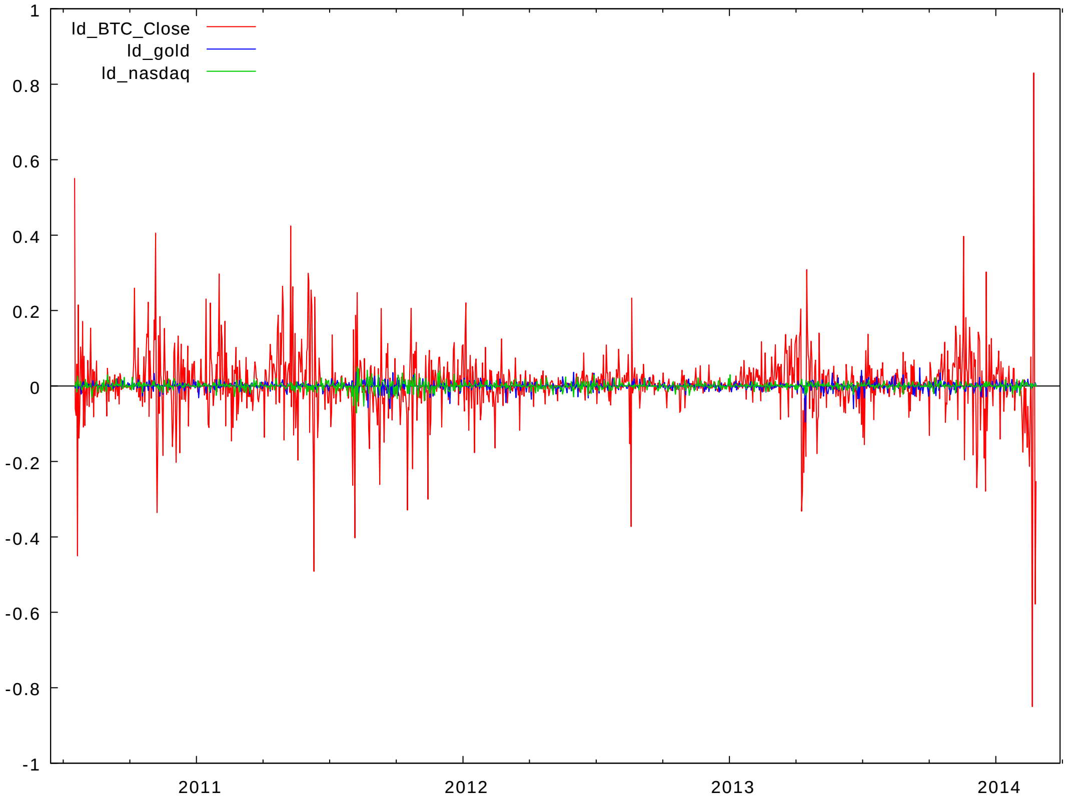


Figure 7 – Comparison of volatility of Bitcoin, gold and NASDAQ index.

Source: Bloomberg, MtGox

From the chart above it can be observed not only that the absolute level of the Bitcoin volatility is much higher than in case of either gold or NASDAQ index but also that the volatility of Bitcoin varies through time. While the volatilities are incomparable in winter 2010 and first half of 2011, there are periods in 2012 where they do not differ much. The third observation that can be made is that there seems to be volatility clustering in the Bitcoin data. As stated by Mandelbrot when speaking about price changes:

"…large changes tend to be followed by large changes – of either sign – and small changes tend to be followed by small changes…" (Mandelbrot, 1963)

5.2 Dataset

The dataset chosen for the econometric part of this paper consists of daily closing Bitcoin prices on MtGox exchange from the first quotation (17th of July 2010) till the very last one before the crash of MtGox (25th of February 2014). Thus it consists of 1320 observations in total. The original data series, shown on the chart below, will be referred to as “BTC_Close” due to the fact that these are closing prices.

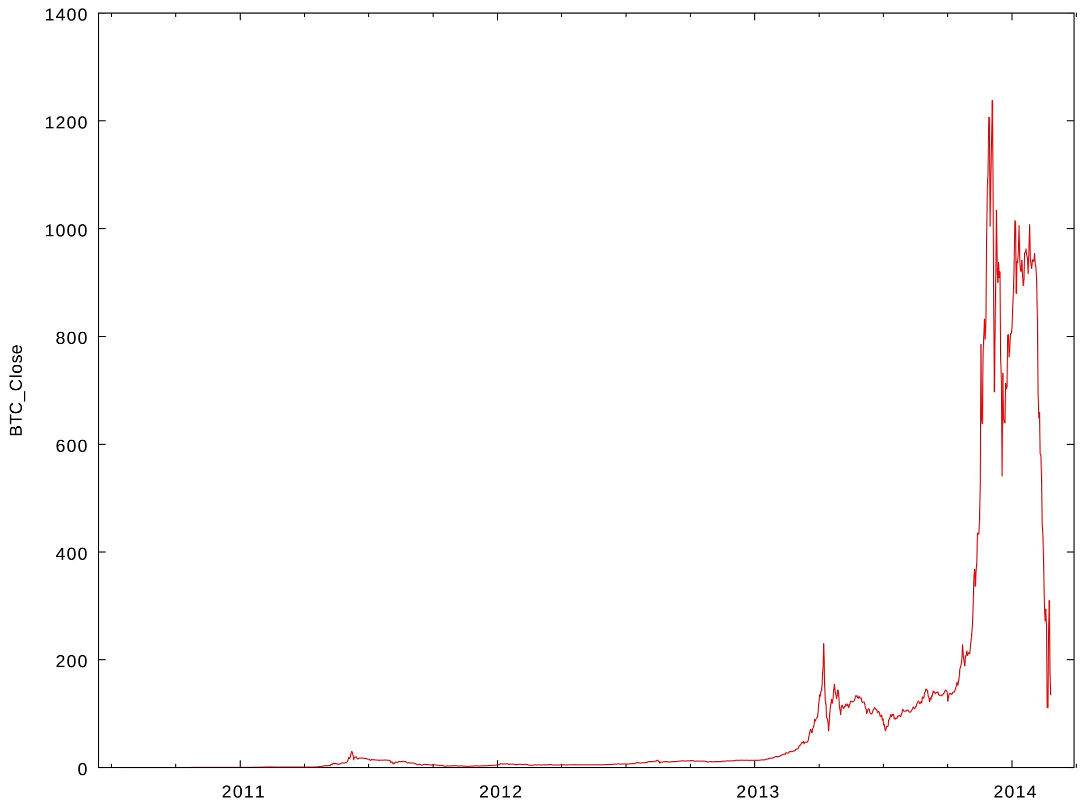


Figure 8 – Time series of MtGox exchange USD/BTC closing price.

Source: Author based on data from MtGox

5.2.1 Stationarity

From the first observation of the plot of the original time-series we assume that the non-stationarity of the time-series will be present. This is a serious problem in any kind of time-series modelling and is often encountered in time-series of asset prices. The issue lies in the fact that any shock in non-stationary time-series would have infinite persistence. Also the issue of spurious regression would make any inference based on econometric models invalid. Thus stationarity of the data is needed to be proven in the first place. For the following process:

$$y_t = \mu + \rho y_{t-1} + u_t \, , u_t \; is \; i.i.d$$

- If ρ > 1 then we obtain explosive process where external shocks multiplicate
- If ρ = 1 then the shocks never die in the system (random walk)
- If ρ < 1 then the shocks die away – stationary series.

To test for stationarity we will first use autocorrelation and partial-autocorrelation functions.

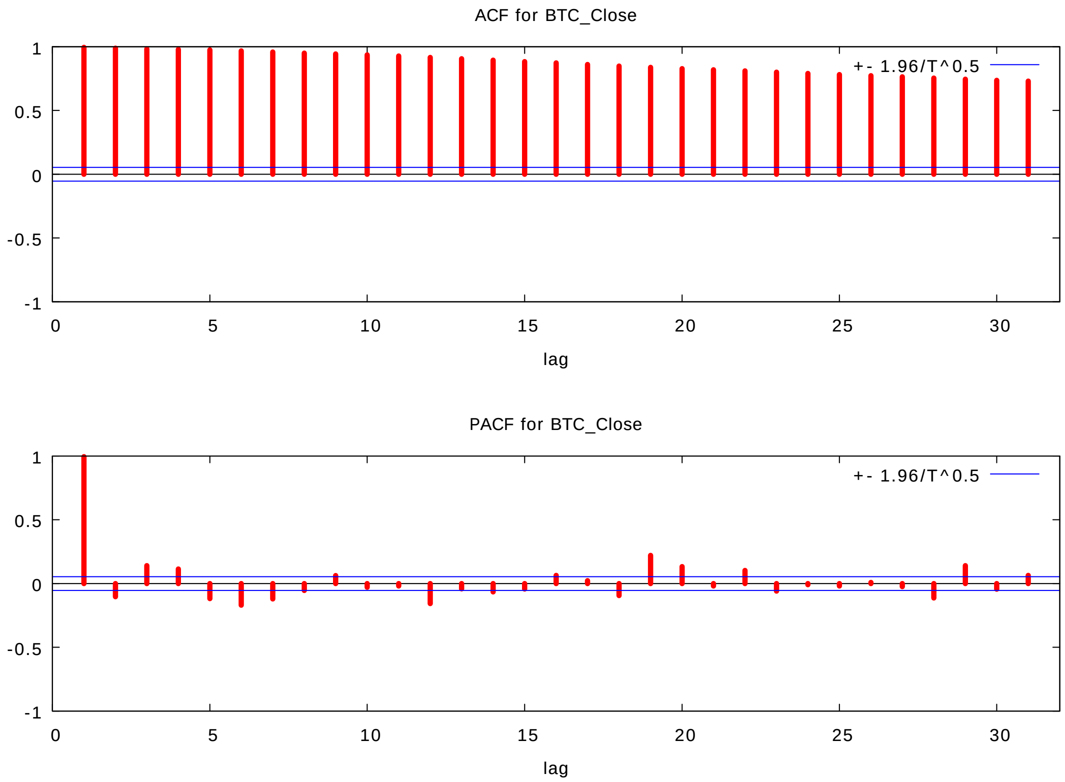


Figure 9 – ACF and PACF of the "Close" data series.

Source: Author based on data from MtGox

The observations of the results shows that there is a high dependency in the data (slow decay in ACF function) and that this dependency should be only connected with first lag of the data (1 significant lag in PACF function and subsequent sharp fall in the following lags. To verify this formally we will also perform Augmented Dickey-Fuller (ADF) test with null hypothesis being non-stationarity of the series and need to difference the data. The results shown in the appendix confirm the hypothesis of unit root presence due to too low absolute value of t-statistics (-1.4441) to be able to reject the null on any significance level.

In order to make the series stationary we will perform the first differentiation of the data with a logarithmic transformation:

$$r_t = \ln P_t - \ln P_{t-1} = \ln(\frac{P_t}{P_{t-1}})$$

The differentiated series shown below does not seem to exhibit patterns of non-stationarity, what is again proven by both ACF/PACF functions and ADF test (along with the summary statistics of the differentiated series can be found in the appendix). Both of these testing methods reject further presence of non-stationarity (ADF test on 1% significance level), even though we can still see some dependency in the differentiated time-series. This dependency however does not compromise the stationarity of the data.

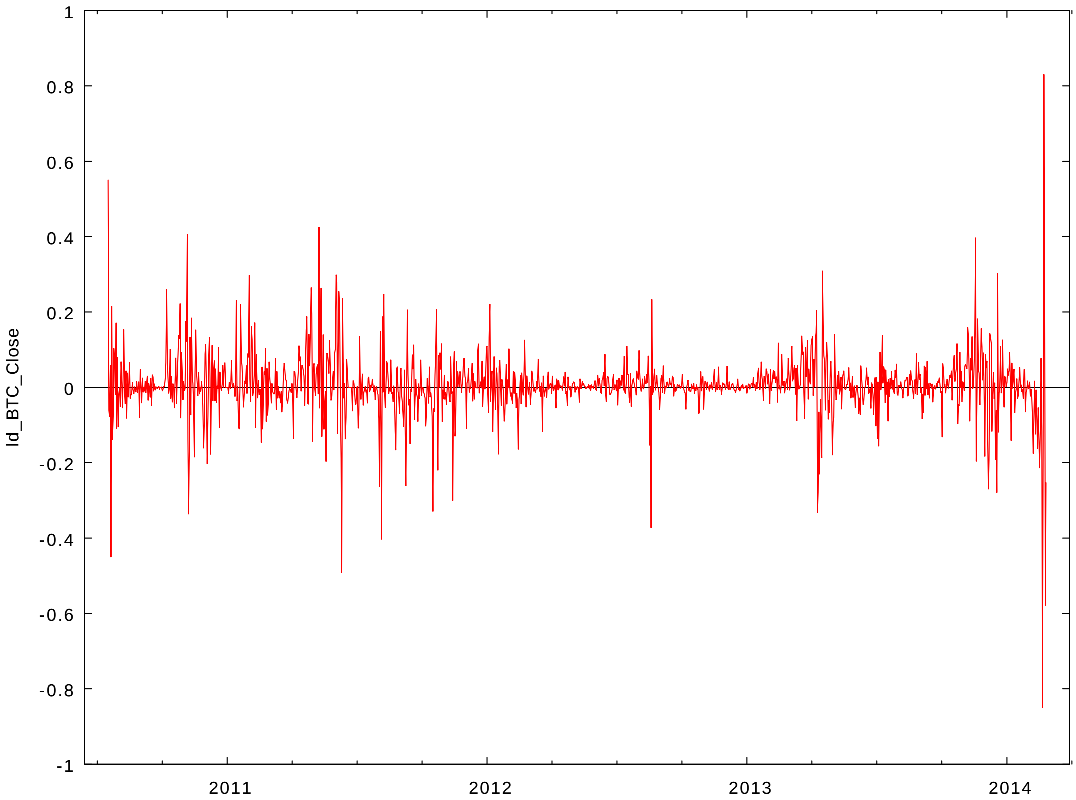


Figure 10 – 1st difference of logarithms of the original series.

