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EXPLORATION OF THE RELATIONSHIPS BETWEEN GOOGLE SEARCHES AND BITCOIN'S VOLATILITY, TRADED VOLUME AND PRICE

Samuli Kesseli

International Business
Bachelor's Thesis
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ABSTRACT OF
BACHELOR'S THESIS

Author: Samuli Kesseli
Title of thesis: Exploration of the relationships between Google Searches and Bitcoin's price, volatility and traded volume

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Supervisor: Roman Stepanov

Bitcoin has gained more and more press coverage during the past few years. Bitcoin is also fairly new phenomena, and as such it has not been researched as much as other, more traditional financial assets. Bitcoin is also highly speculative asset. That is why information demand is important variable when looking at Bitcoin's key figures, which are: price, volatility and traded volume.

This paper uses Google Searches (Google Trend Index) as an independent variable whereas Bitcoin's price, volatility and traded volume are dependent variables. The aim of the study is to find relationships between the independent variable and the dependent variables, through correlations and regression models. The data will be examined yearly from 2014 to 2017.

The paper is exploratory in nature, meaning that it will not make specific hypothesizes, due to the lack of research conducted on Bitcoin, but will make more broad assumptions on the results. The aim of the paper is to create foundation for future research and gain more information on the matter and possibly gain new perspectives.

The main findings of this study were upward trend and overall very high correlations across all years. However, the results for 2017 were significantly higher than the previous years.

All the regression models showed positive coefficients meaning that as the Google Trend Index rises so does Bitcoin price, volatility and traded volume. However, the rise in volatility was fairly limited. Also, nearly all the regression model results were significant. The problem of internal validity existed in the study, which meant that no causal relationship could be found.

Key words: *Bitcoin, volatility, volume, price, google searches, google search index, information demand, behavioral finance, efficient market hypothesis, regression, correlation*

Language: English

Grade:

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1 INTRODUCTION

1.1 Background

1.1.1 Introduction to Bitcoin

Society has used different forms of exchange all the way from furs of different animals to gold coins and gold-based notes also known as fiat currency. In 2009 was born another alternative (Nakamoto, S., 2008). Alias “Satoshi Nakamoto” created decentralized virtual currency called Bitcoin, it was first of its kind and according to Nakamoto, S. (2008) the main idea of the currency was to remove the middle man, usually a bank of some sort, from transactions to decrease transaction costs.

To put it simply Bitcoin is a piece of open source code. It is decentralized, and it works through decentralized network created by its users. Bitcoins are created by application called “mining” and this is done by computers, which solve an equation which gets more and more difficult to solve as the amount of Bitcoin in circulation increases. There is also a limit on how many Bitcoins can be in circulation, which is 21 million (Nakamoto, S., 2008).

Bitcoin has many benefits. Firstly, it makes payments as easy as sending an email. Secondly, due to its decentralized nature and open source code every transaction is public and there is no risk for identity theft. Thirdly, Bitcoin is also cheaper option to sending money as it takes the middleman out of the equation as the whole system is completely peer-to-peer. This means, that Bitcoin cannot be controlled by a third party such as a bank or a government. It is impossible to artificially increase and thus weaken its value, because the maximum supply of Bitcoins is fixed. Finally, transactions are also extremely quick. Global transactions take somewhere between 2-30 minutes whereas bank transactions could take days or even weeks.

There are also drawbacks to Bitcoins. Firstly, mining Bitcoin and upkeeping the Bitcoin network requires massive amounts of energy. Currently Bitcoin network is consuming 42TWh of electricity in a year (Hern, A., 2018). Also, after bitcoins have been sent it is impossible to reverse the transactions as they are logged in to a

public “blockchain”. Bitcoin exchanges have also experienced a number of security breaches which causes insecurity among Bitcoin holders.

1.1.2 Choice of Subject

Bitcoin is a fairly new phenomenon and as such research into it is limited. The literature review will dive into more detail on this matter, but it is important to recognize the importance of all studies conducted into Bitcoin. The core technology used in Bitcoin, also called “blockchain technology” is new and it has been utilized in various different ways. Even though it is most known for Bitcoin, people have found other ways to utilize it. These ways include: smart contracts, digital voting cyber security and improving government efficiency (Forbes.com, 2017). Bitcoin is also being accepted in more places every day, so it is important to research it as more and more consumers use it in their daily lives.

1.1.3 Limitations of the study

This paper will look at how increase or decrease in information demand (Google searches) will affect the dependent variables (price, volatility and volume of Bitcoin). This presents a problem. It is impossible to know for sure that the information demand (Google Searches) is the factor which drives these dependent variables. There could be multiple other variables affecting them. This decreases the internal validity of the study. Due to this fact, this research will not set specific hypothesises, but rather more broad assumptions on what the results might be.

To get the data on searches, a keyword (searched word) must be chosen. This presents another problem. Data on one search word does not represent the whole information demand on the subject.

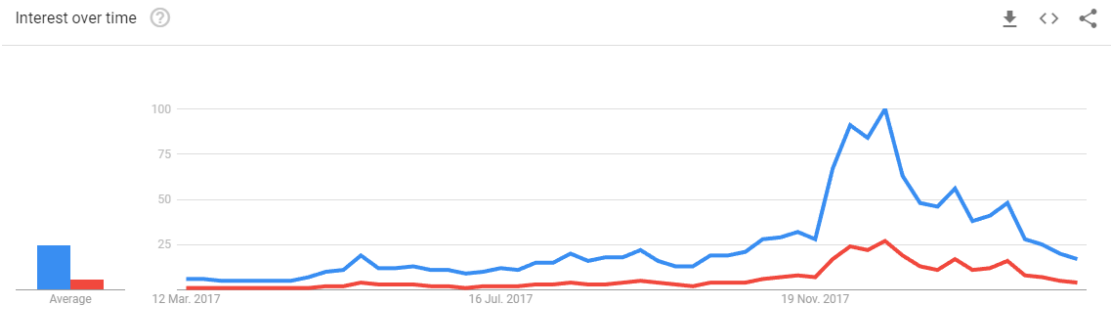

Figure 1: Google Trends graph on terms ‘Bitcoin’ and ‘Bitcoin price’

The keyword this study chose to examine is ‘Bitcoin’, which is the blue line in Figure 1. Although the interest for the word is clearly the highest compared to the second most googled term ‘Bitcoin price’, which is represented with the red line in figure 1, it still an issue, which decreases the validity of the paper. Also, note that Google trends is not case sensitive, so it does not differentiate between ‘Bitcoin’ and ‘bitcoin’.

1.1.4 Defining the nature of the paper

This study will use often in its linguistics the word *relationship.* As the goal of this research is to look at the *relationships* between Google Searches and Bitcoin volatility, traded volume and price it is important to define what it means in the context of this research.

As stated before, the research into Google Searches and bitcoin is very restricted. That is why this paper will not make specific hypothesises between these variables but rather more broad assumptions on what the results might be. Relationship is a neutral term and it refers to the fact that this paper is more exploratory in nature. Its aim is to look at these variables more broadly and through that offer foundation for future research on the subject.

1.1.5 Research Gap

The research landscape on Bitcoin is different compared to many other traditional financial assets. In the research landscape of Bitcoin there are many small gaps. Major areas, such as Bitcoin's volatility, Bitcoin as a currency and Bitcoin as an investment have been researched quite thoroughly but smaller areas and specific subjects such as the subject of this paper have either not been researched at all, or the research conducted on them is very limited. This also means, that theories from more traditional financial assets will be applied, when the research into Bitcoin is lacking.

There is no strictly similar research conducted on the subject as this paper, but few studies have utilized Google searches in their research (Tjernström, M., and Johansson, N., 2014 and De Vries J., and Aalborg H., 2017). It has usually been in the supportive role in, for example, finding reasons for Bitcoin's unusual high volatility (Garcia, D., 2014). In this paper however, Google searches is one of the four key variables and the only independent variable, so this study is in a way, first of its kind.

The research gap is also a problem as supporting and comparing the findings will be difficult. As mentioned above the nature of this paper is to be more exploratory than directly trying to prove hypotheses. The research gap is one of the reasons why this perspective was chosen. Thus one of the objectives of the paper is to provide foundation for future research on the subject and to fulfil the current research gap that exists.

1.1.6 January Effect

As this paper is going to look at chosen variables in different time intervals it is important to note what these time intervals are and why they were chosen.

Bitcoin market has a very unique cycle, which more or less repeats itself every year roughly around the same time. In the Bitcoin community this affect goes with many names. Some call it the "January effect" and some the "end-of-year-effect". No

matter what it is called it is a clear reaction which has repeated itself for the past 4 years roughly around the same time, which is December-January.

This effect follows a pattern; first, Bitcoin price rises progressively starting usually in November. This increase intensifies around December and continues to the beginning of January (see Figures 2-3 below). Around the first two weeks however, the “bubble” bursts and Bitcoin price, as well as the whole cryptocurrency capitalization (from which Bitcoin covers a major portion), decreases rapidly. This usually follows a bearish market for the next few months, due to the increased fear around investors.

