Studies in Applied Finance

AN ECONOMIC ASSESSMENT OF RISKS IN BITCOIN AS AN ALTERNATE ASSET CLASS

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About the Series

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At Compass Lexecon, Dr. van der Merwe provides both consulting and testimonial expertise in matters involving securities class action litigation, regulatory investigations and proceedings, trading disputes including market manipulation, and cryptocurrency and distributed ledger (e.g., blockchain) technologies. Before joining Compass Lexecon, she was a Director of Portfolio Management at the Federal Home Loan Bank of Chicago, where she developed as well as executed trading strategies in fixed-income markets, focusing on debt, derivatives and securitized products.

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ABSTRACT: The current generation of cryptocurrencies provides utility in the crypto-economy and functions as a medium of exchange on the blockchain. Cryptocurrencies and in particular Bitcoin typically do not have the economic features of a fiat currency. This paper revisits the arguments behind Bitcoin as an alternative investment asset and analyzes the salient risks of such an investment. Bitcoin is fundamentally different than stocks and bonds and while it shares some similarity with commodities, the main value proposition of cryptocurrency more generally and Bitcoin in particular is the blockchain technology and corresponding network of participants. Bitcoin return greatly exceeds that of traditional assets but so does its volatility. Using Sharpe and Sortino ratios, this paper shows that Bitcoin's risk-adjusted return is comparable to that of stocks depending on the particular measure of risk. As discussed in detail in this paper, volatility based risk measures are however of limited use because it ignores the latent microstructure and other structural risks that is plaguing Bitcoin.

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[*] The views and opinions I express herein (along with any remaining errors) are mine and mine alone and do not necessarily represent the views of any organization with which I am affiliated or their customers and clients.

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1.0 INTRODUCTION

Public opinion on cryptocurrency is divergent and runs the gamut from comparisons to the 1637 tulip bulb mania in Holland (Mackay (2016)) to predictions that it is the currency of the future with the power to disrupt and radically change existing payment systems (Wan and Hoblitzell (2014)). The estimated global market capitalization of cryptocurrency was well over $255 billion as of June 29, 2018.[1] Most economists remain skeptical, silently agreeing with JPMorgan Chase's CEO Jamie Dimon that cryptocurrency is a fraud (Son, Levitt and Louis (2017).[2] Others such as Fidelity Investments, TD Ameritrade (Fuscaldo (2018)) and DRW Trading are avid public supporters of cryptocurrency (Del Castillo (2018)).

Satoshi Nakamoto is revered as the initial "inventor" of Bitcoin, but less recognized for the fact that he provided novel solutions to the challenges encountered by prior attempts to create a digital currency. Satoshi Nakamoto described his vision for cryptocurrency as "[a] purely peer-to-peer version of electronic cash [that] would allow online payments to be sent directly from one party to another without going through a financial institution." (Nakamoto). Satoshi's description has contributed to the confusion in the popular press and investors about what to make of cryptocurrency. Is Bitcoin money, or is it some new, alternative, risky asset?

Cryptocurrency is strikingly different than traditional capital assets such as stocks and debt issued by public companies. Critics also argue that Bitcoin has no underlying fundamentals that can serve as a benchmark of its intrinsic value. In fact, stripping away the technical complexities behind digital currencies, cryptocurrency at its most basic is a random number. A logical question then is why cryptocurrency has any monetary value – the price of a single Bitcoin was $11,788 as of June 26, 2019.[3]

This paper evaluates Bitcoin from an economic rather than technical perspective.[4] Bitcoin fails as fiat money because it does not have the characteristics economists typically associate with fiat money. A study by the Bank of Canada reached a similar conclusion by

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[1] Cryptocurrency market capitalization from website *CoinMarketCap.com*.

[2] Dimon expressed some regret about his earlier statement and also suggests that there is value in blockchain beyond Bitcoin. See T. Kim, CNBC Report, January 9, 2018, https://www.cnbc.com/2018/01/09/jamie-dimon-says-he-regrets-calling-bitcoin-a-fraud.html.

[3] Bitcoin price according to CoinMarketCap.

[4] Throughout this paper, the discussion centers around features of the public, permissionless distributed ledger technology ("DLT") or the "blockchain" used in the Bitcoin.

analyzing the competition and network effects between cryptocurrencies (Gandal and Halaburda (2014)). Research by Yermack (2013) and Glaser et. al. (2014) both reached the conclusion that Bitcoin is not fiat money but that it behaves more like speculative investment. Ron and Shamir (2013) observe that the majority of mined Bitcoins remain unspent or took more than one year to be spent, which would not be true if Bitcoin was being used as money (Ron and Shamir (2013)).

The persistent low correlations of the return of cryptocurrency and more traditional assets may render cryptocurrency attractive alternative investments that would also expose potential investors to the novel risks embedded in cryptocurrency. This paper contributes to the literature on alternative investments and cryptocurrencies specifically by analyzing the investment risks of Bitcoin both qualitatively and quantitatively.

Section 2 gives a brief overview of Bitcoin, blockchain and the economics of cryptocurrency. Section 3 revisits the economic arguments for why Bitcoin is not fiat money followed by an economic assessment of cryptocurrency as an asset class in Section 4. Asset allocation is a critical component of any rigorous investment strategy. It is therefore important to understand the relationship between a potential Bitcoin investment and an investment in traditional assets such as stocks or bonds. Section 5 introduces a valuation tool for monitoring Bitcoin prices and Section 6 discusses the salient, economic risks inherent in Bitcoin investments. Section 7 concludes.

2.0 BLOCKCHAIN VERSUS CRYPTOCURRENCY

A particular blockchain is a public ledger of digitized information such as a record of the cumulative purchases and sales among Bitcoin participants. In contrast, cryptocurrency such as Bitcoin[5] involves the "digital coins" purchased and sold among participants on the blockchain. Whereas every cryptocurrency must have an associated blockchain, certain types of blockchain networks may have value on their own even without explicit trading of digital coins. For example, blockchain technology can be utilized in settings as diverse as the storage of medical records (Halamka, Lippman, and Ekblaw (2017)) or the clearing of repurchase agreements (Smith (2017)). The application of blockchain technology beyond cryptocurrency typically involves private or permissioned blockchain networks that are controlled by a centralized entity

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[5] I use Bitcoin and cryptocurrency interchangeably, but the conclusions reached in this paper do not necessarily apply to cryptocurrency more generally.

or consortium of entities to facilitate the exchange of information among public participants such as the entity's clients.

This paper discusses and analyzes the features of the *public* blockchains used in trading cryptocurrency such as Bitcoin.[6] The typical crypto-economy consists of four, interrelated components: (i) the distributed ledger or blockchain; (ii) the coins such as Bitcoin; (iii) the active participants or "miners"; and (iv) the passive participants or users. Sections II.A, B and C below discuss the salient features of each of these components in more detail.

2.1   Blockchain and Transaction Blocks

A particular blockchain is comprised of blocks or groups of cryptocurrency transactions. A particular transaction represents the purchase or sale of cryptocurrency between two participants. The number of transactions per block varies – *e.g.,* the original Bitcoin protocol allows up to 2,000 transactions per block. A new block of transactions is added to the Bitcoin blockchain roughly every 10 minutes regardless of how many transactions are included in the particular block. In addition to the group of transactions, each block also contains a unique, digital fingerprint (the "hash"), and the hash of the previous block, which allows blocks to be "chained" together recursively such that each block is uniquely linked to all the prior and all subsequent blocks as illustrated in Figure 1. New blocks are added or appended to the blockchain without altering the information in any of the prior blocks.

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[6] I discuss *private* or "permissioned" blockchains in order to note several key differences between the permissioned and permissionless blockchains at selected points in the discussion that follows.