Source: Author based on data from MtGox

The differentiated series ("ld_BTC_Close") represent the continuous returns of BTC on MtGox exchange. The histogram (appendix) shows the leptokurtic distribution of the data series, what generally corresponds to financial data as the stylized facts of financial returns state.

5.2.2 Explanation of high variance in the data

The first observation of the log-differentiated data suggests not only stationarity of the data but also a strong presence of heteroskedasticity in the sample. The variance of the series is very high in the first half of the data, then it significantly lowers for almost one whole year with only one positive and one negative peak only to grow again at the end of the dataset. A few high peaks, both negative and positive, are present in the whole series.

The reasons for the peaks in the volatility of the Bitcoin price can be traced to the historical events connected to Bitcoin. If we omit the spikes in first five trading days which are caused by the settling of the price then the first peak is on the 6th of November 2010. It is connected with the fact that on this day the capitalization of Bitcoin exceeded for the first time 1 million USD. The peak of the capitalization was, however, only short-term event as the highest value of over 0.5 USD/Bitcoin was not even recorded as a closing price and actually did not appear in closing price series until almost 3 months later. This suggest that already at this time Bitcoin was subject to speculation amongst its users. As was already mentioned in the literature overview, this bubble is also accounted to the financial blockade of Wikileaks on the 7th of December 2010. Moreover an interesting fact is that on the 9th of December 2010 the first call option contract for Bitcoin was sold.[14]

The second important peak in Bitcoin volatility took place 7 months after the first peak on the 11th of June 2011. In the ten days preceding this date the closing price of Bitcoin was sharply growing, from 9.57 USD on the 1st of June to 29.6 USD a week later. The absolute peek also took place on the 8th of June in price of 31.91 USD/Bitcoin. A short decline followed so that on the 11th of June the market was opening at 23.95 USD/BTC only to close at the end of the day at 14.65 USD/BTC, accounting for almost 40% decline in the value.

This event called “The great bubble of 2011” started a big plummet in the price of Bitcoin which took place in the following months causing the price to drop to 2 USD/BTC in November. There are multiple causes which are accounted to this spike in Bitcoin price. It was the first time when Bitcoin received mainstream public attention due to Time (16th of April) and Forbes articles thus attracting possible investors with mainly speculative motives who were pushing the price as high as possible. Another reason is that at the time there was no possibility to short-sell Bitcoins. If there was this possibility the investors who were not optimistic about the price increase could manifest their expectation by short-selling Bitcoins and thus reducing the price increase. The third

[14] Historyofbitcoin.org

possible cause of higher volatility in price in this period could be the founding of Silk-road marketplace which took place in February. (Buterin, 2012)

Another two events reinforced the consequent drop in Bitcoin price. Firstly it was a reported theft of 25 000 Bitcoins on the 13th of June (at the time approx. 375 000 USD). Only six days later a major security breach took place at MtGox exchange. A table with user names, email addresses and password hashes of 60 000 MtGox users leaked out. Furthermore the MtGox exchange had to be closed up for 7 days due to issuance of sell orders for hundred thousands of Bitcoins from an admin account which caused the price to drop to 0.01 USD/BTC. When the exchange was opened again the price was artificially set back to 17.51 USD/BTC, price which preceded the event.

After the burst of the bubble and fall of price a period of relative stability followed. One year between February 2012 and February 2013 was a period of growth in price of Bitcoin from 5 USD/BTC to 20 USD/BTC. Only low variance is observed in this period with one negative and one positive spike in August 2012. This spike in volatility can be accounted to above mentioned fraud of Bitcoin Savings & Trust operated by Trendon T. Shavers (Jeffries, 2012). The Trust was closed on the 17th of August 2012 leaving debts in amount of 500 000 Bitcoins, which represented approximately 5.6 million USD. This resulted in 40% decline in price in following 3 days.

The second bubble in the Bitcoin price was inflated during February, March and first ten days of April in 2013. In this period double-digit daily growth in price of Bitcoin was no exception. However the bubble was deemed to burst after the price spiked at 266 USD/BTC on the 10th of April. In the following week the drop in price took place and stopped at around 100 USD/BTC, which was approximately the price in following 5 months. The closing price on the 9th of April (230 USD/BTC) was almost 5-times the closing price of Bitcoin one month before (46.85 USD/BTC).

One of the possible explanation for this bubble happening is banking crisis in Cyprus. Since the end of 2010 the credit rating of Cyprus, country considered as being a tax-haven, has been falling down (Ehrenfreund, 2013). The country's economic issues eventually resulted in a short span of bank run which was stopped by a bailout by various international institutions such as ECB, European Commission or IMF on the 25th of March 2013.

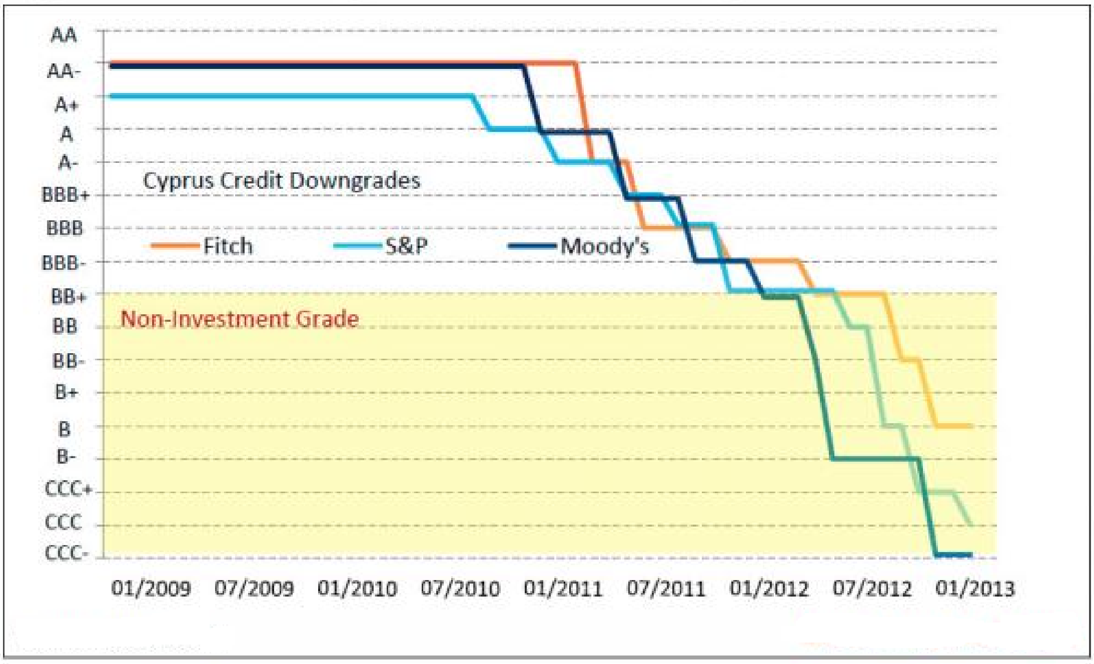


Figure 11 – Evolution of Cyprus credit rating.

Source: Bloomberg

However already on the 16th of March a plan by European Union was announced according to which all deposits in Cyprus' banks exceeding € 100.000 were to be taxed by one-time tax of 9.9% and also maximum limit of cash withdrawals of €400 were introduced (Thompson, 2013). According to CNN, this was one of the reasons why price of Bitcoin rocketed from 47 to 142 just three weeks later and peaking at already mentioned 230 per Bitcoin another 4 days later (Farrell, 2013).

The last important spikes in MtGox price of Bitcoin took place at the end of existence of MtGox exchange. In the last two weeks the daily change in price ranged from -57% to +129%.

5.3 Dataset adjustment

Due to the above mentioned changes in Bitcoin volatility it is impossible to make any sound inferences from regressions performed on the whole dataset. For this reason several changes have to be done before continuing to the econometric part.

5.3.1 Beginning and ending data issue

The first problem is the beginning of the whole dataset. As the 1st price quotation was not based on market inputs (as is for example case of IPOs) it took some time for the price to accommodate the market sentiments. For this reason high volatility can be observed in the first week of Bitcoin trading. For this reason we arbitrarily choose to drop first two weeks of data and start the dataset from the 1st of August 2010.

Similar problem arises at the end of the dataset. The last week of trading on the MtGox exchange is, as was mentioned in the preceding chapter, specific by humongous volatility spikes. However, these spikes are stemming from the lack of trust in MtGox exchange, not lack of trust in Bitcoin itself. On the 7th of February 2014 all withdrawals from MtGox have been halted and three days later a press release has been issued stating that a technical error causes that Bitcoins can be double-spent:

"A bug in the bitcoin software makes it possible for someone to use the Bitcoin network to alter transaction details to make it seem like a sending of bitcoins to a bitcoin wallet did not occur when in fact it did occur. Since the transaction appears as if it has not proceeded correctly, the bitcoins may be resent. MtGox is working with the Bitcoin core development team and others to mitigate this issue." (MtGox, 2014)

For this reason we have again arbitrarily chosen to drop the observations starting with 7th of February 2014.

5.3.2 Structural breaks

When the abnormal volatility at the beginning and end of the dataset is being taken care of the next focus point should be the changing volatility inside the dataset. As was already elaborated on in the previous chapters there are significantly different periods in the dataset from the view of both absolute price and relative volatility. As was proposed by Hillebrand (2005) the changing points of dataset, called structural breaks, have important impact on accuracy of generalized autoregressive conditional heteroskedasticity (GARCH) models in the way that the estimated autoregressive parameters converge to one. In search for the structural breaks I have decided to use Iterated cumulative sums of squares (ICSS) algorithm introduced by Carla Inclán and George C. Tiao in Journal of the American Statistical Association in September 1994 and the following part of text is based on this article. (Inclan & Tiao, 1994)

5.3.2.1 Motivation of the model

This algorithm is designed for “detection of multiple changes of variance in a sequence of independent observations”. It studies the retrospective variance of series to indicate points where variance changes.

The procedure consists of several steps. First of all let’s start with cumulative sum of squares $C_k = \sum_{t=1}^{k} a_t^2$ of uncorrelated random variables $\{a_t\}$ with zero mean and variance σ_t^2 is defined for $t = 1,2, \dots, T$. Let then centered cumulative sum of squares be defined as

$$D_k = \frac{C_k}{C_t} - \frac{k}{T}\ , \ \ k = 1,2, \dots, T; \ \ \ with \ \ D_0 = D_T = 0$$

When D_k is then plotted against k, it should be oscillating around zero for series with homogenous variance. If there is a sudden change in variance in the series a sudden change in pattern in plot of D_k in form of unexpected change of sign, a peak or a trough can be observed.

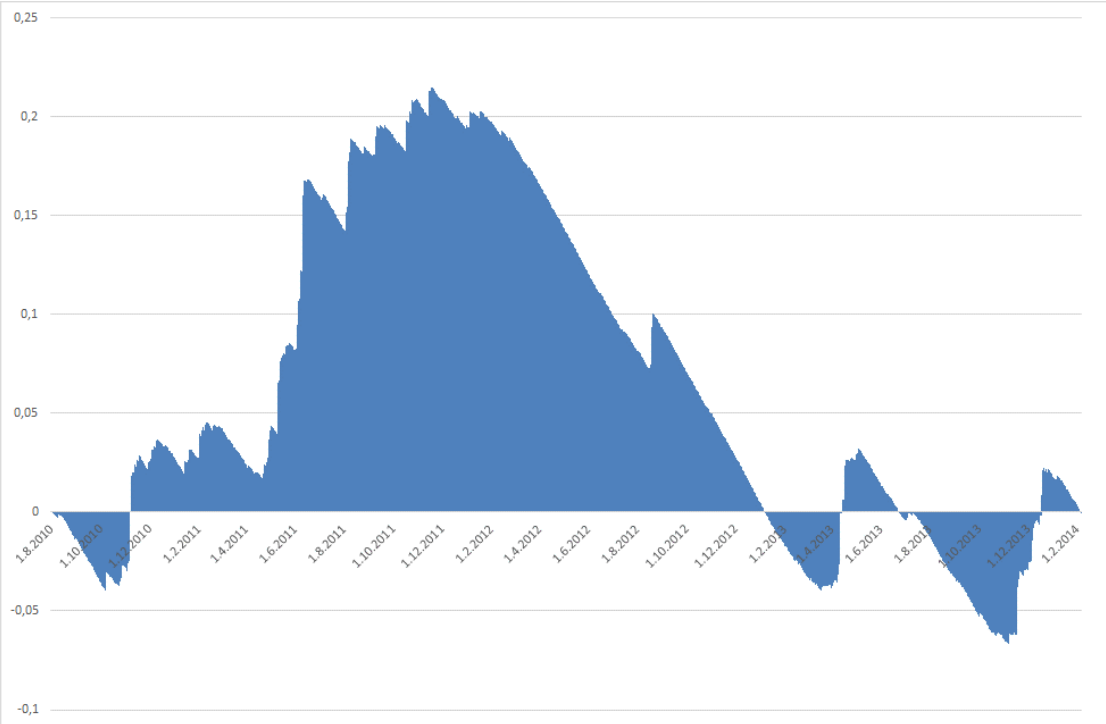


Figure 12 – Plot of D_k values across time. Sudden changes flag out possible structural breaks.