Below are Figures 2-3 to illustrate this. It is important to note that the following figures demonstrate the whole market capitalization of cryptocurrencies, not just Bitcoin. That being said, Bitcoin has dominated the percentage of total market capitalization with it varying from around 85 % in 2014-2017 and around 60% on 2018 (Coinmarketcap.com, 2018). So, when Bitcoin’s price goes down, the whole market capitalization decreases as well.

Figure 2: Cryptocurrency Market Capitalization November 1, 2016 – February 1, 2017

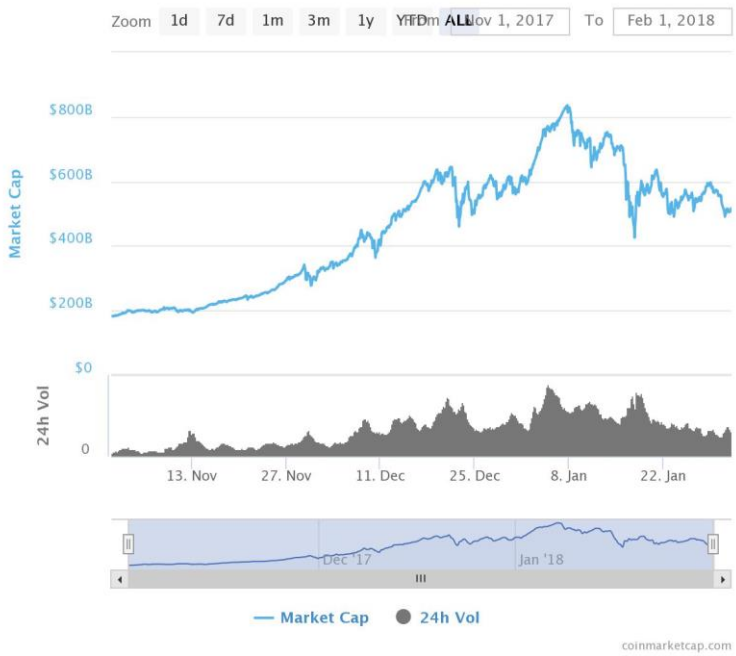

Figure 3: Cryptocurrency Market Capitalization November 1, 2017 – February 1, 2018

The reasons for this effect are still unknown. People in the cryptocurrency community have credited this affect to multiple reasons. Some say that this affect is caused by the Chinese New Year. They say that Chinese investors sell of their Bitcoins, and other cryptocurrencies in order to celebrate this event. Other have credited this effect to tax return policies of different countries, because in many countries income must be reported and taxed by the end of January. Other reasons include Wall Street Bonus systems and “reversed” January effect from usual stock market in the small companies.

Examining the reasons for this effect is not the objective of this paper. This paper is however very interested in this effect, because it shows how important it is to examine the data on a yearly basis to get more accurate results.

2 OUTLINING RESEARCH

2.1 Research problem

Due to Bitcoin's extremely speculative nature and to the fact that it is based solely on supply and demand it is important to research the effects of information demand on it. Only a few studies before this have utilized Google Searches in their research (Tjernström, M., and Johansson, N., 2014 and De Vries J., and Aalborg H., 2017), so it is very much unknown territory, so the aim of this paper is to gain more information on the matter and possibly new perspectives.

The variables which will be investigated are: Google Searches, Bitcoin Price, Bitcoin traded volume and Bitcoin volatility. Google Searches will be represented with Google's own index called Google Trends. Data on Price, volatility and traded volume of Bitcoin will be derived from Coinmarketcap.com which is one of the leading information providers on Bitcoin data. Standard deviation of daily closing prices will function as a measure of volatility.

2.2 Data collection

Bitcoin trading doesn't stop which creates a problem from data collection point of view. The closing time of the market for the day must be specified, and most exchanges and information banks have different time zones and different closing times. So, collecting data from multiple sources is not possible without the threat of distorted information. This paper chooses to use Coinmarketcap.com as its information source. Coinmarketcap.com is one of the largest information providers for cryptocurrencies today. They also have all the information on Bitcoin Price, volatility and traded volume at the same place. Through this the possibility of error in results created by distorted information is limited. Coinmarketcap.com states, that data is collected reported and recorded in UTC time (Coinmarketcap.com, 2018).

2.3 Research Questions and Assumptions

The following research questions are aimed to find if Google Search volume has clear relationship with Bitcoin's volatility, traded volume and price. Relationship in

this context has been defined previously. Correlation and regression models between the variables will be used to gain more information on their connection.

This paper will assume that there is a relationship between Google Searches and Bitcoin's price, volatility and traded volume. It will not however, develop hypothesises for possible results between the variables, due to limited research already conducted on the subject to reduce speculation. Instead of hypothesises, it will make more broad assumptions on the results of correlations and regression models.

The Literature review will dive into more detail on why each of the variables were chosen.

2.3.1 What is the relationship between Google Search volume and Bitcoin's volatility?

Bitcoin volatility is important because it is a measure of the movement of daily closing prices. In a way it is also a measure of trust in the market. High volatility usually indicates uncertainty on the market, so it will be important to see what kind of relationship Google Searches have with this variable. Volatility has also been the topic of much research and discussion with Bitcoin as it has faced quite high volatility in the recent years, so this factor is also very present.

The assumptions of this paper are that some correlation between the variables will be found, because during extreme price increases or decreases Bitcoin has received more news coverage, which should mean also higher information demand. Regression model however, will not likely provide clear prediction possibilities for the volatility of Bitcoin based on the Google search activity, because there are many other variables which can affect volatility.

2.3.2 What is the relationship between Google Search volume and Bitcoin's traded volume?

Trading volume was chosen as a variable because it reflects the overall activity of the market. As we look at the relationship between Google Searches and daily traded volume we might find if the increase in overall interest reflects itself to the market activity in the form of trading volume. Although we cannot imply causality due to the multiple variables which have not been accounted for in the regression models.

Broad assumption of this paper is, that a strong correlation between the variables will be found, since similar results have been found on more traditional financial assets, such as stocks, and information demand (Vlastakis, N. and Markellos, R., 2012). Regression model however, will not in all likelihood, provide to be useful predictor model for Bitcoin's traded volume due to the fact that data analysing method will use weekly averages. Weekly average trading volumes will be very high and too broad to make meaningful conclusions.

2.3.3 What is the relationship with Google Search volume and Bitcoin's price?

Price is important choice as a variable, since it is the value of one Bitcoin at a given time. Bitcoin has experienced a roller coaster in its price during the past few years. Often as the price has risen, so has the media interest. And when media covers Bitcoin more it creates more overall interest on it. This is what Google Searches represent in the study, so looking at the relationship between this interest and the actual price of bitcoin is crucial.

2.4 Research Objectives

The research objectives of this paper are to gain more insights on the relationships between the independent variable and dependent variables and to create foundation for future research on the subject. This paper aims to reach these objectives, by doing yearly correlation tests and by building yearly regression models.

2.4.1 Finding correlations between variables

Finding correlation values between variables is one of the research objectives. Correlation is used to test how strongly different variables are related. It is a crucial part of the study, because it shows the degree to which changes to the value of one variable predict the change to the value of another. However, correlation does not equal causality and as mentioned above, proving causality is a problem in this this study. Also, as the nature of this study is exploratory, correlation test fits to it perfectly.

2.4.2 Building regressive models which examine the relationship between Google searches and bitcoin volatility, traded volume and price

Regression analysis is used to get further knowledge between the independent variable and its effect to the dependent variables. Regression analysis helps to understand how the typical value of the dependent variable changes when independent variable is varied. Regression analysis can be also used for prediction and forecasting and in restricted circumstances to infer causal relationships.

The nature of this research however is exploratory and that is why regression analysis is used merely to deepen the understanding of the relationship between the variables. Also, as stated previously, this research will face limitations on causality as there are too many extraneous variables, which can have an effect on the dependent variables.

3 LITERATURE REVIEW

3.1 Introduction

This literature review will focus on Bitcoin price, traded volume and volatility with increased or decreased interest as drivers of these variables. It will explain the variables which were chosen for the research and explains through theories why these variables were chosen. The main research question of the research is as follows: What is the relationship between Google Search volume and Bitcoin Volatility, Bitcoin Traded volume and Bitcoin's price?

Bitcoin has been the topic of much media, Internet and policy discussion in the past years. Partly due to that and many other reasons, the price of Bitcoin has been increasing and as a result, the Bitcoin market capitalization has increased exponentially during January of 2014 and January of 2018 from 9 billion to 237 billion (Coinmarketcap.com, 2018) Bitcoin is still an emerging market and as such interesting topic of research.

Bitcoin is still fairly new phenomenon and thus, the research conducted to it, is fairly limited. Due to limited research, this paper draws research performed on more traditional financial assets such as stocks, but in cases where Bitcoin research has been available it has been used either as a foundation, reference or inspiration. For example, Poterba and Summers (1989) have shown that media pessimism reflects to the stock market and Vlastakis, N. and Markellos, R., (2012) studied information demand supply at the firm and market level. These, and other similar studies conducted for stocks will be utilized in explaining Bitcoin markets.

First, the paper will demonstrate the conceptual framework visually, after which the elements included in the framework are broken down and explained. Secondly, it will explain and argue why these variables included in the conceptual framework were chosen, through theories and previous studies. Finally, it will examine previous studies with similarity in chosen variables as in the research of this paper.

