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# What influences the price of Bitcoin: 2011-2015

**Senior Thesis**

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## I. Research Question & Motivation for Research

For my research I will look at one of the newest and potentially large scale inventions since the internet, the cryptocurrency known as Bitcoin. I hope to discover which factors influence its price since its inception in 2008. Bitcoin is a new form of currency; one which takes the traditional trust systems centralized at banks and spreads it out to all of its users. Known as a "decentralized trust system" it allows users to send value over the internet securely by utilizing SHA-256 cryptographic hash function without worry or threat of theft or manipulation. (Antonoploulos, 2014, p. 71)

It is also important to provide some background on the Blockchain, the vital part of invention behind Bitcoin which only emerged in 2008. The Blockchain is a public ledger of all Bitcoin transactions that have ever been created. Every full client wallet will have a list of every transaction that has ever occurred on the network and this list is called the Blockchain. The Blockchain receives its name from its technical makeup. It is a chain of "blocks" where within each block there contains a certain number of recorded transactions. The number of blocks in the Blockchain is constantly increasing as dedicated computers known as miners complete complex equations in their attempt to gain a reward. It works in such a way that the first computer to completely solve a complex mathematical equation reaps the reward of solving that block, which as of now is a reward of 25 Bitcoin. However, that number will be halved every four years until the final Bitcoins are mined bringing the total number of Bitcoins that will be created to 21 million. Solving these blocks is important because it is the method by which the Bitcoin network verifies and secures all transactions that occur on its network. This method of rewarding miners with coins in return for use of their computing power to verify the network is the macro-description of the technology that runs behind Bitcoin and other various cryptocurrencies such as

Litecoin and Dogecoin among countless others. The "work" or computational energy used in mining is the only source that truly backs up Bitcoin. (Antonoploulos, 2014, pp. 159-170)

The motivation for delving into this area of study comes from a deep sense that this technology is going to completely change our world and has the potential to make things better for people who have never had access to trusted financial institutions or a stable government issued currency. The sense of change for the better emanated from consistent research and taking part in the first university courses offered on cryptocurrency at the University of Nicosia in Cyprus. The class taught me that by its very nature, Bitcoin is entirely transparent. The rules that govern how new Bitcoins are released was created at its inception. By the very nature of the decentralized ledger if you are using Bitcoins you have to agree to the terms laid out in the programming. This is the true breakthrough of the Bitcoin technology, the trustless system grants one person the ability to send value to another without ever having met them, with only the need for their address. This is verified by every computer that runs a full node (which is a copy of all transactions as they occur) and thus every transaction that has ever occurred is available for all to see based on the programming. All that is required is an internet connection (or just a simple cell phone service) and the address of the person who you are sending the coins to.

Bitcoin has the potential to completely globalize our system of finance and credit by opening up areas in less developed nations that under current conditions have little chance of real access to credit. There are large numbers of people who have access to the internet but lack any real opportunity to access the international banking system. Bitcoin is an answer to this problem. Those with access to the internet can immediately have access to an international, trusted source of finance that cannot be dictated by the needs of any one nation or group of people. For example, small businesses in urban centers throughout the US have difficulty in finding sources

to borrow from. What can be envisioned through Bitcoin is the possibility of an Uber style application for micro lending, person-to-person. Assuming an application of this sort exists one day, users will be able to lend any amount they wish because of the ease of microtransactions with Bitcoin. Anyone with access to a digital wallet and an internet connection could essentially fill all the roles of a bank and yet be fully transparent and decentralized. In addition the lack of centralized control means that the normal barriers to entry into a developed nation's financial system, such as high prices, need of a fixed location or citizenship, and the slow processing of money essentially disappear. As Bitcoin currently stands, the constant changing of price creates issues for retaining value. There have been long periods where price has remained stable and it is estimated that the future will bring continued price stability as we have seen in 2015. (Lee, 2014)

The instantaneous nature of Bitcoin is also a factor, a transaction can occur in a matter of seconds. If you acquire a loan for a specific amount of local currency, the value of Bitcoin will have little weight as you are merely using Bitcoin to transact the value instantly. (Antonoploulos, 2014) For example, say you want to move 100$ of value from the US to Argentina. 100 US dollars buys 100$ worth of Bitcoin, you then send that Bitcoin to a vendor that in return provide you with 100$ worth of Argentine pesos. The amount of time you are using Bitcoins is so short that the change in value would not affect the goal of the transaction. The remittances market, dominated by companies such as Western Union, is one of the first places where Bitcoin could have an immediate impact. The poorest places in the world have the highest fees to transfer money and this is a place where Bitcoin could eliminate the high fees. Bitcoin would make the entire financial system a more peer-to-peer system, similar to email.

Bitcoin in its present state is not the best option for a global currency due to its constantly fluctuating price and early stage of development. However, it is this part of Bitcoin which most

interests me and concerns my research. It is the aim of this research to determine the variables that most influence the current price of Bitcoin. This will help predict whether Bitcoin's value will stabilize in the future, enhancing its usefulness as a source of financing.

## II. Literature Review

Since it is such a recent invention, studies conducted on Bitcoin price have been few and far between. The technology is in its early infancy and its capabilities are only starting to be fully understood. Comparison to the internet in its early stages have been made due to the technical knowledge needed to use the system, whereas visiting a website in 1994 would require a similar level of understanding to use, such as sending an email. Today the internet is becoming much easier to access and use, and reaching a greater number of users every day. My grandparents have no issue receiving and sending emails! It is hypothesized that Bitcoin will one day also reach the same ease of use level.

The most conclusive book that details the world of Bitcoin, how it works, what it is and many of its possibilities was written by Andreas Antonopoulos in 2014. He provided explanations of the technical aspects of Bitcoin on many different levels, for the expert software engineers and developers as well as simple explanations for the non-technical user. Antonopoulos has been interviewed by the finance committees of both Canada and Australia and has the backing of current programmers who are working on the Bitcoin core code. Some of the prominent members include Jeff Garzik, Gavin Andreesen, Wladimir J. van der Laan and Peter Todd. (Bitcoin Project, 2009-2016) The stated goal of the Bitcoin core developers is to provide full validation of Bitcoin "blocks", provide better privacy, a better interface to interact and use Bitcoin, and administer continued support to the network so that it can remain decentralized. The core receives funding from the Bitcoin foundation as well as MIT. The foundation has a similar

goal in their mission statement to that of the core developers: “standardize, protect and promote the use of Bitcoin cryptographic money for the benefit of users worldwide.” The organization was modeled on the Linux Foundation and is funded mainly through grants made by for-profit companies that depend on the Bitcoin technology. Lead Bitcoin developer Gavin Andresen is employed by the foundation as "chief scientist." With respected support in the Bitcoin ecosphere, Antonopoulos’s book breaks Bitcoin down into understandable information for non-coders as well as seasoned coders and provided a firm grasp of the information so that it could be properly relayed in this research. (Antonoploulos, 2014)