Source: Author based on data from MtGox

As can be seen from the chart above there are many pattern changes in the chart of D_k of the dataset. This suggests that there will not only be one break point, but rather multiple change points. In the suspicion of multiple change points an iterated version of cumulative sums of squares must be used.

The idea of the iterated version is to successively apply D_k to pieces of series which are being divided by the newly found change points. Firstly we define $a[t_1{:}\,t_2]$ to represent the series $a_{t_1}, a_{t_1+1}, \dots, a_{t_2}, \quad t_1 < t_2$ and $D_k(a[t_1{:}\,t_2])$ to represent the range over which the cumulative sums of squares are computed.

5.3.2.2 Structural breaks seeking procedure

The calculation algorithm is following:

1. Let $t_1 = 1$
2. Calculate $D_k(a[t_1\colon T])$. Let $k^*(a[t_1\colon T])$ be the point where $\max_k |D_k(a[t_1\colon T])|$ is obtained and let

$$M(t_1\colon T) = \max_{t_1 \le k \le T} \sqrt{(T - t_1 + 1)/2}\, |D_k(a[t_1\colon T])|.$$

If $M(t_1\colon T) > D^*$ then $k^*(a[t_1\colon T])$ is considered to be a change point of the series. The value of D^* is obtained from table of empirical and asymptotic quantiles (included in appendix). The 95% confidence interval value is ranging from 1.27 in empirical case with T=100 up to 1.358 in asymptotic case. If M is not higher than the quantile than there is no evidence of presence of change point.

2.1. Let $t_2 = k^*(a[t_1\colon T])$ and calculate $D_k(a[t_1\colon t_2])$; that is cumulative sum of squares calculated from the beginning to the first change point (t_2). If again the $M(t_1\colon T) > D^*$ test is passed then new change point is obtained and the procedure 2.1 is repeated until $M(t_1\colon T) < D^*$. The last point (t_2) which passed the test will be considered to be the first change point (k_{first}) of the series.

2.2. A similar procedure will be applied from the first found change point in direction to the end of the series with the t_1 newly defined as $t_1 = k^*(a[t_1\colon T]) + 1$. $D_k(a[t_1\colon T])$ is to be newly calculated and point 2.2 is to be repeated until the $M(t_1\colon T) > D^*$ test is not passed. Then the last k will be defined as $k_{last} = t_1 - 1$.

2.3. If $k_{first} = k_{last}$ then only one change point is found and the iteration ends. If however $k_{first} < k_{last}$ then first two steps are being repeated on the middle part of the series ($t_1 = k_{first} + 1$; $T = k_{last}$). In each iteration up to two new change points can be obtained. $\widehat{N}_t$ is the so far found number of change points.

3. If two or more possible change points are detected they first need to be ordered increasingly. Then cp will be the vector of all so far found possible change points. The lowest value will be defined as $cp_0 = 0$ and $cp_{N_T+1} = T$. Now each possible change point must be tested by calculating $D_k\big(a\big[cp_{j-1} + 1\colon cp_{j+1}\big]\big)$, $j = 1,2,\dots,\widehat{N}_{T.}$

If $M\left(cp_{j-1}+1: cp_{j+1}\right) > D^{*}$ the point can be kept, otherwise discarded. The 3rd step is to be repeated until the number of change points is stable and the possible newly found points are "close enough" to those found in previous iteration.

5.3.2.3 Results

By applying the ICSS procedure on the dataset, 26 changing points have been found in total before applying third point of the procedure. After two iterations of point three there are 10 points in total which can be considered as statistically significant break points. The number of observations in between two change points vary from 6 to 231. As 6 is too low number of observations for OLS model and both change points that specify these observations from both sides are strongly significant we have decided not to perform the OLS models on these 6 observations. This means that in the end for OLS we have 9 points where structural change in the series is observed resulting in 10 data periods and for volatility estimation all 10 will be used.

5.4 Inspection of volatility clustering – ARCH models

5.4.1 Motivation

At the beginning of this section where we have pointed out the large volatility of the Bitcoin returns we have also mentioned suspicion relating to volatility clustering. Volatility clustering is considered to be one of stylized facts in finance along with unpredictability of markets and fat tails in distribution of returns. A simple way how to test for the volatility clustering is to plot an autocorrelation function of squares or absolute values of the dataset. If there is slow decay observable then it can be confirmed that there is volatility clustering present in the dataset.

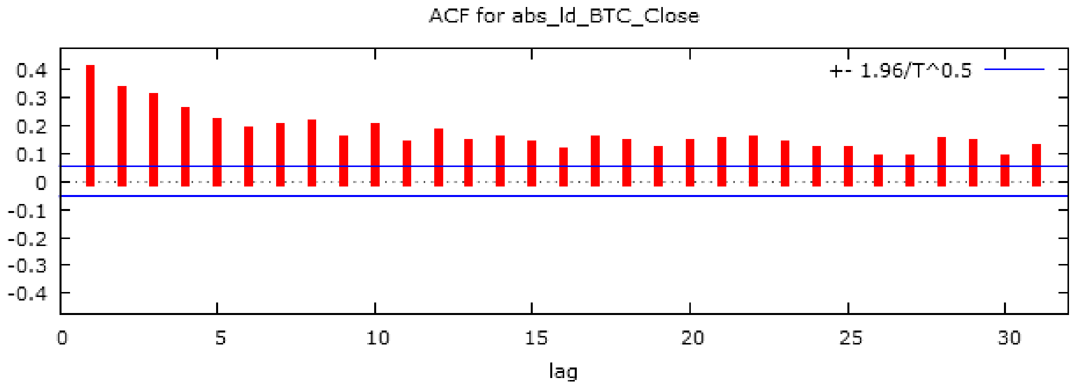


Figure 13 – Autocorrelation function of absolute values of differentiated series.

Source: Author based on data from MtGox

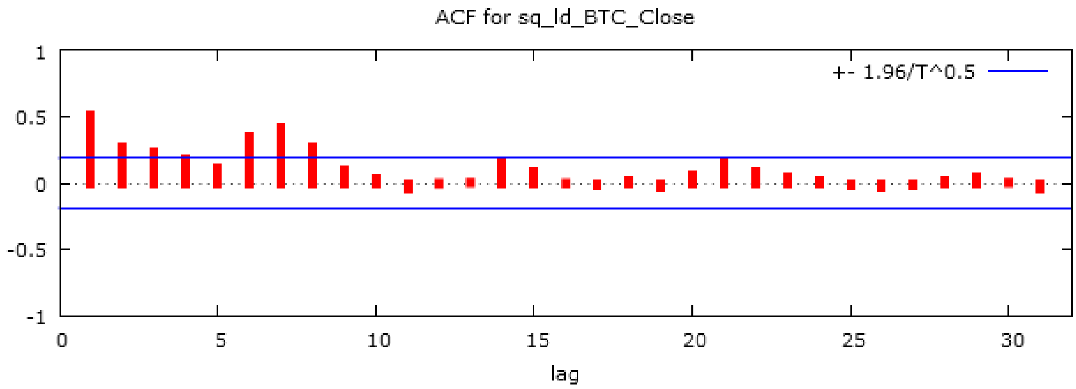


Figure 14 – Autocorrelation function of squared values of differentiated series.

Source: Author based on data from MtGox

From both correlograms it can be seen that the slow decay is present. Also the correlogram of squared series suggest that there is an increased dependency in seven-days cycles.

5.4.2 GARCH models

The first important set of models used for modelling of volatility clusters was introduced by Engle (1982). He proposed to model the heteroskedasticity by relating the conditional variance of the disturbance term at time *t* to the size of the squared disturbance terms in the recent past. The Autoregressive conditional heteroskedasticity model (ARCH (m)) is defined by two main equations:

$$a_t = \sigma_t \varepsilon_t; \quad \varepsilon_t \; is \; i.i.d$$

$$\sigma_t^2 = \alpha_0 + \alpha_1 a_{t-1}^2 + \cdots + \alpha_m a_{t-1}^2$$

Where a_t is mean corrected return $a_t = r_t - \mu_t$ and the process is stationary of $\sum_{i=1}^{m} \alpha_i < 1$. The weaknesses of the basic ARCH model lie in the assumption of identical effect of positive and negative shocks on volatility and large number of squared lagged residuals usually needed for correct specification of the model.

Extension of the ARCH model brought by Tim Bollerslev in 1986 is called Generalized autoregressive conditional heteroskedasticity model (Bollerslev, 1986). The idea of the generalization in the model is that the current volatility may depend also on a lagged autoregressive component – lags of own variances – apart from the past squared residuals introduced by Engel. The GARCH (m,n) model is specified as:

$$a_t = \sigma_t \varepsilon_t; \quad \varepsilon_t \; is \; i.i.d$$

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{m} \alpha_i a_{t-i}^2 + \sum_{j=1}^{n} \beta_j \sigma_{t-j}^2$$

Where again a_t is mean corrected return $a_t = r_t - \mu_t$ and the process is stationary if condition $\sum_{i=1}^{\max(m,n)} (\alpha_i + \beta_i) < 1$ holds. Thus ARCH is specific case of GARCH model where $n = 0$. In comparison with the ARCH model the GARCH model solves the issue of too many necessary squared residual lags as empirically lower orders of m and n, usually up to 2 are sufficient. However it still cannot handle the difference between positive and negative shocks.

To solve the last mentioned disadvantage of ARCH and GARCH models Jean-Michel Zakoïan introduced Threshold generalized autoregressive heteroskedasticity model (referred to as T-GARCH or TARCH) (Rabemananjara & Zakoian, 1993). This specific model allows to differentiate between effects of bad news and good news on the volatility of the asset. The model T-GARCH (m,n) can be specified as:

$$a_t = \sigma_t \varepsilon_t; \quad \varepsilon_t \; is \; i.i.d$$

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{m} \alpha_i a_{t-i}^2 + \sum_{j=1}^{n} \beta_j \sigma_{t-j}^2 + \gamma_1 I_{t-1} a_{t-1}^2$$

Where a_t is mean corrected return $a_t = r_t - \mu_t$ and $I_t = 1$ if $a_t < 0$ and 0 otherwise. The stationarity condition is not as strict here as the model can be stationary in one regime and non-stationary in the other. The model becomes GARCH (m,n) if $\gamma = 0$.

The last ARCH family model used will be the Exponential general autoregressive conditional heteroskedasticity (E-GARCH) proposed by Nelson (1991). The advantage of the model is that even though the parameters can be negative the variance will be positive as we model its logarithm (Nelson, 1991).

$$a_t = \sigma_t \varepsilon_t; \quad \varepsilon_t \; is \; i.i.d$$

$$\log(\sigma_t^2) = \alpha_0 + \sum_{i=1}^{m} \alpha_i \log(a_{t-i}^2) + \sum_{j=1}^{n} \beta_j g(\varepsilon_{t-k})$$

$$g(\varepsilon_t) = \theta \varepsilon_t + \gamma[|\varepsilon_t| - E|\varepsilon_t|]$$

In order to find the conditional heteroskedasticity model that fits the data best information criteria can be used. Usually in the case of autoregressive conditional heteroskedasticity models it is the Akaike information criterion (AIC), the Bayesian information criterion (BIC) and the Hannah-Quinn information criterion (HQIC). The information criteria are not absolute measurement of quality of a model in the sense of hypothesis testing, however they allow to compare two different models in terms of trade-off between goodness of fit and model parsimony.

The Akaike criterion is computed as $AIC = -2\ln(L) + 2k$, the Bayesian criterion is computed as $BIC = -2\ln(L) + k\ln(n)$ and the Hannah-Quinn criterion as $HQIC = -2\ln(L) + 2k\ln(\ln(n))$, where L stands for maximum likelihood function of the model, k stands for parameters in the model and n is the size of a data sample. Thus BIC and HQIC are more punishing in case of too many parameters in the model. The best model is then chosen based on the value of the criteria:

"In application, one computes AIC for each of the candidate models and selects the model with the smallest value of AIC. It is this model that is estimated to be "closest" to the unknown reality that generated the data, from among the candidate models considered." (Burnham & Anderson, 2002)

When the criteria suggest different models more parsimonious model should be selected.

5.4.3 Application of the models

As the ARCH models are working with the residuals of any other econometric model it is first necessary to choose the correct model from which the residuals will be obtained. We have decided to choose ARMA model with constant term to remove any linear dependencies in the data. The general ARMA (p,q) model which combines simple autoregressive (AR (p)) and simple moving average (MA (q)) models must be applied on stationary series. It takes on the following form:

$$r_t = \varphi_0 + \sum_{i=1}^{p} \varphi_i r_{t-i} + \epsilon_t + \sum_{j=1}^{q} \theta_j \epsilon_{t-j}$$

Where $\{\epsilon_t\}$ is white noise series. The first summation in the equation is the AR (p) process and the second summation relates to MA (q) process. The condition for the ARMA (p,q) model to be stationary is that the AR process is stationary. This holds when $S = \left|\sum_{i=1}^{p} \varphi_i\right| < 1$.