3.2 Conceptual Framework

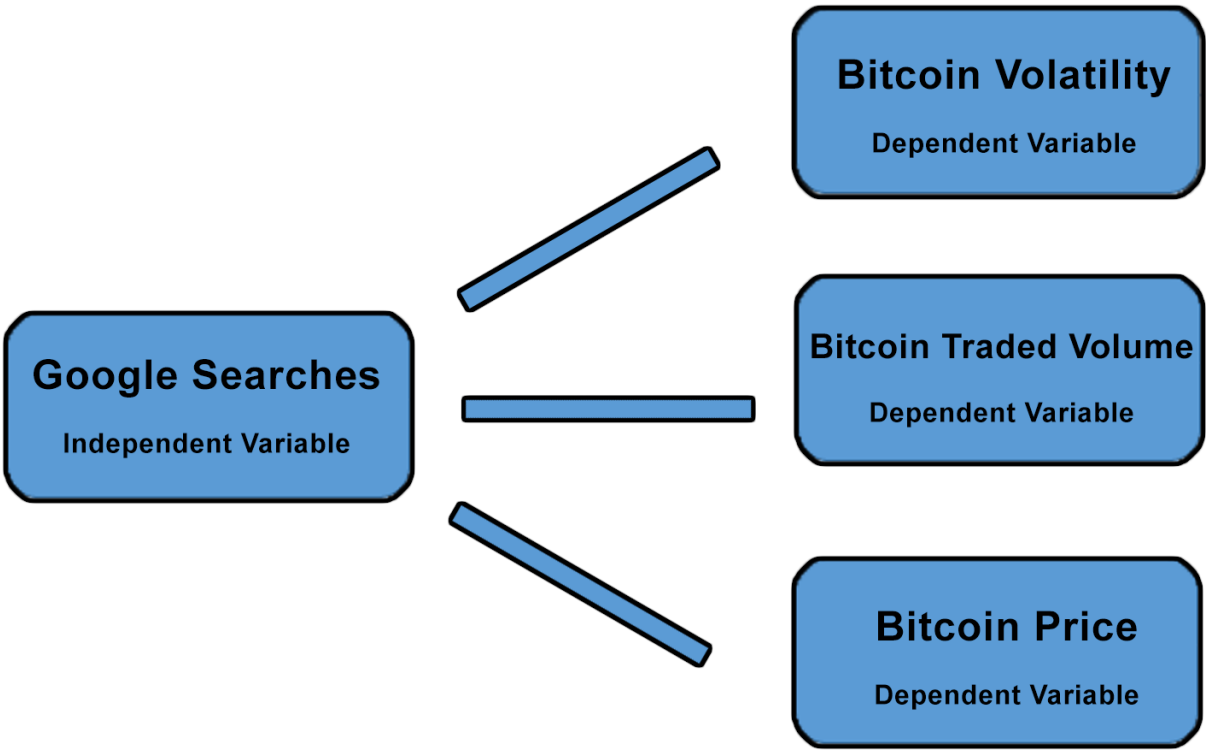

Figure 4: Conceptual Framework

Figure 4 above shows the conceptual framework of the research. The main research questions the research aims to answer is: *What is the relationship between Google Search volume and Bitcoin Volatility, Bitcoin traded volume and Bitcoin price?* Google Search volume will act as an independent variable whereas Bitcoin Volatility, Bitcoin Traded volume and Bitcoin's price are dependent variables. The study will be looking at these variables in different time periods.

The problem of causality will be apparent. It will be impossible to say, that Google search volume is the ultimate indicator for these dependent variables, since there could be many other factors affecting them. For example, volatility and traded volume could be affected by simple technical issues at the biggest exchanges, whereas Bitcoin price could be affected by even more different factors ranging all the way from bad news to singular big investor actions.

The problem of causality will decrease the internal validity of the research. Internal validity is important, since it is concerned if the study demonstrates causal

relationship. Although, showing causal relationship is not the main objective of the study, rather it is to simply examine the relationships between the variables, it would increase the internal validity of the study.

As stated above, it is important to note that the research will look at these variables in different time windows (yearly data), which in itself increase the validity, since it will limit possible factors affecting the dependent variables.

3.2.1 Google Searches

Google Search volume acts as an independent variable. The reason this is variable was chosen is because Google Searches reflect information demand. As such, Google Searches represent increased or decreased interest in Bitcoin and this study aims to find out what is the relationship between increased or decreased interest and the dependent variables.

3.2.2 Bitcoin Volatility

Bitcoin's Volatility has been the subject of many studies recently (Bouri, E., 2016, and Balcilar, M., 2017). As volatility is a measure of a risk it will be interesting and important to see what kind of relationship increased or decreased interest and volatility have.

3.2.3 Bitcoin Traded Volume

Bitcoin's traded volume has not accumulated as much interest in terms of research as volatility has. Traded volume is still very much an interesting variable since it tells about the market's activity and liquidity. When investors feel unsure about the direction the market is heading towards, trading volume tends to increase, so looking at the relationship of information demand, and market activity is important.

3.2.4 Bitcoin Price

Bitcoin's price has baffled everybody in the recent years. Just in 2017 the price of Bitcoin increased more than 1300% (Chaparro, F. 2017). As Bitcoin's price is solely

based on supply and demand rather than on some fundamental value, looking into the relationship between increased information demand and the actual price might provide interesting insights.

3.3 Defining Bitcoin

The digital currency or cryptocurrency Bitcoin (Nakamoto, 2008) can be described as a protocol, currency, a payment system, investment asset and a technology platform. Technically Bitcoin is open source software which can be utilized by everybody including companies, software developers and individuals. Bitcoin enables a public ledger of transactions, coupled with protocols and software that maintain security (Athey, S. 2016).

Dyhrberg, A. (2016) states that economists have compared Bitcoin to gold as they have many similarities and they also point out that since gold and Bitcoin are scarce and costly to extract, that is where they both derive most of their value. Baeck and Elbeck (2014) argue that rather than a currency, Bitcoin should be considered as a speculative commodity and Hong., K. (2016) argues that Bitcoin should be seen as an alternative investment vehicle.

Yermack, D. 2013 argue that, Bitcoin cannot serve as a reliable store of value and become a bona fide currency until its daily value becomes more stable. Norway also declared that it considers Bitcoin as an asset, not a currency (Finextra Research, 2013).

There are some clear disagreements and a lot of debate on how to define Bitcoin. Most studies however seem to come to the conclusion, that Bitcoin is not stable enough to be considered a currency and therefore it should be considered as an investment. That is why this paper also defines Bitcoin as an investment.

3.4 Google Searches

3.4.1 Efficient Market Hypothesis

The Efficient Market Hypothesis (EMH) is an important theory, which presents implication on the relationship between information and asset prices (Fama, 1970). According to Fama, (1970), the EMH assumes that information is fully utilized by the market and due to that the market has properties of a fair game.

As Bitcoin price is not based on any fundamentals and is based solely on supply and demand, through EMH we have a theoretical basis to understand how information is built into prices and that's why it is essential for any analysis of the underlying causes of the assets volatility. Furthermore, since Bitcoin's price is solely dependent on supply and demand and is lacking fundamental value, it indicates that Bitcoin's price is increasingly reliant on information published about it.

Theory of Efficient Markets is firmly related to the random walk theory. Random walk theory states, that tomorrow's price is unrelated to the price today (Malkiel, B., 2003). Also, prices reflect new information and because new information is unpredictable prices must also be unpredictable. This can be applied to Bitcoin price and so, the market is very much speculative (Katsiampa, P., 2017) and since Bitcoin's price is not based on anything except supply and demand the random walk theory becomes more relevant in describing Bitcoin markets.

Urquhart A., (2016) has studied in his research the informational effiency of Bitcoin. He also employs a battery of tests and finds evidence of market inefficiency, but some of the tests indicate market efficiency in the latter period. This means that, he found out from the data collected until 2015, that Bitcoin was moving towards efficient market.

3.4.2 Behavioral Finance

Economists have traditionally assumed that investors are rational in their decisions and that market efficiency displays these decisions (Fama, 1970). However,

behavioral finance highlights the importance of studying the underlying reasons behind investors' decisions.

Prospect theory suggests that framing situations will affect the investors ability to decide rationally on investment decision. In addition, trading decisions by investors are often based upon the beliefs of others by following market price changes (Schwert, 1990). This means that bubbles or contagiously volatile price can be created by socially transmitted price changes (Topol, 1991).

Investor behavior becomes increasingly important when looking at the Bitcoin market. Since it is a speculative market (Katsiampa, P., 2017) we know that information search and news about Bitcoin increase in importance. And as investors search information their behavior to their findings is also important. As stated above, investors don't always make rational decisions and as such it is important to find out what kind of decision they do after they find information about Bitcoin. This is why this research aims to study the Google Searches of Bitcoin's volatility, volume and price. Even though clear causal relationships probably cannot be drawn, it is most likely possible to see the general directions of decisions which reflect to the market.

Through these theories we can conduct that information plays a huge role on Bitcoin markets. This means that by measuring information search (increased or decreased interest), we could find out relationships between that information search and the actual price, volatility and traded volume of Bitcoin. Therefore, the research will use Google Searches as an independent variable.

