Investigating how Crypto Markets Function and Analyzing Methods of Navigating their Volatility

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1. Introduction

As we pass the 10-year anniversary of Satoshi Nakamoto's 2008 publication on Bitcoin, we can look back and see that was landmark event in the history of The United States, the world, and economics overall[1]. Since that publication there have been people across the world dedicating their careers studying technological factors such as cryptography, bitcoin mining, decentralization, smart order contracts, smart order trading, blockchain and more. Software development activity has been increasing massively with thousands of Github commits every day across all of the new currency protocols being introduced[2]. Media coverage of the technology and the different currencies has spanned across renowned news channels to everyday social media. As this explosion of focus on crypto currencies has occurred, the collective market capitalization of all the currencies has reached peaks of ~$500 billion as of just last year[3]. In parallel to this over 300 hedge funds investing exclusively in crypto currencies have spawned[4]. While this phenomenon has been incredibly exciting to see, for many people it has been dangerous and confusing. We constantly see stories of people earning millions of dollars after having investing in a currency such as Bitcoin as early as 2013[5]. However, we also see stories of retail investors losing large percentages of their personal wealth after blindly putting money into an asset they have minimal knowledge of except of what is seen in commercial media.

The broad goal of this paper is to remove some of the uncertainty around the crypto currencies by breaking down how the technology fits in with the rest of the ecosystem of monetary exchange. Since there are too many subjects to study to truly achieve this goal in one paper, we focus our investigation into three areas.

1. Section 3: Comparing the Constructs of Traditional Financial Markets and Crypto Markets

2. Section 4: Data Analysis: Exploring Potential Factors Correlated to Crypto Currencies.

3. Section 5: The Stable Coin

The first of these sections will be theoretical in looking at past literature to analyze the core technology of crypto currencies to see how it impacts how the markets function in comparison to flagship markets. The second will be an implementation effort, as we will create functionality to access data on past crypto prices and do analysis on it. The third section will be an extension focused on introducing a new technology called the stable coin that is garnering attention. We would like to note here that although we will consider other currencies in our analysis, we will

[1] (Nakamoto, 2008)
[2] (Sedgewick, 2018)
[3] ("Cryptocurrency Marketcap, cnbc.com, 2018)
[4] (Palmer, 2018)
[5] (Roberts, 2017)

focus the research on Bitcoin as it is the coin with the largest history and overwhelmingly the largest share of the overall crypto market.

2. Background

2.1 Key Terms

To initialize this study, it will be helpful to first define some key terms to use for the rest of the paper. Given the interdisciplinary nature of this investigation, this will be very valuable in ensuring that readers from varying backgrounds will have a singular context to work with

- Blockchain:
  - A blockchain is a digitized, decentralized, public ledger of all cryptocurrency transactions. Constantly growing as 'completed' blocks (the most recent transactions) are recorded and added to it in chronological order, it allows market participants to keep track of digital currency transactions without central recordkeeping. Each node (a computer connected to the network) gets a copy of the blockchain, which is downloaded automatically[6].

- Cryptocurrency:
  - Any form of currency that only exists digitally, that usually has no central issuing or regulating authority but instead uses a decentralized system to record transactions and manage the issuance of new units, and that relies on cryptography to prevent counterfeiting and fraudulent transactions[7] .

- Bitcoin Mining
  - Bitcoin mining is the process by which transactions are verified and added to the public ledger, known as the block chain, and also the means through which new bitcoin are released. Anyone with access to the internet and suitable hardware can participate in mining. The mining process involves compiling recent transactions into blocks and trying to solve a computationally difficult puzzle. The participant who first solves the puzzle gets to place the next block on the block chain and claim the rewards. The rewards, which incentivize mining, are both the transaction fees associated with the transactions compiled in the block as well as newly released bitcoin[8].

[6] ("Blockchain", Investopedia. 2018)
[7] ("Cryptocurrency", Merriam-Webster. 2018)
[8] ("Bitcoin Mining", Investopedia. 2018)

- Bitcoin Exchange:
    - A bitcoin exchange is a digital marketplace where traders can buy and sell bitcoins using different fiat currencies or altcoins. A bitcoin currency exchange is an online platform that acts as an intermediary between buyers and sellers of the cryptocurrency. Bitcoin exchange platforms match buyers with sellers. Like a traditional stock exchange, traders can opt to buy and sell bitcoin by inputting either a market order or a limit order.[9]

- Financial Market
    - The financial market is a broad term describing any marketplace where trading of securities including equities, bonds, currencies and derivatives occur. Some financial markets are small with little activity, while some financial markets like the New York Stock Exchange (NYSE) trade trillions of dollars of securities daily.[10]

- Stable Coin
    - A new class of cryptocurrencies that offer price stability by way of being backed by a reserve asset [11]

2.2 History of Crypto Markets

Given that we will analyze crypto assets with relation to their historical performance, it will be valuable have a common understanding of the history of the market. As mentioned before, crypto currencies are an extremely young technology and even younger financial instruments. Bitcoin is just reaching its 10 year anniversary from Nakamoto's 2008 publication and it has been just about 5 years since Ethereum came into existence. Taking a look at Bitcoin, we can see it has experienced exponential growth over its time growing to be worth $20,000 late 2017. With this rise, however, there has been an extreme amount of volatility. In the table below we can see this clearly in that with each short term rise, Bitcoin has seen numerous corrections as well. The table below details corrections over 30% since 2012:

[9] ("Bitcoin Exchange", Investopedia. 2018)
[10] ("Financial Market", Investopedia. 2018)
[11] ("Stablecoin", Investopedia, 2018)

Bitcoin (BTC) Historical Corrections

List of Bitcoin major corrections ≥ 30% (from ATH levels) since January 2012

Correction Period ≥ 30%						
Correction Start Date	Correction End Date	# Days in Correction	Bitcoin High Price	Bitcoin Low Price	% Decline	$ Decline
12 Jan 2012	27 Jan 2012	16	$ 7.38	$ 3.80	-49%	-$ 3.58
17 Aug 2012	19 Aug 2012	3	$ 16.41	$ 7.10	-57%	-$ 9.31
6 Mar 2013	7 Mar 2013	2	$ 49.17	$ 33.00	-33%	-$ 16.17
21 Mar 2013	23 Mar 2013	3	$ 76.91	$ 50.09	-35%	-$ 26.82
10 Apr 2013	12 Apr 2013	3	$ 259.34	$ 45.00	-83%	-$ 214.34
19 Nov 2013	19 Nov 2013	1	$ 755.00	$ 378.00	-50%	-$ 377.00
30 Nov 2013	14 Jan 2015	411	$ 1,163.00	$ 152.40	-87%	-$ 1,010.60
10 Mar 2017	25 Mar 2017	16	$ 1,350.00	$ 891.33	-34%	-$ 458.67
25 May 2017	27 May 2017	3	$ 2,760.10	$1,850.00	-33%	-$ 910.10
12 Jun 2017	16 Jul 2017	35	$ 2,980.00	$1,830.00	-39%	-$ 1,150.00
2 Sep 2017	15 Sep 2017	14	$ 4,979.90	$2,972.01	-40%	-$ 2,007.89
8 Nov 2017	12 Nov 2017	5	$ 7,888.00	$5,555.55	-30%	-$ 2,332.45
17 Dec 2017	2 Feb 2018 *	48	$19,666.00	$8,094.80	-59%	-$11,571.20

Bitstamp exchange prices (BTC/USD)

**indicative correction end date and bitcoin low price*

[12]

We can also see below in plots of Bitcoin that these corrections have persisted not only through the massive rise in price of 2017 but also the decline of 2018. [13]With every positive and negative delta of 100%+ there have been proportional paired run in the opposite direction. The functional impact this has is that it becomes very difficult to develop any predictions or process in placing value. It also becomes highly risky to make investments in short term views as there is little control over where the price will head.

