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Is Bitcoin a currency, a technology-based product, or something else?

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ABSTRACT

Cryptocurrencies such as Bitcoin have fascinated technologists and investors alike. They have become prevalent, with over 2,000 Bitcoin-like cryptocurrencies now in use. Most jurisdictions have not regulated cryptocurrencies. Whether existing regulations apply to cryptocurrency turns ultimately on if we classify cryptocurrencies as currencies, securities, or derivatives, or a money services (transfer) vehicle. In this set of exploratory analyses we seek to classify Bitcoin. We utilize a variety of methods to compare aspects of its behavior to: currencies, asset classes such as derivatives, technology-based products and possible technology-based products such as Ether and the security SPY, and speculative financial bubbles. We find that Bitcoin's behavior more closely resembles a technology-based product, an emerging asset class, or a bubble event, rather than a currency or a security; such that it is correct that existing currency and security laws should not apply to cryptocurrencies.

1. Introduction

Research on cryptocurrencies has been focused more on their utility vis-a-vis their elemental nature. Cryptocurrencies are often used by both those who want to verify transactions (Wang et al., 2017) as well as those who view cryptocurrencies as an investment or a better currency (Barber et al., 2012). The underlying blockchain technology has been heralded as the harbinger of the new economy (Swan, 2015) and as a great financial disruptor (Peters and Panayi, 2016). Some have stated that cryptocurrencies straddle the space between blockchains and applications, as well as between currency and technology (Maurer et al., 2013). Once the nascent tender of the black market, cryptocurrencies have become much more commonplace and have amassed large market capitalization in the process. Bitcoin alone reached a market capitalization of over $300 billion by late 2017.

While there is a growing literature base on blockchain technologies, other researchers have investigated the (exchange) value of Bitcoin (Hayes, 2016; Chan et al., 2017; Li and Wang, 2017; Wang and Vergne, 2017a) and its relation to banking (Eyal, 2017; Piazza, 2017). Furthermore, some have conjectured on its potential social implications (Alcantara and Dick, 2017; Scott et al., 2017). The possible social impacts of Bitcoin have been compared to those of Potosí Silver (Zimmer, 2017). Moreover, others have studied Bitcoin's network effects (Gandal and Halaburda, 2016; Luther, 2016). Similarly, future improvements to the technology have already been proposed (Bonneau et al., 2015). Finally, Bitcoin has been studied and evaluated as a market singularity (Dallyn, 2017; White, 2015).

A recent survey suggested that there are three major types of cryptocurrency regulatory issues. Put another way, there are three types of activities that may involve cryptocurrencies that are currently of interest and concern (Werbach, 2018). One type is illegal activities, which cryptocurrencies may facilitate by enabling the private, anonymous transfer of money. Another type is record-keeping activities. The last type is legal activities that are already being regulated and which may be applicable to cryptocurrencies. Determining whether these regulations apply depends on whether we classify cryptocurrencies as currencies, securities, derivatives, or a money services (transfer) vehicle.

But what does it mean to resemble a currency, security, or derivative—or a technology-based product? Though these all have definitions, none has accepted behavioral criteria to define their elemental natures. For the present study we chose to investigate whether cyptocurrencies are currencies by correlating cryptocurrencies to currencies. We chose to investigate whether cryptocurrencies are an asset class by examining their Betas and Sharpe Ratios. We further analyze whether cryptocurrencies are technology-based products or securities by examining their diffusion patterns (Bass, 1969; Bayus, 1987; Richards, 1959; Marinakis, 2012). We also investigated whether Bitcoin follows the pattern of a financial bubble.

These investigations are relevant to those engaging in interdisciplinary studies involving currencies, cryptocurrencies, emerging technologies, innovation, and technology entrepreneurship. They will

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be useful to practitioners seeking to use blockchain technology to verify transactions, to the financial community, and to policymakers studying this new regulatory frontier.

2. Theoretical background

First, we engage the literature by examining the nature of currency through history. We then ask whether Bitcoin can plausibly be considered a currency. Finally, we consider the characteristic signatures of monetary instruments. This engagement extends existing managerial insights into technology diffusion (Rogers, 2010) and technological innovation (Abernathy and Utterback, 1978; Barras, 1986; Linton and Walsh, 2003).

2.1. Currency literature

Currencies form a crucial part of our modern economic environment, but this has not always been the case. As an innovation, currency grew out of inefficiencies in the bartering system, which has been present since the earliest stages of human development. The traditional view (Smith, 1776) saw currencies as a means for improving liquidity in a *quid pro quo* barter system: trade between a butcher and brewer was only possible if they each had something the other wanted. Money, on the other hand, was a common store of value that could be used to purchase anything anybody wanted. Currency was born to fill this niche. As discussed in one study (Kiyotaki and Wright, 1989), the most important factor in determining if something can act as a currency is simple: are there enough economic agents that *believe* it can?

The earliest currencies used materials with a widely-understood intrinsic store of value. Cowry shells were used as currency prior to 1000 BC. (Yang, 2011). Standardized coinage based on electrum, an alloy of gold and silver, was minted in the Mediterranean states of Aegina and Lydia in the decades following 700 BC. (Kagan, 1982). Trade quickly flourished with the introduction of coinage. For nearly two thousand years, currency was transacted with units of traditionally valuable metals: gold, silver, and bronze. Paper currency, present in global commerce for the last thousand years, was often stabilized only when supported by one of these metals.

The establishment of the modern gold standard in the 19th century did much to standardize global currency regimes (Bordo, 2003). However, wars, depressions, and the economic shocks of the 20th century exposed its substantial limitations. After World War II, the Bretton Woods Agreement declared the U.S. Dollar to be solely convertible to gold at $35 per ounce, in turn tethering all other currencies to the dollar (Obstfeld and Rogoff, 1995). The suspension of dollar convertibility to gold in 1971 established the current ‘free floating’ *fiat* system. The gold standard allowed for decades of low inflation and exchange rate volatility (Bordo, 2003), but was incapable of keeping up with varying monetary demand and the high level of global fiscal discipline required.