3.4.3 Google Trends

As explained above, this paper is going to use Google searches in its research and that is why data is needed from those searches. To get more accurate data this paper uses Google Trends. This is Google's own metric which measures the interest over time on a given key word or keywords (Google Trends, 2018).

The way it works is that for a given time period it creates an index in which the numbers from 0 to 100 represent search interest relative to the highest point on the

chart. A value of 100 represents the peak popularity for the term in a given time period. The data is expressed on a weekly basis.

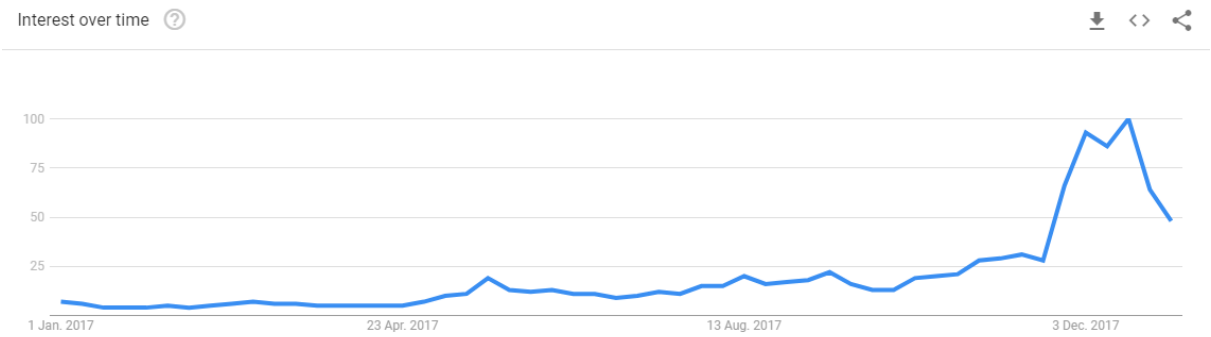

Figure 5: Google Trends Index for the word 'Bitcoin', 2017

Figure 5 shows the search index for the word "bitcoin" for the year 2017 as an example. From the picture can be deducted that the highest interest, so highest number of Google searches, was on the second to last week of 2017.

This index will be used on the research as it is a ready-made index from a reliable source (Google). Google trends has also been already used successfully on another similar study conducted by DeVries (2017), so this paper is not the first one to use it.

3.5 Volatility and Risk

As Bitcoin is mainly used for investment purposes and as this paper as defined Bitcoin as an investment, examining volatility and relationship between it and increased/decreased interest in Bitcoin is of high importance. First though, we need to determine what volatility measures, which is risk.

Risk is a concept which means the potential to lose or gain something of value. In finance risk is determined a bit differently. Business Dictionary defines risk as follows; 'Risk means the probability that an actual return on an investment will be lower than the expected return.' (BusinessDictionary.com, 2018) However, from investing point of view most investors determine risk as the variation from an expected outcome, so risk is most commonly defined by measure of variance.

Since Bitcoin is not a “normal” financial asset, determining its risk is difficult. Calculating Beta or Alpha of Bitcoin is impractical, since there is not a good benchmark for comparison due to its innovative and unclear nature. The same goes for R-squared and for Capital Asset Pricing Model. Due to this unclear nature of Bitcoin the tools able to calculate risk associated with it, are limited.

So, to measure risk of Bitcoin we must go back to the definition in which it was stated that risk is most commonly defined by measure of variance. To calculate variance, we can use Sharpe Ratio, VaR and most importantly, Standard Deviation. These tools can give us a rough estimate on the risk related to Bitcoin.

3.5.1 Standard Deviation

Probably the most used performance measurement for historical volatility is Standard Deviation. Standard Deviation is a mathematical calculation that yields the typical amount by which a return has varied from its historical average (Gustafson, K., 1996). Standard Deviation still has its weaknesses. Israelsen, C. (2000) argues against standard deviation in the following terms:

> ‘Standard deviation’s blind spot is that it does not discriminate between upside and downside volatility. This means, that If the current year's return is far from the historical mean return, it increases standard deviation - regardless of whether the return is higher or lower.’

Nevertheless, standard deviation seems to be one of the strongest tools for volatility measurement and thus is used in the research.

Bitcoin’s exchange rate volatility, calculated with standard deviation, was in 2013 around 142%. Four major currencies, EUR, JPY, CHF, GBP had volatility between 7 and 12% and gold had volatility of around 22% (Yermack, D. 2013). Although this data is quite old, it seems obvious that we look standard deviation alone Bitcoin seems quite a lot riskier than gold or other currencies. However as stated above, this paper defines Bitcoin as an investment and as such it needs to be compared to other investment elements to gain more comprehensive and comparable results.

If we look at Bitcoin's annualized volatility it varied from 50% to all the way to just over 500% (Brown, A., 2017). This however doesn't tell us much, so we need to measure it with stocks using risk adjusted returns. Bitcoin's risk-adjusted return was in 2017 as low as 3.1% whereas for stocks in the same time period it was 11 to 13.8% according to Edwards J. (2017). Even though the return for investing in Bitcoin for the same time period was up to 1900% bitcoin is so volatile that the ability to buy and sell at the right time is diminished which causes the low risk-adjusted return. This is why volatility is important variable to look at.

3.6 Traded Volume

As stated above, traded volume tells about the market's activity and liquidity. Trading volume is also often higher when price of a security is changing dramatically. Therefore, news about Bitcoin's status, developments or problems, whether negative or positive, will usually result in a momentary change in trading volume.

Volume reflects the intensity of a security and as such, high trading volume on a security's current price is often a signal of a high level of interest. Trading volume is especially important tool in the research, since trading volume can be used to determine the strength of measured variable. For example, price rise can be considered as a true indicator if the trading volume is high.

Traded volume has not been the center of many studies, but De Vries J., (2017) found in theirs that transaction volume can predict Bitcoin return and the traded volume of Bitcoin can be predicted from Google Searches. Therefore, traded volume seems to be important variable and its relationship to Google Searches should be looked at.

3.7 Price of Bitcoin

Bitcoin's price is not based on any fundamentals. Unlike a stock it is not based on a company's performance and implications about that performance. Katsiampa, P., (2017), finds that Bitcoin market is highly speculative. We can derive from this, that

Bitcoin price must also be highly speculative and as such Bitcoin's price is important variable when looking at Bitcoin.

Kristoufek, L., (2015) find in their studies that Bitcoin is considered as a speculative asset, and that there are multiple factors which play a role in Bitcoin price over the long term and these factors are: trade, money supply and price level. Pavel, C., (2015) find that new information impacts Bitcoin's price positively and that supply and demand have also a great effect on the price. This is quite obvious though, since the price is solely based upon supply and demand. In addition, they are unable to reject the hypothesis that investor speculations are affecting the price of Bitcoin.

3.8 Previous Studies

Garcia, D., (2014) studied the digital traces of bubbles in the Bitcoin economy through socio-economic signals. They quantified four socio-economic signals which were: price on online exchanges, volume of word-of-mouth communication in online social media, volume of information search and user base growth. They used vector autoregression and found two positive feedback loops that lead to bubbles in the absence of external stimuli: one was word of mouth and the other one new Bitcoin adopters. They also found out that spikes in information search precede drastic price decreases. This research was focused on the years 2013 and 2014 so it is fairly old considering the rapid development of Bitcoin markets.

Another study conducted by Tjernström, M., and Johansson, N. (2014) searched for the drivers which could influence the price volatility of Bitcoin. They identified five variables for empirical study. These variables were: information demand, trade volume, world market index, trend and six specified events, occurring during the chosen sample period. They followed a similar study conducted on stocks by Vlastakis & Markellos (2012). This study by Tjernström, M., and Johansson, N. (2014) faces the same problem of time period studied. Their data was taken from 13.09.2011 – 03.05.2014 so it is also quite old. They also point out that only two Bitcoin exchanges are included in their sample, and today there are hundreds of different exchanges (Coinmarketcap.com, 2018).

De Vries J., and Aalborg H., (2017) studied what variables can explain and predict returns, volatility and traded volume of Bitcoin. The variables which they investigated were: return, volatility, traded volume, transaction volume, change in the number of unique Bitcoin addresses, the VIX index and Google searches for the term Bitcoin. They found that transaction volume can predict Bitcoin return and the traded volume of Bitcoin can be predicted from Google Searches. However, their study seems to lack a focus on time periods as they did not specify proper time periods for their study and due to that the results of the study might be misleading.

4 DATA COLLECTION

4.1 Google Searches

The data on Google Searches will be provided by Google Trends (https://trends.google.fi/trends/). The index results of Google Trends are taken from the word 'Bitcoin', and important to note is that it is not case sensitive so both 'Bitcoin' and 'bitcoin' have been included in the index. The data has been downloaded by setting up a custom time period in Google Trend's explore section. This period is yearly, so for example 2014 data is collected from 1.1.2014 to 31.12.2014. Google Search data is marked as 'Google Trends' in the data tables.