The selection of the best p and q integers relies again heavily on the above mentioned Akaike information criterion, Bayesian information criterion and Hannah-

Quinn information criterion. For our dataset the lowest value of the criteria is achieved when p = 7 and q = 0 what is aligned with the above mentioned seven days pattern. The sum S of AR coefficient is equal to 0.1193 thus the stationarity of the ARMA (7,0) model is confirmed. The presence of ARCH effect is also confirmed by the value of test statistic of LM test being equal to 140.92.

The procedure of finding the best autoregressive conditional heteroskedasticity model starts with finding the best ARCH (m) model. We will be always looking for the best simple model and best model with the structural breaks dummy variables as variance explanatory variables. The best possible fit (minimizing the information criteria) was achieved with ARCH (4) model with the dummy variables.

Moving on to more sophisticated models shifts the focus to GARCH (m,n) models. As was already mentioned above, it is usually enough in the financial data to use models with low m and n parameters, usually $\max(m, n) \leq 2$. This was also confirmed in my dataset as the best model according to the information criteria is GARCH (1,1) with dummy variables.

The most sophisticated method to be estimated is the T-GARCH (m,n) model. In this case it is again the simplicity and parsimony that wins as the criteria reveal that T-GARCH (1,1) with the dummy variables is the best model. For the comparison also results of E-GARCH (1,1) are included. It is again the version with dummy variables that clearly dominates the one without dummies.

The results of the ARCH models are summarized in the following table. The color-coding helps to identify the lowest values of each information criterion, ranging from red being the highest values and green being the low values. The lowest value of each information criterion is marked in blue. Two out of three criteria suggest that T-GARCH (1,1) is the best fit of all the models used. If we would have to choose between T-GARCH (1,1) and T-GARCH (2,2) suggested by AIC, we would always prefer simpler model, T-GARCH (1,1).

	without dummy variables			with dummy variables		
	AIC	BIC	HQIC	AIC	BIC	HQIC
ARCH (1)	-3473,36	-3457,88	-3467,55	-3893,68	-3826,62	-3868,51
ARCH (2)	-3696,66	-3676,03	-3688,92	-3956,46	-3884,24	-3929,35
ARCH (3)	-3743,73	-3717,93	-3734,04	-3961,72	-3884,34	-3932,67
ARCH (4)	-3747,25	-3716,3	-3735,63	-3969,76	-3887,23	-3938,78
ARCH (5)	-3755,87	-3719,76	-3742,31	-3971,11	-3883,42	-3938,19
ARCH (6)	-3755,99	-3714,72	-3740,5	-3970,02	-3877,16	-3935,16
GARCH (1,1)	-3775,67	-3755,04	-3767,92	-3969,42	-3897,2	-3942,31
GARCH (1,2)	-3782,85	-3757,16	-3773,27	-3968,08	-3890,7	-3939,03
GARCH (2,1)	-3775,4	-3749,61	-3765,72	-3967,43	-3890,05	-3938,38
GARCH (2,2)	-3821,46	-3790,51	-3809,84	-3970,7	-3888,16	-3939,71
T-GARCH (1,1)	-3805,69	-3779,9	-3796,01	-3990,65	-3913,28	-3961,6
T-GARCH (1,2)	-3802,85	-3766,74	-3789,3	-3991,32	-3903,62	-3958,4
T-GARCH (2,1)	-3803,96	-3773,01	-3792,34	-3989,68	-3907,14	-3958,69
T-GARCH (2,2)	-3806,32	-3765,05	-3790,82	-3991,79	-3898,94	-3956,93
E-GARCH (1,1)	-3811,49	-3785,7	-3801,81	-3984,87	-3907,49	-3955,82

Figure 15 – Summary of ARCH-family models.

Source: Author

The relevance of the structural breaks in the data sample can be seen in the huge difference between information criteria of the models without the structural breaks dummies and those that incorporate them. Another proof is that for all the ARCH and GARCH models (with the exception of ARCH (1)) without structural breaks dummies the sum of ARCH coefficients (α and β) is exceeding 1. This leads to non-stationarity of the models and is aligned with Hillebrand's theory behind the need of structural breaks in the ARCH regressions. (Hillebrand, 2005)

The results of the T-GARCH (1,1) can be found in the appendix. They reveal that the 6 out of 10 breaking points used are significant on 5% significance level and one more is significant on 10% level. The sum of ARCH coefficients is lower than 1, so stationarity of the model is confirmed. The graphical fit of the model is shown on the figure below. It can be observable that though the difference between model and residuals is still quite high in the first half of the series the second half starting with big drop in volatility is modeled much better.

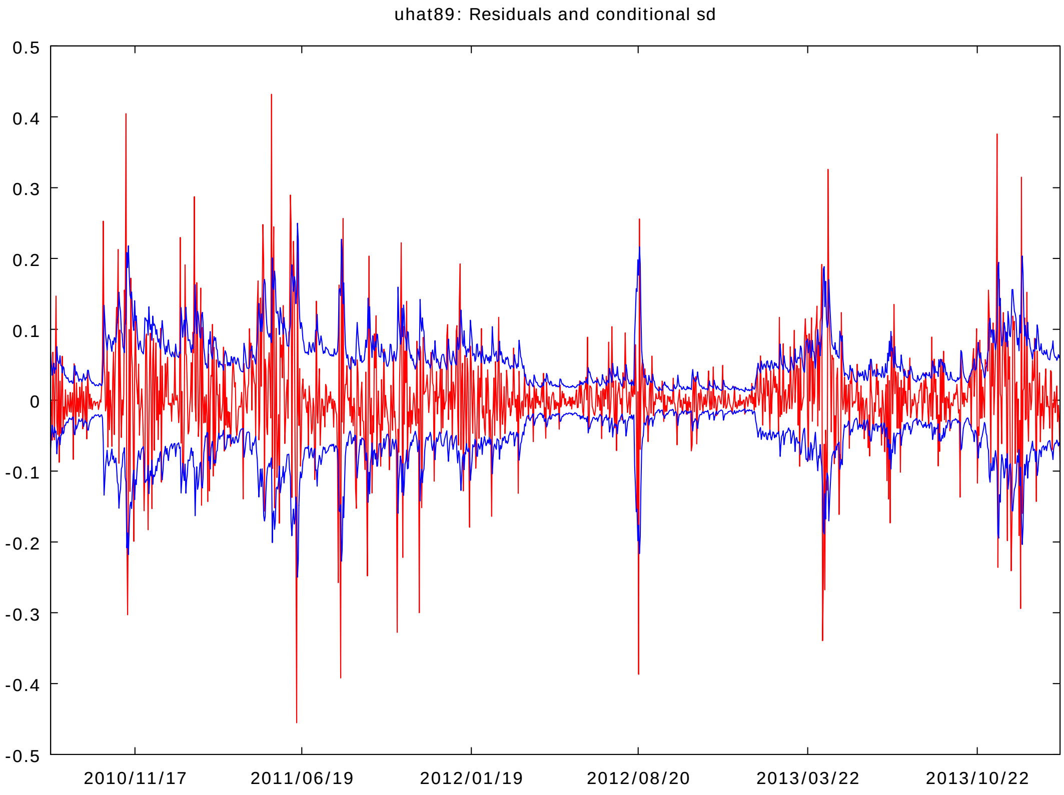


Figure 16 – Plot of residuals (red) and T-GARCH (1,1) model (blue).

Source: Author based on data from MtGox

The formal LM test of any remaining ARCH effect denies presence of any further dependencies on any significant level (p-value = 0.996459). This is also confirmed by non-formal check of correlograms of squares and absolute values of the standardized residuals (see appendix). The test for normality of the residuals rejects the hypothesis of normality; however, with the size of the sample it can be assumed that the residuals are asymptotically normal. Importantly, when the histogram of TARCH (1,1) residuals (see appendix) is compared with the histogram of the original series a huge improvement towards bell curve has been made.

The beta coefficient measuring the persistence of the volatility shocks has value of 0.506 and is significant on any usual significance level. The alpha coefficient measuring the dependence of current period volatility on the past period disturbance has value of 0.309 and is again significant on any common significance level. The sizes of both of these coefficients show that large part of today's volatility can be explained by past volatility and disturbances.

6 Relation between Bitcoin and real economy – OLS models

6.1 Motivation

In the next econometric part of this paper we shift our focus to estimating a connection between Bitcoin and real economy. Our goal is to observe whether there is any link between the "tangible" economy and the price of "intangible" Bitcoin. If any statistically significant dependency would be found it would mean that the future movement of Bitcoin price could be estimated. It would also mean that Bitcoin is not as independent as it is supposed to. By definition Bitcoin should be independent of any financial institutions or financial markets as well as governments or governmental organizations. However, if a proof of a significant dependency between Bitcoin and "tangible" economy was found it would mean that Bitcoin could be endangered by it.

The implications of an existence of a global currency that is independent from any economy and bank are very broad. From the macroeconomics point of view this would be very inconvenient as artificial devaluation and revaluation of the currency would be impossible. Therefore a central bank would lose its best instrument of boosting the country's exports (Mankiw, 2008). The second and in our opinion more important endangerment of current macroeconomic concepts is the implication stemming from the fixed and a priori known amount of Bitcoins on the market at any point of time. As the dollar price of one Bitcoin was soaring in second half of 2013 a double digit deflation actually happened in the Bitcoin "economy". The question of whether the deflation is worse or better than inflation has never been answered and is part of an argument between advisories of inflation, the Keynesians, and deflationists, the Libertarians. Following is a quotation from German libertarian economist Jörg Guido Hülsmann:

"Deflation is far from being inherently bad. Quite to the contrary, it fulfills the very important social function of cleansing the economy and the body politic from all sorts of parasites that have thrived on the previous inflation. In a word: the dangers of deflation are chimerical, but its charms are very real. There is absolutely no reason to be

concerned about the economic effects of deflation — unless one equates the welfare of the nation with the welfare of its false elites. There are by contrast many reasons to be concerned about both the economic and political consequences of the only alternative to deflation, namely, re-inflation—which is of course nothing but inflation pure and simple.” (Hülsmann, 2008)

Economics Nobel prize awardee Paul Krugman is on the other hand known for his anti-deflationary opinions. In one of his essays on deflation he writes:

“There are actually three different reasons to worry about deflation, two on the demand side and one on the supply side.

So first of all: when people expect falling prices, they become less willing to spend, and in particular less willing to borrow.

… A second effect: even aside from expectations of future deflation, falling prices worsen the position of debtors, by increasing the real burden of their debts.

… Finally, in a deflationary economy, wages as well as prices often have to fall – and it’s a fact of life that it’s very hard to cut nominal wages — there’s downward nominal wage rigidity.” (Krugman, 2010)

An application of his view can also be seen in his article about Bitcoin in particular:

“Bitcoin, rather than fixing the value of the virtual currency in terms of those green pieces of paper, fixes the total quantity of cybercurrency instead, and lets its dollar value float. In effect, Bitcoin has created its own private gold standard world, in which the money supply is fixed rather than subject to increase via the printing press.

… it reinforces the case against anything like a new gold standard – because it shows just how vulnerable such a standard would be to money-hoarding, deflation, and depression.” (Krugman, 2011)

For these reasons we test the independence of Bitcoin on real economy. The independence cannot be proved, however we can test whether there is a statistically significant relationship which would be consistent in the long run.

6.2 Dataset

We are using the same dataset with structural breaks as in the previous section. In all time periods the data sample was enhanced by five more time series. NASDAQ composite index was chosen as a representative of United States' economy, Nikkei 225 was chosen as the same measure for Japan and SSE Composite for China. Gold and Crude oil were selected as safe investments.

Our expectations ex ante are that there will be dependence between NASDAQ and Bitcoin and between gold and Bitcoin. Also we would expect some significant dependency between SSE index and Bitcoin. The reason for the first connection, NASDAQ and Bitcoin, is that Bitcoin's main feat is its independence on any national or supranational entity. This entitles it to work as an alternative for investors who do not trust a nation's economy. If the US economy is to be slowing down, the stock indices are to be decreasing. When this happens the investors could either short-sell the indices or buy negatively correlated or uncorrelated assets. We expect Bitcoin to serve exactly in this way (as was proposed above in case of Cyprus) thus our expectation is that NASDAQ would be significant and having a close to zero or negative coefficient in the model.

For the same reason we expect gold to be significant and positive. It has been proven that gold is a safe-haven to many stock and foreign exchange markets (Baur & McDermott, 2009; Capie, Mills, & Wood, 2005) Thus if both gold and Bitcoin would be alternatives in case of distrust in national economy then they should be moving in the same direction.

The reason for high dependency expectation between Bitcoin and SSE index relates only to the year 2013 when Bitcoin was used by Chinese to export wealth out of China as any outflow of Yuan abroad is very closely regulated. We would tend to assume that the relationship would be positive meaning when the Chinese stock index is growing Bitcoins would be used to outflow the wealth out of the country.

The presence of structural breaks in the dataset gives us an opportunity to assess persistence of the relationship in time. Any inference about relationship of Bitcoin and the other variables can be made only if the relationship is long-term, meaning that it would appear in more time periods. Also the relationship would have to be stable in term of sign of the beta coefficient.