Antonopoulos begins by describing Bitcoin as a collection of concepts and technologies that form the basis of digital money. “Units of currency called Bitcoins are used to store and transmit value among participants in the Bitcoin network.” (Antonoploulos, 2014, pp. 1-2) Detailed information follows giving technical details as to how transactions occur, which are above the scope of this research. Information concerning ownership of Bitcoins may be beneficial to grasping such a new technology. Ownership is established through digital keys, Bitcoin addresses (similar to that of email but made up of random letters and numbers), and digital signatures. Digital keys that unlock the funds held on the network are created and stored off network, by users in a simple program that is known as a wallet. “The digital keys in a user’s wallet are completely independent of the Bitcoin protocol and can be generated and managed by the user’s wallet software without reference to the Blockchain or access to the internet.” (Antonoploulos, 2014, p. 61) This key feature provides the cryptographic-proof security model that has maintained such high security through decentralized control and trust. “Every Bitcoin transaction requires a valid signature to be included in the Blockchain, which can only be generated with valid digital keys…Keys come in pairs consisting of a private (secret) key and a

public key." (Antonoploulos, 2014, p. 61) The public key is the one which operates similar to an email; you provide this key to other users so they can send you coins. When you wish to send coins you provide the private code (which through wallet software can be converted into easier to remember passwords) and the combination of the two codes allows for a signature to be made and thus a transaction to occur. The Blockchain technology and Blockchain mining and are both detailed later in this paper. (Antonoploulos, 2014)

Research on the price of Bitcoin was conducted in 2015 by Rainer Böhme, Nicolas Christin, Benjamin Edelman, and Tyler Moore (2015). As of March 2015 the "daily transaction volume was about 200,000 Bitcoins—roughly $50 million at market exchange rates—and the total market value of all Bitcoins in circulation was $3.5 billion." (Boehme, Christin, Edelman, & Moore, 2015, p. 13) Out of the eventual 21 million Bitcoins that will come into existence, only 14 million have thus far been minted. The rate of the minting process is known and can be accurately tracked and may also cause a rise in the price per coin due to the process that assures that every 4 years, the number of Bitcoins mined at any time is halved. As of March 2015 the mining reward is 25 Bitcoins per block solved, and it will halve again in the summer of 2016 around August. This reward is how new coins come into existence and provides motivation for continued mining production. Further examination concluded that Bitcoin "experiences a shallow markets problem…a person seeking to trade a large amount of Bitcoin typically cannot do so quickly without affecting the market price." (Boehme, Christin, Edelman, & Moore, 2015) These swings in price could potentially be caused by large shareholders looking to exchange their coins which in turn flood the market.

Despite the thin literature to retrieve research from, some important work has been completed in the area of the determinants of the price of Bitcoin. For example, a study was done conducted by Ladislav Kristoufek in 2014 asking this very question. (Kristoufek, 2014) Kristoufek examined the sources of price movement and how they behave over time and at different frequencies such as a week, month or multiple months by using the method of continuous wavelet analysis across differing series and scales. The methodology importance is stressed by Kristoufek because as Bitcoin has grown, the drivers of the price have not remained the same. His methodology also allows for distinguishing between the short and long term. The drivers determined by Kristoufek are then examined in groups: Economic drivers, Transaction drivers, Technical drivers, Interest, Safe Haven and Chinese influence. The first variable included in Economic drivers is the ratio between trade and exchange transactions volume (Trade-Exchange ratio), of which the result determines the demand for the currency. This shows what the ratio is between the volume of the exchanges of Bitcoin for other currencies and when Bitcoin is being used for trade in goods, services and asserts. The lower this ratio, then the more Bitcoin is being used in the real world as a payment instrument for a commodity or an asset. Through use of Monte Carlo simulations against the null hypothesis, it was determined that Bitcoin appreciates in the long run and that the increasing price boosts exchange transactions in the short run. Increasing prices at the exchanges create demand for Bitcoin as a speculative asset.

The daily increase of Bitcoin supply leads to a decrease of the price because miners must sell coins to continue operations which results in a pull on price to lower levels (more supply = lower prices). Due to the known algorithmic minting process behind Bitcoin, there are no surprises when it comes to the minting of new coins and as one would expect to find, there is no significant relationship between Bitcoin price and its supply as a result of the creation of more

units. If the price is lower, miners have to sell more coins which flood the market and conversely if prices are higher they sell less. This can be explained because current and future money supply are known and predictable, and thus already included in the expectations of Bitcoin users and investors; therefore growth in the supply of Bitcoin does not directly affect the price in the short term. (Kristoufek, 2014) Fractional reserve banking is possible and is most often found currently being used on exchanges that offer margin and futures trading. While the rate at which Bitcoin is mined is known, the price during any given time period affects the number of coins sold.

Transactional drivers were then examined starting with the theory that the more coins that are used then the higher the demand and thus the higher price. The relationship is muddied however when the prices are driven by speculators, since volatility and uncertainty can lead to a negative relationship between volume and price, but only during certain periods. Measures of usage, trade volume and trade transactions were employed as explanatory variables. He found that the only significant relationships take place at times in 2012 and lose effect in 2013. The trade transactions however sheds light that there was a positive relationship between the number of transactions and the Bitcoin price, that the transactions lead the price, and the price of Bitcoin rises in the long run from an increase in trade. Trade volume switches direction at times and fails to provide any decisive conclusions.

The next area explores the technical drivers, i.e., miners and the two potential counteracting effects which result from mining. Increased Bitcoin price motivates market participants to invest in mining equipment, which expands supply. However the difficulty of mining increases because as more equations are completed, remaining problems are more difficult, which increases the necessary hardware and electricity required, therefore raising costs

and forcing participants to leave the mining pool. The relationship was found to be clearer: Bitcoin prices lead difficulty, and that an increase in Bitcoin prices attracts new miners more than it turns them away. A net increase in mining implies subsequent fall in Bitcoin prices. If prices slowly decrease over time then the offset of costs for mining force some additional miners to close up shop. In essence, there is a natural balance occurring of mining operators opening and closing based on price over a certain period of time (the amount of time depends on how much a particular mining operation can lose before having to close or conversely how much price rises to attract miners because of the increased ability to receive profits).