4.2 Volatility

For the volatility, daily standard deviation of the daily closing prices is calculated, after which the data is arranged to weekly data. This is done by taking the weekly average of the standard deviations. Closing prices will be provided by Coinmarketcap.com. Volatility is marked in the data sheets as "Std Dev".

4.3 Traded Volume

For the data on traded volume this paper uses daily traded volume provided by Coinmarketcap.com. As there are hundreds of different exchanges it is impossible to get the exact traded volume for the day but Coinmarketcap.com comes quite close. In their daily traded volume, they have included 400 biggest exchanges based on percental volume from 8% to all the way to 0.05% (Coinmarketcap.com, 2018), so

the total daily volume can be considered as accurate as possible. Daily trading volumes have been taken and then changed into weekly averages by taking the average of that week's daily trading volumes. The data is in USD. Traded Volume is market in the data sheets as 'Traded Volume'.

4.4 Price

Price is taken also from coinmarketcap.com and it is the daily closing price for each day in the given period. Prices will then be change into weekly average prices by taking the average of that week's daily prices. Price is marked in the data sheets as 'Price'.

5 RESULTS AND ANALYSIS

5.1 Empirical Results

The structuration of the results is as follows; on each dependent variable there are three tables. Yearly correlations, yearly R squares of the regression models and the yearly regression model coefficients and significances. These tables have been compiled from the data outputs which can be found in the appendices.

5.1.1 Google Search volume and Bitcoin's volatility

	2014	2015	2016	2017
Correlation	0.383	0.297	0.394	0.474

	2014	2015	2016	2017
R Square	0.147	0.088	0.155	0.225

	B	Std. Error	Beta	t	Sig.
2014					
(Constant)	0.019	0.006		3.352	0.002
Google Trends	0.00	0.00	0.383	2.931	0.005
2015					
(Constant)	-0.004	0.016		-0.281	0.78
Google Trends	0.001	0.00	0.297	2.197	0.033
2016					
(Constant)	-0.009	0.01		-0.935	0.354
Google Trends	0.00	0.00	0.394	3.034	0.004
2017					
(Constant)	0.033	0.004		7.677	0.00
Google Trends	0.001	0.00	0.474	3.845	0.00

From the three variables which were examined Bitcoin volatility had the lowest correlation with Google Searches. Even though there is an upward trend from 2015 to 2017 and the correlation can be considered relatively high as it is on average around 0.35, it is still much lower than on the other dependent variables.

R squares of the regression model were also the lowest from the three variables. These values vary from the lowest of 0.088 in 2015 to the highest of 0.225 in 2017. Which means that they can be considered quite stable especially when comparing to same values of other dependent variables. Even though the results of the regression model on every year were significant the coefficients are extremely low, meaning that the model doesn't accurately predict rise or fall in volatility when search volume increases or decreases.

The results were within expectations. Correlations were found, and they were not as high as with the other variables. Regression models also did not provide clear prediction possibilities, but the results were still significant, as expected.

5.1.2 Google Search volume and Bitcoin's traded volume

	2014	2015	2016	2017
Correlation	0.546	0.551	0.644	0.911

	2014	2015	2016	2017
R Square	0.299	0.304	0.415	0.831

	B	Std. Error	Beta	t	Sig.
2014					
(Constant)	13544751.27	2914020.1		4.648	0.00
Google Trends	370716.884	80366.915	0.546	4.613	0.00
2015					
(Constant)	-28622423.3	13563642		-2.11	0.04
Google Trends	1106857.738	236794.67	0.551	4.674	0.00
2016					
(Constant)	-26568123.9	19031831		-1.396	0.169
Google Trends	1834030.472	308141.95	0.644	5.952	0.00
2017					
(Constant)	-572502051	288352361		-1.985	0.052
Google Trends	156041579.8	9864926.4	0.911	15.818	0.00

The correlation results between traded volume and Google Searches were interesting. From 2014 to 2016 the correlation was already relatively high and stable

but in 2017 correlation jumped to 0.9 which is almost full correlation between the variables. This meant that the results were within expectations even though the result for 2017 was surprising.

The same jump can be seen in the R square which doubled from 0.415 to 0.831. Coefficient analysis showed that the results can be considered significant on every year. It also shows that as the search index value rises so does the average weekly trading volume.

One thing to point out from the results is the coefficient increase from 1.8 million in 2016 to the 156 million in 2017. This shows the massive increase in the total market capitalization are with that the trading volume from the end of 2016 to 2017 which has been referred to previously. Both Google Search index and trading volume are indicators of increased interest which makes this increase even more significant.

The results of the traded volume were within expectations. Trading volume usually indicates increased interest in an asset (Vlastakis, N. and Markellos, R., 2012) so it is only natural that it shows in the regression model as well. Unfortunately, it is not possible to read much more into these results as they are taken from the weekly averages and thus the size of the volumes are massive.

5.1.3 Google Search volume and Bitcoin's price

	2014	**2015**	**2016**	**2017**
Correlation	0.613	0.592	0.659	0.943

	2014	**2015**	**2016**	**2017**
R Square	0.375	0.35	0.434	0.89

	B	Std. Error	Beta	t	Sig.
2014					
(Constant)	368.55	33.863		10.883	0.00
Google Trends	5.119	0.934	0.613	5.481	0.00
2015					
(Constant)	94.614	34.575		2.736	0.009
Google Trends	3.132	0.604	0.592	5.189	0.00
2016					
(Constant)	154.16	67.355		2.289	0.026
Google Trends	6.749	1.091	0.659	6.189	0.00
2017					
(Constant)	630.85	255.049		2.473	0.017
Google Trends	177.16	8.726	0.943	20.303	0.00

Highest correlation between the variables were between Google Searches and Bitcoin's price. From 2014 to 2016 it was hovering around 0.6 and for 2017 it jumped to 0.94 which can be considered almost fully correlating. This is an interesting finding, which shows how deeply these two variables are connected. The prediction, that highest correlations would be in with Bitcoin's price, also proved to be true.

R square results showed the same strong relationship, as it doubled from the average of 0.38 of 2014-2016 to 0.89 of 2017. Significance test showed that the results were significant on every year. The coefficients stayed quite stable in the first three years and the regression model shows that even then the increase in the google index meant also an increase in Bitcoin's price, although there are multiple extraneous variables which have not been accounted for, which means Google Searches cannot be assumed to be the driving factor for Bitcoin's price.

The huge increase in the coefficient for 2017 (from 6.7 in 2016) can be partially explained with the price increase in 2017. Price increased from around 960 dollars in 1st of January to 12 788 dollars of 31st of December of the same year (Coinmarketcap.com, 2018). This means an increase of 1200% in just one year. It also makes the results more interesting since the significance test showed that the results of the model are significant. So even with 1200% increase the Google search index has a strong relationship with Bitcoin's price.

5.2 Analysis

5.2.1 Gauss-Markov Theorem

To analyze the regression model results in a meaningful manner this paper uses Gauss-Markov theorem. Gauss-Markov theorem states that under its 7 assumptions the ordinary least squares (OLS) estimator is the best linear unbiased estimator (BLUE) of the true parameters. These 7 assumptions are:

1. Regression is linear in parameters
2. Error term has zero population mean
3. Error term is not correlated with X's
4. No serial correlation
5. No heteroskedasticity
6. No perfect multicollinearity
7. Error term is normally distributed

5.2.1.1 Linearity

The first assumption is that the regression model needs to be linear. This means that the model needs to have the right variables and no omitted variables. The model also needs to be in the correct functional form. This is all untestable, so we need to rely on economic theory. Finally, the model must have an additive error term.

5.2.1.2 Error Term Has Zero Population Mean

The second assumption is that the error term has zero population mean. This means that every observation in the model has a random error with a mean of zero. This

error term accounts for the variation in the dependent variable that is not explained by the model.

5.2.1.3 Exogeneity

The third assumption is that the all the explanatory variables are uncorrelated with the error term. So, if the error term and X (explanatory variable) are positively correlated then the estimated coefficient would probably be higher than it would have otherwise been.

5.2.1.4 No Serial Correlation

The forth assumption is serial correlation. This means that the error terms across observations are correlated with each other. This is most important in time series, so if error is correlated an increase in the error term in one time period affects the error term in the next.

5.2.1.5 Homoskedasticity

Homoskedasticity means that the error has a constant variance. This means that the variance of the error term cannot change for each observation or range of observations. If it does, there is heteroskedasticity present.

5.2.1.6 No Perfect Multicollinearity

If there is perfect collinearity between two independent variables it implies that they are really the same variable or that one is multiple of the other. This is not an issue in this research as this research has looked only one independent variable (Google Searches).

5.2.1.7 Normally Distributed Error

Final assumption is that the error term follows a bell-shape, meaning that it is normally distributed. This is not required for OLS, but it is important for hypothesis testing

5.2.1.8 Gauss-Markov Theorem in This Research

The research in this paper does not fulfill all the assumptions. The regression models used in this study were linear in parameters and the error term has zero population mean. The error terms were not correlated with X, but there is a problem of serial correlation as the data is taken yearly. There was also heteroskedasticity present but as only one independent variable was used, the assumption number six, no perfect multicollinearity, was fulfilled. Finally, the errors were not normally distributed.