In our current system, most of our monetary supply is not held as currency, but is created through lending (McLeay et al., 2004). For example, the $1.6 trillion of US Currency currently in circulation (Federal Reserve 2017) is a fraction of the $15.3 trillion of monetary stock redeemable on demand (MZM 2017). Commercial banks issue new loans, in effect creating money by crediting the borrower with a bank deposit equal to the size of the loan. Likewise, repaying these loans destroys money. Central banks can control monetary policy at the national level by setting the interest rate on reserves, encouraging or restraining lending by banks. In turn, this has pronounced effects on inflation, employment, and investment across an economic area.

2.2. Cryptocurrencies as currencies

Much of the initial scholarly research on cryptocurrencies was based on the assumption that they were emerging currencies. Many technical researchers assume Bitcoin to be a currency “*ipso facto*” by virtue of its existence. Researchers also see Bitcoin as a representative of a practical decentralized currency (Gervais et al., 2014). However, in 2013 it was convincingly demonstrated that Bitcoin failed to perform most of the basic functions of all currencies (Yermack, 2013). This investigation found that cryptocurrencies lacked substantial transaction value and were poor stores of value. We further this and other academic research by investigating whether this is still the case today.

The contemporary case for free-floating currencies (Friedman, 1953) holds that nation states can preserve monetary independence and avoid disruptive economic shocks that occur when a peg is adjusted for value. The novelty of cryptocurrencies is that they are truly supranational, digital, decentralized and independent of national interest. Cryptocurrencies also possess some of the characteristics of gold: the supply is finite, and they are both fungible and universally available.

Interestingly, however, the role of the nation state in currency (Plassaras, 2013) also presents cryptocurrencies with their greatest obstacle for widespread adoption. Successful decentralized currencies like Bitcoin currently offer little incentive to be adopted by national governments, since they offer little in the way of monetary policy control. Likewise, widespread adoption of cryptocurrencies could undermine the effectiveness of central banks, by making legal restrictions surrounding their adoption more likely.

The greatest hurdle in establishing any currency is credibility as a means for exchange (Böhme et al., 2015). In this sense, Bitcoin has improved dramatically in recent years. Daily transaction value has increased to roughly $5 billion dollars a day in December 2017, from roughly $200 million just the year before (Blockchain 2017). Similarly, the number of daily Bitcoin transactions has increased, but more modestly, moving from 270,000 to roughly 400,000 in the same period (Bitcoin 2017). Compared to other currencies in the $5-trillion daily foreign exchange market, the value transacted by Bitcoin approximates the daily turnover of minor currencies such as the Hungarian Forint or Indonesian Rupiah (BIS 2017).

Does Bitcoin serve the same function as money? Money serves three functions (Ali et al., 2014): it offers a store of value, a medium of exchange, and lastly, a unit of account. Many objects, including cryptocurrencies, can be stores of value for an individual: examples include real estate, collectibles and art. Mediums of exchange require at least two parties to coordinate their valuation, and this is a hurdle that cryptocurrencies like Bitcoin pass easily. However, units of account require that many people use a currency across many different transactions (Woodford, 2011). Central banks’ primary role is controlling that unit of account. For cryptocurrencies like Bitcoin, this is a harder hurdle to pass. While spot transactions and (as of November 2017) future markets exist for cryptocurrencies, and more specifically Bitcoin, using it in day-to-day society requires another medium of exchange. We cannot, as of yet, take out mortgages exclusively in cryptocurrencies or invest exclusively in investments and markets denominated in cryptocurrencies. For instance, for an employee to be paid wages in cryptocurrency, they must first get an employer to convert their native currency into cryptocurrency. This is a process that would be identical to an employee requesting that their employer pay them in smartphones, golf balls, or any other non-currency item. In this light, the startup costs for digital currencies are immense.

These non-mutually-exclusive questions attempt to resolve the nature of cryptocurrencies as an investment (Yermack, 2015). If cryptocurrencies like Bitcoin are currencies, do they behave like them? Furthermore, if cryptocurrencies actually represent a separate asset class, what sort of assets offer the closest proxies?

2.3. The nature of the use of cryptocurrencies, currency, asset classes, and technology

In order to understand the nature of cryptocurrencies, we have investigated the literature that compares or indicates cryptocurrencies as a particular instrument. Here, we discuss adoption patterns of currencies, asset classes and technology-based products. We follow these discussions with a comparison of cryptocurrency adoption patterns to the occurrence of financial bubbles.

2.3.1. *Currencies*

As discussed, many have defined cryptocurrency as a currency. Yet currencies have a specific adoption rate signature. Over the past four decades since the adoption of the Bretton Woods system (Obstfeld and Rogoff, 1995), there has been a rise in the use of the sometimes-volatile free-floating currencies. In our methods section, we calculate their adoption rates and examine the similarities and differences between cryptocurrencies and traditional currencies.

The question of whether Bitcoin is useful as a currency or as a speculative asset has been addressed by a line of research that makes use of advanced research techniques such as cross-quintilograms, multifractal spectra, the Quantile Nonlinear Autoregressive Distributed Lag (QNARDL) model, and copulas.

Whereas the quantilogram comprises a correlogram of quantile hits and measures predictability in different parts of the distribution of a stationary time series, the cross-quantilogram comprises cross-correlations of quantile-hit processes. The cross-quantilogram allows a user to detect, between time series, the magnitude, duration, and direction of a relationship, the quantile-to-quantile relationships, and the extreme quantiles dependencies (E. Bouri et al., 2018). Since it allows a user to estimate lead-lag relation between time series simultaneously at different lags and quantiles, the cross-quantilogram was the technique of choice to investigate whether Bitcoin is a better safe-haven investment than gold and commodities (E. Bouri et al., 2019). An asset was defined in the study as a strong safe-haven if there is evidence of predictability from a stock index to that asset in the low quantiles of both the stock and the asset returns and the sign of this predictability is negative. An asset was defined as a weak safe-haven if there is no evidence of predictability from a stock index to that asset in the low quantiles of both the stock and the asset returns. For potential havens the study utilized daily spot prices data for Bitcoin, Gold, and the S&P Goldman Sachs Commodity Index, which were investigated as potential safe-havens for five Morgan Stanley Capital International stock indices, namely world, developed, emerging markets, China, and the US. It was shown that Bitcoin, gold, and commodities did not show the strong safe-haven property for any of the stock indices; Bitcoin, gold, and commodities each showed the weak safe-haven property for the world stock market; only gold showed the weak safe-haven property for developed stock markets; gold and commodities each showed the weak safe-haven property for emerging markets; Bitcoin and commodities each showed the weak safe-haven property for the Chinese stock market; and only commodities showed the weak safe-haven the U.S. stock market (E. Bouri et al., 2019).