Figure 1 – Illustrative Blocks in the Blockchain
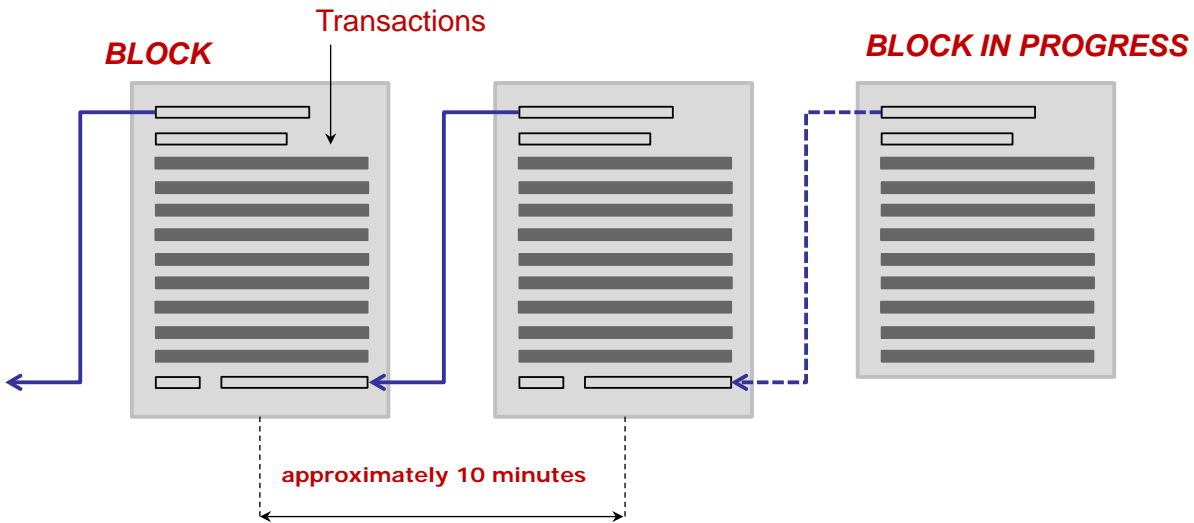
A particular blockchain is maintained by a decentralized, dispersed network of active participants or miners as discussed in Section II.B. Transacting parties connect to the Blockchain and could store their Bitcoins in wallets, which are explained in more detail in Section II.C.

2.2   Blockchain Mining

Miners are the active participants responsible for "building" a particular public blockchain. The challenge of the blockchain design is to devise a protocol that will establish consensus among geographically dispersed miners (active nodes) with competing incentives in the absence of a contracting or central authority to resolve disputes among miners.[7] The relevant consensus outcome is an agreement amongst miners about the group of transactions that should be included in a particular block.

Agreeing on the group of transactions to be included in a block and therefore appended to the blockchain is not as simple as ordering cryptocurrency purchases and sales according to their time stamps. Transacting participants broadcast transactions and/or requests to buy or sell cryptocurrency to all nodes on a particular blockchain; but, because of the geographically, distributed nature of blockchain participants, the latency or time delay between the submission of a transaction and its receipt by other nodes can differ widely depending on their physical

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[7] By contrast, only certain, permissioned entities are allowed access to the typical private or permissioned blockchain. See, Burnside and Takar (2018).

locations. Latency differences render transaction time stamps an ineffective means for ordering transactions (Narayanan, Bonneau, Felten, Miller and Goldfeder (2016)). The ordering of purchases and sales should obey certain rules, for example, transactions that double spend the same Bitcoins or any other type of malicious transactions should not be confirmed and added to the blockchain.

The Bitcoin blockchain relies on a cryptographic principle referred to as "proof-of-work" to facilitate trust and coordination among miners and ensure that only legitimate transactions are confirmed (Nakamoto). Proof-of-work requires miners to expend considerable computational capacity to solve a complex, mathematical puzzle. The mathematical puzzle is not necessarily difficult to solve, but the solution requires a significant amount costly computational power.

Bitcoin miners will only participate in the maintenance of the blockchain if it is economically viable for them to do so. Miners typically compete for economic rewards in the form of transaction fees and a pre-determined amount of new cryptocurrency that is generated when new blocks are added to the blockchain. Only the miner that generates the consensus block receives the reward. Miners could add more computational power with the hope of increasing their probability of generating the consensus block. But increasing the required network computational power will by design increase the difficulty of the mathematical puzzle, thereby ratcheting up the required future computational power required for subsequent mining. This negative feedback mechanism ensures that each block contains at most ten minutes worth of Bitcoin transactions (*see* Figure 1). A natural outcome is that miners combine resources to create mining pools to aggregate computational power and share the mining rewards (Lin, Cong and He (2018)).

2.3 Wallets and Coins

Passive participants, or user nodes, access the blockchain using a wallet[8] akin to a digital bank account. Each wallet is associated with a public-private "key pair." The public key is shared and visible to other participants. The public key is part of the information included in a particular transaction request. For example, if you want to buy Bitcoins from Bob, you could send a purchase order to Bob (specifically the public key associated with Bob's wallet). The private key

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[8] The first step to trading cryptocurrency is the creation of a wallet, which simply entails downloading software to your digital device.

is known only by the wallet owner and needed to spend the Bitcoins in a particular wallet and should therefore be kept secure by their owners. Similar to a bank account, a wallet is essentially a record of unspent Bitcoins. There is no limit to the number of wallets per person.

Unlike the contents of a bank account that is visible only to the owner, the contents of a wallet are publicly visible. Table 1 shows the contents of Bitcoin wallet number 967 as of March 1, 2018.[9] The public key associated with this wallet is 12ib7dApVFvg82TXKycWBNpN8kFyiAN1dr. The private key for this wallet is stored by the owner and not publicly available. This wallet was created on May 13, 2010. Bitcoins were last received by this wallet on February 20, 2018, and last sent out from this wallet on July 24, 2010. This wallet shows a total of 51,000 unspent Bitcoins. As of April 30, 2018, most coins in this wallet remain unspent — *viz.,* out of 52,700 Bitcoins received in 55 transactions, only 21,700 were spent in 4 sent/sell transactions.

Table 1 – Example of the Contents of a Bitcoin Wallet

Wallet 967	Number of Bitcoin	First Transaction	Last Transaction
Balance	31.0K BTC		
Received	52.7K BTC (55 ins)	05/13/10	02/20/18
Sent	21.7K BTC (4 outs)	06/02/10	07/24/10
Unspent Outputs	51.0K BTC		

2.4   Economics of Bitcoin

Barriers to entry for the introduction of a new cryptocurrency is relatively low. Anyone can introduce a new cryptocurrency by publishing a whitepaper[10] that establishes the rules of the particular distributed network, including the creation of new blocks, the procedure generating new cryptocurrency and the mechanism for reaching consensus.

A challenge of any new cryptocurrency and its associated public blockchain is to attract sufficient demand from users that value the proposed coins as well as demand from miners willing to expend resources to generate the blockchain. Out of the more than 1,500

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[9] See https://blockchain.info/, last accessed April 30, 2018.

[10] The technical document that describes the blockchain/cryptocurrency protocol and other rules governing a particulate digital currency is colloquially referred to as a *whitepaper*.

cryptocurrency coins that have been created to date, Bitcoin is the dominant and most popular cryptocurrency with a market share of 62%.[11] Table 2 below shows the market capitalization and share for the top five coins as of June 30, 2019.[12] The combined market share of the top five coins was 82% as of June 30, 2019.

Table 2 – Market Share of Top Coins (June 30, 2019)

Cryptocurrency	Market Capitalization	Market Share
Bitcoin	$194 billion	62.0%
Ethereum	$31 billion	10.0%
Ripple	$17 billion	5.4%
Litecoin	$8 billion	2.5%
Bitcoin Cash	$7 billion	2.3%

Source: CoinMarket.