There are many speculative reasons past studies have stated to be the reason for this high volatility. Some have stated that it is just purely the nascency of the coins that causes this. Others say it is the high exposure to external factors such as cyber attacks and government rules on securitization[14]. Overall the practical impact we can take away for this section is that while it is valuable to look at the overall history of Bitcoin, it is very important to look at specific sections of time in order to understand the volatile trends.

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[12] ("A History Of Bitcoin Price Collapses Over the Years", CCN. 2018)

[13] (Bitcoin Chart, Trading View. 2018)

[14] (Pryzmont, 2016)

BITCOIN (2013-2018)[15]

In looking for specific sections to focus on we can begin by looking at a large window above. From this plot of Bitcoin from 2013-2018 above, and from the large amount of attention given in the rise, we can easily see that the 2017 run up and 2018 decline will be very important sections to focus on. Some people have noted that this period was a time in which Bitcoin experienced many effects of market manipulation and speculation, while others have noted that it was the early effect of large adoption[16].This will consistently be a debated discussion, however, regardless it is clearly an important time period to analyze.

Another section that comes to note is November 2013 to January 2015, zoomed in below, where we see the price of Bitcoin rise more than 500% from $205 (Nov '13) to $1100 (Dec '13) and then fall to $315 (Jan '15). This is certainly an extremely large range over at small period of time. However, it is important to underline this period with the understanding that this was in a period where the market capitalization of Bitcoin was only just about $6bn. Compared to the peak of 2017, this is just 12% the size. By being in this early period the price will inherently be far more susceptible to wild swings in price based off small increases and decreases in demand. This late 2013 period was also the time when Coinbase and other common retail exchanges came live and brought an influx of buyers, further indicating a larger demand of coins. Given this linking variable we will make the decision to exclude this interval in analysis as it can give way to confounding results.

[15] (Bitcoin Price, CoinMarketCap, 2018)
[16] (Rooney, 2018)

BITCOIN CHART (2013-2015)[17]

3. Comparing the Constructs of Traditional Financial Markets and Crypto Markets

Stakeholders of all sorts have viewed the innovation of cryptocurrencies in many ways. Some common use cases that have been categorized are[18]:

1. Investment – where people gain value by earning money on the relative appreciation in price of currencies
2. Medium of Exchange – where people gain value by having a more efficient means of transferring money from people to people, especially internationally
3. Payment Rail – where people gain value from having a theoretically secure and decentralized form of purchasing/selling goods
4. Other Non-monetary uses – where people gain value through projects they build off the core blockchain technology.

While each of these cases will be important to analyze, and will inherently impact each other, we will focus this study on the first use case. In doing so we will indirectly consider the other uses as well. As there has been a large increase in the value of crypto markets, investors can tend to get caught up in thinking of these currencies as a security similar to that of traditional markets. This as a result separates analysis of the investment from the technology. In this section we will focus on how the technology of crypto currencies inherently impacts how it functions as a tool for investment and makes it unique from other common securities.

[17] (Bitcoin Price, CoinMarketCap, 2018)
[18] (Hileman, 2017)

The pricing of all of entities in a market is decided by the core concept of supply and demand. If there are more people looking to purchase than sell, the price will go up and vice versa. However, there are 3 areas where we see structures tend to diverge when comparing across the traditional markets to crypto markets. These three areas are: ownership structure, price perception, and exchange structure. We will function under this framework to illustrate how the different markets function. We will begin by laying the information of how traditional financial markets, specifically public equities and commodities, function and then move forward to compare to cryptomarkets.

3.1 Fundamentals of Financial Markets

When considering the overarching universe of investable markets, we see a massive amount of nuanced products, from credit default swaps to real estate investment trusts that have become mainstays in investor tools. Together all of these products sit together in a larger ecosystem where they all hold levers that can directly or indirectly have mutual impacts. For this study we fill focus on the commodities and public equities market. We choose these to get a wide range of exposure to retail investors, as public equities have a lot and commodities have few[19]. Prior to exploring the statistical relationships of cryptos and these markets it is important to understand how these markets are actually set up and how this compares to the make-up of crypto markets. The information for the following section is sourced primarily through the Corporate Finance Institute and prior knowledge.[20]

3.1.1 Public Equities

Ownership Structure: For the purposes of this study when we consider the public equities market we refer directly to the stock market. The stock market is where investors can exchange shares in publicly traded companies. There is first the primary market, where new stock issuant are first given out via events such as Initial Public Offerings. Then there are secondary markets where shareholders are able to trade shares for listed prices. Whenever a share is bought the purchasing party then owns a piece of this business and, given enough volume, has a say in how the business will run.

Price Perception: The listed price of a share is determined by the supply of outstanding shares the owners of the business have issued and the demand from the public. Consequently, the total value, or market capitalization, of these businesses is considered to be the amount of outstanding shares times the price of the shares. The demand for these shares is stated to be determined by the public sentiment for the ability of the businesses to have strong earnings. If a business makes more money than expected, people feel strongly in the value of owning the business and its future, and so they are willing to pay more to own a share and the price shoots up. In order to assess how these earning will turn out investors create projections on the future cash flows of

[19] (FINRA, 2016)
[20] (Corporate Finance Institute, 2017)

the business. The general quantitative approach to placing value is the Discount Cash Flow method shown here:

$$DCF = \frac{CF_1}{(1+r)^1} + \frac{CF_2}{(1+r)^2} + \overbrace{\ldots + \frac{CF_n}{(1+r)^n}}^{\text{Terminal Value}}$$

CF = Cash Flow
r = Discount Rate (WACC)

Discounted Cash Flow's in short simply calculate all of the projected future cash flows of a business, discount them by a value termed the Weighted Average Cost of Capital (WACC), and add them to get the present value of these values. This distinction on how investors are able to understand the intrinsic value of stocks will be important when comparing to how we look at cryptos later[21].

Exchange Structure: The final piece to understand about this market is how these shares are actually exchanged. When you register with stock trading account what you do is that you sign on with a stock broker. A stock broker is a regulated person who will take your orders and actually go execute them by connecting a buyer with someone selling their shares. The broker takes a fee on executing the trade and in turn facilitates the transaction. This process rests on the regulation and trust that the trading systems each of these brokers use will process the transaction securely and accurately.