Multifractal spectra are Hausdorff dimensions $f(\alpha)$ measured over a range of different singularities (α) (Marinakis, 1994). Multifractal asymmetric detrended cross-correlation analysis (MF-ADCCA) quantifies asymmetric multifractality in cross correlations, i.e., it quantifies the scaling behavior of a range of singularities in cross correlations where there are greater or lesser correlations when the time series are rising or falling. Application of MF-ADCCA between leading conventional currencies (Swiss Franc, Euro, British Pound, Yen, and Australian dollar) and main cryptocurrencies (Bitcoin, Litecoin, Ripple, Monero, and Dash) found that Bitcoin and its fork, Litecoin are the cryptocurrencies that exhibit the most multifractal behavior and smaller cryptocurrencies such as Monero and Ripple generally exhibit lower multifractal behavior (Kristjanpoller and Bouri, 2019).

The Quantile Nonlinear Autoregressive Distributed Lag (QNARDL) model is a combination of the nonlinear ARDL (NARDL) model and the quantile ARDL (QARDL) model (E. Bouri et al., 2018). It allows for asymmetric behavior and for asymmetry of the position of the dependent variable within its own distribution. Application of the QARDL found that the relation between Bitcoin price and gold prices is statistically significant but varies between the short and long runs and is asymmetric, non-linear, and quantile dependent; such that Bitcoin and gold markets share some common fundamentals (E. Bouri et al., 2018).

Copulas characterize average movements and the joint extreme movements between time series and enable a user to measure both tail dependence and the asymmetric dependence (E. Bouri et al., 2018). They enable a user to measure quantile dependencies, as conventional methods are unable to do so because the bivariate joint distribution is not normally distributed. Application of Copulas, in combination with the Granger causality in distribution test, found that global financial stress causes Bitcoin returns at the left tail (deficient performance) and the right tail (superior performance) but not at the middle (average performance) of the joint distribution, suggesting Bitcoin's ability to act as a safe-haven against global financial stress for approximately 60 days (E. Bouri et al., 2018). Further applications of advanced techniques are available (Al-Khazali et al., 2018; E. Bouri et al., 2018; El Alaoui et al., 2018; Ji et al., 2018; E. Bouri et al., 2019).

2.3.2. *Asset classes*

Convincing arguments have been made for the speculative nature of cryptocurrency investments from an asset-pricing perspective. Many investment organizations are marketing cryptocurrencies, not as a currency, but as a unique investment product (Burniske and White, 2017). Yet researchers have shown cryptocurrencies to be mainly uncorrelated with major asset classes and that they are used as a primarily speculative tool (Baur et al., 2017). Researchers have postulated that cryptocurrencies are primarily driven by the demand of investors for an alternative investment vehicle, making them a unique (if separate) asset class (Glaser et al., 2014). In particular, Bitcoin has been compared to a limited number of other asset classes (Brière et al., 2015; Wu et al., 2014).

2.3.3. *Technology-based products*

Other researchers have discussed cryptocurrency as a technology rather than a currency (Maurer et al., 2013). Technology-based product diffusion curves present a unique signature, which can be described using the Richards Model. The Richards model is a flexible, four-parameter model, and is able to fit a full range of sigmoidal shapes. It was introduced in 1959 in the context of plant growth (Bayus, 1987) and was recently applied to technology diffusion data (Richards, 1959). The model has been modified and reparameterized by several researchers. As modified (Sugden et al., 1981), the model is:

$$W_t = W^{\infty}[1 - -(1 - -m)\exp[-k(t - -T^{\infty})/m^{m/(1-m)}]]^{1/(1-m)}$$

where W_t is the weight or growth at time t, W^{∞} is the asymptotic weight, k is the maximum relative growth rate per unit time, T^{∞} is the time to asymptote, and m is a shape parameter with the property that $m^{1/(1-m)}$ is the relative weight at time T^{∞}. We will operationalize this model for comparison to cryptocurrencies in our methods section.

2.3.4. *Cryptocurrencies and financial bubbles*

Are cryptocurrencies acting as a financial bubble? Researchers investigated this issue in 2015 (Godsiff, 2015). We define a financial bubble as the unsustainable increase in asset prices that precedes a price collapse. The question remains a difficult and complex one, as bubbles require a concise definition. Here, we borrow the definition famously used by one seminal study (Case and Shiller, 2003) that a 'financial bubble'

> "refers to a situation in which excessive public expectations of future price increases cause prices to be temporarily elevated."

2.4. Regulatory research

A sweeping review of regulatory issues around cryptocurrency (Tu and Meredith, 2015) showed that there is no consensus, national or internationally on whether to regulate cryptocurrency. The review also reported on a survey the Law Library of the U.S. Congress of forty foreign jurisdictions, which showed that most of these jurisdictions had not acted to regulate cryptocurrency. The review also suggested existing U.S. Federal or state laws could be applicable to cryptocurrency depending on how cryptocurrency is classified. Finally, the review examined legislative possible rationale for regulating cryptocurrency and found that such regulation would be justified.

A full law review note was devoted to investigating cryptocurrency in the context of money laundering and tax evasion (Sánchez, 2017). The article noted that the only currency that could be used on Silk Road was Bitcoin. It further noted that cryptocurrency exchanges, under the terms of a Department of Treasury Guidance report, are not subject to the Bank Secrecy Act, an anti-money laundering statute. However, the Internal Revenue Service categorized cryptocurrencies as property, making individuals liable for investment gains.

We now seek to operationalize our literature review to make comparisons between these instruments and cryptocurrencies in order to more fundamentally understand cryptocurrencies.