The supply of Bitcoin is deterministic and an embedded part of the protocol design and therefore not a function of the price of Bitcoin. The technical details of the Bitcoin protocol are beyond the scope of this article, but it is important to know that new cryptocurrency is being created in an orderly, predictable way. For example, the supply of Bitcoin is capped at 21 million and the amount of new coins created with every new block decreases deterministically over time. According to some calculations, 99% of all new Bitcoin will have been created by 2032 Burniske and Tatar (2018)). The amount of time needed to reach the total supply is somewhat misleading because the Bitcoin protocol can be adjusted to add smaller amount of Bitcoin per block. Because of its digital nature, Bitcoin is infinitely divisible so that fractional amounts of coins per block are feasible.[13]

It is easy to fixate on the technical details of cryptocurrency and lose sight of the fact that billions of dollars are tied up in what is essentially a digitally stored, random number. An often-overlooked part of Satoshi's Bitcoin invention is that the blockchain – the distributed ledger technology that forms the backbone of the crypto-economy – is integral to the value of Bitcoin. There are effectively two sides to the value proposition for cryptocurrency.

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[11] See https://coinmarketcap.com, last accessed June 30, 2019.

[12] Statistics reported by CrytoCoinCharts, https://cryptocoincharts.info/coins/info/.

[13] A potential area for future research is whether the infinite divisibility of bitcoin would be viable without devaluation of the currency.

First, the blockchain protocol is designed to create a deliberate, fixed maximum supply of coins in a deterministic and controlled fashion. The blockchain protocol associated with Bitcoin controls the number of new coins created per block, and the frequency with which new blocks are added to the blockchain. Yet the demand for cryptocurrency is theoretically unlimited, resulting in a perceived scarcity that adds value to Bitcoin.

Second, the value of cryptocurrency is intricately linked to the perceived worth it has among the transacting participants on the related blockchain. An everyday analogy is a digital, social network such as Facebook. The commodity of exchange on Facebook is personal information posted by members that can be viewed by other members. A Facebook member's utility or value depends on the number of other members that are willing to comment on and exchange personal information with that member. To wit, if none of your friends are Facebook members, then what is the value of posting pictures of your exotic African safari? Similar to the Facebook example, Bitcoin has value because a sufficient number of blockchain participants derive economic utility from the Bitcoin crypto-economy (Garcia, Tessone, Mavrodiev and Perony (2014)).[14]

Robert Metcalfe, the inventor of the Ethernet protocol, suggested a simple relationship between the value of a network and the number of users of the network. Now known as Metcalfe's Law, the postulated relationship in Metcalfe's Law indicates that the value of a network is proportional to the square of the number of users of the network. Metcalfe's Law has successfully been applied to Facebook and other social networks (Zang, Liu and Xu (2015)).

Dr. Ken Alabi and Robert Lee of Fundstrat both found that Metcalfe's Law can be used to gain insight into the network value hypothesis of cryptocurrency (Alabi (2017)).[15] Positive network effects are present if the value of a product increases with the number of users. I apply Metcalf's Law to Bitcoin for the period February 2014 through February 2018. The supply of Bitcoin is either fixed or changing deterministically and not affected by price so that changes in

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[14] Garcia, Tessone, Mavrodiev and Perony presented an analysis supporting the network hypothesis of cryptocurrency analysis showed that the value of Bitcoin is causally linked to "social factors, which are composed by the interactions between the actors of the market." Garcia's analysis ended in October 2013 and they used the Bitcoin to USD price from the now bankrupt exchange Mt. Gox.

[15] FundStrat top strategist Rob Lee introduced the idea of applying Metcalfe's Law to value Bitcoin. See http://www.businessinsider.com/bitcoin-price-how-to-value-fundstrat-tom-lee-2017-10.

price is a good indication of the changes in demand. Figure 2 shows the Bitcoin price versus a proxy for the worldwide interest in Bitcoin, which I approximate as the square of the Google Trends score of searches using the term "Bitcoin."[16] An increased number of searches could be generated by increased coverage of mainstream media or an interest by investors who are gathering information on Bitcoin.

The correlation between Bitcoin price and its adoption rate is 0.82 for the period February 2014 through November 2018.[17]

Figure 2 - Bitcoin Price versus Bitcoin Adoption
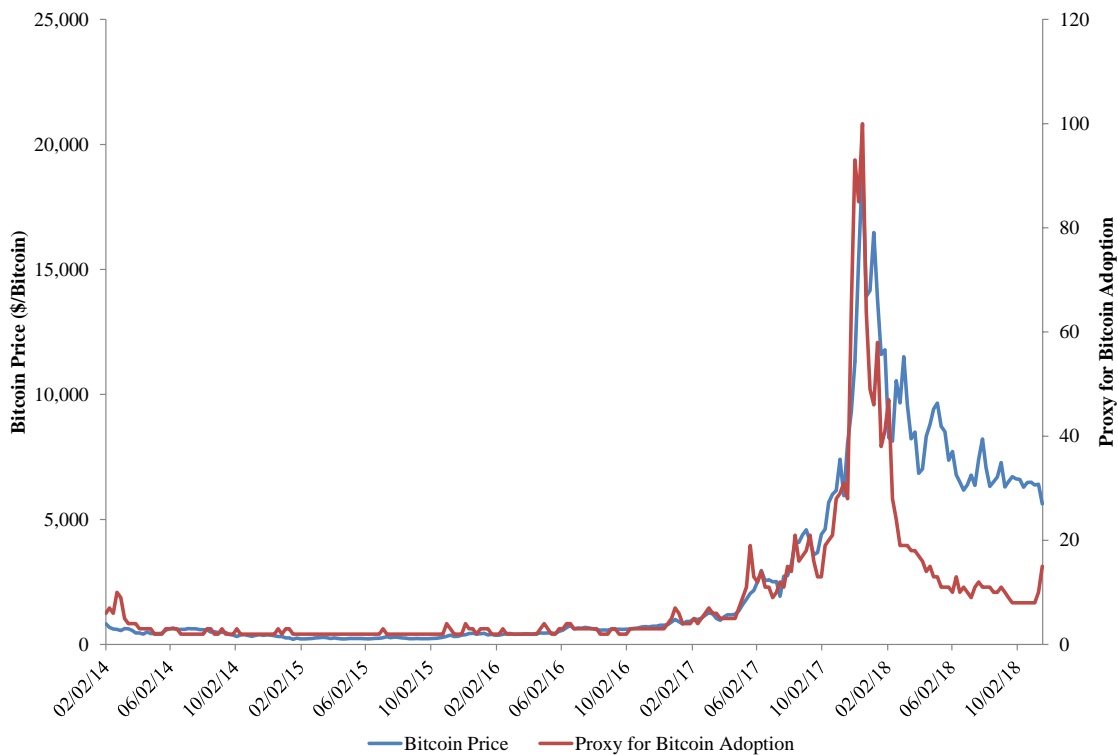
Sources: Bitcoin closing price from Coinmarkets.
Bitcoin adoption (relative volume of Google searches), Google trends.

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[16] The Google Trends score measures the absolute volume of a search term relative to the number of searches received by Google. The highest value of the score is 100. No quantitative measurement is assigned to the score though it measures the relative popularity of the search term over the specified time period. See, http://searchanalysisguide.blogspot.com/2013/04/understanding-google-trends.html?m=1.

[17] The correlation is statistically significant at the 1% level. Correlation measures the strength of a linear relationship between two variables and the correlation typically lies between one or minus one. If there is no linear relationship between two variables the correlation is zero.

3.0   CRYPTOCURRENCY VERSUS MONEY

Satoshi described cryptocurrency as "electronic cash" (Nakamoto), which has led to much confusion and debate about cryptocurrencies as potential substitutes for money.[18] According to the conventional definition, "money" fulfills three functions as a store of value, a medium of exchange, and a unit of account (Mankiw (2007), Yeager (2007), and Friedman (1969)).