3.1.2 Commodities:

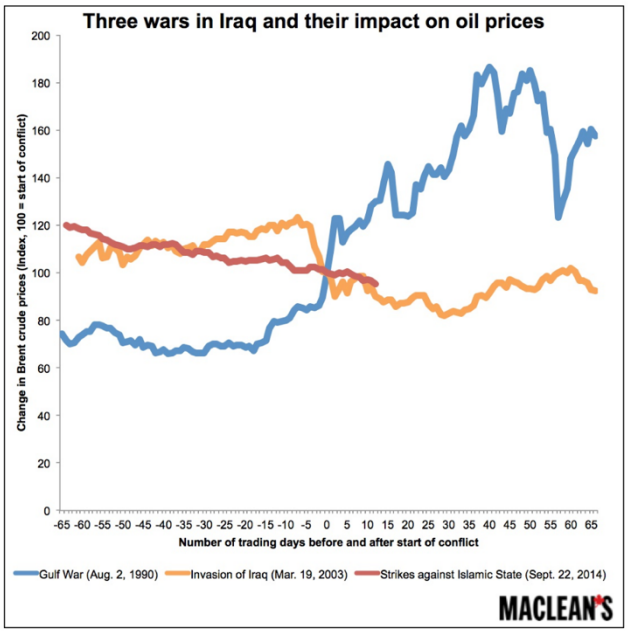
Ownership structure: The commodities market is the exchange of raw products such as gold, coffee, barley, energy, oil, and more. These products as we generally know them are resources used to produce other finer goods that businesses run on. We often take ownership of them as well indirectly through every day purchases such as gasoline for the car. However, many people also look at these products as securities to invest in. Although many investors look to buy and sell the physical goods, for most people this is a difficult process logistically. Alternatively common structures used include investing in futures contracts, exchange traded funds, and mutual funds.

Price Perception: Price is again determined by flows of supply and demand across these different assets. The supply however is less malleable than traditional equities as it directly requires the process of procuring these raw goods. For instance, if a large set of gold is mined then the supply will shoot up and will then affect the price. Consequently a majority of the technical analysis in this area focuses on creating large macro models

[21] (Cuninghame-Green, 1965)

that directly predict changes in supply and demand. The price of these assets are also heavily impacted by geo-political factors. For instance we can see a relatively recent example of this by taking a look at the graph below[22]. Here we see how the volatility of prices increase markedly when conflict of the gulf war occurred and caused major uncertainty. Investors have generally looked at commodities as a great source of diversification equity hedging[23].

Exchange Structure: As stated on the note on ownership structure, a large amount of the actual exchange in the commodities market is done through future contracts. Though we will not delve into the mechanics of these contracts here, they are essentially bets on the future price of assets. These contracts are traded again via a brokerage account you set up with someone licensed to execute these contracts. Since the structure of futures contracts do not give us a great basis to compare across markets, we will use the spot price do recognize the value of commodities. Some people will exchange the physical good of the commodity however this is primarily popular amongst people who have the means to store the assets. [24]



3.2 Fundamentals of Crypto Currency Markets

Now that we have detailed the structure of how these two traditional financial markets function, we can discuss the current crypto markets while analyzing the similarities and differences at hand. While crypto markets, like all others, are subject to pricing being

[22] (Kirby, 2014)
[23] (Lamont, 2016)
[24] ("Commodities Trading Overview", Investopedia, 2018)

determined by the forces of supply and demand, the structure of exchange and content are far different.

Exchange Structure:

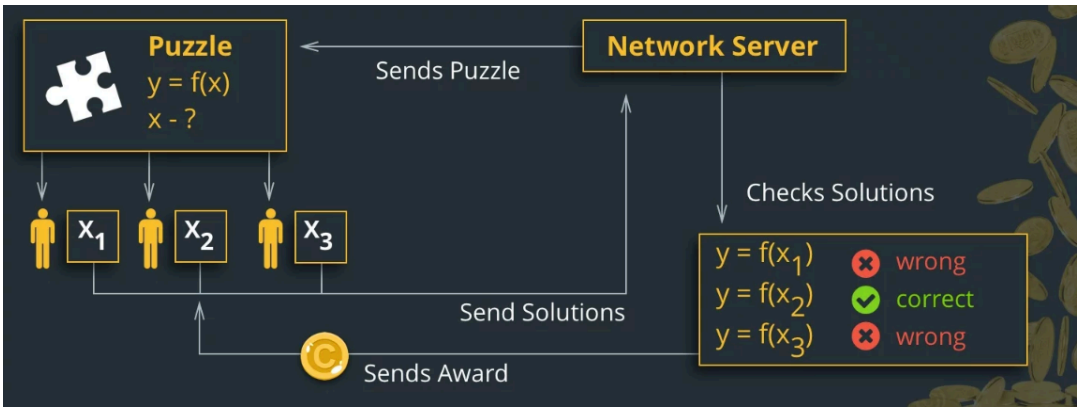
Cryptoassets are primarily acquired through one of two avenues. One is through mining and another is through exchange. One of the most important and revolutionary principles of cryptoassets is how exchange is handled. We discuss the exchange option first and then the mining option. The information on this applied to how markets function through the original paper by Satoshi Nakamoto and the technical review by Florian Tschorsch and Bjorn Scheuermann[25,26]

Mining: On a high level mining is the process of solving a highly difficult computational problem in order to add block to the blockchain and complete a transaction. This process is enforced through the concept of Proof of Work. Proof of Work is essentially the application of Hal Finney's concept that it should be really extremely computationally onerous to have an attack on a protocol. In crypto currencies the main idea is that a block for a transaction should only be available after a computational barrier is crossed. This barrier is presented in the form of a computationally difficult problem that must be solved. Currently this difficulty is adjusted every 2016 blocks, thereby adjusting the time it takes to mine a block (currently this time is 10min). In each reevaluation the difficulty is determined by[27]:

$$Difficulty\ Next = \frac{2016\ blocks\ x\ Difficulty\ Previous\ x\ 10min}{Previous\ Block\ Time}$$

Miners are constantly working to solve these problems and complete transaction to in turn receive rewards in fees and currencies. This process however can be highly expensive as owning and operating a mining rig comes with a heavy computational burden. A view of this mining process is diagrammed below by Coin Telegraph[28].

[25] (Tschorsch, 2016)
[26] (Nakamoto, 2008)
[27] (Siriwardena, 2017)
[28] (Tar, 2018)