3. Methods

We analyze the nature of Bitcoin by comparison to other instruments. We first compare Bitcoin to currency by measuring its correlations with other currencies. We then compare Bitcoin to commodities and newer assets categories such as derivatives, through calculation of Betas and Sharpe Ratios. We then compare Bitcoin valuation time series to well-known bubble events. We investigate Bitcoin diffusion through application of a technology diffusion model by comparing Bitcoin diffusion to large-scale technology diffusion, and for contrast, to the diffusion of the Euro, to the diffusion of Ether, and to the diffusion of a security (SPY).

3.1. Analyzing Bitcoin as currency

We first analyze the nature of Bitcoin as a currency. We propose that Bitcoin should superficially resemble one of the existing currencies during the early stages of its economic development and this resemblance should be detectable through correlation analysis. We examine the database of 18,937 USD-based monthly currency pairs since 1977 and compare them to Bitcoin's monthly changes in value between 2010 and 2016. Running correlations were computed using 77 months of Bitcoin values. Currencies with insufficient time data were dropped, and the resulting currency pairs were sorted by correlation. Currency data was obtained from the PACIFIC Exchange Rate Service at the University of British Columbia Sauder School of Business (Antweiler, 2019).

3.2. Analyzing Bitcoin as asset class

In our investigation of Bitcoin, we next expand our correlation matrix to include 32 different currencies, indices, and other investments, thus offering an exceptionally thorough and effective comparison of Bitcoin. We provide a finer analysis by sorting the data into three time periods: 2010–2016, the full breadth of Bitcoin's history; 2013–2016, the more recent period where Bitcoin had a total market capitalization greater than $500 million; and the 2015–2016 period of rapid appreciation. Data ends at December 31, 2016, the most recent data available on the WRDS CRSP service.

Despite Bitcoin's most recent classification and acceptance as a commodity, it resembles none of the other major commodities (Business Insider 2017). Indeed, Bitcoin throughout its history is inversely correlated to gold, silver, and oil. Yet, in the most recent period (2015–2016), Bitcoin is positively correlated to silver and gold, but still strongly negatively correlated to oil prices.

Bitcoin also fails to correlate well with major currencies. It has always been negatively correlated to the five major currencies studied, but in the most recent period of appreciation, the negative correlation to the British Pound and Chinese Yuan has been profound. Bitcoin, similar to cryptocurrencies in general, behaves as a *contra-currency* relative to other entities. It moves in ways and magnitudes that are effectively opposite the major currencies. Most consistently, Bitcoin has been most correlated to *bxysm*, the CBOE S&P 500 2% OTM BuyWrite Index, and *bxmd*, the CBOE S&P 500 30-Delta BuyWrite Index. Both are options indices. Furthering the view of some academic experts that cryptocurrencies are *de facto* havens for speculators, the movement and expansion of Bitcoin has resembled the high growth and volatility found in the derivatives market. The underlying options measured by the BuyWrite index are used as a portfolio enhancement strategy to improve returns and reduce risk (CBOE 2017).

We next examine whether Bitcoin would be similarly effective in a portfolio of securities to improve performance and reduce risk. For the period of 2014–2017, we calculated the 1-year and 3-year monthly Betas on Bitcoin. Beta measures the relative risk-to-return relationship between a security and the overall market in a diversified portfolio. Market risk has a Beta of 1; riskier securities have higher Betas. To further examine the relative reward-for-risk ratio, we also compute the Sharpe Ratio, defined by the following formula (Sharpe, 1966):

$$S_p = \frac{\overline{R_p} - \overline{R_f}}{\sigma_p}$$

Where $\overline{R_p}$ is the mean return of the portfolio; $\overline{R_f}$ is the mean return on three-month U.S. treasury bills (here, the risk-free rate of interest); and σ_p is the standard deviation of portfolio returns. The $\overline{R_p} - \overline{R_f}$ return is also described (Morningstar 2005) as the average monthly excess return:

$$\overline{R_e} = \frac{1}{n}\sum_{i=1}^{n}(R_i - RF_i)$$

Where $\overline{R_e}$ is the average excess return of the portfolio, computed monthly; R_i is the return of the portfolio in month I; and RF_i is the return of the risk-free benchmark. In our example, we calculate the Sharpe Ratio for Bitcoin as a portfolio. Usually, this statistic would not be tested for individual stocks, but given the role and dominance of Bitcoin as the *ipso facto* representative of the cryptocurrency asset class, we find it potentially useful for investors. This reward-for-risk ratio is then annualized to provide consistency and estimates the returns of Bitcoin when controlling for total risk. The higher the Sharpe Ratio, the better; values greater than 1 are considered desirable for investors.

3.3. Bitcoin as bubble

Measuring bubbles can be difficult and mathematically complex. One study (Jarrow et al., 2011) created an effective model for measuring bubbles in internet stocks during the 1998–2001 technology bubble. Another (Stöckl et al., 2010) provides a thorough analysis of widely accepted bubble-measuring techniques in the experimental asset-pricing literature. These papers provide a sound analytical framework for a future paper on cryptocurrencies, but the extant models are far from decisive. Additional research (Urquhart, 2016) has gathered evidence demonstrating that Bitcoin's pricing inefficiencies contribute to (often) incorrect valuation, providing the groundwork for speculative bubbles.

Does Bitcoin meet the definition of a bubble? One way of examining Bitcoin is to consider its growth in valuation relative to other speculative assets. For example, one study (Garber, 1990) details the mania surrounding the Dutch Tulip Bubble. Introduced from the Ottoman

Empire in the 16th century, tulips were a desirable luxury commodity that appreciated rapidly from 1634–1637, eventually exceeding the price of some luxury houses in Amsterdam before crashing abruptly in 1637. Another study (Thompson, 2007) considers Tulip mania a by-product of an inefficient futures market, rather than a true bubble, but it remains an often-cited example of early and unsupported rises (and falls) of asset prices.

The South Sea Bubble of 1720 surrounded the South Sea Company, a joint-stock firm first established to consolidate British debt, and later granted a trade monopoly with South America (Garber, 1989). Shares in the company were in high demand by investors, who believed the foreign trade value to be profoundly significant. After widespread interest across British society, the value of the stock increased tenfold in 1720 from £100 to nearly £1000 per share. While the broad economics of trade with the South Sea remained sound, the arrival of fraudulent competitors and the passing of the regulatory Bubble Act of June 1720 produced a liquidity crisis in the market as investors grew disenchanted (Garber, 1989). The price quickly collapsed to £150 by autumn, costing many investors a fortune – including, famously, Sir Isaac Newton.