6.3 Procedure

All the above mentioned series were adjusted the same way as BTC_Close, meaning that the first differences of logarithmic prices were used. The reason for this is again to achieve stationary data and avoid spurious regression problem.

The model performed is in the following form:

$$ld\_BTC\_close_t = \alpha_0 + \beta_1 * ld\_gold_t + \beta_2 * ld\_crude_t + \beta_3 * ld\_nasdaq_t + \beta_4 * ld\_nikkei_t + \beta_5 * ld\_SSE_t + \epsilon_t\,, \quad where\ \epsilon_t\ is\ i.i.d.$$

It has been firstly applied on the total series (N=1285) with no change points. The results included in appendix show that all explanatory variables are strongly insignificant except for crude oil, which is significant on 10% significance level. However these results cannot be trusted from various reasons. Not only is the R-squared of the model smaller than 0.4%; there is also very strong proof of presence of both autocorrelation and autoregressive conditional heteroskedasticity in the residuals. It can also be seen that the normality of residuals is not achieved in the model, however due to the sample size asymptotic normality is achieved via law of large numbers.

6.4 OLS results in observed periods

The following table shows results of OLS regressions performed on given time periods. The variables significant on 5% level are emphasized in bold letters; corresponding p-values are shown beneath the values of the Beta coefficients. Also the numbers of total observations in given time periods are shown at the end of the table.

		constant	ld_gold	ld_crude	ld_nasdaq	ld_nikkei	ld_sse	N
period 1	1.8.2010	0,0018	-0,5880	0,1227	0,4541	0,3677	0,0216	68
	- 7.10.2010	0,69	0,50	0,68	0,33	0,35	0,97	
period 2	8.10.2010	0,0194	-0,0120	-1,8321	**4,4846**	-1,5165	0,1168	126
	- 10.2.2011	0,03	0,99	0,10	**0,00**	0,18	0,88	
period 3	11.2.2011	0,0015	-0,0895	0,1135	-1,1438	-0,0449	0,4917	69
	- 20.4.2011	0,82	0,94	0,82	0,15	0,90	0,57	
period 4	21.4.2011	0,0219	-2,1167	**2,2967**	-2,0626	-0,2057	0,8314	110
	- 8.8.2011	0,07	0,25	**0,01**	0,08	0,90	0,59	
period 5	9.8.2011	-0,0037	0,4271	**0,9774**	0,4454	-0,8435	**-1,2464**	231
	- 26.3.2012	0,42	0,24	**0,03**	0,23	0,10	**0,01**	
period 6	27.3.2012	0,0068	-0,1509	0,0826	0,1389	0,0586	-0,2095	140
	- 13.8.2012	0,00	0,52	0,66	0,61	0,82	0,48	
period 7	20.8.2012	0,0036	0,0252	-0,1612	-0,0212	0,2772	-0,0929	148
	- 14.1.2013	0,11	0,95	0,47	0,95	0,33	0,71	
period 8	15.1.2013	0,0226	**1,7248**	0,5454	**-3,2866**	0,0090	0,3673	109
	- 3.5.2013	0,01	**0,03**	0,57	**0,01**	0,99	0,69	
period 9	4.5.2013	0,0062	0,1461	**-0,9311**	**-1,0745**	0,0174	**0,8296**	186
	- 5.11.2013	0,04	0,56	**0,01**	**0,03**	0,93	**0,01**	
period 10	6.11.2013	0,0139	-1,9479	-0,1179	-1,1482	0,8419	2,2033	93
	- 6.2.2014	0,19	0,14	0,94	0,47	0,35	0,12	

Figure 17 – Results of OLS regressions across time periods.

Source: Author based on data from MtGox and Bloomberg

It is shown in the table that there is no significant dependency between returns on Bitcoin and returns on Japanese stock market index, Nikkei 225, in any of the observed periods. US stock index NASDAQ is significant in 3 out of 10 periods and the same holds for returns on crude oil. Gold is significant on 5% significance level in one model only. It is also important to mention that there are 5 models in which none of the proposed explanatory variables is significant.

To test for validity of the OLS method tests of normality, collinearity, two tests for autocorrelation (Durbin Watson and Breusch-Godfrey) and two tests of heteroskedasticity (White and Breusch-Pagan) have been performed separately for each model. The summed up results of all the tests can be found in the appendix. The results have shown that in all the models where no significant explanatory variable has been found the coefficients are best linear unbiased estimators (BLUE). This is also true for models in period 4 and period 9.

Models in period 2, 5 and 8 had to be re-estimated to account for the autocorrelation in the data and heteroskedasticity in model 5. The method chosen for autocorrelation and heteroskedasticity robust model was OLS estimation with heteroskedasticity and auto-correlation robust standard errors (HAC). Estimations using HAC result in non-consistent estimator, however asymptotically valid testing is possible (Kiefer, 2001). With the autocorrelation-robust model significance of estimators in all three models changes compared to the results shown in the table above. In period 2 crude oil becomes significant on 5% significance level and loses its significance in period 5. In period 8 NASDAQ index is no longer significant explanatory variable.

6.5 Comments on the results

Only one explanatory variable, the Japanese Nikkei index, stays insignificant across all 10 data periods. Our ex ante anticipation of significant variables being NASDAQ, SSE and gold have been confirmed. Also Crude oil is significant variable in at least one time period.

The periods with at least one significant explanatory variable have higher explanatory power measured by R-squared. The period two with two significant variables has R-squared of 8.75%. The significant variables are crude oil and NASDAQ, which, in the contrary to expectations, does not have negative sign of beta coefficient. The coefficient is positive and surprisingly high (4.6192) meaning that one percent change in NASDAQ index was reflected by more than 4.6% change of Bitcoin price in the same direction.

		constant	ld_gold	ld_crude	ld_nasdaq	ld_nikkei	ld_sse	N
period 1	1.8.2010	0,0018	-0,5880	0,1227	0,4541	0,3677	0,0216	68
	- 7.10.2010	0,69	0,50	0,68	0,33	0,35	0,97	
period 2	8.10.2010	0,0194	-0,0120	**-1,8321**	**4,4846**	-1,5165	0,1168	126
	- 10.2.2011	0,02	0,99	**0,04**	**0,01**	0,21	0,89	
period 3	11.2.2011	0,0015	-0,0895	0,1135	-1,1438	-0,0449	0,4917	69
	- 20.4.2011	0,82	0,94	0,82	0,15	0,90	0,57	
period 4	21.4.2011	0,0219	-2,1167	**2,2967**	-2,0626	-0,2057	0,8314	110
	- 8.8.2011	0,07	0,25	**0,01**	0,08	0,90	0,59	
period 5	9.8.2011	-0,0037	0,4271	0,9774	0,4454	-0,8435	**-1,2464**	231
	- 26.3.2012	0,44	0,26	0,06	0,23	0,11	**0,01**	
period 6	27.3.2012	0,0068	-0,1509	0,0826	0,1389	0,0586	-0,2095	140
	- 13.8.2012	0,00	0,52	0,66	0,61	0,82	0,48	
period 7	20.8.2012	0,0036	0,0252	-0,1612	-0,0212	0,2772	-0,0929	148
	- 14.1.2013	0,11	0,95	0,47	0,95	0,33	0,71	
period 8	15.1.2013	0,0226	**1,7248**	0,5454	-3,2866	0,0090	0,3673	109
	- 3.5.2013	0,01	**0,04**	0,54	0,15	0,99	0,63	
period 9	4.5.2013	0,0062	0,1461	**-0,9311**	**-1,0745**	0,0174	**0,8296**	186
	- 5.11.2013	0,04	0,56	**0,01**	**0,03**	0,93	**0,01**	
period 10	6.11.2013	0,0139	-1,9479	-0,1179	-1,1482	0,8419	2,2033	93
	- 6.2.2014	0,19	0,14	0,94	0,47	0,35	0,12	

Figure 18 – Results of OLS regressions across time periods with robust standard errors where necessary.

Source: Author based on data from MtGox and Bloomberg

The possible explanation for this could be twofold though both ideas are interconnected. Firstly, in this period the 1 million USD capitalization was first recorded. As it was mentioned in the previous section this was more speculation than real value of Bitcoin for its users. The changes in Bitcoin prices were very closely following changes in NASDAQ index which also peaked on 6th of November, so the price growth of Bitcoin might have been a spillover effect of US market growth. More importantly, this was very early period, less than three month after MtGox exchange was opened. The volume traded on the MtGox exchange was also very low both in term of BTC and USD meaning the market was not deep enough. Generally speaking at this time Bitcoin was still considered to be rather a curiosity than a serious investment possibility and an average daily trade on this period was amounting to 5640 USD, thus the market could have been swung by a single person. For these reasons we do not consider the result of this period to be important in explanation of Bitcoin price.

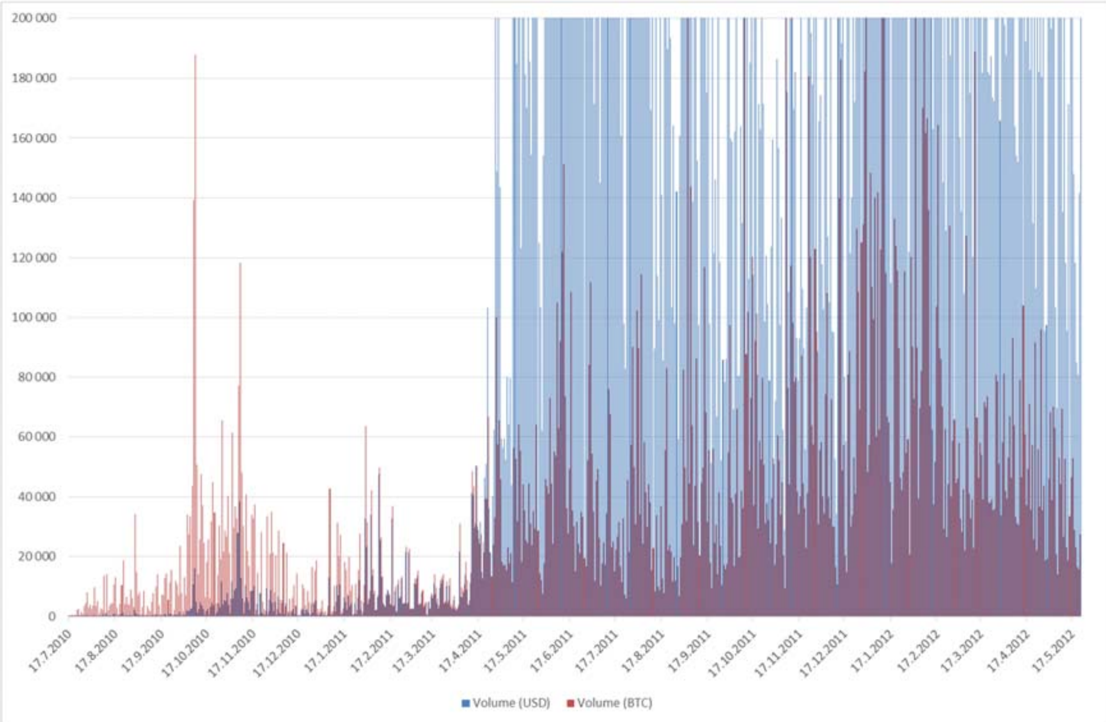


Figure 19 – Volume of Bitcoin trade on MtGox expressed in USD (blue) and BTC (red).

Source: Author based on data from MtGox

The only other period where NASDAQ is revealed as significant explanatory variable is period number 9. In this period NASDAQ is significant on 5% significance level and has negative coefficient of -1.0745 meaning that one percent increase of NASDAQ index would result in approximately one percent decrease of Bitcoin price. This confirms the ex-ante expectations of Bitcoin being an alternative to investment into US stock market through NASDAQ index. Also the market depth at both of these periods was high enough with approximately 8 million dollar worth of Bitcoins traded per day.

The Chinese SSE index is significant in two periods, number 5 and 9. In the fifth period the coefficient is negative and positive in the latter, in both cases significant on 1% level. The second observation does correspond to our expectation of positive correlation between SSE and Bitcoin; however, the relationship in the 5th period is surprising for us. It is also worth mentioning that in the tenth period SSE is also positive and close to being significant on 10% significance level.

One of the biggest surprises in the results is only one period of significant connection between price of Bitcoin and gold. As gold is considered to be the safe investment for investors this would imply that Bitcoin does not have this property. However, it is no coincidence that the strong positive relationship between gold and Bitcoin appears in the period 8 which covers first five months of year 2013. As it was mentioned above this was the period when Cyprus banking crisis culminated and both Bitcoin and gold were considered to be safer alternatives than Cyprus assets.

To sum up the results of the performed OLS regressions we have to state that no long-term nor stable relationship can be observed. The significance of the explanatory variables differs greatly amongst the 10 observed periods with none of them being significant in more than 3 periods and none being significant in two periods in a row. There is also no consistence in the sign of the significant beta coefficients. Even though the explanatory power of models where the significant variables can be found ranges between 7 to 10%, a good result for daily financial data, we reject our initial hypothesis of long-term relationship between Bitcoin and real economy. This means that the independency of Bitcoin was not rejected and there is no way of creating expectations of Bitcoin value based on the variables used.