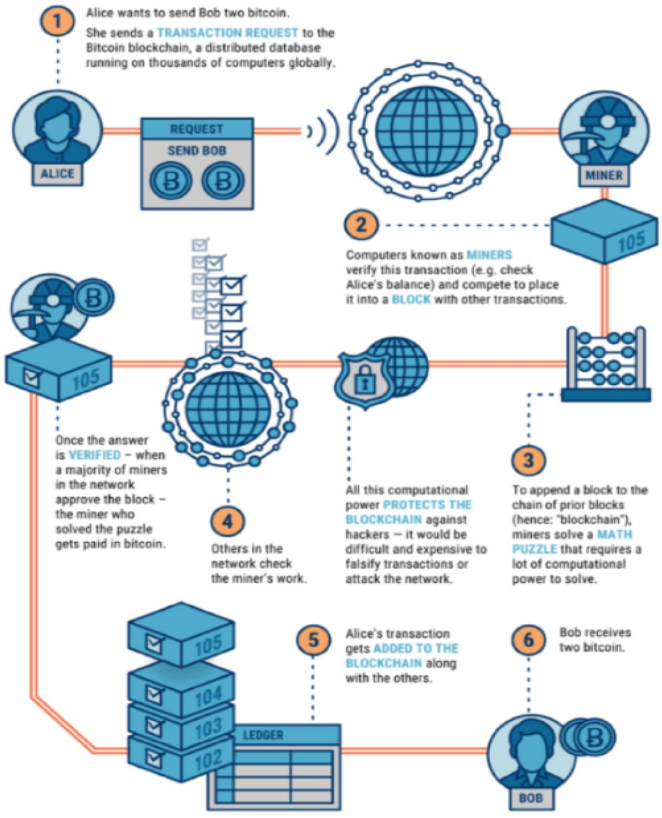


An important component to note is that the amount of bitcoin "generated" with each block decreases geometrically with the maximum being 21 million. This along with this relatively complicated process for "providing supply" of bitcoin is highly unique from that of public equities. There is a heavy technological dependency on these coins being able to be mined. On top of this there is an understood cap on this supply as well. Functionally this cap can be overcome through fractional reserve banking however the official securitization of coins would first need to occur. Public equities such as stocks have no such cap and no such constraint in supplying shares. Commodities have an implied constraint based of natural supplies however this cap is far from being realized on a calculable level like Bitcoin. A symbolic connection we can see here however is that Bitcoin's supply is heavily impacted by the amount that is mined or "discovered" much like commodities like metals.

Exchange: As we discuss this concept, a diagram giving an abstract look at the transaction process is available below[29]. Crypto currencies like bitcoin were designed to be decentralized forms of exchange where transactions would reside in blockchain, a public ledger available to everyone. Considering bitcoin specifically, each user that has a wallet has a public-private key pair. In this pair the private key is a random number that the wallet software creates while the public key is given by the Elliptic Curve Digital Signature Algorithm. Connecting the private key of the sender, the public key of the receiver, and the prior transaction in our network we can generate the transaction. Again these transactions are stored in blocks which contain the key pairs, as well as a timestamp, which is known as a nonce, and a hash connecting to the last transaction. These blocks are chained together via the underlying protocol of the coin to create the blockchain. In order for this ledger to be accessible on millions of computers and safe to transact on, the protocol has to ensure that there is enough computational power spent on creating a block that can be added to a chain. The process of making this check is called Proof of Work, discussed previously.

[29] (CBInsights Research, 2018)

This form of exchange was the decentralized exchange with no middle man involved. For the purposes of this study however we have to look at the exchanges that have been most ubiquitously used and those, such as Kraken, Bittrex, and Coinbase, are all centralized exchanges. They are all centralized because they process transactions through their own software where they pair people who are looking to buy or sell crypto currency. These companies have people working for them, monitoring the transactions and earning fees on them. This form of exchange has been the most accessible to investors and so will be structure we consider. This year there has been a large focus on decentralized exchanges becoming more standardized, however these are all developing systems. Delving into the benefits and drawbacks of both decentralized and centralized exchanges is itself a long debate to consider, however an important factor is that each gives way to components of security. [30]Security is a vital component in what we study here right now as this explained form exchange heavily relies on the digital process through blockchain to be protected. When it has been attacked we have seen heavy losses in the price of Bitcoin. [31]



[30] (Khatwani, 2018)
[31] (Khatwani, 2018)

Ownership Structure:

Owning a crypto currency such as bitcoin is technically understood as the ability to send a certain amount of bitcoin to another address. Say you own *x* amount of bitcoin in your bitcoin wallet. What you actually own there is the key to access *x* bitcoin to hold or transact. More generally speaking anyone owning a crypto coin of any sort is owning a place in the protocol for the currency and has the ability to transact with it. While some currencies are made solely for the purpose of transactions others are built upon larger projects. For our purposes of analyzing the prices of currencies we will focus solely on the idea of owning a place on the protocol. Again this concept is significantly different across public equities, which involves owning shares of companies, and commodities, which involved owning a futures contract on the price of an asset.

Price Perception:

The perceived value of crypto currencies has been a highly contentious concept[32]. As many people have seen the value of coins such as Bitcoin sky rocket, many have argued that these coins have no intrinsic value. As with all the equities we discussed previously, the concept of price will be determined by supply and demand.

Stepping deeper from supply and demand, people have looked to identify factors that can capture the true value of a coin. Some factors people have looked at are energy usage and difficulty required to create a coin, the underlying utilities of the coins, the security of the protocols, and the velocity of holding. People have looked to create larger models such as the Work Utility Model, Access Based Token Model, and Proof of Burn Model (Sockin, 2018). Each of these in themselves have been a part of larger studies in themselves however there has been no commonly used practice like the discounted cash flow that people have adopted. We can delve into the many efforts people have made in creating frameworks to capture the value of coins however that in itself will be an extensive analysis. We do however study one case study of valuing currencies as Medium-of-Exchange tokens discussed by Vitalik Buterin, the founder of Ethereum[33].

Valuing Currencies as Medium of Exchange tokens:

The theory of looking at crypto currency projects as “network mediums of exchange” is oriented around the idea that developers create networks that are systems of a sharing economy. They will consist of sellers, that create and provide the technological tools for the protocol, and buyers that pay for the services. The key to this process being that the sale of the “utility” within the networks needs to be done through the token that is being sold, thereby creating value for it. This token value under the medium of

[32] (Bearman, 2018)
[33] (Buterin, 2017)

exchange framework will depend on the ongoing chain where one set of buyers purchases tokens for *$x*, extracting value *y* and then selling to another set of buyers who view the tokens to have some value *u* < $y. On and on this cycle will continue until the coin does not have value any longer.

Using traditional economic theory, we can apply this framework for crypto currencies under the formula:

$$MC = TH$$

Where M = total coin supply, C = Price of currency, Holding period, T= Transaction volume. Here M*C will simply equal the market cap.

This formula provides a promising framework to approach valuing coins. However, we can see directly the value of a token depends on buyers holding a coin. This would make work fine if exchanges persist to have delays in being able to transact on coins. However, projects focused on creating hyper-efficient exchanges are being built up, inherently crushing this framework.

Again, we can spend more time on this framework, and others of its kind, but what we see is they provide high difficulty in being treated as a fundamental valuation model. This is a significant departure from the traditional financial markets we discussed previously as it creates an economy without clear valuation rules.

In summary of this subsection we can see that there are significant differences in the current functional structures of crypto markets and traditional markets. While traditional markets have, after years of being in practice, developed commonly used valuation processes, crypto currencies have not. Moreover, the process of how cryptocurrencies function is inherently dependent on how the technology is structured. In the next section we use a data driven approach to understand how these differences have played out in recent history.

4. Data Analysis: Exploring Potential Factors Correlated to Crypto Currencies

Now that we have a foundational understanding of the history and structure of how crypto markets function we can delve deeper to explore the correlations to traditional markets. In this section we perform a data driven analysis of the correlations of past Bitcoin and Ethereum prices against traditional markets. As we know from basic statistics, correlations do not prove causation. Moreover since we are looking at a paired linear correlation, our insights on the meaning of the results are purely focused on what the results were rather than the driving factors. However, given our background on the technology, we should be able to develop context to these results through this analysis. Moreover we will be able to utilize the information we extract on these correlations to generate a model that can have practical uses.