The third (and most modern) bubble proxy we examine is the technology bubble and collapse of 1998–2001. Driven by the promise of computer technology, technology stocks rose five-fold between 1997–2000 (Griffin et al., 2011). Many technology firms failed (notably Pets.com and Webvan), while others saw precipitous declines in stock prices. Priceline (PCLN) saw prices surge to nearly $1000 per share in April 1999 before falling to below $10 per share in December 2000. Cisco Systems, Inc. (CSCO) saw prices fall from $80 per share to below $14 in nearly the same period.

We compared Bitcoin's appreciation through November 2017 to these three bubbles. Data for the Dutch Tulip Crisis was obtained from extant research (Garber, 1990; Thompson, 2007); the South Sea Bubble used both Garber's data (Garber, 1989) and data from the Yale International Center for Finance South Seas Bubble 1720 Project. Data for Cisco Systems was obtained from daily stock data accessible from the WRDS CRSP database. We examined the price appreciation and collapse over a 30-month period scaled with a common baseline of month 0 = 100 during the first month of available data (Yale 2017).

3.4. Bitcoin as a technology-based product, security, or commodity

This method compares the diffusion of Bitcoin, the Euro, Ether, and the security SPY. If the diffusion was r-shaped, then it occurred through environmental learning-based (individual learning-based) adoption; if the diffusion was s-shaped, then it occurred through cultural transmission-based adoption (Henrich, 2001). The large-scale diffusion of technology-based products generally occurs through cultural transmission and traces out s-shaped curves (Marinakis et al., 2017). The number of euros in circulation shows how currency diffuses. The time series of the total number of Bitcoin that have already been mined was obtained from Blockchain (Blockchain 2019). The time series of the diffusion of the number of Euro bank notes and coins was obtained from the European Central Bank website (ECB 2019). For further comparisons and insights, diffusion data of another cryptocurrency, Ether (Etherscan 2019), and of a security (an exchange traded fund), SPY (Ycharts 2019), were also obtained.

Unlike Ether, Bitcoin was not released as part of a programming platform that requires its use in order for programs to function. Users pay miners in Ether to run applications (i.e., record transactions) on the Ethereum blockchain, leading Ether to be compared allegorically to the oil or gasoline that is necessary to run an internal combustion engine. Commodities Futures Trading Commission chairman Heath Tarbet recently opined that he believes Ether is a commodity (Roberts, 2019). The Richards model was also applied to U.S. field production of crude oil from 1860 to present (USEIA 2019) and U.S. Corn production (USDA-NAS 2019). If the time series can be fit by a sigmoidal model, then the diffusion occurred through cultural transmission.

Table 1
Bitcoin Correlation to Major USD Currency Pairs, 1977–2016.

Panel A: Currencies Ranked by Highest Correlation to Bitcoin, 1977–2016

Rank	*Currency Pair*	*Currency*	*End Period*	*Correlation*
1	THB/USD	Thai Baht	Dec 2000	0.918
2	CAD/USD	Canadian Dollar	Aug 2001	0.903
3	KRW/USD	Korean Won	Dec 2000	0.880
4	ARS/USD	Argentine Peso	May 2005	0.874
5	GHS/USD	Ghanaian Cedi	Feb 2012	0.862
6	MYR/USD	Malaysian Ringgit	Dec 2000	0.862
7	VEF/USD	Venezuelan Bolivar	Mar 2013	0.855
8	AUD/USD	Australian Dollar	Apr 2001	0.849
9	MXN/USD	Mexican Peso	Jan 2012	0.847
10	SGD/USD	Singapore Dollar	Dec 2000	0.841
11	ESP/USD	Spanish Paseta	Jul 2000	0.840
12	JMD/USD	Jamaican Dollar	Feb 2012	0.838
13	TWD/USD	Taiwan New Dollar	Jan 2001	0.834
14	ISK/USD	Icelandic Króna	Nov 2011	0.831
15	JMD/USD	Jamaican Dollar	May 2006	0.830

Panel B: Currencies Ranked by Lowest Correlation to Bitcoin, 1977–2016

Rank	*Currency Pair*	*Currency*	*End Period*	*Correlation*
1	MYR/USD	Malaysian Ringgit	Oct 2010	−0.861
2	JPY/USD	Japanese Yen	Jun 1981	−0.859
3	PEN/USD	Peruvian Sol	Oct 2010	−0.855
4	ILS/USD	Israeli New Shekel	Jan 2011	−0.854
5	THB/USD	Thai Baht	Jun 2010	−0.848
6	SGD/USD	Singapore Dollar	Oct 2010	−0.848
7	PLN/USD	Polish Zloty	Dec 2007	−0.842
8	PEN/USD	Peruvian Sol	Oct 2007	−0.837
9	GBP/USD	British Pound	Jan 2007	−0.825
10	CNY/USD	Chinese Yuan	Apr 2011	−0.823
11	PHP/USD	Philippine Peso	Oct 2010	−0.823
12	CHF/USD	Swiss Franc	May 2014	−0.821
13	INR/USD	Indian Rupee	Dec 2007	−0.811
14	KWD/USD	Kuwaiti Dinar	Oct 2006	−0.806
15	JPY/USD	Japanese Yen	Dec 2011	−0.802

The data analysis for this paper was generated using SAS software, Version 9.3 of the SAS System for Unix. Copyright © 2012 SAS Institute Inc. SAS and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA. The Richards model was fit to the data using SAS Proc NLIN (SAS Institute Inc. 2013).