This paper does will not go into further detail on attempting to prove all the 7 assumptions of the Gauss-Markov theorem. The datasets were not changed after it was found that not all the assumptions are fulfilled. This paper however acknowledges these assumptions and their usefulness in examining regression models and their effectiveness.

5.2.2 Google Search volume and Bitcoin volatility

The results on the relationship between Google Searches and Bitcoin volatility were interesting. As it has been established before in this paper, volatility often moves hand in hand with high price increases and decreases and that moves together with fluctuation in interest on a given financial asset. Even though the results were significant and yearly correlations were relatively high, this study didn't find as strong relationships between the variables as it predicted. Based on studies conducted on other financial assets (Vlastakis, N. and Markellos, R., 2012), the results could have been higher.

The reason for these surprising results could be the sample. The data was taken on a yearly basis and the interest in bitcoin seems to vary a lot depending on the time period and how much it is being discussed in the mainstream media based on the increased number of Bitcoin related articles around the end of the year. Usually, Bitcoin sees a surge in interest around the end of the year, but other time periods are either stable or low. However, Bitcoin's volatility stays relatively high throughout these time periods, which then shows in the results.

This surge can affect the results as they are taken from weekly averages and because of how the Google trend index works. The data showed that especially on 2016 and 2017 the volatility was from 60-80% higher at the end of the years than at the beginning of the years, whereas the same difference on Google Index was around 30-40%. However, it must be noted that this does not apply to the results on Bitcoin price, which was also very surprising.

As stated in the Literature review, Bitcoin's volatility has been one of the most researched subjects about Bitcoin. Garcia, D., (2014), found that spike in volume of information search preceded Bitcoin bubble's. De Vries J., and Aalborg H., (2017) found significant relationships between Google Searches and Bitcoin volatility. Both studies found stronger relationships between Bitcoin's volatility and increased interest than this one. The data period used in all three studies varied, so that is one factor, which explain the difference between the results. Data analysis methods also varied.

The results seem to also support Topol, (1991), as they found that bubbles or contagiously volatile price can be created by socially transmitted changes. This seems logical since high volatility is often a signal of uncertainty on the market and this usually also reflects on information demand.

5.2.3 Google Search volume and Bitcoin traded volume

This paper predicted significant relationships between these two variables. This was due to the fact, that trading volume is known to have a strong relationship with information supply and demand. This has been found on other assets such as stocks (Moussa, BenOuda and Delhoumi, 2017). The results were in line with the literature, not only from the studies conducted on Bitcoin's traded volume but also on other financial assets, especially stocks.

De Vries J., and Aalborg H., (2017) found significant relationships between Bitcoin's traded volume and Google trends data. Even though their study lacked time period focus, they found in their model that Google Searches can explain and predict the rise and decrease in trading volume. Their results are very much in line with this paper. Interesting finding, which they also made, is that they found no significant relationships between these two variables in their daily model but on their weekly

model the relationships were significant, and this paper chose to look at weekly data also.

The results for 2017 showcase how strong relationship information demand and traded volume have. Correlation of 0.91 and the R square of 0.83 show how deeply these two variables are connected. Correlation of 0.91 can be considered to be almost fully correlating, which is interesting as 2017 was the year when Bitcoin saw a lot of discussion in the media and high trading volume on a security's current price is often a signal of a high level of interest. Due to this and many other factors Bitcoin saw a rise in new users' investors and adopters which then increased the trading volumes.

5.2.4 Google Search volume and Bitcoin Price

Bitcoin's price has increased, during the study period, from the beginning of 2014 of around 770 dollars to 13 800 dollars at the end of 2017. This is an increase of over 1600% (Chaparro, F. 2017). This makes the results of this study more significant and interesting, as the data showed highest correlations and R squares for the regression models between these two variables.

Firstly, the results seem to follow the consensus of the studies conducted to the area. Garcia, D., (2014), De Vries J., and Aalborg H., (2017), and Tjernström, M., and Johansson, N. (2014), all had Bitcoin price as a variable in their studies although they used it differently. However, all three found strong relationships between Bitcoin's price and information demand. Garcia, D., (2014), focus more on the social media word-of-mouth as a measure of information demand whereas De Vries J., and Aalborg H., (2017), and Tjernström, M., and Johansson, N. (2014) used Google Trends.

All three studies also point out the same thing in their conclusions. Bitcoin is a speculative asset. This means that, as it has been established before, Bitcoin's price is not tied to anything, so it is based solely on supply and demand. The results can be credited to this fact, because even though Bitcoin has seen some incredible price rises and decreases throughout the study period the correlations have stayed high. It is also important to note, that there are only these few studies which have somehow

connected and used these two variables, Bitcoin price and information demand, in their studies, so comparing results between each other is challenging and interpreting the differences even more so.

Urquhart, A., (2016) study of informational efficiency of Bitcoin showed that Bitcoin markets indicated market efficiency in 2014 and 2015. The results of this study seem to also support the findings of their study, which was that Bitcoin markets were moving towards more efficient markets.

Vlastakis, N., Markellos, R., (2012), found similar results on the information demand and the stock market. Unfortunately, it is not accurate to compare these results as the price formation of Bitcoin and stocks is different as stocks can be considered to have basic value through the companies they represent, unlike Bitcoin. It is still important to show the similarities in research results between these different financial assets.

6 CONCLUSION

This paper studied the relationships between Google Searches and Bitcoin's price volatility and traded volume. First it introduced the subject and gave reasoning for choosing the subject. Then it went through the current studies and what they have found about these variables in the form of Literature Review. Then it created yearly datasets on the given variables and examined the data through correlations and regression models. Finally, it explained the results and analyzed them.

This paper found high correlations between all the examined variables. Variations existed as Bitcoin's volatility had the lowest yearly correlations, then traded volume and the highest correlations were with Bitcoin's price.

Regression model results were significant in the most part. The models show that increase in search volume, or in other words increase in interest (Google Index), increases Bitcoin's price, traded volume and volatility. The results varied a lot between the three variables and due to the nature of this paper, accurately analyzing them is challenging, as it is not accurate to say that increased information demand

increases the values of these three variables, since there are many other factors that can influence them also.

6.1 Contribution to literature and practice

As stated in the beginning of this paper, the research on Bitcoin is still very limited. There are clear holes in the research on many different aspects and especially on information demand and its relationship to different variables. It is important to research this subject as Bitcoin is very speculative in nature and further knowledge on its price formation and volatility are crucial for its survival and development.

The aim of this paper was to bring out new information regarding information demand and its effect to the three variables. Although the results of this paper are on the simplistic side, they offer good foundation for future research. Also, due to the research topic, this paper had to examine a lot of different studies, not only from the field of Bitcoin, but from other financial assets. This lead to cross-referencing between the similarities and differences of Bitcoin studies and studies conducted to similar financial assets, which can be useful for future researchers.

6.2 Suggestions for Further Research

As Bitcoin can be considered extremely speculative asset, it is the strong opinion of this paper that more research must be made on it, its possibilities and its affects to investors and consumers.

This paper demonstrated very strong relationships between Google Searches and Bitcoin's price, volatility and traded volume. Future research should dive into more detail on these. This could be done by doing research which limits extraneous variables, which can have an effect to these three dependent variables. By doing this, a clearer view on the actual causal relationship on information demand and its affect to these variables could be achieved.

7 REFERENCES

Athey, S., Parashkevov, I., Sarukkai, V. and Xia, J. (2016). *Bitcoin Pricing, Adoption, and Usage: Theory and Evidence*. [online] Ideas.repec.org. Available at: https://ideas.repec.org/p/ecl/stabus/3469.html [Accessed 8 Jan. 2018].

Baek, C. and Elbeck, M. (2014). Bitcoins as an investment or speculative vehicle? A first look. *Applied Economics Letters*, [online] 22(1), pp.30-34. Available at: http://www.tandfonline.com.libproxy.aalto.fi/doi/full/10.1080/13504851.2014.916379?scroll=top&needAccess=true [Accessed 1 Feb. 2018].

Balcilar, M., Bouri, E., Gupta, R. and Roubaud, D. (2017). *Can volume predict Bitcoin returns and volatility? A quantiles-based approach*. [online] Available at: http://www.sciencedirect.com.libproxy.aalto.fi/science/article/pii/S0165176517302501?via%3Dihub [Accessed 27 Nov. 2017].

Brown, A. (2017). *Bitcoin Has an Unusual Relationship With Volatility*. [online] Bloomberg.com. Available at: https://www.bloomberg.com/view/articles/2017-11-20/bitcoin-has-an-unusual-relationship-with-volatility [Accessed 1 Feb. 2018].

Bouri, E., Azzi, G. and Dyhrberg, A. (2016). *On the Return-Volatility Relationship in the Bitcoin Market around the Price Crash of 2013*. [online] Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2869855 [Accessed 27 Nov. 2017].

Blunch, N. (2011) 'Chapter 4: The Classical Model' [PowerPoint]. Lecture notes distributed in *Washington and Lee University;* 2011. Available from: https://www2.iona.edu/faculty/rjantzen/eco310/studenmund6eppts/Studenmund_Ch04_v2.ppt [Accessed 1 Apr. 2018].