Public interest in Bitcoin was the next category of investigation. Kristoufek found using wavelet coherence analysis that Google and Wikipedia search queries for "Bitcoin" expanded dramatically over time, and found that the relationship changes with time. "Wavelet coherence analysis is a complex-valued square integratable function generated by functions of the form

$$\psi_{u,s}(t) = \frac{\psi\left(\frac{t-u}{s}\right)}{\sqrt{s}}$$

with scale *s* and location *u* at time *t*. Given the admissibility condition, any time series can be reconstructed back from its wavelet transform. A wavelet has a zero mean and is standardly normalized." (Kristoufek, 2014, pp. 2-3) From 2008 to halfway through 2012, prices lead the interest in Bitcoin though by the beginning of 2013 the relationship begins to change towards interest leading prices but this was not always the case. He suggests that the interest in Bitcoin appears to be asymmetric during the formations of bubbles. Interest assists in raising prices during bubble formation and during the bursting it pushes the price further down, essentially expressing a compounding effect on price swings up or down during bubble-like conditions. The

frequencies of the influence of interest changes has an increased effect when price is contracting, but less so during the buildup of a bubble. (Kristoufek, 2014, pp. 10-11)

Bitcoin has at times been dubbed a safe haven asset and Kristoufek cites the economic crisis in Cyprus in early 2012 as the first instance of this. Examining the relationship between the Financial Stress Index (FSI) and the price of gold in Swiss francs Kristoufek hypothesized that if Bitcoin were a safe haven then it would positively correlate with these two variables. The Financial Stress Index is a general index of financial uncertainty provided by the Federal Reserve Bank of Cleveland. The index is composed of 16 different components that include Real Estate Markets, Securitization Markets, Foreign Exchange Markets, Credit Markets, Interbank Markets and Equity Markets. (Federal Reserve Bank of Cleveland, 2015) He found a positive relationship between the FSI and Bitcoin only in early 2012 coinciding with the disaster in Cyprus. But all other time periods found no definitive correlation and thus ultimately found to be insignificant. (Kristoufek, 2014, p. 12)

The final area of research was into the influence that China has on the price of Bitcoin. The study examined the prices and exchange volumes between the Chinese renminbi (CNY) and the US dollar markets. He would examine the price of Bitcoin in China and the US to determine if there were differences across exchanges. A strong positive relationship is found at almost all time periods during the entire length of the study but no causal relationship could be established between the CNY and USD markets, meaning that price difference between the two markets was not statically significant. (Kristoufek, 2014, pp. 12-14)

An empirical study conducted by researchers Michal Polasik and Anna Piotrowska, Radoslaw Kotkowski, Tomasz Wisniewski and Geoffrey Lightfoot (2014) found a positive link between media attention and the value of Bitcoin. The research team included stock market

fluctuations, the number of transactions conducted in Bitcoin and media appearances that help to tell the story of how popular the currency is. (Polasik, Piotrowska, Wisniewski, Kotkowski, & Lightfoot, 2014, pp. 34-38) Because this research was conducted in 2014 it will be interesting if their findings hold true with a new year of data, which will be explored in my study.

Florian Glaser, Kai Zimmermann, Martin Haferkorn, Christian Moritz Weber and Michael Siering (2014) conducted empirical research on the question of why people purchase Bitcoin, and the question of whether it is being purchased and used as a currency or rather as a long term asset. They examined the exchange volume of MT.Gox in different time periods from early 2011 to 2013 (MT. Gox accounted for 80% of the total market of Bitcoin transactions in this time (Glaser, Zimmermann, Haferkorn, Weber, & Siering, 2014, p. 14)). They included a variable to control for both positive and negative events, observing the number of searches on Wikipedia concerning Bitcoin and dates of important Bitcoin events, like a new regulated exchange opening or the crisis in Cyprus.

> "To investigate users' rationality and dispassion towards their Bitcoin price evaluation, we acquire different major events in order to make the insights on user behavior more expressive…. The events focus either on exceptional positive (new exchange launches, legal successes or significant news articles) or negative (major system bugs, thefts, hacks or exchange breakdown) news which are directly related to the Bitcoin system, security and infrastructure." (Glaser, Zimmermann, Haferkorn, Weber, & Siering, 2014, p. 8)

They found that new Bitcoin users tend to use it as an asset rather than a currency, and that interest expressed in Wikipedia and Google searches increases overall volume traded at the exchanges. The results were interpreted as saying that new users who are buying their first coins tend to keep those coins on the exchanges for speculative purposes and do not appear to be

attempting to pay for goods and services. Their findings further supported the asset definition by the reactions of users to positive and negative news events within the Bitcoin ecosystem, since they were biased towards positive news. They explain that because many Bitcoin users are limited in their level of professionalism and objectivity they are biased to positive news, essentially positive news leads to more coins being bought then periods of selling during times of negative news. These findings suggest I should possibly include two variables, where one is representing of positive and one of negative news events that may affect Bitcoin price. (Glaser, Zimmermann, Haferkorn, Weber, & Siering, 2014)

Research conducted at the Coase-Sandor Institute for Law and Economics (Evans, 2014) examined the economic aspects of Bitcoin and additional decentralized, public ledger cryptocurrencies. They explain various aspects of cryptocurrencies as well as examining it through the lens of gold or in comparison to mPesa transactions in Kenya. mPesa is a mobile phone-based money transfer system that can be used for various forms of finance and is predominantly run by Vodafone throughout Kenya and Tanzania. It has since 2008 expanded to other nations such as India, South Africa, Afghanistan and parts of Europe. (Saylor, 2012, p. 304) The mPesa system provides users the ability to perform actions such as deposit, withdraw and send money to other users on the system without the need of a physical bank.

Included in their reports were tables that examine the daily price of Bitcoin along with its transaction volume. Given mPesa's popularity across parts of Africa, Evans research shines a light on a place with broad potential for Bitcoin. He goes on to explain that Bitcoin could provide a more efficient system for remittances then is currently available. Given that there are high fees for sending money from country to country and these fees are largely a result of regulation and security, Bitcoin provides an alternative that has the ability to address both issues. Evans admits

that until companies exist to provide these services or until Bitcoin usage becomes easy enough for the average user, Bitcoin could not immediately replace the remittance market as it exists today. (Evans, 2014, p. 18) The study also reviewed aspects that do not directly relate to this papers research but examine some of the aspects that may come into the minds of investors. One such aspect is the method of governance through the public ledger. The structure is a loose governance model as it is an open-source, volunteer based group of core developers. Decisions proposed to make changes in the software are presented to the entire community and if broad consensus is reached then the change is adopted. For smaller, noncontroversial changes the core development team will simply adopt and adjust the code themselves. Due to the nature of Bitcoin and other open source projects such as the computer operating system known as Linux, it is possible that alternative versions of Bitcoin can arise. An occurrence known as a "hard fork" is what occurs when this split happens; Litecoin is an example of a hard fork as it shares much of the code of Bitcoin. Evans concludes that

> "it is unclear whether the public ledger currency platforms will adopt governance systems that would enable them operate efficient, or even viable, financial service businesses. The few large open source software projects that have succeeded do not provide any evidence that the public ledger platforms will succeed too….the public ledger platforms are much more complicated…" (Evans, 2014, p. 19)

Debate within the community is well known to be a long process and many investors in Bitcoin would be aware of the difficulties and the expectations of faith in the governance structure would be included in the price.