3.1   Store of Value

Absent inflation, money provides some security that it can be used for purchases on future dates. In other words, one dollar bill today will be one dollar bill tomorrow, even if its value may be lower than one dollar today due to the effect of the time value of money. Money can be saved and used to smooth the purchasing of physical goods and services over time.[19]

In contrast, there is no guarantee that the value of a Bitcoin today will be the same tomorrow. Observable prices of Bitcoin are determined by demand at cryptocurrency exchanges (the supply of Bitcoin is deterministic based on the Satoshi design). The Bitcoin to USD exchange rate has been very volatile (see next section for more detail) which inhibits its use as a means to smooth purchases over time. Yermack (2013) compared the exchange rate of Bitcoin to USD against the exchange rate of fiat currencies to USD for the period May 2010 through March 2014 and found that "[b]itcoin's daily exchange rate with the U.S. Dollar has virtually zero correlation with the Dollar's exchange rates against other prominent currencies such as the Euro, Yen, Swiss Franc, or British Pound" (Yermack 2013)).

Similar to cryptocurrency, the U.S. dollar has not been backed by a physical commodity such as gold since 1974 (Elwell (2011)).

Cryptocurrency also has other characteristics that make it fundamentally different than money. Whereas the quantity of money is controlled by central banks and affected by macroeconomic trends, the quantity of Bitcoin is deterministic. The supply is embedded in the cryptocurrency/blockchain protocol, and its value is not affected by macroeconomic events in the same way as money (Ali, Clews and Southgate (2014)).

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[18] We use *money* here to refer to fiat currency such as the U.S. dollar, Euro or British Pound.
[19] Money can also be deposited at a bank or in a certificate of deposit to earn interest over time.

3.2   Medium of Exchange

People can use a "medium of exchange" as a commonly and widely accepted means for transacting purchases and sales. Cryptocurrency indeed functions as a medium of exchange within the confines of the crypto-economy on the blockchain, but *only* for participants in the blockchain. Can it replace money in the retail economy more generally?

Unlike cryptocurrency, the U.S. government recognizes money (dollars) as a legal tender, whereas the U.S. government does not recognize cryptocurrency as a legal tender. For example, one cannot pay one's U.S. federal income taxes in Bitcoin. In fact, the absence of a central, governing body is at the heart of the crypto-economy, and, hence, is a key impediment to its universal acceptance as a reliable medium of exchange.

Some developments might suggest that Bitcoin is making headway as a medium of exchange. Thirteen retailers including Amazon, Expedia and Microsoft are accepting Bitcoin as a form of payment.[20] Nevertheless, the number of merchants willing to accept payment in Bitcoin is still incredibly small relative to the global retail world. The digital currency exchange Coinbase released a service for merchants to accept cryptocurrency, including Bitcoin, as a form of payment.[21] The high volatility of the exchange rate for Bitcoin to USD undermines the role of Bitcoin as a medium of exchange in an economy with money as an established unit of account. As a practical matter, the value of Bitcoin fluctuates far too much and too often to facilitate updating posted prices, especially for retail goods and services (Carlton (1979)). To the extent Bitcoin can serve as a medium of exchange, it is more akin to frequent flier miles or credit card reward points exchangeable for cash or tangible rewards—yet in general no one considers credit card reward points a replacement for money.

Bitcoin transactions, moreover, are irreversible. Payment platforms such as credit cards include procedures to reverse or dispute unwanted transactions post-trade, but the Bitcoin protocol is designed without such procedures so that unwanted purchases or payments cannot be undone (Bohme, Christin, Edelman and Moore (2015)).

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[20] https://www.lifewire.com/big-sites-that-accept-bitcoin-payments-3485965, last accessed on February 14, 2018.

[21] "Coinbase Releases Tool for Merchants to Accept Cryptocurrencies," *Bloomberg News*, February 14, 2018.

3.3 Unit of Account

A unit of account is a common base for expressing the prices of goods and services. In the United States, prices of goods and services are always quoted in dollars and cents. The most important aspect of "money" as a unit of account is that it must be nearly universally accepted as the basis for the quotation of the prices of goods and services, which makes it easy to compare prices of alternative goods. For example, a $1 apple is twice as expensive as a 50 cent apple.

The digital nature of Bitcoin means that each Bitcoin is divisible into smaller units. The smallest unit of a Bitcoin is a Satoshi equal one hundredth million of a Bitcoin. Machines can easily keep track of numbers with several decimal digits, but it is very challenging for most humans to keep track of prices to eight decimals. For example, a $2.95 Starbucks latte would cost 0.00085631 Bitcoin,[22] making it very challenging for people to compare prices of different goods. A coffee at Starbucks (0.00085631 Bitcoin) is more expensive than coffee at Dunkin (0.00056604 Bitcoin) but it is very challenging for most humans to tell how much more expensive the Starbucks latte is.

As discussed in Section 3.2, moreover, the exchange rate of Bitcoin to fiat currency such as the U.S. dollar changes more often (and with larger relative sizes) than the frequency with which many merchants update their posted prices, whether for hotel rooms or a Starbucks latte. Although some merchants may accept Bitcoin payments at then-prevailing exchange rates, many will still prefer to post and adjust prices in dollars. Until that changes, sticky prices for many goods and services will remain a significant barrier to cryptocurrencies such as Bitcoin becoming a standard unit of account.

4.0 CRYPTOCURRENCY AS AN ASSET CLASS

Bitcoin is purchased as an asset rather than a means of payment outside the confines of the crypto-economy. If participants purchased Bitcoin with the primary intention of using it as substitute for money and as a medium of exchange, one would expect that purchasers of Bitcoin would use it to buy goods and services so that the majority of Bitcoin holdings would be circulated rather than locked up in wallets. Empirical results show the exact opposite – most Bitcoins are held and not spent. Figure 3 shows the distribution of Bitcoin holdings by Bitcoin

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[22] I use the Bitcoin exchange rate of $3,445.01 $/BTC as of February 2, 2019.

wallet address. The distribution is skewed such that approximately 74% of Bitcoin wallets are holding less than 0.2% of coins, and less than 1% of wallets are holding over 87% of coins.

Bitcoin is an intangible asset with no reliable or objective criteria to measure its value (Garcia, Tessone, Mavrodiev and Perony (2014)). Unlike debt or equity, Bitcoin is not issued by or tied to any particular publicly traded company and its underlying assets and cash flows. While it is true that the stock of companies such as Facebook or Amazon may derive some of their value from intangible characteristics such as the brand name of the company (Myers (1977)), investors can still estimate the expected prices using assumptions of future cashflows and company fundamentals.[23] Bitcoin is therefore not part of capital assets, but it shares some economic characteristics of commodities. The supply of cryptocurrency is based on the blockchain protocol, which introduces a perceived scarcity value. Similar to the price of physical commodities, the price of cryptocurrency is linked to the balance between supply and demand in a specific, albeit digital market.

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[23] According to calculations by FundStrat, stocks such as Facebook, Amazon, Netflix and Apple have over 85% of their value tied to intangibles. FundStrat Presentation at the Upfront Summit, January 31, 2018, Slide 33.