4. Results

4.1. Bitcoin as currency

In Panel A, we present an overview of the currencies ranked by their highest correlation to Bitcoin. *End Period* marks the last month in the 77-month correlation period. For simplicity, adjacent months from the same currency pair with slightly lower correlations were omitted from the table. For example, the *End Period* Nov 2003 CNY/USD correlation was 0.920, but it was omitted from the table for being representative of the same economic period and circumstances. We define adjacent periods as occurring within six months of the period of maximum or minimum correlation in Table 1. The most interesting observation is the large correlations between several historical currencies and Bitcoin: the Malaysian Ringgit through October 2004, the Bermudan Dollar through March 2011. When Bermuda dropped the *Bermuda Pound* in favor of the *Bermuda Dollar* in the early 1970s, it pegged the currency at 1:1 to the US Dollar. Likewise, the Malaysian Ringgit was temporarily pegged to the US Dollar from 1998 to 2005 at 3.80 Malaysian Ringgits per dollar. The correlation is imperfect, because while Bitcoin is expressed is relative value to dollars, Bitcoin itself does not move *with* the US Dollar. While the directional variation of these currencies was similar (all demonstrated extended periods of appreciation), the magnitudes of the currency changes were substantially lower than the substantial month-

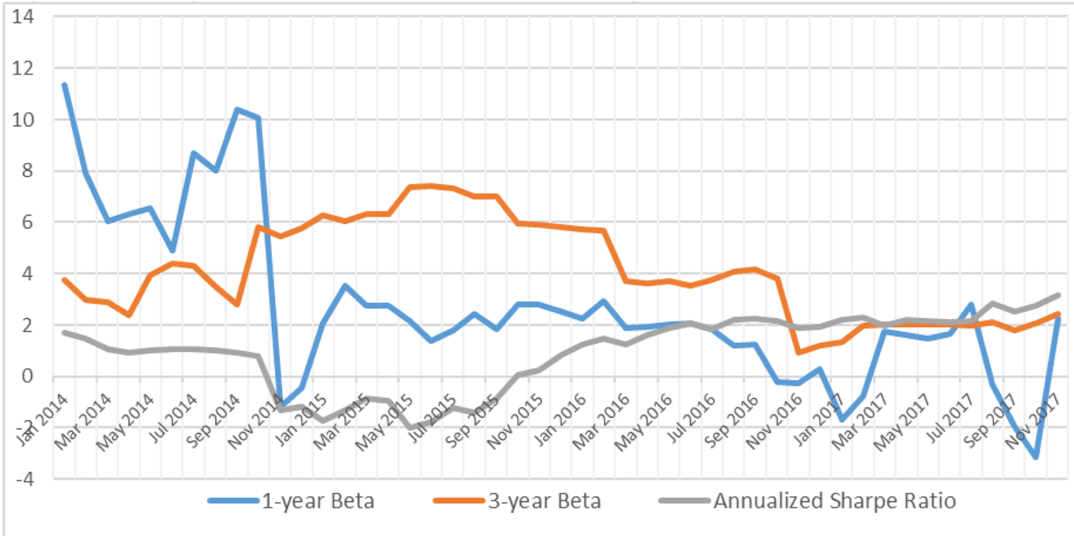


Fig. 1. Rolling 1-year Betas, 3-year Betas, and Sharpe Ratios for Bitcoin from 2014–2017.

on-month volatility associated with Bitcoin.

Similarly, Panel B ranks the least correlated currencies to Bitcoin since 1977. Particularly with regards to the Hungarian Lempira and Russian Ruble, the 77-month periods coincided with substantial declines in the currency's value relative to the dollar. The vast majority of currencies most and least correlated to Bitcoin are usually developing currencies in times of substantial economic and political volatility.

Although these results are interesting, the correlations not only do not imply causation, but in many cases the links are spurious. Long-term currency appreciation has been seen in other currencies. However, Bitcoin's magnitude of appreciation has no precedent in the post-Bretton Woods era.

4.2. Bitcoin as an asset class

We present our analytical results in Fig. 1 and Table 2 below. Major currencies are highlighted in green and commodities are highlighted in yellow. We display in Fig. 1 Bitcoin's Sharpe Ratios, along with 1- and 3-year Rolling Betas, to see if Bitcoin is more or less volatile than the market as a whole (Petkova and Zhang, 2005). We use Rolling Betas and Sharpe Ratios monthly data from January 2014 to November 2017 in our analysis. We show our results below in Fig. 1. Bitcoin is shown to be more volatile than other instruments.

We supplement Fig. 1 visual data with a more precise discussion in Table 2. Bitcoin's One-year Betas, computed with monthly data, were highly volatile. Bitcoin's reported Betas are greater than 10 as late as November 2014 and are below zero (indicating an opposite risk correlation to the market) several times in 2017. Bitcoin's 3-year Betas were demonstrably more consistent and mathematically appropriate. For much of 2015, Bitcoin's high Beta values were nearly unprecedented, even when compared to other mid-cap and large-cap equity securities. However, by late 2016, Bitcoin's Betas dropped to around 2. This is a higher-than-average risk security, but not significantly riskier than some stocks frequently held by investment managers in portfolios (for comparison, as of December 2017, AMD reported a beta of 2.44 and Brazilian energy firm Petrobras 2.41). From a Beta standpoint, we show Bitcoin to be a broadly investible commodity since the beginning of 2017.

When we calculated the Sharpe Ratio for both Fig. 5 and Table 2, our results were similar. Bitcoin's annualized Sharpe Ratio languished until early 2016, when it approached and exceeded a value of 2. This value makes Bitcoin a potentially desirable asset from a reward-for-risk perspective. This exceeded the market risk-free rate substantially. Further, Bitcoin's total volatility (relative to its return) was at manageable levels for high returns. In this respect, Bitcoin resembles a high-risk, high-return asset highly correlated to derivative indices and inversely correlated to major currencies. Moreover, the improvement of its portfolio metrics corresponded to the beginning of its rapid appreciation in 2017, suggesting a predictive framework exists for determining cryptocurrency value.

4.3. Bitcoin as a bubble

We analyzed the financial failure patterns of: Tulipmania from 1634 to 1637; the South Sea Bubble 1720 to 1722; and Cisco 1998 to 2000, since they are well-studied financial bubbles. We next analyzed the Bitcoin scaled value data. We display our results in real and logarithmic terms in Fig. 2 Panel A and Fig. 2 Panel B below.

We measure Bitcoin against these bubble events. We chose two older bubble events – the South Sea Bubble and the Tulipmania Bubble – and a much more recent bubble event – Cisco. Bitcoin's imposed pattern shows that it is acting as a “bubble event”, but at a scale that is much larger than ever before relative to their pre-bubble asset prices.