It can be posited that larger, global macroeconomic forces have also had an effect on the price of Bitcoin. To further understand this, it was helpful to examine the research that has

looked into what affects stock prices which behave similarly to Bitcoin. Research conducted in 1986 by Nai-Fu Chen, Richard Roll and Stephen A Ross examined economic forces and their effect on the stock market. The variables they used included the following: Inflation, Treasury-bill rate, Long-term government bonds, industrial production, Low-grade bonds, equally weighted equities, Value-weighted equities, Consumption, and Oil prices. The researchers used one monthly data. Their conclusions found that industrial production, changes in risk premiums, changes in the yield curve and, with less strength, changes in unanticipated inflation were significant in describing expected stock returns (Chen, Roll, & Ross, Jul, 1986). These conclusions will help craft the research in this paper by using similar variables to see if they can coincide with an effect on the price of Bitcoin in a similar time series experiment including more observations.

Gold is another store of value whose price can be subject to speculative movements. The situation with gold differs slightly from Bitcoin as governments across the world have stores of gold which are about the same levels that are left to be mined from the planet. Those governments at any point could sell part of their stock, increasing the global supply of gold and in theory lowering the price. Studies have been conducted examining the effects of the government's policy of selling their stores of gold and predicting future sale of those stores. In the context of this papers research it helps to understand how the release of goods into the market place can affect the price of said good.

A study conducted in 1978 by Stephen W. Salant and Dale W. Henderson examined this very topic. They observed the anticipations by the gold market to potential government policies pertaining to the price of gold. While Bitcoin is not a good that is hoarded by governments, it is certainly hoarded by individuals, and there have also been cases of

government that stumbled into "criminal" activity seizing and auctioning Bitcoins. Bitcoin also carries more similarities to gold in that Bitcoins cannot be created, only mined, and there is a predictable amount that is mined on a daily basis. Additionally, the price of Bitcoin is subject to the whims of mass sell-offs by its holders, whether by governments or individuals. Salant and Henderson (1978) go on to describe their model, borrowing from the simple standard model of exhaustible resources but adding variables to account for the possibility of government sell-offs of their gold reserves. With their additions, they concluded that the anticipations by the market can affect capital formation, i.e., increased or decreased investment in that industry or the rate at which a resource is depleted, and they affirm that this does not only apply to gold. However they determined that unknown sales effectively lower the gold price and if for some reason gold was demanded by the government then prices would effectively rise. Because sell offs of large amount of gold are unpredictable, the time at which they occur are not predictable and remain described as unknown sales. The large sale of gold requires miners to sell more gold to pay for current lower prices of mining which both increases the rate of depletion and creates more supply in the market. (Salant & Henderson, 1978)

Another paper examined the changes in the price of gold and its effects on the prices of other commodities (Eder, 1938). His research looked at various products such as wheat, sugar, coffee, cotton, wool, silk, hides, copper, lead, tin, zinc, and petroleum across the United States and Europe. He also compared the price of gold in the US to commodity price fluctuations in the US, which saw the World Staple Commodities rise in similar fashion to the rise in the price level of gold. These findings were found also to carry over into England where similar results were found between the price level of gold in England and the price of English primary products. Eder's research concluded that "an increase in the price of gold, however, wherever and

whenever this may occur, automatically produces an immediate and corresponding increase in prices for other world staple commodities over and above world prices for those same commodities, measured in terms of gold." With this knowledge I hope to examine whether a similar effect could be felt in the price of Bitcoin as it has been compared to gold and even been given the name "digital gold". If gold is viewed in a similar fashion to Bitcoin then a strong correlation should be found with examination. (Eder, 1938)

## III. Hypothesis

The aim of the research is to examine the price of Bitcoin, a cryptocurrency which came into existence in late 2008. I hope to gain an understanding of Bitcoin's price fluctuations and its pattern of usage as a currency through empirical analysis. A number of variables will be looked at as contributing variables, including stock market fluctuations to determine if the direction of the market affects when money rushes in or out of Bitcoin. Major macroeconomic indicators such as the financial stress index will be included to account for stresses on a global scale. The goal of the research is to find and illustrate a correlation between the level of notoriety in media, macroeconomic influences and the price fluctuations of Bitcoin. This research will add to the general knowledge of this area by expanding the time period studied to through to the end of 2015. In this year, 2015, the price of Bitcoin has remained as stable as it ever has been. With this stability I hope to garner information that is more accurate than previous studies as well as covering the longest amount of time, stretching from 2011 to the end of the year 2015.

## IV. Data and Methodology

A regression will be run using variables such as "Bitcoin" term searches and usage across Google and Wikipedia appearances globally. This will capture some of the popularity of

Bitcoin. The price history of Bitcoin will be examined as provided by the website Coindesk. The values will be denominated in US dollars for the markets from the oldest dates in the US. The data collected will be the most current information available and add to the understanding available in the field, providing data for the entire year of 2015. Compounded return on stocks used by the MSCI stock market Index will provide for the effect of global stock market changes as well as the personal saving rate. I also aim to use both gold and silver to determine if Bitcoin's price is affected by shifts in the price of gold and silver. The use of valuable metals is to determine if the public sees Bitcoin as a place to store long term value similar to gold, thus making it more valuable and thus potentially increasing its popularity. Additionally OECD oil prices, the Cleveland financial stress index, and inflation will be examined to determine if there is a correlation between Bitcoin and major macroeconomic indicators. The data that will be most useful to this examination will be the data within the year 2015 as it has been a year of significant price stability for Bitcoin compared to its earlier years, all dates from 2011 until present will be employed. The periods of time utilized standard averaging throughout the month to acquire monthly statistics. Using all of this information, this research will provide the most current and wide ranging evidence for the use and growth of Bitcoin and the effects on its price level.

## V. Model

$$P(\text{Bitcoin}) = f(GOOG + WIKI + MSCI + OIL + SAVE + INFLATE + GOLD + SILVER + STRESS) + \varepsilon$$

| Variable | Description | Standard Deviation | Average | (n) # of Observations | Time Period |
|---|---|---|---|---|---|
| P(Bitcoin) | Price of Bitcoin beginning in Jan 2011 | 230.6121 | 200.2394 | 60 | Monthly |
| (GOOG) | Popularity measured in Google Trends | 20.95055 | 19.3 | 60 | Monthly |
| (WIKI) | Popularity measured in page views on Wikipedia | 412339.2 | 314432.2 | 60 | Monthly |
| (MSCI) | MSCI across all nations | 44.53419 | 371.4072 | 60 | Monthly |
| (OIL) | Price of barrels of crude oil | 20.5596 | 85.76783 | 60 | Monthly |
| (SAVE) | Personal Saving Rate | 1.230887 | 5.648333 | 60 | Monthly |
| (INFLATE) | Rate of Inflation | 1.089225 | 1.703275 | 59 | Monthly |

| | | | | | |
|---|---|---|---|---|---|
| | (CPI) in the US | | | | |
| (GOLD) | Price of Gold | 213.4815 | 1415.325 | 60 | Monthly |
| (SILVER) | Price of Silver | 7.881816 | 24.98787 | 60 | Monthly |
| (STRESS) | Cleveland Financial Stress Index Indicator | 1.008388 | 0.056333 | 60 | Monthly |