Figure 3 - Distribution of Bitcoin Holdings

Source: BitInfoCharts
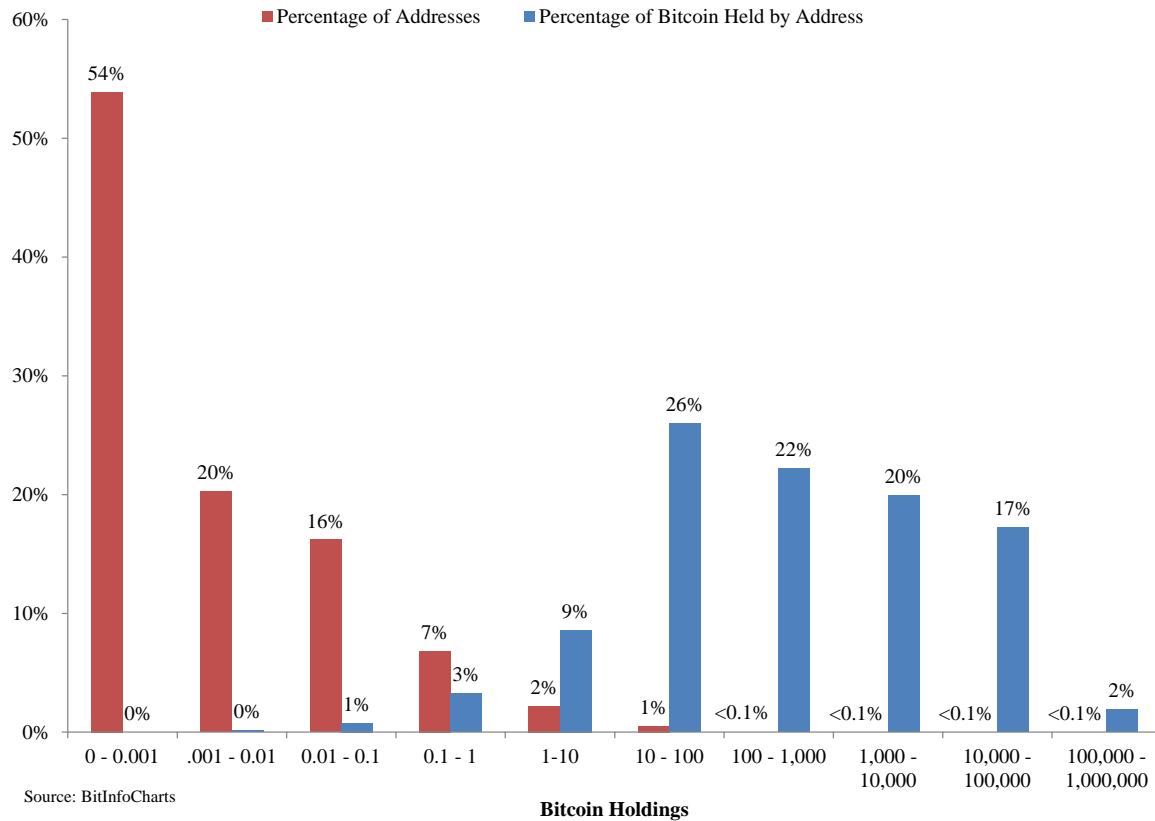
Potential investors in Bitcoin should recognize differences and similarities between Bitcoin and other more traditional assets to ensure that the desired level of portfolio diversification is being achieved when adding digital assets.

4.1   Quantitative Comparison – Risk and Return

This section compares the historical, ex-post risk and return of Bitcoin with similar measures for more traditional asset classes, namely stocks, bonds, foreign exchange and commodities. This analysis uses aggregate market indices to represent each of these assets.[24] I first discuss summary statistics for each asset and then compare the performance of assets using the Sharpe and Sortino risk adjusted return measures.

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[24] Stock is represented using the Ibbotson U.S. Large Stock Total Return Index from Morningstar; debt is represented using the Investment Grade Bond Index; foreign exchange is represented using the average of the equal weighted monthly return of exchange rates of USD versus Euro, Yen and GBP respectively published by Morningstar; and commodities are represented using Bloomberg WTI Crude Oil Sub-Index Total Return.

The table below shows summary statistics for monthly returns for the period January 2014 through September 2018.[25] The return on Bitcoin is higher than that of the other assets, but the high return is tempered by a high volatility. Table 3 also shows that Bitcoin is uncorrelated with foreign exchange and negatively correlated with corporate debt. Stocks and commodities show a small positive correlation with Bitcoin over this period.[26]

Table 3 –Monthly Return Statistics

Statistic[27]	Bitcoin	Stock	Commodity	Foreign Exchange	Corporate Debt
Mean Return	6.29%	1.01%	0.34%	0.32%	0.23%
Volatility	5.47%	0.08%	0.63%	0.03%	0.01%
Kurtosis	0.35	0.60	1.48	-0.37	1.48
Skewness	0.66	-0.01	0.30	0.03	-0.35
Correlation with Bitcoin	1	0.18	0.10	0.06	-0.06

Sources: Morningstar, Bloomberg and CoinMarketCap.

The distribution of Bitcoin is not symmetric which limits the usefulness of risk management techniques such as normal Value-at-Risk ("VAR") that is typically based on the assumption of symmetric distributions.

The Sharpe ratio measures return per unit of risk (measured using standard deviation). According to this ratio shown in Table 4, stocks outperformed Bitcoin on a risk-adjusted basis.[28] The Sharpe ratio considers the risk of the asset without distinguishing between upside and downside risks (Sharpe (1994)). For assets with normal distributions and no fat tails it makes sense to include both upside and downside risks. For assets with skewed or fat tailed distributions such as Bitcoin (see Table 3), the Sortino ratio is also useful. The Sortino ratio, like the Sharpe ratio is a measure of risk adjusted return but unlike the Sharpe ratio reflects only downside risk or the standard deviation of returns below a specified target level (Culp and Mensink (1999)). For the analysis below, I used the 30-day Treasury return as the target level in

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[25] January 2014 was selected so as to be well after the bankruptcy date of the Mt. Gox cryptocurrency exchange in February 2013.

[26] Correlation varies between minus one and plus one.

[27] Kurtosis measures the size of the tails of the distribution relative to the tails of the standard normal distribution. Skewness measures the symmetry of the return distribution around zero.

[28] The Sharpe ratio is defined as the return on the asset in excess of the risk free rate (30-day U.S. Treasury return) divided by the standard deviation of returns. Volatility measures the total risk in the asset, including systemic and idiosyncratic risks. A higher Sharpe ratio represents a higher risk adjusted return.

estimating the Sortino ratio. The Sortino ratio is intuitively appealing because investors would typically be more interested in knowing the ratio of expected returns to downside risk (i.e. the risk of underperformance or loss instead of upside risk). The results show that stocks outperformed the other assets, including Bitcoin over this period. Bitcoin performance is on-par with stock performance under a more conservative measure of risk.

Table 4 – Performance Ratios of Assets

Statistic[29]	Bitcoin	Stock	Commodity	Foreign Exchange	Corporate Debt
Sharpe Ratio	0.27	0.35	0.16	0.15	0.15
Sortino Ratio	0.17	0.18	0.03	0.10	0.10

Sources: Morningstar, Bloomberg and CoinMarketCap

The Sortino ratio is lower than the Sharpe ratio for all assets. These analyses benchmark Bitcoin as a speculative asset to more traditional assets. The quantitative analysis shows that the statistical properties of the historical return distribution of cryptocurrency is very different than any of the other investments so that it can bring important diversification to an investment portfolio. These simple performance metrics do not fully capture the other risks of Bitcoin as discussed in more detail in Section 6.

5.0   VALUATION OF CRYPTOCURRENCY INVESTMENTS [30]

The development of indicators for evaluating whether a particular cryptocurrency presents a fairly valued, an overvalued or an undervalued investment is still is its infancy. I discuss a ratio below that is comparable to stock price multiples such as the price-to-earnings ("PE") ratio used by equity investors to evaluate the performance of stocks. The PE ratio is a single number summarizing the relationship between a stock's price, or the dollar invested, relative to the value the investor derives from it (Stowe, Robinson, Pinto and McLeavey (2007)). The cryptocurrency value indicator is referred to as the network value of transactions ("NTV") spearheaded by Coinmetrics. This ratio is a single number summarizing the relationship between

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[29] Standard deviation is a proxy for the volatility of the asset. Kurtosis measures the size of the tails of the distribution relative to the tails of the standard normal distribution. Skewness measures the symmetry of the return distribution around zero.

[30] The ideas presented in this section were developed and refined by D. Kalichkin at Cryptolab Capital, as well as C. Burnsike and W. Woo at Coin metrics. I performed all calculations for the results and prepared all the results discussed in this section.