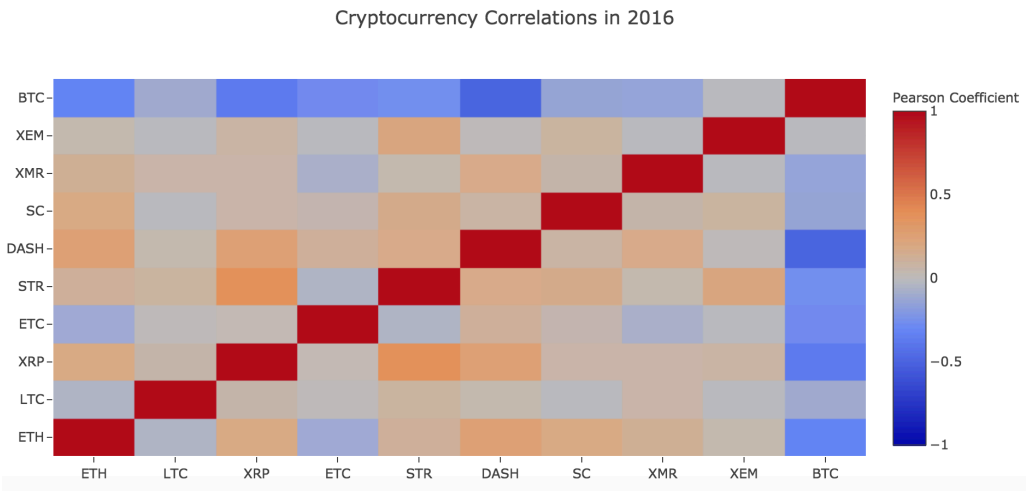
We organize this section by focusing on comparing past prices to commodities and then public equities separately. After this we perform a mean-variance analysis to experiment a basket of instruments we could pair together to minimize volatility. For reference the correlation we are calculating is Pearson Coefficient given by:[34]

$$r = r_{xy} = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{\sqrt{n\sum x_i^2 - (\sum x_i)^2}\sqrt{n\sum y_i^2 - (\sum y_i)^2}}.$$

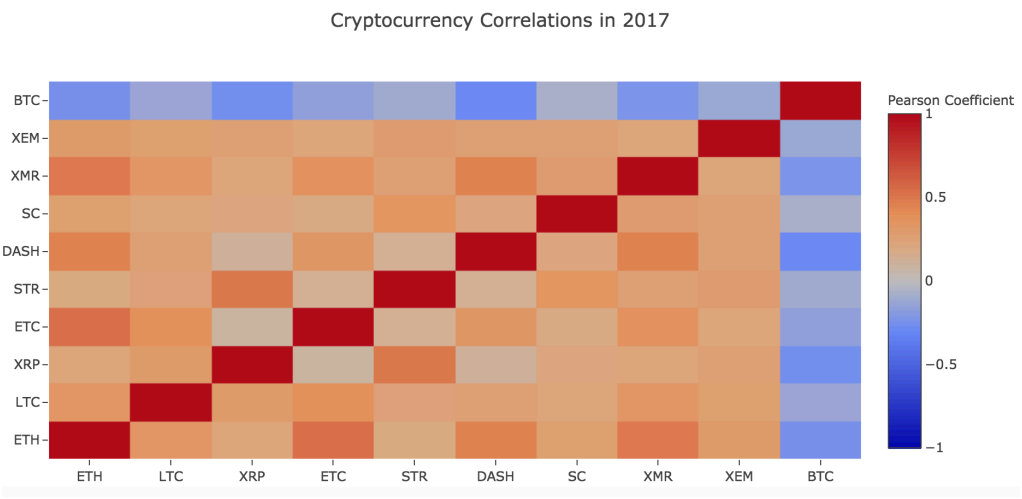
We will also be using the daily changes in price rather than the absolute values in addressing the correlations thereby focusing on the change in prices.

First Steps and Data Sourcing

To start our analysis we first created a python function, derived through a tutorial that accessed the historical prices of 10 different currencies through the Quandle API[35]. This step was taken preceding focusing on any market correlations to see if there was any specific area worth exploring. In this process we looked at historical growth, cross correlations of currencies and also differences in prices across different exchanges. We show heat map of the correlations between currencies in 2016 and 2017:

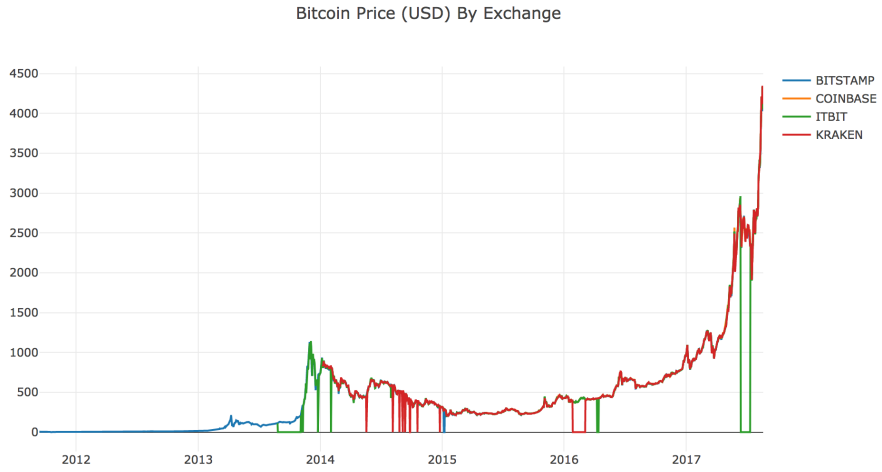


[34] ("Pearson Correlations – Quick Introduction", 2016)
[35] (Triest, 2017)



We display these two charts because we noticed a larger increase in overall cross correlations amongst currencies from 2016 to 2017. Looking at an even weighted value of all of the currencies, we saw a 24.2% increase in overall correlation. Our initial thoughts on what may have caused this is the large influx of hedge funds. When there are more traders using larger sets of capital to hedge bets on crypto currencies, there will inherently be larger levels of correlations since similar strategies would be applied. Confirming this or exploring other theories would be a large tangent, but given this marked change we made sure to include this interval (mid 2016-mid 2017) along with the two sections of interest we noted in the background section.

In analyzing the correlations between markets, we chose to source all of our data through Bloomberg. This is based entirely of reliability and ease of access. One thing we noticed in our Python function is that in accessing the data from exchanges we face a large amount of incorrect historical data. The graph below depicts this clearly in the anomalous drops throughout all of the different exchanges:



4.1 Public Equities and Crypto Markets

In this sub section we look at the correlations of public equity markets in the U.S. against crypto markets. To represent the public equity markets we will use the indices: Standards & Poor's 500 (S&P 500) and the Nasdaq. Each of these indices gives a view of how the overall U.S. market is performing. In addition to these market proxies, we include the CBOE Volatility Index (VIX). The reason for this is that this measures the volatility of the U.S. markets and can therefore, given our analysis in the previous section of how Bitcoin can be highly volatile, potentially give us light on if there has been a positive or negative relationship in this volatility. We considered including other international markets, however, we made the choice to focus on the U.S. to specifically see this relationship. Based off the discussion preceding this section as well as the historical background, we chose to focus on three specific intervals: mid 2016-mid 2017, mid 2017-mid 2018, and 2015-Nov 2018. The mid's we consider here are exactly the middle of the year July 1st. We chose to just use Bitcoin and Ethereum in this analysis as they provided the largest length of available data and have been the major proxies for the overall market for the longest period of time. These tables below are the results for what the correlations of Bitcoin and Ethereum were with the two major U.S. indices, and a volatility index.