VI. Results

The results of the initial regression (Figure 1) discovered results that were not fully unexpected. [EXPLAIN – which variables were or were not statistically significant? For those that were significant, did any get the opposite sign from what you expected?] Variables GOOG, MSCI, INFLATE, SILVER, and SAVE were correlated [DO YOU MEAN HAD SIGNIFICANT IMPACTS ON BITCOINP? SAY SO]; however a Durbin-Watson test suggested there was significant evidence of autocorrelation with a Durbin-Watson statistic of 1.137087. To correct for this evidence of autocorrelation, a Prais-Winsten estimation was ran (Figure 2). The results of the test provided a better Durbin-Watson Statistic of 1.265164, however, GOOG, STRESS, and to a lesser extent INFLATE were now the only significant variables. Observing that the Durbin-Watson statistic remains to be low, there still exists evidence of autocorrelation that needs to be

accounted for. Before searching for a better solution to the problem of autocorrelation, there was an examination into evidence of non-stationarity. To test for this a Dickey Fuller test was ran (Figure 3) and found that there was not significant evidence of non-stationarity so that is not an issue for the model.

Due to the autocorrelation issue in the model further action was required. The process of taking first differences – calculating the changes in each variable both dependent and independent – was utilized. The first run of the regression (Figure 4) helped reduce evidence of autocorrelation by raising the Durbin-Watson statistic to 1.340428. To further improve this result a Prais-Winsten regression was ran (Figure 5) and found the statistic improved to 1.693244 which provided the best result to correct for autocorrelation in the model. GOOG, MSCI, INFLATE, and STRESS were all found to be significant, with GOOG and STRESS having the largest effects [how did you determine this? You can't just look at the size of the coefficient, you would estimate the effect of a one-standard deviation change in that variable on the dependent variable.]. This reflects the findings in the initial regression with the exception of SILVER and SAVE without too much change in the explanatory power of the significant variables [what do you mean? R-squared? T-statistics? Say so]. Moving from the simple regression to first differences regression provides convincing evidence for the case that these variables lend insight into their effect on the price of Bitcoin.

Further examination into the potential collinearity among the explanatory variables was conducted by adding and removing variables to examine how they affected the model. Figure 6 shows what occurs when GOLD is removed; overall there is not much change though STRESS does become more significant. The same is true when SILVER is removed (Figure 7), indicating that GOLD and SILVER have similar effects on the equation. Removing MSCI (Figure 8) finds

that OIL becomes more important which makes sense as some of the movement of the stock market could be found in areas such as futures or companies that utilize petroleum. Removing STRESS (Figure 9) increases the power of GOLD and INFLATE while limiting the explanatory power of GOOG slightly. This indicates that GOLD and INFLATE capture some of the financial stress experienced in an economy. Figures 10 and 11 present the results of removing GOOG and WIKI respectively. When GOOG is removed WIKI becomes significant which makes sense as WIKI should reflect GOOG in a similar manner as they are both measures of attention in the media through searches on either Google or Wikipedia. Removing WIKI increases the significance of GOOG, reinforcing this interpretation.

The conclusion of the various tests discovers that STRESS and MSCI are negatively correlated with the price of Bitcoin and that GOOG and INFLATE are positively correlated. MSCI is a gauge of stock market activity. If stocks became more attractive, market participants will pull their money out of alternatives such as Bitcoin, hence creating the negative effect on Bitcoin price. As investment in the stock market increases, investment in Bitcoins will decrease and this is reflected in the regression results. In addition STRESS was used to track distress in the US financial system through six markets: credit, equity, foreign exchange, interbank, real estate and securitization markets. This indicates that during times of economic hardship, economic participants pull out of various financial instruments such as Bitcoin or other forms of savings to increase their ability to remain solvent. A contracting economy forces the importance of money to increase over that of long-term financial instruments [is bitcoin a lt instrument? No. but it is not transactions-money]; this is what Keynes called liquidity preference. GOOG and INFLATE provided the two positively correlated results. It makes sense that GOOG is positively related with price because the first thing someone would do if they are first learning about

Bitcoin is to look it up on the most widely available means of learning, a google search. Though WIKI was not found to be significant when in used in the full model, it gained importance when GOOG was removed meaning that its explanatory effect is similar to that of GOOG.

INFLATE's result was surprising because normally when the price of real goods goes up, the purchasing power of each unit of currency goes down. This could be due to using Bitcoin as a haven to protect against the rising inflation rates in various countries or possibly because of the price of Bitcoin being on a steady rise since its inception. The insignificance of OIL, GOLD, SILVER, and SAVE was a surprise. With GOLD and SILVER holding little correlation it is possible that Bitcoin is not being used a store of long term value. GOLD does gain power when removing STRESS from the model so it is possible that STRESS is capturing some of the explanatory power of GOLD when included in the full model. OIL experiences a similar effect when MSCI is removed from the model which could mean that economic downturns are correlated with Bitcoin price and commodity prices such as oil that often precede these downturns hold some effect but not as much as the MSCI indicator. The fact that SAVE holds little importance could be attributed to the relatively small market size that bitcoin holds ($7,116,964,949) compared to other resources in the economy. (Coin Cap, 2016) It could be that the majority of participants in the economy have not yet heard of Bitcoin and as such do not dedicate a portion of their savings to Bitcoin.

Data Tables

Figure 1

| Source | SS | df | MS | Number of obs | = | 59 |
|---|---|---|---|---|---|---|
| | | | | F(9, 49) | = | 40.32 |
| Model | 2719388.32 | 9 | 302154.258 | Prob > F | = | 0.0000 |
| Residual | 367189.375 | 49 | 7493.66072 | R-squared | = | 0.8810 |
| | | | | Adj R-squared | = | 0.8592 |
| Total | 3086577.7 | 58 | 53216.8569 | Root MSE | = | 86.566 |

| PBITCOIN | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| GOOG | 6.020768 | .9960544 | 6.04 | 0.000 | 4.019122 | 8.022414 |
| WIKI | -.0000383 | .0000436 | -0.88 | 0.383 | -.0001259 | .0000492 |
| MSCI | 2.546502 | .6375299 | 3.99 | 0.000 | 1.265338 | 3.827666 |
| OIL | -.6151112 | 1.292402 | -0.48 | 0.636 | -3.21229 | 1.982067 |
| INFLATE | 120.1049 | 26.67037 | 4.50 | 0.000 | 66.50878 | 173.701 |
| GOLD | .1650913 | .1785105 | 0.92 | 0.360 | -.1936389 | .5238216 |
| SILVER | -18.71614 | 4.696623 | -3.99 | 0.000 | -28.15436 | -9.277928 |
| STRESS | -25.94123 | 26.68143 | -0.97 | 0.336 | -79.55958 | 27.67711 |
| SAVE | 30.33811 | 13.73029 | 2.21 | 0.032 | 2.746045 | 57.93017 |
| _cons | -936.4857 | 364.609 | -2.57 | 0.013 | -1669.195 | -203.7764 |