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a cryptocurrency's price and the monetary value that the crypto-economy offers its users. The NTV is based on two readily observable metrics – the market capitalization of the particular coin and its average transaction volume. Investors can use this ratio to detect over-and-under valuation of a particular cryptocurrency, but it can also be used to measure the relative performance of different cryptocurrencies versus other asset classes such as equities.[31]

The volume of on-blockchain transactions measures the value that users associate with a particular coin. The relevant transaction volumes here are the on-blockchain transactions and not exchange-traded cryptocurrency that occurs on the internal network of the exchange and are off-blockchain. On-blockchain transaction volume is a superior measure of value because much of the trading at Bitcoin exchanges is speculative and not necessarily representative of user value.

The market capitalization or network value measured as the price of Bitcoin times the amount of cryptocurrency coins in circulation captures the monetary value of the crypto-economy.

$$Market\ Cap = \ Price\ \times Circulating\ Supply$$

Combining these two measures leads to a single metric that captures dollar invested relative to user utility,[32]

$$Network\ Value\ to\ Transactions = NTV = \frac{Network\ Value}{Daily\ Transaction\ Volume}$$

The calculations in Figure 4 show a slightly refined version of the NTV defined as,

$$NTV = \frac{Network\ Value}{90\ Day\ Moving\ Average\ of\ Daily\ Transaction\ Volume}$$

Using a 90-day moving average of transaction volume provides a better approximation of the fundamental value of the network.[33] Using the NTV ratio we can detect the difference between

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[31] The equivalent of the NTV ratio for equities would measure market capitalization to sales volume. https://www.norupp.com/nvt-ratio-and-nvt-signal-ratio-detect-bitcoin-bubbles/.

[32] This ratio was introduced and developed and refined by Coin metrics and Cryptolab Capital. See, https://medium.com/cryptolab/https-medium-com-kalichkin-rethinking-nvt-ratio-2cf810df0ab0.

[33] https://medium.com/cryptolab/https-medium-com-kalichkin-rethinking-nvt-ratio-2cf810df0ab0.

consolidations and bubbles. If the NTV ratio stays within a normal range, we are not in bubble territory. If it climbs above the normal range, it's a sign that the transactional activity is not sustaining the new valuation and we expect a price correction.
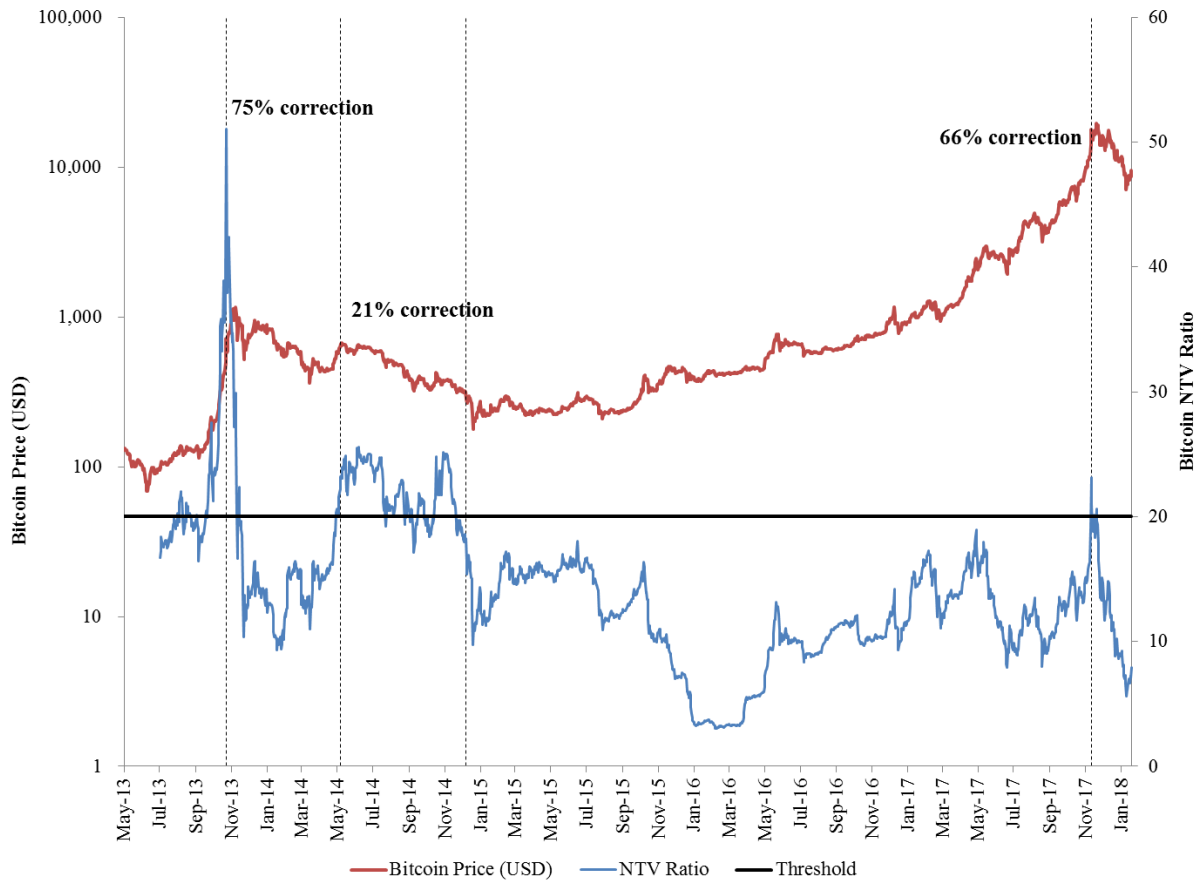
Proponents of the Bitcoin NTV suggest that it can be used to detect price bubbles—more specifically, an NTV greater than 20 typically preceded price corrections.[34] Figure 4 shows the NTV versus Bitcoin USD price for the period 2013 through 2018. Price corrections of 75% in the Fall 2013 and 21% during Spring 2014 clearly followed after NTV exceeded 20. The significant correction during Fall 2013 coincided with the problems at the then dominant Mt. Gox exchange.

The intuition behind NTV is simple: if the value of the network grows faster than the number of users or the value of the network to its users (assuming no other value-enhancing developments), that indicates a bubble. It is interesting that NTV barely exceeded 20 prior to the December 2017 price correction (as of February 15, 2018, the price fell approximately 66% from the high price in December 2017), which could point to the fact that other market developments not measured by on-chain transactions caused the price increase. The CME and the Chicago Board Options Exchange (CBOE) launched Bitcoin futures in December 2017. Trading at the CBOE commenced on December 10 and at the CME on December 17, 2017. Bitcoin futures can be used to express a view on Bitcoin prices without transacting in the underlying coins.

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[34] https://medium.com/cryptolab/https-medium-com-kalichkin-rethinking-nvt-ratio-2cf810df0ab0.

Figure 4 – Bitcoin Price versus NTV Ratio

6.0   ADDITIONAL RISKS OF CRYPTOCURRENCY INVESTMENTS

Investors in cryptocurrency should be cognizant of the salient risks associated with this asset class. In addition to the relatively high price volatility discussed before, there are several other risks associated with Bitcoin, such as the inherent risks of the protocol as well as trading and execution risks.

6.1   Risks Inherent to the Bitcoin Protocol

Some risks arise from vulnerabilities of the design protocol (e.g. the fact that Bitcoin transactions are irreversible), whereas other risks are more mundane, such as the settlement/confirmation of transactions on the blockchain. An on-chain Bitcoin transaction is not final until the transaction has been confirmed by at least six miners and does not settle until it has been included in a block and appended to the blockchain, which can take up to ten minutes per block (Bohme, Christin,

Edelman and Moore (2015)). The average ten minute inter-block time lapse places an upper limit on the transaction speed on-chain.[35]

The Bitcoin protocol, moreover, relies on an expensive process of proof-of-work to reach consensus among anonymous, decentralized parties. As described in more detail in Section II, miners maintain the blockchain but compete for the economic reward of doing so. For example, allegedly colluding miners controlling more than 50% of the blockchain could potentially prevent transactions from being confirmed or enable double spending (this is called launching a "51% attack") (Narayanan, Bonneau, Felten, Miller and Goldfeder (2016)). Budish explained that if Bitcoin blockchain becomes large enough, the gains from a majority attack by miners could outweigh the cost of maintaining the blockchain, which limits the scalability of the current Bitcoin blockchain (Budish (2018)). While not a current risk per se, investors should consider this limitation when adding Bitcoin to their long-term investment portfolio.