Mid 2016-Mid 2017			
	S&P	Nasdaq	VIX
Bitcoin	0.03	0.00	0.04
Ethereum	0.05	0.05	-0.06
Mid 2017- Mid 2018			
	S&P	Nasdaq	VIX
Bitcoin	-0.04	-0.03	0.01
Ethereum	0.06	0.08	0.08
2015-2018			
	S&P	Nasdaq	VIX
Bitcoin	0.06	0.07	-0.02
Ethereum	0.03	0.03	0.05

The results we see here are that there is little to no correlation between the returns of Bitcoin and Ethereum to the major U.S. markets. When breaking our analysis into sub periods, we see a small shift in the 2017-2018 period to a negative correlation for Bitcoin. However the overall magnitude of any change is low. Although taking any causational knowledge from these results will not be possible, we can definitely see that the lack of correlation is in line with the massive volatility displayed in section 2. This is also in line with the vulnerability to speculation and external factors the core technology of Bitcoin has in comparison to traditional equities. An important point we can also take away from these results is that U.S. public markets can act as a legitimate hedge to Bitcoin as its daily returns have in the past moved independently.

4.2 Selected Commodities and Crypto Markets

In this section we shift our focus to the commodities market. We follow the same structure in our selection of periods as we did in the preceding section so that we can directly compare the two. We chose in this case to focus in on three of the commonly invested metals on the side of commodities. We considered including several different categories of commodities however we chose to focus in on one category rather than expanding the analysis into too many sub cases. Below we have a similar table as the previous subsection, showing our results for the correlation in each of the three buckets.

Mid 2016-Mid 2017			
	Gold	Silver	Platinum
Bitcoin	-0.02	-0.02	-0.05
Ethereum	-0.05	-0.05	-0.03
Mid 2017- Mid 2018			
	Gold	Silver	Platinum
Bitcoin	-0.02	-0.02	0.03
Ethereum	0.02	0.02	0.01
2015-2018			
	Gold	Silver	Platinum
Bitcoin	0.01	0.01	-0.03
Ethereum	-0.01	-0.01	-0.03

The results here give similar insight as the results from the correlation analysis on public equities. There is little to no correlation in the returns of Bitcoin or Ethereum to those of either of the three metals we look at here. This also goes again in line with being another representation of what can be the effect of the large volatility in crypto currencies.

4.3 Mean-Variance Analysis

The main take away from the results in the previous two subsections is that there is little to no correlation between Bitcoin and Ethereum to U.S. markets and three primary metals. Consequently, as we move forward from this initial finding, we see that trying to perform any predictive or even regression analysis would not be effective. Regression analysis in particular due to the inherently high multicollinearity between the factors we explore here. However, an analysis we can do here that can provide for applicable use is to perform a mean-variance analysis. From the context we have in our analysis on the history and technology of Bitcoin, we see that a major contributing factor to the lack of correlation can be the volatility of Bitcoin and Ethereum. In addition to this, we know that Bitcoin has experienced large positive movements in price. While this can be exciting, volatility for investors is a major representation of risk because it is the movement in price that they cannot account for. This volatility however can be mitigated if the volatility is mixed into a basket with other less volatile options. This is the concept of diversification. Here is where a mean-variance statistical analysis can be useful.

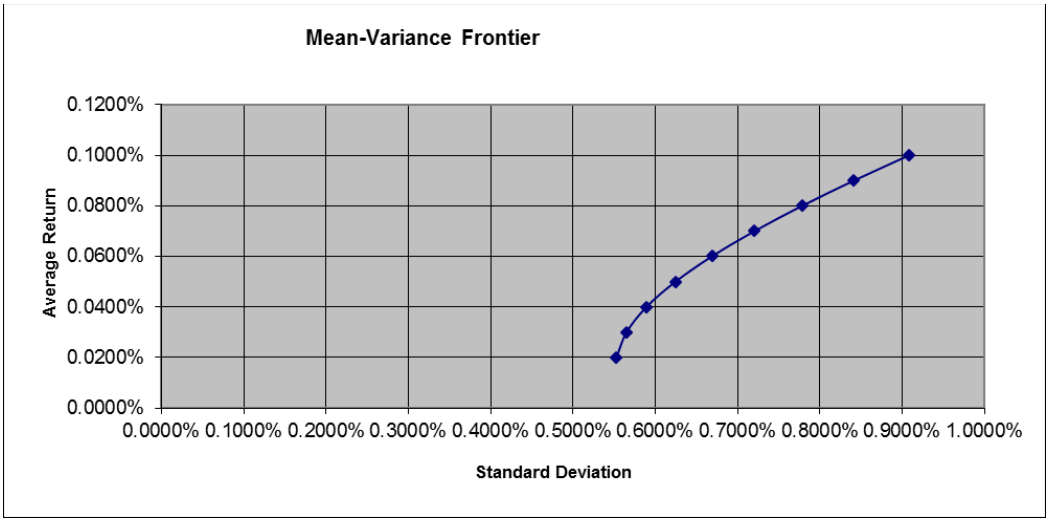
The core purpose of a mean-variance analysis is to find a way to achieve a set mean while minimizing the standard deviation in the data. The way this standard deviation is minimized is by testing the weightage the different pieces that are being put together in the said basket. The data we are considering in our application here is a portfolio consisting of Bitcoin and other instruments. From our analysis in the previous two subsections, we now know that U.S. public equities and metals have low correlation to the volatility of Bitcoin. Therefore we should be able to, considering we are convinced that we want to own Bitcoin, reduce the risk of owning Bitcoin by purchasing these other uncorrelated assets as well.

Hence the analysis we conducted was to take the returns of all 7 analyzed investment opportunities from the period of the beginning of 2015 to Nov 2018 and then look to optimize the portfolio consisting of 7 weights. We did this for 9 different means, which represent the daily return of the portfolio. Once we set these expected returns, we used the Solver functionality in Excel to minimize the standard deviation by adjusting the weights of the 7 assets. We set up the Solver function to essentially test different sets of weights to find the combination that both attains the mean but also results in the lowest possible standard deviation.

The table below displays the results from this mean-variance optimization process using the returns from 2015-2018.