Durbin-Watson d-statistic( 10, 59) = 1.137087

Figure 2

```
Iteration 0:  rho = 0.0000
Iteration 1:  rho = 0.4293
Iteration 2:  rho = 0.6834
Iteration 3:  rho = 0.8185
Iteration 4:  rho = 0.8901
Iteration 5:  rho = 0.9270
Iteration 6:  rho = 0.9427
Iteration 7:  rho = 0.9481
Iteration 8:  rho = 0.9497
Iteration 9:  rho = 0.9502
Iteration 10:  rho = 0.9504
Iteration 11:  rho = 0.9504
Iteration 12:  rho = 0.9504
Iteration 13:  rho = 0.9504
Iteration 14:  rho = 0.9504
Iteration 15:  rho = 0.9504

Prais-Winsten AR(1) regression -- iterated estimates
```

| Source | SS | df | MS | | |
|---|---|---|---|---|---|
| | | | | Number of obs | = 59 |
| | | | | F(9, 49) | = 5.75 |
| Model | 174264.484 | 9 | 19362.7205 | Prob > F | = 0.0000 |
| Residual | 165118.777 | 49 | 3369.77096 | R-squared | = 0.5135 |
| | | | | Adj R-squared | = 0.4241 |
| Total | 339383.261 | 58 | 5851.43554 | Root MSE | = 58.05 |

| PBITCOIN | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| GOOG | 3.432532 | .6915186 | 4.96 | 0.000 | 2.042874 | 4.822191 |
| WIKI | -2.61e-06 | .0000213 | -0.12 | 0.903 | -.0000455 | .0000402 |
| MSCI | -.5804471 | .6420208 | -0.90 | 0.370 | -1.870636 | .709742 |
| OIL | -.8960879 | 1.520349 | -0.59 | 0.558 | -3.951344 | 2.159168 |
| INFLATE | 54.40348 | 27.01587 | 2.01 | 0.050 | .1130489 | 108.6939 |
| GOLD | -.0531332 | .240166 | -0.22 | 0.826 | -.5357648 | .4294984 |
| SILVER | -.952101 | 5.868519 | -0.16 | 0.872 | -12.74533 | 10.84113 |
| STRESS | -63.622 | 20.99099 | -3.03 | 0.004 | -105.805 | -21.43902 |
| SAVE | 2.796014 | 8.685513 | 0.32 | 0.749 | -14.65818 | 20.25021 |
| _cons | 410.2188 | 386.2764 | 1.06 | 0.293 | -366.0327 | 1186.47 |
| rho | .9504471 | | | | | |

```
Durbin-Watson statistic (original)    1.137087
Durbin-Watson statistic (transformed) 1.265164
```

Figure 3

Dickey-Fuller test for unit root  Number of obs = 59

| | Test Statistic | Interpolated Dickey-Fuller: 1% Critical Value | 5% Critical Value | 10% Critical Value |
|---|---|---|---|---|
| Z(t) | -1.258 | -3.567 | -2.923 | -2.596 |

MacKinnon approximate p-value for Z(t) = 0.6480

Figure 4

| Source | SS | df | MS | Number of obs | = | 58 |
|---|---|---|---|---|---|---|
| | | | | F(9, 48) | = | 6.12 |
| Model | 186905.572 | 9 | 20767.2857 | Prob > F | = | 0.0000 |
| Residual | 162817.334 | 48 | 3392.0278 | R-squared | = | 0.5344 |
| | | | | Adj R-squared | = | 0.4471 |
| Total | 349722.906 | 57 | 6135.48958 | Root MSE | = | 58.241 |

| diff_PBITC~N | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| diff_GOOG | 3.454029 | .6788071 | 5.09 | 0.000 | 2.089196 | 4.818862 |
| diff_WIKI | -1.50e-06 | .0000209 | -0.07 | 0.943 | -.0000436 | .0000406 |
| diff_MSCI | -.8585382 | .650872 | -1.32 | 0.193 | -2.167204 | .4501276 |
| diff_OIL | -.3773452 | 1.561007 | -0.24 | 0.810 | -3.515959 | 2.761269 |
| diff_INFLATE | 55.13477 | 26.66259 | 2.07 | 0.044 | 1.52604 | 108.7435 |
| diff_GOLD | -.0247279 | .2407566 | -0.10 | 0.919 | -.5088015 | .4593456 |
| diff_SILVER | -.366209 | 5.827232 | -0.06 | 0.950 | -12.08264 | 11.35023 |
| diff_STRESS | -65.85335 | 20.71104 | -3.18 | 0.003 | -107.4957 | -24.21101 |
| diff_SAVE | 3.861141 | 8.549435 | 0.45 | 0.654 | -13.32865 | 21.05093 |
| _cons | 6.950248 | 7.843083 | 0.89 | 0.380 | -8.819327 | 22.71982 |

Durbin-Watson d-statistic( 10, 58) = 1.340428

Figure 5

```
Iteration 0:  rho = 0.0000
Iteration 1:  rho = 0.3185
Iteration 2:  rho = 0.4105
Iteration 3:  rho = 0.4273
Iteration 4:  rho = 0.4299
Iteration 5:  rho = 0.4303
Iteration 6:  rho = 0.4304
Iteration 7:  rho = 0.4304
Iteration 8:  rho = 0.4304
Iteration 9:  rho = 0.4304

Prais-Winsten AR(1) regression -- iterated estimates
```

| Source | SS | df | MS | | |
|---|---|---|---|---|---|
| | | | | Number of obs | = 58 |
| | | | | F(9, 48) | = 5.30 |
| Model | 137601.596 | 9 | 15289.0662 | Prob > F | = 0.0001 |
| Residual | 138580.874 | 48 | 2887.10154 | R-squared | = 0.4982 |
| | | | | Adj R-squared | = 0.4041 |
| Total | 276182.469 | 57 | 4845.30648 | Root MSE | = 53.732 |

| diff_PBITC~N | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| diff_GOOG | 2.64402 | .5722466 | 4.62 | 0.000 | 1.493441 | 3.794599 |
| diff_WIKI | -1.47e-06 | .0000158 | -0.09 | 0.927 | -.0000333 | .0000304 |
| diff_MSCI | -.6886757 | .5035235 | -1.37 | 0.178 | -1.701078 | .3237262 |
| diff_OIL | -1.248681 | 1.477616 | -0.85 | 0.402 | -4.219627 | 1.722265 |
| diff_INFLATE | 52.7579 | 26.20681 | 2.01 | 0.050 | .0655651 | 105.4502 |
| diff_GOLD | -.0290314 | .2147007 | -0.14 | 0.893 | -.460716 | .4026533 |
| diff_SILVER | 1.084833 | 5.242105 | 0.21 | 0.837 | -9.455125 | 11.62479 |
| diff_STRESS | -60.6575 | 16.88851 | -3.59 | 0.001 | -94.61413 | -26.70087 |
| diff_SAVE | .2643717 | 6.866831 | 0.04 | 0.969 | -13.54232 | 14.07106 |
| _cons | 5.621945 | 12.33017 | 0.46 | 0.650 | -19.16951 | 30.4134 |
| rho | .4303724 | | | | | |

```
Durbin-Watson statistic (original)    1.340428
Durbin-Watson statistic (transformed) 1.693244
```