Acknowledging the limitations of Bitcoin is important but it should not detract from the value of cryptocurrency more generally. Some limitations of the Bitcoin blockchain have been overcome with subsequent evolutions of cryptocurrency technology. For example, Ethereum replaced the Bitcoin proof-of-work protocol with a proof-of-stake protocol, making the Ethereum blockchain more efficient and readily scalable (Buterin).

6.2   Market Structure of Cryptocurrency Trading

Cryptocurrency can be traded "on-chain" – in an over-the-counter ("OTC") market in which brokers facilitate transactions directly between participants (Lielacher (2018)). Transactions in the OTC market are typically large (on the order of $100,000), non-anonymous and customizable to high-net worth individuals.

Cryptocurrency can also be traded "off-chain" at a centralized cryptocurrency exchange. Such venues allow participants to exchange cryptocurrency for money or exchange cryptocurrency for cryptocurrency. For example, the Coinbase exchange platform Global Digital Asset Exchange (GDAX) allows users to trade Bitcoin, Litecoin and Ethereum against several

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[35] There are typically two measures of on-chain bitcoin transactions. The confirmation time refers to the time it takes for a transaction to transfer between wallets. The other is the amount of transactions per section, which determines the scalability of the network. https://medium.com/coinmonks/understanding-cryptocurrency-transaction-speeds-f9731fd93cb3.

currencies, including USD, Euro and British Pound.[36] There are numerous cryptocurrency exchanges worldwide – some exchanges facilitate trading between users and the exchange while others allow peer-to-peer order book trading.[37]

The cryptocurrency exchange landscape has not yet stabilized in terms of the number of exchanges or the services offered by these exchanges. For example, exchanges differ in the number of trading pairs offered, the types and comprehensiveness of security features, the amount and types of fees, the availability of any dispute resolution and the availability of market liquidity. I discuss market liquidity in the next section and focus on other differences below. Table 5 compares a number of features of cryptocurrency exchanges – each of these exchanges requires a two factor authentication on all trade executions. The number of trading pairs vary between 14 at Bitstamp to over 800 at HitBTC. Market makers fees are lower than market taker fees at all exchanges, market makers pay no fees at Bitstamp, Coinbase and Kraken and HitBTC subsidize liquidity provision by paying a rebate to market makers. Differences between exchanges manifest in differences in exchange rates for the same currency pair at the same point in time. For example, the mid-market price of Bitcoin as April 30, 2019 was $5,530.51 at Bitfinex versus $5,200.08 at Coinbase.

Table 5: Features of Select Cryptocurrency Exchanges

Cryptocurrency Exchange	Trading Type	Trading Pairs	Maker Fee[a]	Taker Fee[a]
Bitstamp	Mostly Fiat/Crypto	14	0%	0.1% to 0.25%
Coinbase Pro	Fiat/Crypto and Crypto/Crypto	25	0%	0.10% to 0.30%
CEX.io	Fiat/Crypto and Crypto/Crypto	28	0% to 0.16%	0.1% to 0.25%
Kraken	Fiat/Crypto and Crypto/Crypto	72	0.00%	0.25%
Bitfinex	Fiat/Crypto and Crypto/Crypto	100	0% to 0.1%	0.055% to 0.2%
HitBTC[b]	Crypto/Crypto	803	-0.01%	0.10%

　　a.　A range is shown where fees are based on the 30-day traded volume.
　　b.　The negative market fee on HitBTC represents a rebate to market makers for liquidity provision.
Source: https://blockexplorer.com/news/best-cryptocurrency-exchanges-2019-guide/.

Trading of cryptocurrency is fragmented among a number of exchanges. As the price of a cryptocurrency pair at one exchange gets too far out of line with the price of the same currency pair at a different exchange around the same time, participants will in theory arbitrage such

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[36] https://hackernoon.com/beginners-guide-to-gdax-an-exchange-of-coinbase-to-trade-btc-eth-and-ltc-e418fd1acd1b.

[37] As of June 2019, CoinMarketCap reported volume on 258 exchanges. See, https://coinmarketcap.com/rankings/exchanges/.

differences to bring prices back in line. Ignoring potential differences in trading fees and other costs such as deposit and withdrawal fees and market liquidity, I next analyze whether forces of arbitrage are at work in crypto trading.[38]

In theory, arbitrage exists if a market participant can implement a trading strategy with a sure profit and not net cash or investment outlay (apart from any required collateral) without taking any risk. For example, if a market participant can buy Bitcoin at one exchange, turn around and sell the Bitcoin at a second exchange at a higher price (or put differently, a higher USD to Bitcoin exchange rate) for a sure, riskless profit arbitrage is possible. To empirically test for arbitrage, I consider the ratio of Bitcoin to USD at Bitfinex versus Coinbase, Bitstamp, Kraken and CEX.io. A ratio of one implies no arbitrage opportunities exist inter-exchange under the above assumptions.

Table 6 shows the statistics of the exchange rate ratio for the period May 5, 2017 through May 5, 2019. The median and average ratios are close to one. Outliers are however more relevant for identifying a potential trading opportunity. Accordingly, Table 6 also shows the ratio at the 25th percentile is less than one on these exchanges, implying that the exchange rate of Bitcoin/USD is on average higher at Bitfinix than at either Bitstamp, Coinbase, Kraken or CEX.io on 25 percent of the days in the sample.

Table 6: Statistics of the Ratio of USD/BTC at Exchanges
May 2017 through May 2019

Statistic of Ratio	Coinbase to Bitfinix	Bitstamp to Bitfinix	Kraken to Bitfinix	CEX.io to Bitfinix
Average	0.99577	0.99399	0.99455	1.0170
Median	0.99947	0.99933	0.99942	1.0058
Minimum	0.93906	0.92158	0.92015	0.9231
25th percentile	0.98654	0.98384	0.98455	0.9976

As alluded to before, prices at different exchanges could vary because of other factors (which I ignore in this empirical analysis) that place limits on arbitrage. For example, the ratio analysis does not account for differences in fees or market liquidity (discussed below). More esoteric

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[38] This is not a comprehensive analysis of arbitrage because I consider only a handful of exchanges and only analyze prices once per day. Statistics may be different at different times or from different exchanges.

factors also play a role—the rules surrounding fund withdrawal at cryptocurrency exchanges vary (Samson and Stafford (2017)):

> "Coinbase, the most popular US exchange, '*temporarily disabled*' buying and selling midway through the trading day on Friday, citing 'today's *high traffic*'. It warned customers trying to withdraw funds into accounts denominated in euros to expect delays of up to 10 days owing to the 'extremely high volume of transactions.'"

To shed additional light on the nature of competition among cryptocurrency exchanges, consider the two models that have evolved among U.S. derivatives exchanges. On the one extreme are futures exchanges, each with their own portfolio of products, and trading and clearing typically congregate at a single, dominant exchange. Even if multiple futures exchanges list the same products, after an initial period, a single exchange usually dominates with over 95 percent of the market share for a particular product. Futures exchanges are liquidity driven – more buyers and sellers attract even greater liquidity. Moreover, exchanges typically use the clearing house associated with their exchange.

In contrast, options trading is fragmented among a number of exchanges. Options in public company stock are fungible – you could open a position at one exchange (long or short an option) and close the position at a different exchange depending on which exchange offers the better price. Because options are not held by the exchange, but at the common clearing house (Options Clearing Corporation), the option trader is exchange agnostic. The divergence in inter-exchange competition between the futures and options exchanges is a result of differences in regulation and clearing arrangements. According to Gorham (Gorham (2012)):

> "[o]nly when imposed by a regulator, are exchanges forced to accept a clearing arrangement that results in vigorous competition – this is what the SEC imposed on the options industry from the beginning. The result is serious competition on trading fees."