4.4. Bitcoin as a technology-based product, security, or commodity

Does Bitcoin act as a technology-based product? Technology diffusion patterns can be fit by the Richards Model (Richards, 1959). The Richards model was fit to the total number of Bitcoins (Fig. 3, Tables 3a, 3b). Bitcoin minting is scheduled to terminate at 21 million Bitcoins, but the forecast shows that minting will asymptote at 18 million Bitcoins. Bitcoin minting approaches its asymptote somewhere between 2000 and 3000 days after its initial introduction. Average Bitcoin block size reaches its asymptote 4000 days after its initial introduction. Bitcoin blockchain size reaches its asymptote more than 5000 days after its initial introduction.

For contrast, the diffusion curve of the Euro is distinctly r-shaped rather than sigmoidal (Fig. 4). This finding was validated by the inability to fit the Richards model to the data. Per (Antweiler, 2019), this result suggests the working hypothesis that currencies diffuse through environmental (individual) learning rather than through cultural transmission. Further initial currency offerings will need to be examined to validate this hypothesis. The diffusion curve of the cryptocurrency Ether is also r-shaped (Fig. 5) and could not be fit by the Richards model. The fact that cryptocurrencies are differentiated by their diffusion patterns suggests that they are differentiated in terms of their

Table 2

Bitcoin Correlation Table Between Bitcoin and Major Market Indicators

In this table, we show the correlation of Bitcoin prices with major market indicators in three different time periods ending on December 31, 2016. The first period begins on August 17th, 2010 when data became available; the second period begins on March 13, 2013, the week when Bitcoin achieved a market capitalization of $500 Million; the third beings on January 1, 2015.

Symbol	Key Description	August 17, 2010 - December 31, 2016 Coin	Correlation	Significance	March 13, 2013 - December 31, 2016 Coin	Correlation	Significance	January 1, 2015 - December 31, 2016 Coin	Correlation	Significance
bfly	CBOE S&P 500 Iron Butterfly Index	bitcoin	1.000	0.000	bitcoin	1.000	0.000	bitcoin	1.000	0.000
bitcoin	Bitcoin	bxysm	0.805	0.000	bxysm	0.516	0.000	bxmd	0.873	0.000
bnd	US Aggregate Bonds	bxmd	0.802	0.000	cmbo	0.487	0.000	putsm	0.870	−0.018
bndx	International Bonds	cmbo	0.800	0.000	bxmd	0.486	0.000	cllz	0.847	0.000
bxmd	CBOE S&P 500 30-Delta BuyWrite Index	cllz	0.799	0.000	cllz	0.470	0.000	cmbo	0.818	0.000
bxmsm	CBOE S&P 500 BuyWrite Index	sptr	0.795	0.000	putsm	0.463	0.000	bxmsm	0.814	0.000
bxysm	CBOE S&P 500 2% OTM BuyWrite Index	spy	0.793	0.000	bxmsm	0.456	0.000	xlk	0.798	−0.008
cll	CBOE S&P 500 95–110 Collar Index	spxsm	0.793	0.000	xlk	0.407	−0.944	bxysm	0.775	0.000
cllz	CBOE S&P 500 Zero-Cost Put Spread Collar	putsm	0.791	0.000	sptr	0.406	0.000	sptr	0.738	0.000
cmbo	CBOE S&P 500 Covered Combo Index	bxmsm	0.789	0.000	spy	0.398	0.000	bndx	0.728	0.000
cndr	CBOE S&P 500 Iron Condor Index	pput	0.787	0.000	spxsm	0.398	0.000	spxsm	0.570	0.000
cyb	Chinese Yuan	xlk	0.777	0.000	pput	0.356	0.000	spy	0.565	0.000
euo	UltraShort Euro	cll	0.766	0.000	cll	0.295	0.000	bfly	0.484	0.000
fxb	British Pounds	nfo	0.705	0.000	bfly	0.238	0.000	slv	0.462	0.000
fxe	Euro	shy	0.491	0.000	bndx	0.231	−0.002	gld	0.403	0.000
gld	Gold	uup	0.363	0.000	nfo	0.199	0.000	mub	0.351	−0.621
jnk	Junk Bonds	euo	0.267	0.000	mub	0.140	−0.003	pput	0.237	0.000
mub	Munincipal Bonds	mub	0.258	0.000	shy	0.134	−0.009	bnd	0.167	0.000
nfo	Investor Sentiment	bndx	0.231	0.000	bnd	0.003	0.000	uup	0.135	0.000
pput	CBOE S&P 500 5% Put Protection Index	bnd	−0.235	0.000	fxe	−0.014	0.000	euo	0.069	0.000
putsm	CBOE S&P 500 PutWrite Index	cndr	−0.284	0.000	uup	−0.024	−0.365	shy	0.031	0.000
shy	Short Term Treasuries	jnk	−0.292	0.000	euo	−0.039	0.000	nfo	−0.036	0.000
slv	Silver	vxosm	−0.401	0.000	udn	−0.042	−0.758	cll	−0.150	0.000
sptr	S&P 500® Total Return	vix	−0.408	0.000	slv	−0.060	−0.003	vix	−0.281	0.000
spxsm	S&P 500®	fxb	−0.411	0.000	gld	−0.072	−0.196	vxosm	−0.322	0.000
spy	S&P 500	fxe	−0.441	0.000	cndr	−0.104	−0.024	jnk	−0.414	0.000
udn	US Dollar Bear	cyb	−0.459	0.000	jnk	−0.121	−0.120	fxe	−0.452	0.000
uso	Crude Oil	uso	−0.516	0.000	uso	−0.136	−0.606	udn	−0.474	0.000
Uup	US Dollar	udn	−0.522	0.000	vix	−0.196	0.000	cndr	−0.555	0.000
vix	Volatility	bfly	−0.561	0.000	fxb	−0.213	−0.401	uso	−0.700	−0.033
vxosm	CBOE S&P 100 Volatility Index	gld	−0.643	0.000	vxosm	−0.244	0.000	cyb	−0.808	−0.575
xlk	SPDR Tech Sector ETF	slv	−0.674	0.000	cyb	−0.487	0.000	fxb	−0.919	−0.272

elemental nature, i.e., Bitcoin is more like a technology-based product and Ether is more like a currency. The diffusion curve of SPY is r-shaped and could not be fit by the Richards model (Fig. 6), suggesting SPY is also more like a currency than a technology-based product.