BusinessDictionary.com. (2018). *risk*. [online] Available at: http://www.businessdictionary.com/definition/risk.html [Accessed 1 Feb. 2018].

Chaparro, F. (2017). *BITCOIN EXCHANGE: Orders for bitcoin cash are 'exploding'*. [online] Nordic.businessinsider.com. Available at: http://nordic.businessinsider.com/bitcoin-price-following-fork/ [Accessed 1 Feb. 2018]

Coinmarketcap.com. (2018). *Global Charts | CoinMarketCap*. [online] Available at: https://coinmarketcap.com/charts/ [Accessed 1 Feb. 2018].

Coinmarketcap.com. (2018). *Bitcoin (BTC) historical data | CoinMarketCap*. [online] Available at: https://coinmarketcap.com/currencies/bitcoin/historical-data/ [Accessed 15 Mar. 2018]

Coinmarketcap.com. (2018). *CoinMarketCap FAQ*. [online] Available at: https://coinmarketcap.com/faq/ [Accessed 15 Mar. 2018].

Cutler, David M., James M. Poterba, and Lawrence H. Summers. (1989) What moves stock prices? *Journal of Portfolio Management*, [online] 15(3), pp.4-12. Available at: http://www.nber.org/papers/w2538 [Accessed 1 Feb. 2018].

de Vries, J. and Aalborg, H. (2017). *What can explain the price, volatility and traded volume of Bitcoin?*. [online] Available at:

https://brage.bibsys.no/xmlui/handle/11250/2456812 [Accessed 27 Nov. 2017].

Dyhrberg, A. (2016). *Bitcoin, gold and the dollar – A GARCH volatility analysis*. [online] Available at: http://www.sciencedirect.com.libproxy.aalto.fi/science/article/pii/S1544612315001038?_rdoc=1&_fmt=high&_origin=gateway&_docanchor=&md5=b8429449ccfc9c30159a5f9aeaa92ffb [Accessed 27 Nov. 2017].

Edwards, J. (2017). *Bitcoin is so volatile its risk-adjusted return is worse than stocks*. [online] Nordic.businessinsider.com. Available at: http://nordic.businessinsider.com/bitcoin-volatility-risk-adjusted-return-worse-than-stocks-2017-12?r=US&IR=T [Accessed 1 Feb. 2018].

Fama, E. (1970). Efficient Capital Markets: A Review of Theory and Empirical Work. *The Journal of Finance*, [online] 25(2), pp.383-417. Available at:

https://www.jstor.org/stable/2325486?seq=1#page_scan_tab_contents [Accessed 1 Feb. 2018].

Finextra Research. (2013). *Norway says bitcoin an asset, not a currency*. [online] Available at: http://www.finextra.com/news/fullstory.aspx?newsitemid=25547 [Accessed 1 Feb. 2018].

Forbes.com. (2017). *What Is Blockchain Used For Besides Bitcoin?*. [online] Available at: https://www.forbes.com/sites/quora/2017/11/17/what-is-blockchain-used-for-besides-bitcoin/#328d5089446e [Accessed 15 Mar. 2018].

Garcia, D., Tessone, C., Mavrodiev, P. and Perony, N. (2014). *The digital traces of bubbles: feedback cycles between socio-economic signals in the Bitcoin economy*. [online] Journal of The Royal Society Interface. Available at: http://rsif.royalsocietypublishing.org/content/11/99/20140623 [Accessed 12 Dec. 2017].

Gustafson, K., Lummer, S., (1996) Measuring risk is a risky business *Pension Management*, [online] 32(4) pp.26-27. Available at: https://search-proquest-com.libproxy.aalto.fi/docview/219245112/439FCBD13AF2420FPQ/9?accountid=27468 [Accessed 1 Feb. 2018].

Google Trends. (2018). *Google Trends*. [online] Available at: https://trends.google.com/ [Accessed 15 Mar. 2018].

Hern, A. (2018). *Bitcoin's energy usage is huge – we can't afford to ignore it*. [online] the Guardian. Available at: https://www.theguardian.com/technology/2018/jan/17/bitcoin-electricity-usage-huge-climate-cryptocurrency [Accessed 15 Mar. 2018].

Hong, K. (2016). Bitcoin as an alternative investment vehicle. *Information Technology and Management*, [online] 18(4), pp.265-275. Available at: https://link-springer-com.libproxy.aalto.fi/article/10.1007%2Fs10799-016-0264-6 [Accessed 1 Feb. 2018].

Israelsen, C., (2000) Investments - Seeing The Blind Spot: The measurement of standard deviation does not discriminate between upside and downside volatility.

Financial Planning, [online] pp.23-34. Available at: https://search-proquest-com.libproxy.aalto.fi/docview/210948003/439FCBD13AF2420FPQ/1?accountid=27468 [Accessed 1 Feb. 2018].

Johansson, N. and Tjernström, M. (2014). *The Price Volatility of Bitcoin - A search for the drivers affecting the price volatility of this digital currency*. [online] Umu.diva-portal.org. Available at: http://umu.diva-portal.org/smash/get/diva2:782588/FULLTEXT01.pdf [Accessed 1 Feb. 2018].

Katsiampa, P. (2017). *Volatility estimation for Bitcoin: A comparison of GARCH models*. [online] Available at: http://www.sciencedirect.com.libproxy.aalto.fi/science/article/pii/S0165176517302501?via%3Dihub [Accessed 27 Nov. 2017].

Keynes, John M., 1936, *The General Theory of Employment, Interest, and Money* (MacMillan, London)

Kristoufek, L. (2015). *What Are the Main Drivers of the Bitcoin Price? Evidence from Wavelet Coherence Analysis*. [online] Europepmc.org. Available at: http://europepmc.org/backend/ptpmcrender.fcgi?accid=PMC4398561&blobtype=pdf [Accessed 1 Feb. 2018].

Lecture 4: Econ 488 (2011). [PowerPoint]. Lecture notes distributed in *Washington and Lee University;* 2011. Available from: http://faculty.csuci.edu/cameron.kaplan/Econ_488_files/Lecture%204.ppt [Accessed 1 Apr. 2018].

Malkiel, B. (2003). The Efficient Market Hypothesis and Its Critics. *Journal of Economic Perspectives*, [online] 17(1), pp.59-82. Available at: https://eml.berkeley.edu/~craine/EconH195/Fall_14/webpage/Malkiel_Efficient%20Mkts.pdf [Accessed 1 Feb. 2018].

Moussa, F., BenOuda, O. and Delhoumi, E. (2017). The use of open source internet to analysis and predict stock market trading volume. *Research in International Business and Finance*, [online] 41, pp.399-411. Available at: https://www-sciencedirect-

com.libproxy.aalto.fi/science/article/pii/S0275531916302446?via%3Dihub [Accessed 5 Apr. 2018].

Nakamoto, S. (2008). Bitcoin: A peer-to-peer electronic cash system

Pavel, C., Miroslava, R., d'Artis, K., (2015). The economics of Bitcoin price formation. *Applied Economics*, [online] 48(19), pp.1799-1815. Available at: http://www.tandfonline.com.libproxy.aalto.fi/doi/full/10.1080/00036846.2015.1109038 [Accessed 1 Feb. 2018].

Schwarz, J. (2011) 'Research Methodology: Tools, Applied Data Analysis (with SPSS) – Lecture07: Introduction to Regression Analysis' Lecture notes distributed in *Lucerne University of Applied Sciences and Arts;* April 2011

Schwert, G. (1990) Stock Market Volatility. *Financial Analysts Journal*, [online] 46(3), pp.23-34. Available at: http://www.scirp.org/(S(czeh2tfqyw2orz553k1w0r45))/reference/ReferencesPapers.aspx?ReferenceID=51304 [Accessed 1 Feb. 2018].

Topol, R. (1991). Bubbles and Volatility of Stock Prices: Effect of Mimetic Contagion. *The Economic Journal*, [online] 101(407), pp.786-800. Available at: https://ideas.repec.org/a/ecj/econjl/v101y1991i407p786-800.html [Accessed 1 Feb. 2018].

Urquhart, A. (2016). *The inefficiency of Bitcoin*. [online] Sciencedirect.com.libproxy.aalto.fi. Available at: http://www.sciencedirect.com.libproxy.aalto.fi/science/article/pii/S0165176516303640?via%3Dihub [Accessed 8 Jan. 2018].

Vlastakis, N., Markellos, R., (2012). Information demand and stock market volatility. *The Journal of Banking and Finance*, [online] 36(6), pp.1808-1821. Available at: https://econpapers.repec.org/article/eeejbfina/v_3a36_3ay_3a2012_3ai_3a6_3ap_3a1808-1821.htm [Accessed 1 Feb. 2018].

Yermack, D. (2013). 'Is Bitcoin a Real Currency? An Economic Appraisal' [online] Available at: http://www.nber.org/papers/w19747.pdf
[Accessed 27 Nov. 2017].