Mean - Variance Analysis								
Weights							Portfolio Vol.	Portfolio Mean
Bitcoin	S&P	Nasdaq	Ethereum	Gold	Silver	Platinum	Std Dev	Mean
1.5998%	47.6224%	0.0000%	0.6169%	18.1796%	22.0884%	9.8929%	0.5528%	0.0200%
3.0524%	49.3688%	0.0000%	0.2424%	17.9218%	21.9563%	7.4583%	0.5651%	0.0300%
4.5323%	51.0388%	0.0000%	0.0000%	17.6994%	21.8054%	4.9240%	0.5893%	0.0400%
6.0617%	52.5810%	0.0000%	0.0000%	17.3313%	21.8067%	2.2192%	0.6245%	0.0500%
7.4638%	47.5882%	5.9754%	0.0000%	17.2863%	21.6863%	0.0000%	0.6689%	0.0600%
8.9745%	38.7811%	15.0908%	0.0000%	15.9584%	21.1951%	0.0000%	0.7206%	0.0700%
10.4853%	29.9741%	24.2062%	0.0000%	15.4673%	19.8671%	0.0000%	0.7786%	0.0800%
11.9958%	21.1680%	33.3207%	0.0000%	14.1159%	19.3996%	0.0000%	0.8416%	0.0900%
13.5067%	12.3600%	42.4370%	0.0000%	12.8115%	18.8847%	0.0000%	0.9085%	0.1000%

This data gives us a set of weights to put on our 7 considered options to minimize our volatility for each of the expected returns we want. For instance if we wanted to spend $100,000 across all options and we considered the last option presented in the table, we would want to spend approximately $13,506 on Bitcoin, $12,360 on S&P stocks, $42,4370 on Nasdaq stocks, $12,811 on gold, $18,884 on silver, and nothing on Ethereum or platinum. Going in line with our understanding of the direct relationship between accepting higher risk for higher portfolio mean, we see that as our expectation for mean goes up, our weightage to Bitcoin goes up as well while some of the other allocations go down. Another point to note from here is that the weight given to Ethereum was relatively low throughout the frontier. The indication this gives is that the cost volatility in Ethereum was not worth the upward movement in price. In the plot below we can see a graphical representation of how all of these sets weights come together to form a frontier of most efficient portfolios.



Overall from this process we can see that there are ways to mitigate the effects of volatility in Bitcoin by utilizing other investment instruments. This analysis began in section 3 to understand how the technology behind Bitcoin makes its functionality so different from what investors have seen in the past. From there we were able to take a data driven approach to see that other markets have generally been uncorrelated to Bitcoin and Ethereum. Then we were able to utilize this understanding to create a framework by which we can mitigate the effects of volatility in owning these coins.

In reading this it can be easy to focus in on thinking that the information is purely useful for the use case of the investor and not for the others stated. However that would be ignoring the fact that all owners are exposed to the risks in constant fluctuations of Bitcoin. As we discussed in section 3 there are several factors that can contribute to the fluctuation. However, as an owner, say with the purpose of owning for the purposes of exchange, having this exposure can be very difficult to ignore. This analysis provides the owners the ability to palate movements in the short term, in order to maintain whatever long term use they may have.

As an extension on this discussion on volatility, we consider a new technology that helps provide price stability: the stable coin.

5. The Stable Coin

The stable coin, often referred to as the “holy grail of cryptocurrency”, is a cryptocurrency, unlike Bitcoin, that is able to stay at a consistent price level throughout its existence.[36] . In achieving this goal of a coin with consistent value, there have been 3 primary designs that have been created:

[36] (Senner, 2018)

1. Fiat-Collateralized Coins
2. Crypto-Collateralized Coins
3. Non-Collateralized Coins

Below we explain each of these designs and how their concepts formed. The core idea of each of these efforts is to develop cryptocurrency into becoming something that provides an adoptable currency for people to use. This however is an extremely difficult project to pursue as it aims to create a currency that is immune to the natural fluctuations of supply and demand. Nevertheless projects have continued to grow aiming to solve this problem. In this process of creating a viable currency they have often been said to have three goals: be a medium of exchange, be a storage of value, and be a unit of account.[37]

5.1 Fiat-Collateralized Coins

The idea behind these coins is given in the name. It is simply the implementation that for every unit of a coin there is an equitable fiat currency materially being stored[38]. For instance we can take Tether. Tether is considered the currency that is pegged to the U.S. currency. Hence for every tether sold, there was an equitable amount stored in the banking ecosystem. This is a 1:1 system that has to be regulated through audits that determine whether or not this equal backing is actually occurring[39]. Examples of these coins today include “Tether”, “Stably”, “Saga”, “TetherUSD”, and “Arccy”. This is the easiest implementation of a stable coin as it requires just a mapping to real asset. However, the problem in this solution is that it goes against the core concept of a decentralized currency that is immune to fluctuations. The value is inherently pegged to an asset, such as the U.S. dollar, which fluctuates in price. Additionally, there is a centralized party that requires trust to audit and process this ecosystem. This would also create a need to connect the cryptocurrency ecosystem with that of the banking system which would provide a large set of operational issues[40].

5.2 Crypto-Collateralized Coins

These type of coins use cryptocurrencies as the form of backing rather than fiat currencies in the preceding model. The first thought on this is often that this does not do anything to account for the issue of volatility. The way this is attempted to be solved is a concept called over-collateralization[41]. This is essentially a process of creating leverage where you create a ratio of, say 3:1 or 4:1, of crypto backing to stable coin. This essentially buffers the impact of large fluctuations in price by creating an overflow of backing for the stable coin. In the near terms this helps reduce the large impact of constant volatility, however, in the case that the cryptocurrency that the stable coin is pegged to goes straight to 0, also known as a

[37] (Senner, 2018)
[38] (Bajic, 2018)
[39] (Senner, 2018)
[40] (Snider, 2018)
[41] (Senner, 2018

black swan event, there is no fall back[42]. Moreover, there is no certainty that the over-collateralization set is enough to protect the stable coin. Coins that have been known to adopt this model include “Dai”, “Havven”, “Alchemint”, “Fragments”, “BitUSD”, and “BitCNY”. Dai is over-collateralized and to Ethereum. BitUSD and BitCNY are over-collateralized with BitShares, a fixed supply crypto. Alchemint is over-collateralized to NEO[43]. Considering Dai, and the other currencies, the process that occurs when Dai is purchased is that you deposit a set amount of Ether, bought with USD. However, when you exchange back to Ether, the Dai is destroyed.

Overall the issue we see here is that while the issue of centralization is solved and there is a buffer added to protect against small changes in value, there is still a vulnerability to large drops or increases. Moreover there is a constant uncertainty of what the best level of collateralization should be when there is dependency on over-collateralization.

5.3 Non-Collateralized Coins

This final approach is a form of coin which is not backed by any asset but is rather based on maintaining a stable value through the sale of special bonds[44]. The manner in which this works is that while the coin is not backed by any asset, it is pegged to an asset. Hence when it is first allocated out it is based off this peg. Then when the demand of the coin increases or decreases, the supply follows by the creation or destruction of these bonds. In the case, for instance, that the price of the stable coin falls below that of the pegged asset, bonds are issued that can be bought using the coins. This process reduces the supply of the coin and hence brings price back up. Concurrently, in the case that the price goes above, new stable coins are issued, first going to bondholders, and thereby increasing the supply to bring down the price. This approach, also known as the seigniorage approach, seems like a great solution to the stability issue and has definitely been regarded as one of the most exciting approaches[45]. However it also comes with its own issues. One large issue is that it rests on the hope that there is regular periods of pricing rising above the peg. Otherwise, thinking of the below case in infinite rounds, the coin could essentially just keep spiraling down to eventually having no value. Additionally contracting the supply of coins is not as easy as the process of selling bonds sounds. The idea of removing coins from circulation is that bonds are sold to coin holders with the promise that they will pay out with reward in the future. This payout is a promise to get paid later on when there is a need to have coins come back in circulation. This case again can theoretically lead to an event where bondholders are not paid out and hence breaking the cycle. Essentially those coin owners considering converting to bonds have to take on risk. Popular stable coins that follow this model are “Basecoin”, “Carbon”, and “Kowala”[46]. Basecoin is the most prominent of these aims to combat the latter mentioned issue by creating bond price floors and bond expirations, essentially turning the bond into an option rather than a

[42] (Senner, 2018)
[43] (Senner, 2018)
[44] (Senner, 2018)
[45] (Snider, 2018)
[46] (Senner, 2018)

classic bond. Carbon tries to modify the classic model by creating an option for users to freeze some of their funds to try and wait out cyclical changes. Kowala's design is to create a variable fee to miners, thereby indirectly controlling the supply and demand of coins based off the incentive people have to produce the coin[47]. Each of these models and others as well come with their own risks that users will have to find a way to weigh.