As of 2019, cryptocurrency exchange development has been driven by innovation and the natural evolution has been unhindered by any overarching exchange regulations. The nature of competition among cryptocurrency exchanges will most likely evolve over time as the industry matures.

6.3 Cryptocurrency Market Liquidity

Market microstructure identifies the features of a liquid market as tightness of bid-ask spread, depth and resiliency. A tight bid-ask spread enables a market participant to enter or exit a position at short notice. A deep market depth indicates that a desired volume of transactions can be immediately executed without introducing slippage to the price, and market resiliency measures the speed with which prices revert to their equilibrium levels following any transaction flow. Market depth and resiliency indicate the market's ability to absorb significant volumes without adverse effects on prices. Different exchanges necessarily involve a trade-off between these various dimensions (van der Merwe (2015)).

To fully capture the multi-dimensional aspect of market liquidity I compare the aggregated traded volume, the average bid-ask spread and the average number of trades per minute at 10 exchanges for the two-year period ending on June 26, 2019 in Table 7. More than 80 percent of the aggregate volume was traded at the top five exchanges during the period. The table also shows the bid-ask spread, measured at the best bid and offer, and the slippage at ten BTC worth of orders removed from the best bid and offer and at 100 BTC worth of orders from the best bid and offer.[39] The latter measures the depth of the market. The average trades per minute measures the speed of trading.

Table 7: Market Liquidity at Ten Cryptocurrency Exchanges

Cryptocurrency Exchange	Aggregate Traded Volume (BTC)	Bid-Ask Spread (%)	Bid-Ask Spread (%) at 10 BTC	Bid-Ask Spread (%) at 100 BTC	Average Trades per Minute
Bitfinex	24,100,992	0.01	0.13	0.70	52.58
Coinbase Pro	10,555,969	0.01	0.12	0.88	47.17
Bitstamp	8,255,488	0.08	0.29	1.09	19.26
Kraken	4,552,625	0.05	0.38	1.81	12.93
Gemini	4,114,432	0.03	0.23	1.16	9.17
HitBTC	2,474,448	0.12	1.16	8.52	9.98
Bit-x	2,244,662	1.94	3.13	7.99	1.27
itBit	2,144,388	0.06	0.40	3.29	2.85
CEX.IO	686,393	0.15	1.07	9.33	7.38
EXMO	374,352	0.26	3.01	31.12	6.32

Source: https://data.bitcoinity.org/markets/exchanges/USD/2y#rank_desc.

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[39] The bid-ask spread as a percentage is calculated as $\left(\frac{Ask-Bid}{Ask}\right)$.

According to these statistics, Bitfinix has the highest aggregated traded volume, the smallest bid-ask spread, the deepest market (measured at either 10 or 100 orders) and the highest average trades per minute. Other exchanges such as itBit have relatively narrow best bid-offer spreads (0.06%), but little market depth (bid-offer spread to execute 100 orders is 3.29%) and relatively slow trading (at approximately 3 trades per minute).

Table 7 shows a snapshot of market liquidity. Another useful measure of market liquidity is the Amihud measure, which captures market depth or price impact of trading over a period of time. Less liquid products have a relatively larger change in price for a given volume traded (Amihud and Mendelson (1986)). A higher Amihud ratio indicates lower market liquidity.
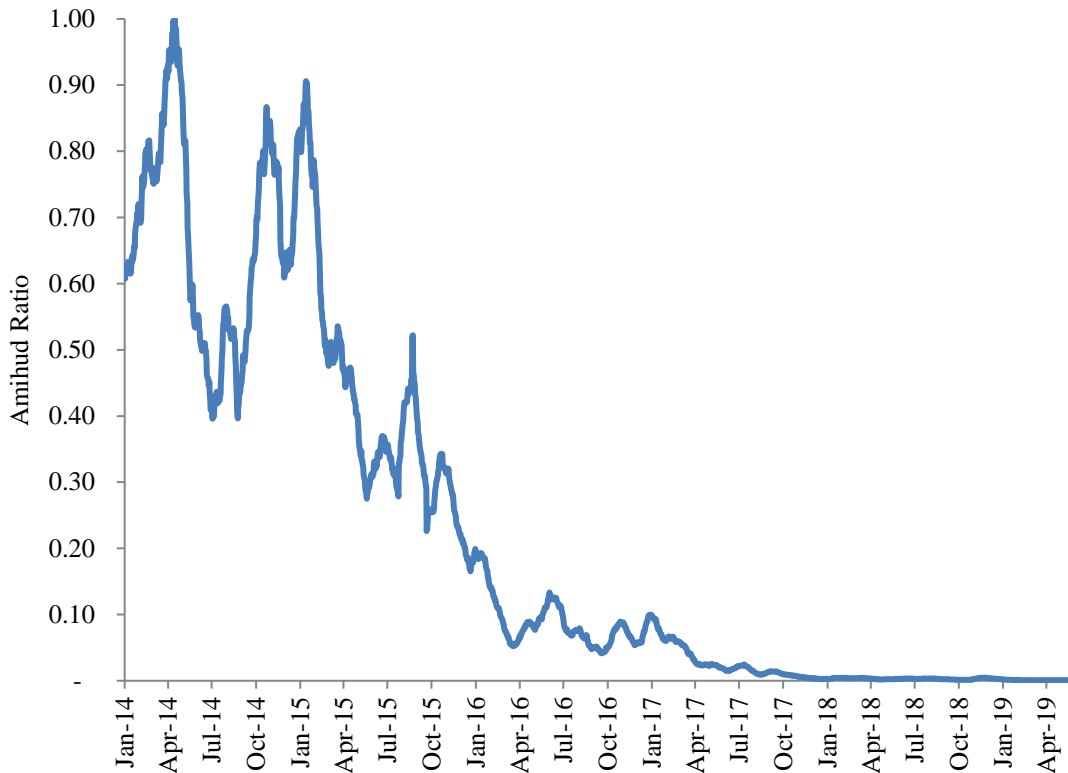
$$\text{Amihud measure} = \text{Average of the Per Period} \left[\frac{\text{Absolute Price Return}}{\text{Traded Volume}} \right]$$

The next figure shows the 30-day moving average of the daily Amihud measure. This calculates the price return from the daily high and low price of Bitcoin versus USD published by Coin Market Cap.[40] The decreasing Amihud ratio shows that market liquidity for Bitcoin improved significantly over time as cryptocurrency became more mainstream.

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[40] https://coinmarketcap.com/currencies/bitcoin/historical-data/?start=20130428&end=20180217.

Figure 8
Average of Daily Amihud Ratio

7.0 CONCLUSIONS

The real innovation behind Bitcoin is the blockchain, which enables user-to-user trading among decentralized participants and settlement and recordkeeping of such transactions without a trusted, centralized authority. Transactions are settled by a collection of anonymous, active participants referred to as miners. This paper shows that the price of Bitcoin is closely linked to the number of participants assigning value to it by engaging in trading.

Bitcoin is not fiat money, but it could we used as a medium of exchange on the blockchain. In the broader economy, Bitcoin functions as a digital, intangible asset with little resemblance to most traditional asset classes. From an economic perspective, Bitcoin shares the limited supply characteristic of non-renewable commodities – in the case of Bitcoin the limited supply is an artificial scarcity embedded in the protocol design. Bitcoin may add diversity to an investment portfolio because of its low correlation with more traditional assets. A potential investor should however recognize the qualitative and quantitative risks typically associated with an investment in Bitcoin such as the high price volatility and unique market structure.

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Blockchain has several applications beyond Bitcoin. One of the key limitations of the current Blockchain network is the inefficacy and power consumption of Bitcoin mining. The regulatory framework for cryptocurrency is evolving and requires coordinated efforts among regulatory agencies across international borders.

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