8 APPENDICES

8.1 Yearly Data

8.1.1 2014

8.1.1.1 Descriptive statistics

Year 2014	*Price*	*Traded Volume*	*Std Dev*	*Google Trends*
Mean	530.693	25286495.659	0.033	31.673
Median	506.341	24511431.429	0.030	24.000
Standard Deviation	148.918	12092605.795	0.021	17.822
Kurtosis	-0.253	0.999	0.781	4.017
Skewness	0.629	1.018	1.068	2.061
Minimum	324.146	6311585.714	0.005	19.000
Maximum	870.074	59819400.000	0.095	100.000

8.1.1.2 Correlation

Year 2014	*Price*	*Traded Volume*	*StdDev*	*Google Trends*
Price	1			
Traded Volume	0.315	1		
StdDev	0.146	0.641	1	
Google Trends	0.613	0.546	0.383	1

8.1.1.3 Regression

8.1.1.3.1 Price

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.613[a]	.375	.363	118.86777921668894

a. Predictors: (Constant), Google Trends

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	424534.534	1	424534.534	30.046	.000[b]
	Residual	706477.447	50	14129.549		
	Total	1131011.980	51			

a. Dependent Variable: Price

b. Predictors: (Constant), Google Trends

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	368.550	33.863		10.883	.000
	Google Trends	5.119	.934	.613	5.481	.000

a. Dependent Variable: Price

8.1.1.3.2 Traded Volume

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.546[a]	.299	.284	10228862.273117902

a. Predictors: (Constant), Google Trends

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2226305690911592.000	1	2226305690911592.000	21.278	.00
	Residual	5231481170120736.000	50	104629623402414.720		
	Total	7457786861032328.000	51			

a. Dependent Variable: Traded Volume

b. Predictors: (Constant), Google Trends

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	13544751.265	2914020.056		4.648	.000
	Google Trends	370716.884	80366.915	.546	4.613	.000

a. Dependent Variable: Traded Volume

8.1.1.3.3 Volatility

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.383[a]	.147	.130	.019755291770749

a. Predictors: (Constant), Google Trends

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.003	1	.003	8.593	.005[b]
	Residual	.020	50	.000		
	Total	.023	51			

a. Dependent Variable: StdDev

b. Predictors: (Constant), Google Trends

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	.019	.006		3.352	.002
	Google Trends	.000	.000	.383	2.931	.005

a. Dependent Variable: StdDev

8.1.2 2015

8.1.2.1 Descriptive statistics

Year 2015	*Price*	*Traded Volume*	*StdDev*	*Google Trends*

Mean	270.918	33680895.948	0.030	56.288
Median	245.685	26193387.500	0.026	55.500
Standard Deviation	56.733	21509184.369	0.022	10.716
Kurtosis	2.968	9.637	7.589	6.462
Skewness	1.839	2.711	2.303	2.177
Minimum	214.186	15307128.571	0.007	44.000
Maximum	455.591	136419242.857	0.130	100.000

8.1.2.2 Correlation

Year 2015	*Price*	*Traded Volume*	*StdDev*	*Google Trends*
Price	1			
Traded Volume	0.776	1		
Std Dev	0.134	0.511	1	
Google Trends	0.592	0.551	0.297	1

8.1.2.3 Regression

8.1.2.3.1 Price

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate

1	.592[a]	.350	.337	46.194232919018140

a. Predictors: (Constant), Google Trends

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	57456.218	1	57456.218	26.925	.000[b]
	Residual	106695.358	50	2133.907		
	Total	164151.576	51			

a. Dependent Variable: Price

b. Predictors: (Constant), Google Trends

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	94.614	34.575		2.736	.009
	Google Trends	3.132	.604	.592	5.189	.000

a. Dependent Variable: Price

8.1.2.3.2 Traded Volume

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.551[a]	.304	.290	18121636.793669112

a. Predictors: (Constant), Google Trends

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	7175209619468398.000	1	7175209619468398.000	21.849	.000[b]
	Residual	1641968600408310.000	50	32839372008166 2.200		
	Total	2359489562355150 8.000	51			

a. Dependent Variable: Traded Volume

b. Predictors: (Constant), Google Trends

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-28622423.268	13563642.005		-2.110	.040
	Google Trends	1106857.738	236794.674	.551	4.674	.000

a. Dependent Variable: Traded Volume

8.1.2.3.3 Volatility

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.297[a]	.088	.070	.021279441586795

a. Predictors: (Constant), Google Trends

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.002	1	.002	4.827	.033[b]
	Residual	.023	50	.000		
	Total	.025	51			

a. Dependent Variable: StdDev

b. Predictors: (Constant), Google Trends

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	-.004	.016		-.281	.780
	Google Trends	.001	.000	.297	2.197	.033

a. Dependent Variable: StdDev

8.1.3 **2016**

8.1.3.1 Descriptive statistics

Year 2016	***Price***	***Traded Volume***	***StdDev***	***Google Trends***
Mean	561.975	84249640.385	0.020	60.423

Median	580.732	73583692.857	0.016	55.500
Standard Deviation	132.411	36799594.991	0.016	12.921
Kurtosis	-1.055	3.445	2.121	1.266
Skewness	0.252	1.759	1.579	1.311
Minimum	378.161	36121700.000	0.004	45.000
Maximum	874.899	212040971.429	0.071	100.000

8.1.3.2 Correlation

Year 2016	*Price*	*Traded Volume*	*StdDev*	*Google Trends*
Price	1			
Tarded Volume	0.488	1		
StdDev	0.027	0.692	1	
Google Trends	0.659	0.644	0.394	1

8.1.3.3 Regression

8.1.3.3.1 Price

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate

1	.659[a]	.434	.422	100.628610912833180

a. Predictors: (Constant), Google Trends

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	387865.009	1	387865.009	38.303	.000[b]
	Residual	506305.867	50	10126.117		
	Total	894170.876	51			

a. Dependent Variable: Price

b. Predictors: (Constant), Google Trends

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	154.164	67.355		2.289	.026
	Google Trends	6.749	1.091	.659	6.189	.000

a. Dependent Variable: Price

8.1.3.3.2 Traded Volume

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate

1	.644[a]	.415	.403	28433826.212034587

a. Predictors: (Constant), Google Trends

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	28640596114537176.000	1	28640596114537176.000	35.425	.000[b]
	Residual	40424123652809256.000	50	808482473056185.100		
	Total	69064719767346432.000	51			

a. Dependent Variable: Traded Volume

b. Predictors: (Constant), Google Trends

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	-26568123.921	19031831.420		-1.396	.169
	Google Trends	1834030.472	308141.949	.644	5.952	.000

a. Dependent Variable: Traded Volume

8.1.3.3.3 Volatility

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.394[a]	.155	.139	.014726593085056

a. Predictors: (Constant), Google Trends

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.002	1	.002	9.205	.004[b]
	Residual	.011	50	.000		
	Total	.013	51			

a. Dependent Variable: StdDev

b. Predictors: (Constant), Google Trends

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.009	.010		-.935	.354
	Google Trends	.000	.000	.394	3.034	.004

a. Dependent Variable: StdDev

8.1.4 **2017**

8.1.4.1 Descriptive statistics

Year 2017	*Price*	*Traded Volume*	*StdDev*	*Google Trends*
Mean	4063,732	2451171580,593	0,044	19,377

Median	2600,823	1315308142,857	0,037	12,000
Standard Deviation	4149,138	3782586006,989	0,026	22,094
Kurtosis	3,556	6,077	1,038	5,345
Skewness	1,991	2,601	1,222	2,404
Minimum	842,159	103693285,714	0,013	4,000
Maximum	18060,657	15432328571,429	0,119	100,000

8.1.4.2 Correlation

Year 2017	*Price*	*Traded Volume*	*StdDev*	*Google Trends*
Price	1			
Traded Volume	0.969	1		
StdDev	0.513	0.571	1	
Google Trends	0.943	0.911	0.474	1

8.1.4.3 Regression

8.1.4.3.1 Price

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate

1	.943[a]	.890	.888	1390.1467303926297

a. Predictors: (Constant), Google Trends

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	796639968.489	1	796639968.489	412.231	.000[b]
	Residual	98557904.533	51	1932507.932		
	Total	895197873.022	52			

a. Dependent Variable: Price

b. Predictors: (Constant), Google Trends

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	630.851	255.049		2.473	.017
	Google Trends	177.159	8.726	.943	20.303	.000

a. Dependent Variable: Price

8.1.4.3.2 Traded Volume

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate

1	.911[a]	.831	.827	1571667397.8449268

a. Predictors: (Constant), Google Trends

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	618036699931926300000.000	1	618036699931926300000.000	250.203	.000[b]
	Residual	125977058881880830000.000	51	2470138409448643600.000		
	Total	744013758813807200000.000	52			

a. Dependent Variable: Traded Volume

b. Predictors: (Constant), Google Trends

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	-572502050.65	288352360.71		-1.985	.052
	Google Trends	156041579.80	9864926.425	.911	15.818	.000

a. Dependent Variable: Traded Volume

8.1.4.3.3 Volatility

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.474[a]	.225	.210	.023283184677607

a. Predictors: (Constant), Google Trends

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.008	1	.008	14.783	.000[b]
	Residual	.028	51	.001		
	Total	.036	52			

a. Dependent Variable: StdDev

b. Predictors: (Constant), Google Trends

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	.033	.004		7.677	.000
	Google Trends	.001	.000	.474	3.845	.000

a. Dependent Variable: StdDev