7 Conclusion

This paper examines features of the new and arguably first broadly used virtual currency, Bitcoin. In the first part we have explained the term virtual currency and have examined the current legal status of Bitcoin in various countries around the world and focused on the history of formerly most important Bitcoin exchange, MtGox. The price of Bitcoin at MtGox has become the basis of our econometric study. We have struggled with the structure of the dataset as it has been spoiled by the effects of MtGox entering and exiting the market. Also very high spikes and changing volatility has been observed. To account for the changes in the dataset we have employed the Iterated cumulative sums of squares (ICSS) algorithm introduced by Inclan & Tiao (1994) and found 10 significant structural breaks in the dataset.

Our first econometric research focused on presence of conditional heteroskedasticity in the data and the importance of structural breaks in its modelling. We have confirmed the presence of conditional heteroskedasticity and applied models from autoregressive conditional heteroskedasticity (ARCH) family. The TARCH (1,1) model with structural breaks as variance dummy variables was found to be the best fit for the data. Also the importance of incorporating the structural breaks in the explanation of conditional heteroskedasticity has been shown and this result is consistent with the literature.

The second part of my research focused on finding any significant relationship between "intangible" Bitcoin and "tangible" economy through method of Ordinary least squares (OLS). We have used NASDAQ composite index, Nikkei 225, SSE Composite, gold and crude oil prices to find any significant relationship between them and Bitcoin. The structural breaks have been used to divide the data sample into 10 time periods. Even though there have been found some relationships between Bitcoin and the mentioned variables, these relationships differed through the time periods in terms of both significance and sign. Our conclusion here is that there is no significant long-term relationship between the price of Bitcoin and the "tangible" economy. This results reinforces the hypothesis of Bitcoin's independency.

8 References

Anderson, W. S. (1969). *Ballentine's Law Dictionary With Pronunciations* (3 edition.). Lawyers Co-Op Pub Co.

Ball, J. (2011, June 22). LulzSec rogue suspected of Bitcoin hack. *The Guardian*. Retrieved from http://www.theguardian.com/technology/2011/jun/22/lulzsec-rogue-suspected-of-bitcoin-hack

Baur, D. G., & McDermott, T. K. (2009). *Is gold a safe haven? International evidence* (The Institute for International Integration Studies Discussion Paper Series No. iiisdp310). IIIS. Retrieved from http://ideas.repec.org/p/iis/dispap/iiisdp310.html

BBC. (2014, March 21). MtGox finds 200,000 lost bitcoins. *BBC News*. Retrieved from http://www.bbc.com/news/technology-26677291

Bitcoin Co. Ltd. (2013, July 29). Trading suspended due to Bank of Thailand advisement. Retrieved from https://bitcoin.co.th/trading-suspended-due-to-bank-of-thailand-advisement/

Bollerslev, T. (1986). Generalized autoregressive conditional heteroskedasticity. *Journal of Econometrics*, *31*(3), 307–327.

Brito, J., & Castillo, A. (2013). BITCOIN: A Primer for Policymakers. Mercatus Center at George Mason University. Retrieved from http://mercatus.org/sites/default/files/Brito_BitcoinPrimer_embargoed.pdf

Burnham, K. P., & Anderson, D. R. (2002). *Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach*. Springer.

Buterin, V. B. on J. (2012, June 8). Anniversary of the Great Bubble of 2011. *Bitcoin Magazine*. Retrieved from http://bitcoinmagazine.com/1546/anniversary-of-the-great-bubble-of-2011/

Capie, F., Mills, T. C., & Wood, G. (2005). Gold as a hedge against the dollar. *Journal of International Financial Markets, Institutions and Money*, *15*(4), 343–352.

Cieslak, M. (2013, November 1). First Bitcoin ATM opens in Canada. *BBC*. Retrieved from http://www.bbc.co.uk/news/technology-24756030

Dillet, R. (2013, August 23). Feds Seize Another $2.1 Million From Mt. Gox, Adding Up To $5 Million. *TechCrunch*. Retrieved from http://techcrunch.com/2013/08/23/feds-seize-another-2-1-million-from-mt-gox-adding-up-to-5-million/

Ehrenfreund, M. (2013, March 27). Cypriot banks to reopen amid criticism of bailout. *The Washington Post*. Retrieved from http://www.washingtonpost.com/business/cypriot-banks-to-reopen-amid-criticism-of-bailout/2013/03/27/dd56757c-96e1-11e2-b68f-dc5c4b47e519_story.html

Engle, R. F. (1982). Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of United Kingdom Inflation. *Econometrica*, *50*(4), 987–1007.

European Central Bank. (2012, October). Virtual Currency Schemes. Retrieved from https://www.ecb.europa.eu/pub/pdf/other/virtualcurrencyschemes201210en.pdf

Eyal, I., & Sirer, E. G. (2013). Majority is not Enough: Bitcoin Mining is Vulnerable. *CoRR*, *abs/1311.0243*. Retrieved from http://dblp.uni-trier.de/db/journals/corr/corr1311.html#EyalS13

Farrell, M. (2013, March 28). Bitcoin prices surges as post-Cyprus bailout. *CNNMoney*. Retrieved May 5, 2014, from http://money.cnn.com/2013/03/28/investing/bitcoin-cyprus/index.html

Financial Crimes Enforcement Network of United States department of the Treasury. Application of FinCEN's Regulations to Persons Administering, Exchanging, or Using Virtual Currencies (2013).

Finnish Tax Administration. Virtuaalivaluuttojen tuloverotus, Tax law (2013).

Gotthold, K., & Eckert, D. (2013, August 17). Bitcoins als Geld anerkannt. *Welt Online*. Retrieved from http://www.welt.de/print/die_welt/finanzen/article119111153/Bitcoins-als-Geld-anerkannt.html

Government of Canada, C. R. A. (2013). *What you should know about digital currency* (News Release). Retrieved from http://news.gc.ca/web/article-en.do?nid=787789

Graf, K. S. (2013). On the origins of Bitcoin: Stages of monetary evolution. Retrieved from http://konradsgraf.com/storage/On%20the%20Origins%20of%20Bitcoin%20Graf%2003.11.13.pdf

Grinberg, R. (2011). *Bitcoin: An Innovative Alternative Digital Currency* (SSRN Scholarly Paper No. ID 1817857). Rochester, NY: Social Science Research Network. Retrieved from http://papers.ssrn.com/abstract=1817857

Hannestad, A. (2014, March 25). Bitcoin-gevinster kan stikkes direkte i lommen. *www.politiken.dk*. Retrieved May 10, 2014, from http://politiken.dk/oekonomi/dkoekonomi/ECE2244816/bitcoin-gevinster-kan-stikkes-direkte-i-lommen/

Hern, A. (2013, December 18). Bitcoin plummets as China's largest exchange blocks new deposits. *The Guardian*. Retrieved from http://www.theguardian.com/technology/2013/dec/18/bitcoin-plummets-china-payment-processors-digital-cryptocurrency

Hillebrand, E. (2005). Neglecting parameter changes in GARCH models. *Journal of Econometrics*, *129*(1-2), 121–138.

HM Revenue and Customs. Revenue & Customs Brief 09/14 (2014). Retrieved from http://www.hmrc.gov.uk/briefs/vat/brief0914.htm

Hülsmann, J. G. (2008). *Deflation and Liberty*. Ludwig von Mises Institute.

Inclan, C., & Tiao, G. C. (1994). Use of Cumulative Sums of Squares for Retrospective Detection of Changes of Variance. *Journal of the American Statistical Association*, *89*(427), 913. doi:10.2307/2290916

Internal Revenue Service. (2014, March 25). Virtual Currency Guidance - Notice 2014-21. Retrieved from http://www.irs.gov/pub/irs-drop/n-14-21.pdf?utm_source=3.31.2014+Tax+Alert&utm_campaign=3.31.14+Tax+Alert&utm_medium=email

Jeffries, A. (2012, August 27). Suspected multi-million dollar Bitcoin pyramid scheme shuts down, investors revolt. *The Verge*. Retrieved May 5, 2014, from http://archive.today/4SplF#selection-2893.0-2893.82

Jones, H. (2013, December 13). EU banking watchdog warns of risks from Bitcoin. *Reuters*. London. Retrieved from http://www.reuters.com/article/2013/12/13/us-eu-bitcoin-idUSBRE9BC00820131213

Kaplanov, N. M. (2012). *Nerdy Money: Bitcoin, the Private Digital Currency, and the Case Against Its Regulation* (SSRN Scholarly Paper No. ID 2115203). Rochester, NY: Social Science Research Network. Retrieved from http://papers.ssrn.com/abstract=2115203

Karpeles, M. (2014). *Announcement regarding an Application for commencment ofa procedure of civil rehabilation*. Tokyo. Retrieved from http://www.mtgox.com/img/pdf/20140228-announcement_eng.pdf

Kiefer, N. M. (2001). *Heteroskedasticity-Autocorrelation Robust Standard Errors Using the Bartlett Kernel without Truncation* (Working Paper No. 01-13). Cornell University, Center for Analytic Economics. Retrieved from http://ideas.repec.org/p/ecl/corcae/01-13.html

Kristoufek, L. (2013). BitCoin meets Google Trends and Wikipedia: Quantifying the relationship between phenomena of the Internet era. *Sci. Rep.*, *3*(3415). Retrieved from http://dx.doi.org/10.1038/srep03415

Krugman, P. (2010, August 2). Why Is Deflation Bad? *Paul Krugman Blog*. Retrieved from http://krugman.blogs.nytimes.com/2010/08/02/why-is-deflation-bad/

Krugman, P. (2011, September 7). Golden Cyberfetters. *Paul Krugman Blog*. Retrieved from http://krugman.blogs.nytimes.com/2011/09/07/golden-cyberfetters/

Lee, B. (2013, December 20). An Open Letter from Bobby Lee, CEO of BTC China.

Lenz, K.-F. (2013, June 8). Internal Market Principle and Bitcoin Regulated Market. *Lenz Blog*. Retrieved from http://k.lenz.name/LB/?p=9486

Lorentzen, Ma. (2013, November 21). Skatteetaten har bestemt seg: Handler du bitcoins må du ut med både skatt og moms. *E24*. Retrieved from http://e24.no/digital/handler-du-bitcoins-maa-du-ut-med-skatt-og-moms/22639792

Mandelbrot, B. (1963). The Variation of Certain Speculative Prices. *The Journal of Business*, *36*(4), 394–419. doi:10.2307/2350970

Mankiw, N. G. (2008). *Principles of Macroeconomics* (5th ed.). Cengage Learning.

Marian, O. Y. (2013). *Are Cryptocurrencies "Super" Tax Havens?* (SSRN Scholarly Paper No. ID 2305863). Rochester, NY: Social Science Research Network. Retrieved from http://papers.ssrn.com/abstract=2305863

MtGox. (2014, February 10). MtGox - Bitcoin Exchange. Retrieved from https://web.archive.org/web/20140210122955/https://www.mtgox.com/press_release_20140210.html

Nakamoto, S. (2012). Bitcoin: A peer-to-peer electronic cash system, 2009. *URL: Http://www. Bitcoin. Org/bitcoin. Pdf*.

Nelson, D. B. (1991). Conditional Heteroskedasticity in Asset Returns: A New Approach. *Econometrica*, *59*(2), 347–70.

Nestler, F. (2013, August 16). Digitale Währung Deutschland erkennt Bitcoins als privates Geld an. *FAZ.NET*. Retrieved from http://www.faz.net/aktuell/finanzen/devisen-rohstoffe/digitale-waehrung-deutschland-erkennt-bitcoins-als-privates-geld-an-12535059.html

Pronina, L., & Kravchenko, S. (2014, January 24). Bitcoin Backed by Sberbank's Gref as Russia Plans Curbs. *Bloomberg*. Retrieved May 5, 2014, from http://www.bloomberg.com/news/2014-01-24/bitcoin-gains-support-from-sberbank-s-gref-as-russia-plans-curbs.html

Rabemananjara, R., & Zakoian, J. M. (1993). Threshold Arch Models and Asymmetries in Volatility. *Journal of Applied Econometrics*, *8*(1), 31–49.

Roio, D. J. (2013). Bitcoin, the end of the Taboo on Money. Dyne.org digital press. Retrieved from http://www.dyndy.net/2013/04/bitcoin-ends-the-taboo-on-money/

Sakawee, S. (2014, February 17). Bank of Thailand says country's top Bitcoin exchange can resume... *Tech in Asia*. Retrieved May 8, 2014, from http://www.techinasia.com/bank-thailand-countrys-top-bitcoin-exchange-resume-operations/

Seizure warrant. 1:13-mj-01085-SAG (US district of Maryland court June 19, 2013).

State Duma. FEDERAL LAW OF THE RUSSIAN FEDERATION About Central Bank of the Russian Federation (Bank of Russia), Pub. L. No. 86-FZ (2002).

Šurda, P. (2012). *Economics of Bitcoin: is Bitcoin an alternative to _at currencies and gold?* (Diploma thesis). University of Economics and Business, Vienna.

The Bank of Russia, P. service. (2014). *Об использовании при совершении сделок «виртуальных валют», в частности, Биткойн*. Moscow: The Central Bank of the Russian Federation.