Overall in this section we see models for an idea that could genuinely change the way in which our currency functions. The eventual aim is that maybe one of these designs, and one of the coins of these designs, will be able to become stable, scalable, secure, and decentralized thereby providing all of the technological benefits for exchange of the cryptocurrency technology, without the risks of volatility[48]. Solving this problem could give way to being able to focus on some of the non-investment oriented use cases of cryptocurrencies without having to worry about what the fiat conversion is on a daily basis.

6. Conclusion

As we cross the 10 year mark of Bitcoin being introduced to the world, we have a large set of events to look back on. From the massive rises and falls in price, to data hacks, to forks in Bitcoin we have seen what feels like a long and winding road. However, when looking at the overall landscape of what we have developed to what can theoretically do with cryptocurrencies, we can see we still in the early stages of development. As we navigate these stages, being able to understand how to approach ownership and all other use cases of currencies like Bitcoin will become more and more important everyday.

What this paper accomplishes is that it focuses in on how these crypto markets, and particularly Bitcoin, fit along with some of the other traditional markets. Building upon this framework it performs a data driven effort to review these traditional markets can be used as leverage against the volatility of Bitcoin. Then it finishes by introducing a new technology, the stable coin, that can potentially become the standard that solves some of the core issues Bitcoin has had.

Moving forward from this there are many avenues we can build on. It will be very useful to continue to canvas how cryptocurrencies will reside in an over arching economic environment. In doing so again we will need to be focused on originating our process by first looking at the technology and then the market economics. Looking at different factors and time periods can potentially lead to results that can allow us to better utilize the currencies, much like the mean-variance analysis attempts to do. One area we considered heavily to explore was looking more particularly at fundamental factors such as twitter posts and github commits in relation to crypto currencies and analyzing how this may give light on price changes. Though we did not end up seeing this to be included into our framework, developing a framework around

[47] (Senner, 2018)
[48] (Snider, 2018)

these components can be very valuable. Moreover, a highly interesting space to expand upon is the stable coin as discussed in the last section. As we presented the information on what the coin is and represents, working towards a stable coin that can be used a standard will be an important frontier to pursue.

Overall we can see that we are still in the early innings of this space. As a result, there is a lot of room for confusion but opportunity as well. By taking on efforts to remove uncertainty, as this paper does, we create the room to explore a multitude of questions that can potentially lead to having high impact in the area of study. Therefore, we encourage the academic community to take advantage of this nascency.

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Appendices

Appendix A: Markowitz Proposition on Mean-Variance Optimization

Proposition 2.1. *Let* $A \in \mathbb{R}^{m\times n}$, $B \in \mathbb{R}^{m\times t}$, $E \in \mathbb{R}^{s\times n}$, $F \in \mathbb{R}^{s\times t}$, $M \in \mathbb{R}^{t\times n}$, $Q \in \mathbb{R}^{n\times n}$ *and* $H \in \mathbb{R}^{t\times t}$ *with* Q *and* H *symmetric, and let* $r \in \mathbb{R}^m$, *and* $h \in \mathbb{R}^s$. *Further assume that the symmetric matrix*

$$\hat{Q} = \begin{bmatrix} Q & M^T \\ M & H \end{bmatrix}$$

is positive semi-definite. If the following quadratic program is feasible, then it has finite optimal value and a solution attaining this optimal value exists:

$$\begin{array}{ll} \textit{minimize} & \frac{1}{2}\left[u^T Q u + 2v^T M u + v^T H v\right] \\ \textit{subject to} & Au + Bv \leq r \\ & Eu + Fv = h \\ & 0 \leq u\ . \end{array}$$

Appendix B: 2016 Raw data on crypto currency cross correlations

	ETH	LTC	XRP	ETC	STR	DASH	SC	XMR	XEM	BTC
ETH	1.000000	-0.051124	0.199242	-0.109752	0.116542	0.265428	0.200544	0.133377	0.046819	-0.327599
LTC	-0.051124	1.000000	0.059151	0.008495	0.100791	0.049311	-0.009401	0.064910	-0.017937	-0.100194
XRP	0.199242	0.059151	1.000000	0.035870	0.379668	0.256534	0.070210	0.072334	0.089173	-0.377603
ETC	-0.109752	0.008495	0.035870	1.000000	-0.040610	0.126283	0.055670	-0.070667	-0.011921	-0.269099
STR	0.116542	0.100791	0.379668	-0.040610	1.000000	0.176667	0.168506	0.053071	0.205805	-0.255761
DASH	0.265428	0.049311	0.256534	0.126283	0.176667	1.000000	0.089201	0.179454	0.018902	-0.501129
SC	0.200544	-0.009401	0.070210	0.055670	0.168506	0.089201	1.000000	0.062530	0.101173	-0.138523
XMR	0.133377	0.064910	0.072334	-0.070667	0.053071	0.179454	0.062530	1.000000	-0.012822	-0.145900
XEM	0.046819	-0.017937	0.089173	-0.011921	0.205805	0.018902	0.101173	-0.012822	1.000000	-0.005662
BTC	-0.327599	-0.100194	-0.377603	-0.269099	-0.255761	-0.501129	-0.138523	-0.145900	-0.005662	1.000000

Appendix C: 2017 Raw data on crypto currency cross correlations

	ETH	LTC	XRP	ETC	STR	DASH	SC	XMR	XEM	BTC
ETH	1.000000	0.335706	0.227470	0.536937	0.203959	0.459261	0.281221	0.494407	0.313196	-0.247547
LTC	0.335706	1.000000	0.313353	0.387137	0.247210	0.260563	0.238521	0.330728	0.282681	-0.125812
XRP	0.227470	0.313353	1.000000	0.100923	0.505234	0.120932	0.221503	0.230399	0.255036	-0.258136
ETC	0.536937	0.387137	0.100923	1.000000	0.144432	0.327403	0.200231	0.366974	0.228184	-0.155159
STR	0.203959	0.247210	0.505234	0.144432	1.000000	0.139536	0.361438	0.269953	0.295723	-0.098035
DASH	0.459261	0.260563	0.120932	0.327403	0.139536	1.000000	0.220524	0.460793	0.264977	-0.292277
SC	0.281221	0.238521	0.221503	0.200231	0.361438	0.220524	1.000000	0.289826	0.254208	-0.064651
XMR	0.494407	0.330728	0.230399	0.366974	0.269953	0.460793	0.289826	1.000000	0.243155	-0.225937
XEM	0.313196	0.282681	0.255036	0.228184	0.295723	0.264977	0.254208	0.243155	1.000000	-0.114747
BTC	-0.247547	-0.125812	-0.258136	-0.155159	-0.098035	-0.292277	-0.064651	-0.225937	-0.114747	1.000000

Appendix D: Plots of crypto currency prices over time; extracted using the Quandle tool