Figure 6

```
Iteration 0:  rho = 0.0000
Iteration 1:  rho = 0.3184
Iteration 2:  rho = 0.4104
Iteration 3:  rho = 0.4272
Iteration 4:  rho = 0.4299
Iteration 5:  rho = 0.4302
Iteration 6:  rho = 0.4303
Iteration 7:  rho = 0.4303
Iteration 8:  rho = 0.4303
Iteration 9:  rho = 0.4303

Prais-Winsten AR(1) regression -- iterated estimates

      Source |       SS           df       MS      Number of obs   =        58
-------------+----------------------------------   F(8, 49)        =      6.08
       Model |  137549.959         8  17193.7449   Prob > F        =    0.0000
    Residual |  138633.826        49  2829.26176   R-squared       =    0.4980
-------------+----------------------------------   Adj R-squared   =    0.4161
       Total |  276183.786        57  4845.32957   Root MSE        =    53.191

------------------------------------------------------------------------------
diff_PBITC~N |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   diff_GOOG |    2.642548    .566383     4.67   0.000     1.504359    3.780737
   diff_WIKI |   -1.12e-06   .0000155    -0.07   0.943    -.0000322      .00003
   diff_MSCI |   -.6851089    .497779    -1.38   0.175    -1.685433    .3152154
    diff_OIL |   -1.189585   1.397494    -0.85   0.399    -3.997955    1.618784
diff_INFLATE |    52.29903   25.72447     2.03   0.047     .6037831    103.9943
 diff_SILVER |    .5504544   3.410628     0.16   0.872    -6.303458    7.404367
 diff_STRESS |   -61.54297    15.4128    -3.99   0.000    -92.51615   -30.56978
   diff_SAVE |    .4201098   6.701895     0.06   0.950    -13.04785    13.88807
       _cons |    5.705994   12.18942     0.47   0.642    -18.78957    30.20156
-------------+----------------------------------------------------------------
         rho |    .4303152
------------------------------------------------------------------------------
Durbin-Watson statistic (original)    1.341021
Durbin-Watson statistic (transformed) 1.690351
```

Figure 7

```
Iteration 0:  rho = 0.0000
Iteration 1:  rho = 0.3193
Iteration 2:  rho = 0.4095
Iteration 3:  rho = 0.4257
Iteration 4:  rho = 0.4282
Iteration 5:  rho = 0.4286
Iteration 6:  rho = 0.4286
Iteration 7:  rho = 0.4287
Iteration 8:  rho = 0.4287
Iteration 9:  rho = 0.4287

Prais-Winsten AR(1) regression -- iterated estimates

      Source |       SS           df       MS      Number of obs   =        58
-------------+----------------------------------   F(8, 49)        =      6.07
       Model |  137514.158         8  17189.2697   Prob > F        =    0.0000
    Residual |  138708.826        49  2830.79237   R-squared       =    0.4978
-------------+----------------------------------   Adj R-squared   =    0.4159
       Total |  276222.984        57  4846.01726   Root MSE        =    53.205

------------------------------------------------------------------------------
diff_PBITC~N |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   diff_GOOG |    2.637228   .5652888     4.67   0.000     1.501237    3.773218
   diff_WIKI |   -9.85e-07   .0000155    -0.06   0.950    -.0000322    .0000302
   diff_MSCI |   -.6836305   .4983263    -1.37   0.176    -1.685055    .3177937
    diff_OIL |   -1.125806   1.344304    -0.84   0.406    -3.827286    1.575673
diff_INFLATE |    52.61836   25.94212     2.03   0.048     .4857114     104.751
   diff_GOLD |    .0043348   .1397894     0.03   0.975    -.2765826    .2852522
 diff_STRESS |   -61.35058   16.41774    -3.74   0.000    -94.34326   -28.35791
   diff_SAVE |    .4533559   6.748706     0.07   0.947    -13.10868    14.01539
       _cons |    5.673329    12.1724     0.47   0.643    -18.78802    30.13468
-------------+----------------------------------------------------------------
         rho |     .428655
------------------------------------------------------------------------------
Durbin-Watson statistic (original)    1.338436
Durbin-Watson statistic (transformed) 1.691948
```

Figure 8

```
Iteration 0:  rho = 0.0000
Iteration 1:  rho = 0.3207
Iteration 2:  rho = 0.4056
Iteration 3:  rho = 0.4200
Iteration 4:  rho = 0.4221
Iteration 5:  rho = 0.4224
Iteration 6:  rho = 0.4224
Iteration 7:  rho = 0.4224
Iteration 8:  rho = 0.4224

Prais-Winsten AR(1) regression -- iterated estimates

      Source |       SS           df       MS      Number of obs   =        58
-------------+----------------------------------   F(8, 49)        =      5.63
       Model |  132388.165         8  16548.5206   Prob > F        =    0.0000
    Residual |  143998.498        49  2938.74486   R-squared       =    0.4790
-------------+----------------------------------   Adj R-squared   =    0.3939
       Total |  276386.663        57  4848.88883   Root MSE        =     54.21

------------------------------------------------------------------------------
diff_PBITC~N |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   diff_GOOG |    2.475583   .5635664     4.39   0.000     1.343054    3.608112
   diff_WIKI |    3.06e-06   .0000157     0.20   0.846    -.0000285    .0000346
    diff_OIL |   -1.518848   1.477507    -1.03   0.309    -4.488011    1.450314
diff_INFLATE |    54.50841   26.41435     2.06   0.044     1.426798      107.59
   diff_GOLD |   -.0134611   .2167479    -0.06   0.951    -.4490323    .4221102
 diff_SILVER |     .687105    5.29124     0.13   0.897     -9.94604    11.32025
 diff_STRESS |   -57.01263   16.86667    -3.38   0.001    -90.90746   -23.11779
   diff_SAVE |    1.139709   6.923459     0.16   0.870     -12.7735    15.05292
       _cons |    4.675864   12.25538     0.38   0.704    -19.95225    29.30398
-------------+----------------------------------------------------------------
         rho |    .4224355
------------------------------------------------------------------------------
Durbin-Watson statistic (original)    1.334533
Durbin-Watson statistic (transformed) 1.692981
```