The Bank of Thailand. (2014, March 18). Bitcoin and other similar electronic units. Retrieved from http://www.bot.or.th/Thai/PressAndSpeeches/Press/News2557/n0857t.pdf

The People's Bank of China. (2013). *The People's Bank of China and Five Associated Ministries Notice: "Prevention of Risks Associated with Bitcoin."* Retrieved from https://vip.btcchina.com/page/bocnotice2013

Thompson, M. (2013, March 17). Rush to ATMs in Cyprus on EU bailout tax. *CNNMoney*. Retrieved May 5, 2014, from http://money.cnn.com/2013/03/16/news/economy/europe-cyprus-bailout/index.html

Trading Titan Blog. (2012). What U.S. Regulations Apply to Bitcoins as Commodities? *Bitcoin Titan & Trading Titan*. Retrieved from http://blog.bitcointitan.com/post/17789738826/what-u-s-regulations-apply-to-bitcoins-as-commodities

United States Magistrate Judge Mazzant, A. L. Securities and Exchange Commission v. Trendon T. Shavers and Bitcoin Savings and Trust, No. 4:13-CV-416 (US District Court, Eastern District of Texas, Sherman division August 6, 2013).

Wierciszewski, M. (2013, December 18). MinFin: Bitcoin nie jest nielegalny. *Puls Biznesu*.

9 Appendix

9.1 Dataset adjustment

1) Summary statistics of the original dataset

```
Summary statistics, using the observations 2010/07/17 - 2014/02/25
for the variable 'BTC_Close' (1320 valid observations)

  Mean                         90.788
  Median                       9.0196
  Minimum                    0.049510
  Maximum                      1238.0
  Standard deviation           220.54
  C.V.                         2.4292
  Skewness                     3.2556
  Ex. kurtosis                 9.7771
  5% percentile              0.065525
  95% percentile               784.01
  Interquartile range          75.740
  Missing obs.                      0
```

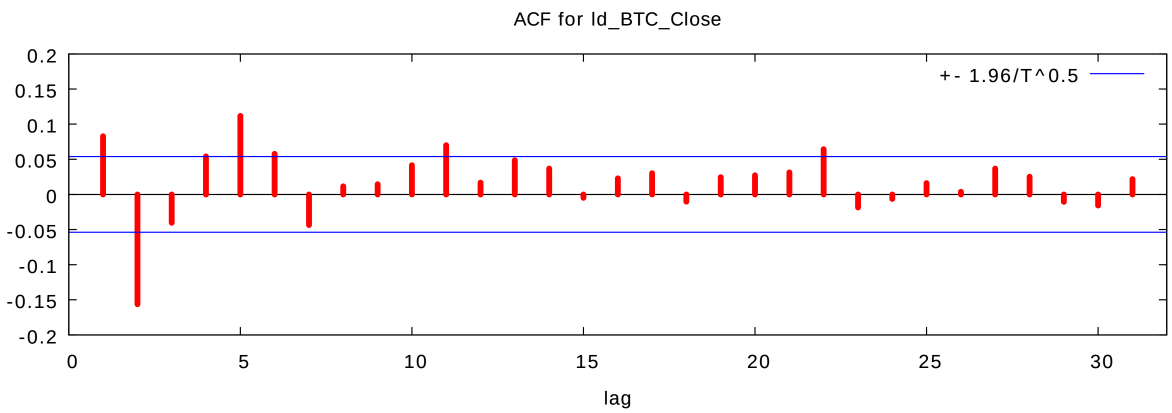
2) Results of Augmented Dickey-Fuller test of the original dataset

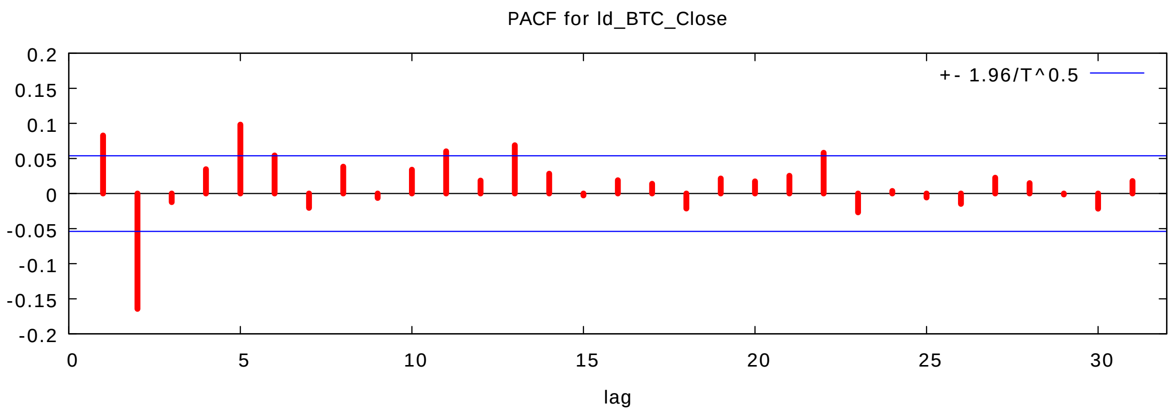
```
Augmented Dickey-Fuller test for BTC_Close
including 21 lags of (1-L)BTC_Close (max was 22)
sample size 1298
unit-root null hypothesis: a = 1

   test with constant
   model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
   1st-order autocorrelation coeff. for e: 0.005
   lagged differences: F(21, 1275) = 18.607 [0.0000]
   estimated value of (a - 1): -0.00397387
   test statistic: tau_c(1) = -1.44414
   asymptotic p-value 0.5621

   with constant and trend
   model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + ... + e
   1st-order autocorrelation coeff. for e: -0.001
   lagged differences: F(22, 1272) = 17.975 [0.0000]
   estimated value of (a - 1): -0.00793909
   test statistic: tau_ct(1) = -2.33164
   asymptotic p-value 0.4161
```

3) Summary statistics of the differentiated dataset

```
Summary statistics, using the observations 2010/07/17 - 2014/02/25
for the variable 'ld_BTC_Close' (1319 valid observations)

  Mean                          0.0059976
  Median                        0.0022765
  Minimum                       -0.85018
  Maximum                        0.83021
  Standard deviation            0.084921
  C.V.                            14.159
  Skewness                      -0.35474
  Ex. kurtosis                    21.355
  5% percentile                 -0.10870
  95% percentile                 0.12611
  Interquartile range           0.045828
  Missing obs.                         1
```

4) ACF and PACF of the differentiated series

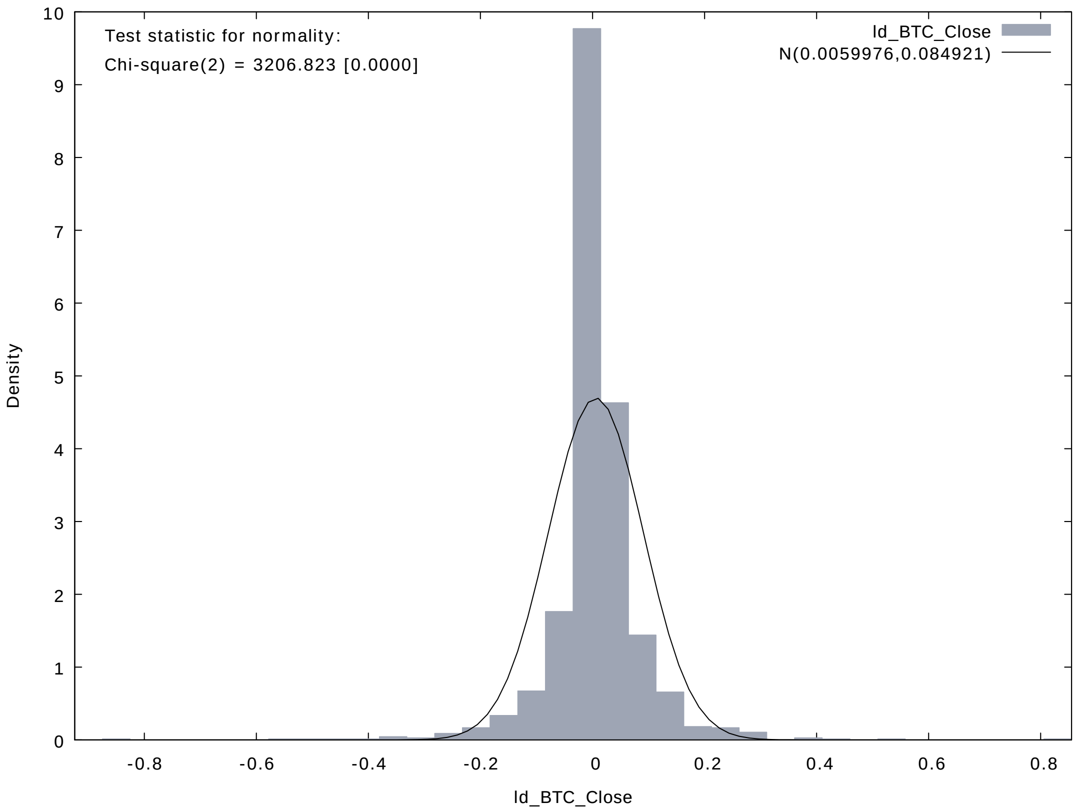




5) Results of Augmented Dickey-Fuller test of the differentiated dataset

```
Augmented Dickey-Fuller test for ld_BTC_Close
including 21 lags of (1-L)ld_BTC_Close (max was 22)
sample size 1297
unit-root null hypothesis: a = 1

   test with constant
   model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
   1st-order autocorrelation coeff. for e: 0.002
   lagged differences: F(21, 1274) = 4.950 [0.0000]
   estimated value of (a - 1): -0.540814
   test statistic: tau_c(1) = -4.78051
   asymptotic p-value 5.618e-005

   with constant and trend
   model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + ... + e
   1st-order autocorrelation coeff. for e: 0.002
   lagged differences: F(21, 1273) = 4.924 [0.0000]
   estimated value of (a - 1): -0.549844
   test statistic: tau_ct(1) = -4.8475
   asymptotic p-value 0.0003531
```

6) Histogram of the differentiated series



7) Table of quantiles for ICSS procedure

Table 1. Empirical and Asymptotic Quantiles of $\max_k \sqrt{T/2}\,|D_k|$

T	100		200		300		400		500		∞
p	q_D	SE	q_D	SE	q_D	SE	q_D	SE	q_D	SE	D^*_{1-p}
.05	.44	.003	.47	.003	.47	.003	.48	.003	.049	.003	.520
.10	.50	.003	.52	.003	.53	.003	.53	.003	.054	.002	.571
.25	.60	.004	.63	.003	.63	.003	.64	.003	.065	.003	.677
.50	.75	.004	.78	.003	.78	.003	.79	.003	.080	.003	.828
.75	.94	.004	.97	.004	.97	.004	.97	.004	1.00	.004	1.019
.90	1.14	.006	1.16	.006	1.18	.007	1.18	.006	1.20	.006	1.224
.95	1.27	.009	1.30	.004	1.31	.008	1.31	.010	1.33	.009	1.358
.99	1.52	.004	1.55	.012	1.57	.028	1.57	.020	1.60	.018	1.628

9.2 Volatility inspection results

1) ARMA (7,0) regression results

```
Model 89: ARMA, using observations 2010/08/02-2014/02/06 (T = 1285)
Estimated using Kalman filter (exact ML)
Dependent variable: ld_BTC_Close
Standard errors based on Hessian

             coefficient    std. error      z       p-value
  ---------------------------------------------------------
  const       0.00738803    0.00226870    3.257     0.0011  ***
  phi_1       0.0889880     0.0278373     3.197     0.0014  ***
  phi_2      -0.0504209     0.0279274    -1.805     0.0710  *
  phi_3      -0.0155251     0.0274095    -0.5664    0.5711
  phi_4       0.000182732   0.0278149     0.006570  0.9948
  phi_5       0.0676618     0.0278612     2.429     0.0152  **
  phi_6       0.0886970     0.0278144     3.189     0.0014  ***
  phi_7      -0.0603038     0.0278951    -2.162     0.0306  **

Mean dependent var   0.007405   S.D. dependent var   0.072704
Mean of innovations  2.68e-06   S.D. of innovations  0.071649
Log-likelihood       1563.842   Akaike criterion    -3109.683
Schwarz criterion   -3063.257   Hannan-Quinn        -3092.254

                        Real  Imaginary    Modulus  Frequency
  -----------------------------------------------------------
  AR
    Root  1           1.7871    -0.3052     1.8130    -0.0269
    Root  2           1.7871     0.3052     1.8130     0.0269
    Root  3          -1.4471     0.0000     1.4471     0.5000
    Root  4          -0.8130    -1.1255     1.3884    -0.3496
    Root  5          -0.8130     1.1255     1.3884     0.3496
    Root  6           0.4848    -1.2544     1.3448    -0.1913
    Root  7           0.4848     1.2544     1.3448     0.1913
  -----------------------------------------------------------
```

2) ARCH LM test of ARMA (7,0) results

Test for ARCH of order 7

	coefficient	std. error	t-ratio	p-value	
alpha(0)	0.00256906	0.000498780	5.151	3.01e-07	***
alpha(1)	0.229653	0.0279902	8.205	5.61e-016	***
alpha(2)	0.0775903	0.0287228	2.701	0.0070	***
alpha(3)	0.120862	0.0288034	4.196	2.90e-05	***
alpha(4)	0.0155046	0.0289990	0.5347	0.5930	
alpha(5)	-0.0107500	0.0288036	-0.3732	0.7090	
alpha(6)	-0.00240071	0.0287225	-0.08358	0.9334	
alpha(7)	0.0712341	0.0279907	2.545	0.0110	**

Null hypothesis: no ARCH effect is present
Test statistic: LM = 140.918
with p-value = P(Chi-square(7) > 140.918) = 3.26464e-027

3) Results of TARCH (1,1) with dummies

Model: TARCH(1,1) [Zakoian] (Normal)
Dependent variable: uhat89
Sample: 2010/08/02-2014/02/06 (T = 1285), VCV method: Robust

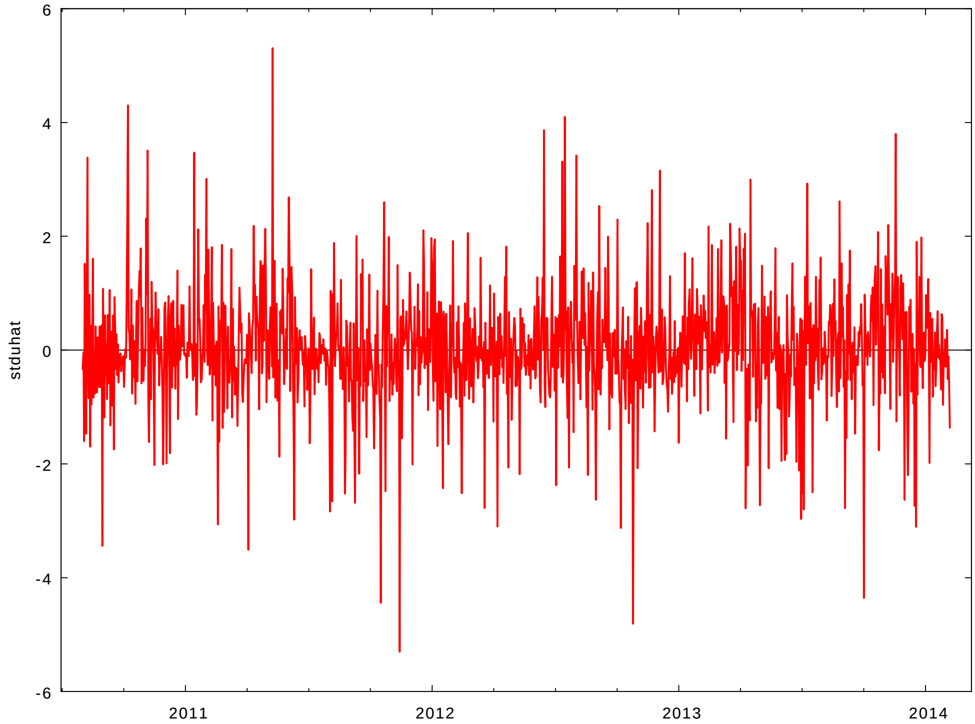
Conditional mean equation

	coefficient	std. error	z	p-value	
const	-0.00305799	0.000854231	-3.580	0.0003	***

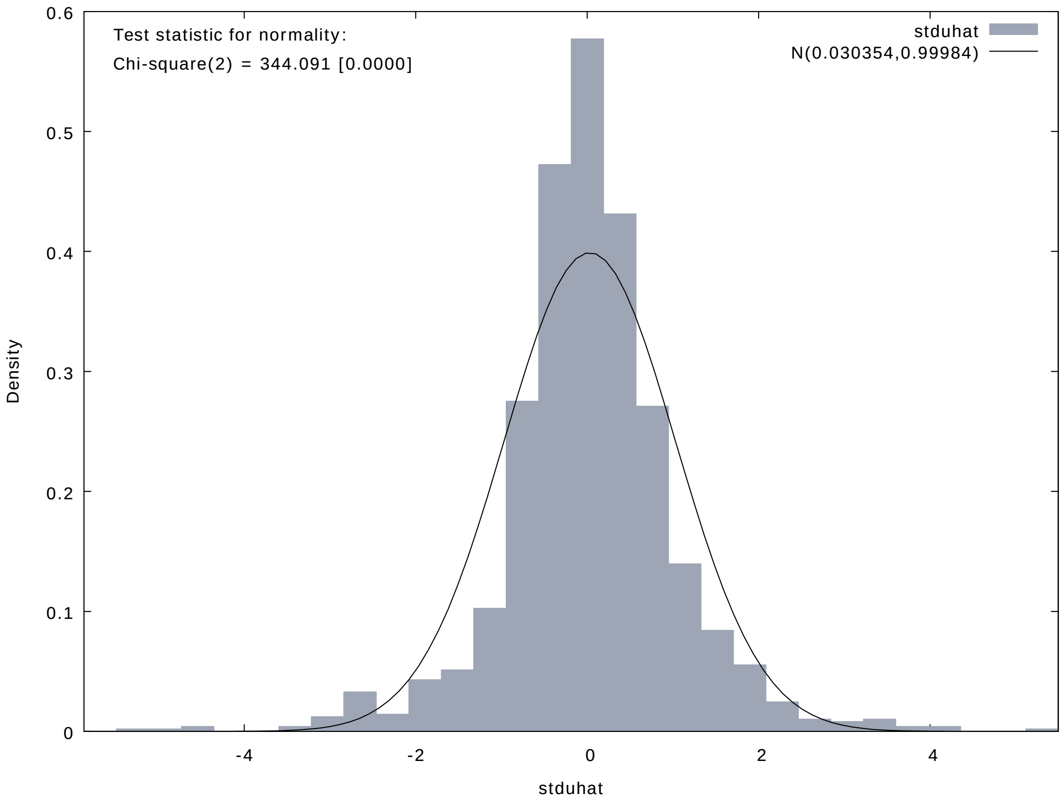
Conditional variance equation

	coefficient	std. error	z	p-value	
const	0.000652217	0.000218164	2.990	0.0028	***
d7_10_10	0.00134634	0.000477979	2.817	0.0049	***
d11_2_11	0.000531722	0.000310779	1.711	0.0871	*
d21_4_11	0.00143595	0.000682344	2.104	0.0353	**
d9_8_11	0.000726689	0.000287274	2.530	0.0114	**
d27_3_12	-0.000105730	0.000194425	-0.5438	0.5866	
d14_8_12	0.00452651	0.00205451	2.203	0.0276	**
d20_8_12	-0.000259177	0.000193453	-1.340	0.1803	
d15_1_13	0.000549206	0.000252095	2.179	0.0294	**
d4_5_13	0.000155664	0.000203231	0.7659	0.4437	
d6_11_13	0.00112926	0.000453459	2.490	0.0128	**
alpha	0.308519	0.0529153	5.830	5.53e-09	***
gamma	0.0202051	0.0642172	0.3146	0.7530	
beta	0.506357	0.0721206	7.021	2.20e-012	***

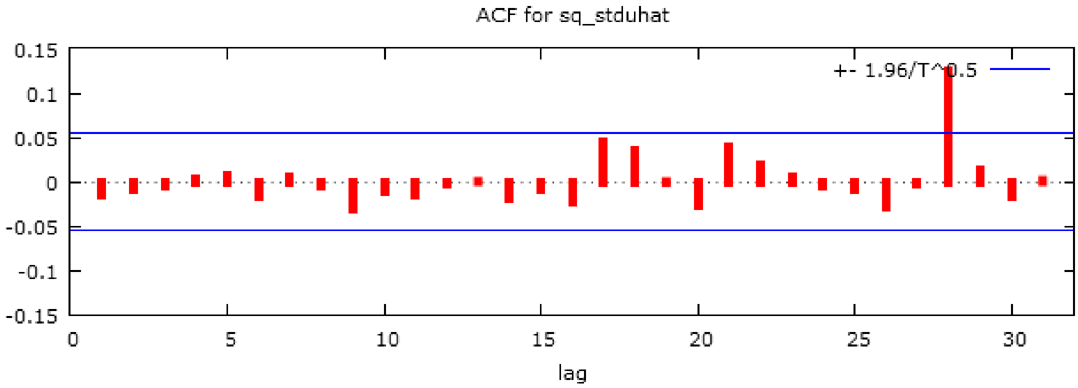
4) Standardized residuals of TARCH(1,1) model



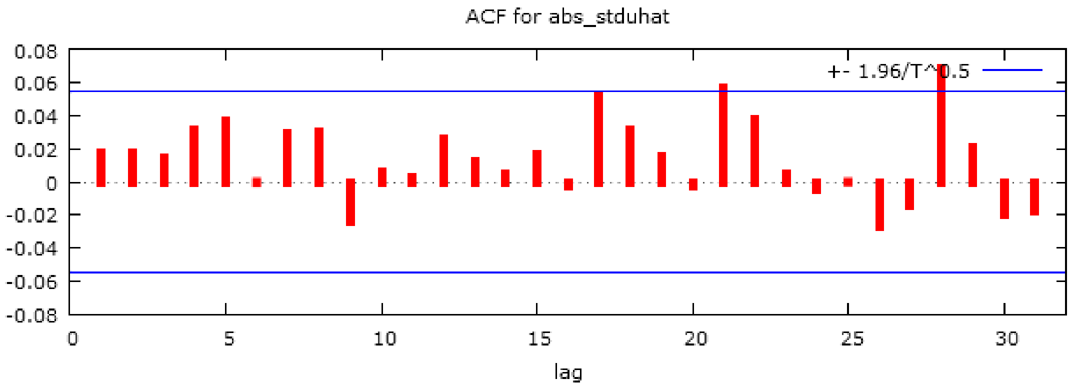
5) Histogram of standardized residuals of TARCH (1,1) model



6) Correlogram of squared standardized residuals of TARCH (1,1) model



7) Correlogram of absolute values of standardized residuals of TARCH (1,1) model



9.3 OLS regression results

1) Results of OLS model performed on the whole dataset

```
Model 47: OLS, using observations 2010/08/02-2014/02/06 (T = 1285)
Dependent variable: ld_BTC_Close

             coefficient   std. error   t-ratio   p-value
  --------------------------------------------------------
  const       0.00730010   0.00203215   3.592     0.0003   ***
  ld_gold     0.0580854    0.209835     0.2768    0.7820
  ld_crude    0.355216     0.186543     1.904     0.0571   *
  ld_nasdaq   0.0114785    0.230086     0.04989   0.9602
  ld_nikkei   0.0273693    0.182544     0.1499    0.8808
  ld_SSE      0.0178844    0.226668     0.07890   0.9371

Mean dependent var   0.007405   S.D. dependent var   0.072704
Sum squared resid    6.759959   S.E. of regression   0.072700
R-squared            0.003996   Adjusted R-squared   0.000102
F(5, 1279)           1.026279   P-value(F)           0.400563
Log-likelihood       1548.181   Akaike criterion    -3084.362
Schwarz criterion   -3053.411   Hannan-Quinn        -3072.742
rho                  0.085176   Durbin-Watson        1.828128

Excluding the constant, p-value was highest for variable 14 (ld_nasdaq)

Breusch-Pagan test for heteroskedasticity -
  Null hypothesis: heteroskedasticity not present
  Test statistic: LM = 6.87322
  with p-value = P(Chi-square(5) > 6.87322) = 0.230241

White's test for heteroskedasticity -
  Null hypothesis: heteroskedasticity not present
  Test statistic: LM = 18.8177
  with p-value = P(Chi-square(20) > 18.8177) = 0.533706

Test for normality of residual -
  Null hypothesis: error is normally distributed
  Test statistic: Chi-square(2) = 1028.01
  with p-value = 5.90341e-224

LM test for autocorrelation up to order 7 -
  Null hypothesis: no autocorrelation
  Test statistic: LMF = 5.48133
  with p-value = P(F(7,1272) > 5.48133) = 3.19909e-006

Test for ARCH of order 7 -
  Null hypothesis: no ARCH effect is present
  Test statistic: LM = 133.815
  with p-value = P(Chi-square(7) > 133.815) = 1.00209e-025
```

2) Summary of OLS regressions results

		H_0 = homoskedasticity		H_0 = normality			H_0 = no autocor.		
		Breusch-Pagan	White	Normality	R-squared	Collinearity	Autocorrelation	Durbin Watson	ARCH
period 1	1.8.2010 - 7.10.2010	0,0550	0,8200	0,0000	5,57%	no	no	no	no
period 2	8.10.2010 - 10.2.2011	0,8179	0,9836	0,0000	8,75%	no	yes 0,03	yes	yes 0
period 3	11.2.2011 - 20.4.2011	0,8166	0,9577	0,2267	3,98%	no	no	no	no
period 4	21.4.2011 - 8.8.2011	0,1157	0,9904	0,0000	7,09%	no	no	no	no
period 5	9.8.2011 - 26.3.2012	0,0048	0,0073	0,0000	9,39%	no	yes 0,02	yes	no
period 6	27.3.2012 - 13.8.2012	0,0193	0,8486	0,0000	1,30%	no	no	no	no
period 7	20.8.2012 - 14.1.2013	0,0120	1,0000	0,0000	1,22%	no	no	yes	no
period 8	15.1.2013 - 3.5.2013	0,1509	0,0133	0,0003	8,98%	no	yes 0,00	yes	yes 0
period 9	4.5.2013 - 5.11.2013	0,0294	0,5108	0,0000	9,10%	no	no	no	yes 0
period 10	6.11.2013 - 6.2.2014	0,2168	0,0486	0,0066	6,88%	no	no	no	yes 0,0033