Figure 9

```
Iteration 0:  rho = 0.0000
Iteration 1:  rho = 0.2562
Iteration 2:  rho = 0.3553
Iteration 3:  rho = 0.3816
Iteration 4:  rho = 0.3875
Iteration 5:  rho = 0.3887
Iteration 6:  rho = 0.3889
Iteration 7:  rho = 0.3890
Iteration 8:  rho = 0.3890
Iteration 9:  rho = 0.3890
Iteration 10:  rho = 0.3890

Prais-Winsten AR(1) regression -- iterated estimates

      Source |       SS           df       MS      Number of obs   =        58
-------------+------------------------------       F(8, 49)        =      3.56
       Model |  102101.343         8  12762.6679   Prob > F        =    0.0025
    Residual |  175621.127        49  3584.10463   R-squared       =    0.3676
-------------+------------------------------       Adj R-squared   =    0.2644
       Total |  277722.47         57  4872.32403   Root MSE        =    59.867

------------------------------------------------------------------------------
diff_PBITC~N |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   diff_GOOG |    2.481644   .6425458     3.86   0.000       1.1904    3.772888
   diff_WIKI |    5.96e-06   .0000179     0.33   0.740    -.0000299    .0000418
   diff_MSCI |   -.3966284   .5644102    -0.70   0.486    -1.530853    .7375964
    diff_OIL |   -1.071336    1.65284    -0.65   0.520    -4.392843     2.25017
diff_INFLATE |    79.45857   28.00149     2.84   0.007     23.18747    135.7297
   diff_GOLD |   -.3295676   .2225146    -1.48   0.145    -.7767274    .1175922
 diff_SILVER |    4.645829   5.780382     0.80   0.425    -6.970283    16.26194
   diff_SAVE |   -2.161599   7.738931    -0.28   0.781    -17.71356    13.39036
       _cons |    5.061638   12.84655     0.39   0.695    -20.75447    30.87774
-------------+----------------------------------------------------------------
         rho |    .3889941
------------------------------------------------------------------------------

Durbin-Watson statistic (original)    1.477394
Durbin-Watson statistic (transformed) 1.818720
```

Figure 10

```
Iteration 0:  rho = 0.0000
Iteration 1:  rho = 0.4048
Iteration 2:  rho = 0.4698
Iteration 3:  rho = 0.4742
Iteration 4:  rho = 0.4745
Iteration 5:  rho = 0.4745
Iteration 6:  rho = 0.4745

Prais-Winsten AR(1) regression -- iterated estimates
```

| Source | SS | df | MS | | |
|---|---|---|---|---|---|
| Model | 76175.2297 | 8 | 9521.90372 | Number of obs | = 58 |
| Residual | 199661.481 | 49 | 4074.72411 | F(8, 49) | = 2.34 |
| | | | | Prob > F | = 0.0327 |
| | | | | R-squared | = 0.2762 |
| | | | | Adj R-squared | = 0.1580 |
| Total | 275836.711 | 57 | 4839.24054 | Root MSE | = 63.834 |

| diff_PBITC~N | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| diff_WIKI | .0000291 | .0000166 | 1.75 | 0.086 | -4.26e-06 | .0000625 |
| diff_MSCI | -.1632785 | .5700347 | -0.29 | 0.776 | -1.308806 | .9822491 |
| diff_OIL | -1.130414 | 1.744023 | -0.65 | 0.520 | -4.63516 | 2.374332 |
| diff_INFLATE | 37.63721 | 30.82027 | 1.22 | 0.228 | -24.29844 | 99.57286 |
| diff_GOLD | -.0067442 | .2519563 | -0.03 | 0.979 | -.5130693 | .4995809 |
| diff_SILVER | -.7358577 | 6.138753 | -0.12 | 0.905 | -13.07214 | 11.60043 |
| diff_STRESS | -51.15333 | 19.57909 | -2.61 | 0.012 | -90.49898 | -11.80767 |
| diff_SAVE | 1.334874 | 7.998968 | 0.17 | 0.868 | -14.73965 | 17.4094 |
| _cons | 6.016443 | 15.82084 | 0.38 | 0.705 | -25.77673 | 37.80962 |
| rho | .4745143 | | | | | |

```
Durbin-Watson statistic (original)    1.178825
Durbin-Watson statistic (transformed) 1.682533
```

Figure 11

```
Iteration 0:  rho = 0.0000
Iteration 1:  rho = 0.3184
Iteration 2:  rho = 0.4104
Iteration 3:  rho = 0.4272
Iteration 4:  rho = 0.4298
Iteration 5:  rho = 0.4302
Iteration 6:  rho = 0.4303
Iteration 7:  rho = 0.4303
Iteration 8:  rho = 0.4303
Iteration 9:  rho = 0.4303

Prais-Winsten AR(1) regression -- iterated estimates
```

| Source | SS | df | MS | | |
|---|---|---|---|---|---|
| | | | | Number of obs | = 58 |
| | | | | F(8, 49) | = 6.08 |
| Model | 137578.139 | 8 | 17197.2674 | Prob > F | = 0.0000 |
| Residual | 138605.824 | 49 | 2828.69029 | R-squared | = 0.4981 |
| | | | | Adj R-squared | = 0.4162 |
| Total | 276183.964 | 57 | 4845.3327 | Root MSE | = 53.185 |

| diff_PBITC~N | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| diff_GOOG | 2.621282 | .5112123 | 5.13 | 0.000 | 1.593962 | 3.648601 |
| diff_MSCI | -.6789265 | .4873735 | -1.39 | 0.170 | -1.65834 | .3004873 |
| diff_OIL | -1.214646 | 1.416905 | -0.86 | 0.395 | -4.062024 | 1.632732 |
| diff_INFLATE | 52.71338 | 25.93601 | 2.03 | 0.048 | .5930122 | 104.8338 |
| diff_GOLD | -.0257904 | .2096805 | -0.12 | 0.903 | -.4471592 | .3955784 |
| diff_SILVER | 1.012982 | 5.132022 | 0.20 | 0.844 | -9.300203 | 11.32617 |
| diff_STRESS | -60.45482 | 16.57522 | -3.65 | 0.001 | -93.76397 | -27.14568 |
| diff_SAVE | .3756055 | 6.692988 | 0.06 | 0.955 | -13.07446 | 13.82567 |
| _cons | 5.651719 | 12.19939 | 0.46 | 0.645 | -18.86387 | 30.16731 |
| rho | .4303075 | | | | | |

```
Durbin-Watson statistic (original)    1.340713
Durbin-Watson statistic (transformed) 1.693292
```

# VII. References


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