U.S. field production of crude oil from 1860 to present does appear sigmoidal (Fig. 7; 89) but the Richards model was unable to fit it, probably due to the upturn near the end of the data. The Richards model was able to fit U.S. Corn production (Fig. 8; Tables 4a, 4b; 90).

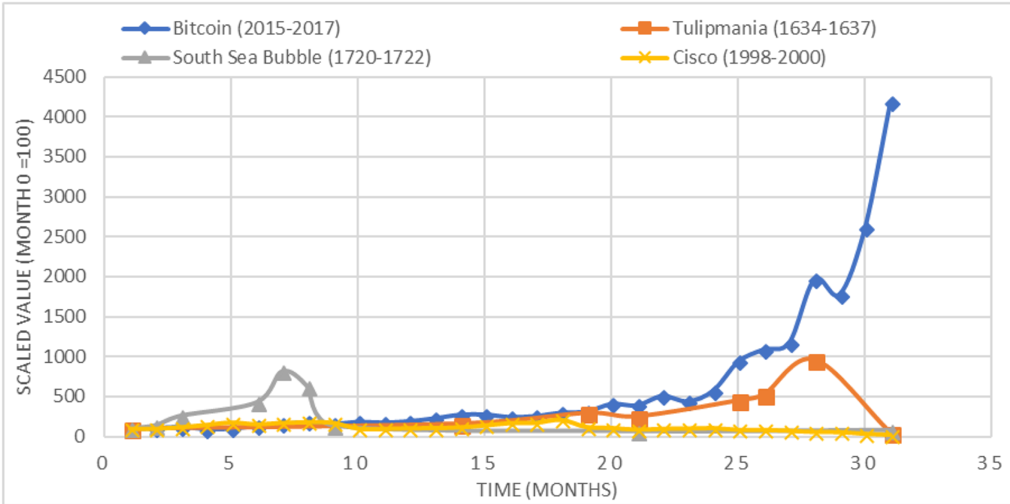
5. Discussion

Is Bitcoin a currency, a technology-based product, or something else? Abductive reasoning suggests that Bitcoin's behavior more closely resembles a technology-based product, an emerging asset class, or a bubble event, rather than a currency or a security. It is unclear whether it is a commodity.

As a currency, Bitcoin fails as a unit of account, despite its rapidly appreciating physical and transactional value. The high correlation of Bitcoin to derivative indices suggests significant speculative elements in its valuation, making absolute economic valuation difficult. At the same time, its inverse correlation to major currencies and competitive risk/return characteristics make it a viable portfolio investment. Expansion of the options and futures markets to include Bitcoin will enable greater arbitrage between exchanges and could improve both market liquidity and pricing in the future. Bitcoin behaves like a risky emerging asset class, with high persistent correlations to derivative indices and an inverse relationship to major currencies. In fact, Bitcoin behaves unlike any national currency over at least the last 40 years. The return-for-risk profile has improved substantially since 2015, making Bitcoin potentially appealing as a portfolio investment instrument. However, its resemblance to several historical asset price bubbles poses substantial risks.

When compared to other widely-accepted bubbles, Bitcoin exceeds all others in length and magnitude. The rapid appreciation of Bitcoin, particularly in 2017, has been unprecedented when compared to price increases among historical bubbles. This does not necessarily lead to a valuation market, since Bitcoin certainly possesses some underlying transactional economic value in parallel markets. However, even among economically-viable entities like the South Sea Company in the 18th century or Cisco in the 21st century, substantial price collapses

Panel A: Actual Values with Month 0=100.



Panel B: Logarithmic Values with Month 0=100.

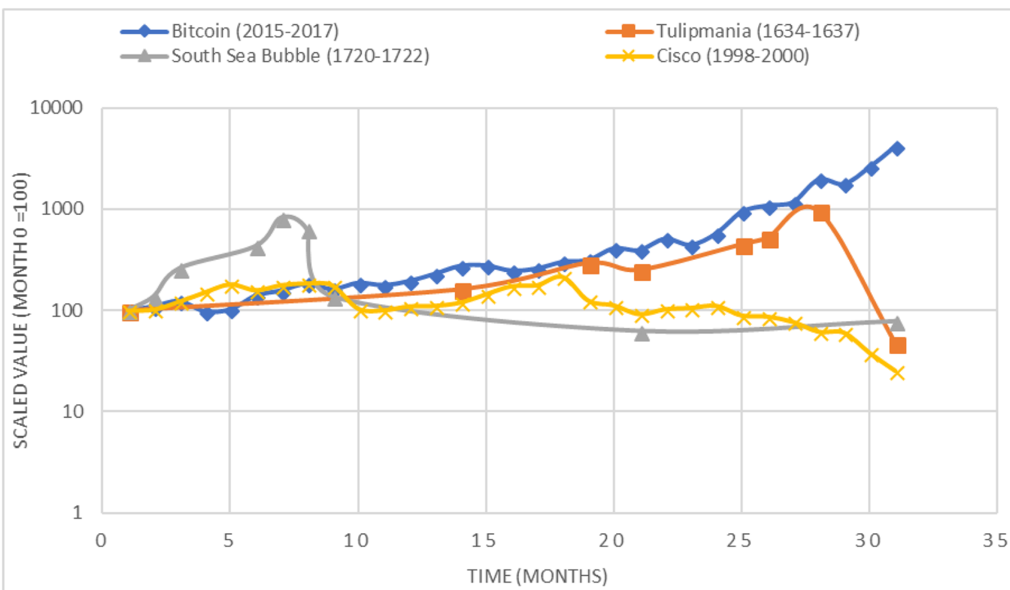


Fig. 2. Panel A, 30 Months of Asset Price Bubble Valuations.

followed periods of rapid appreciation. Applying the most relevant research definitions (Glaser et al., 2014; Brière et al., 2015; Wu et al., 2014; Sugden et al., 1981; Godsiff, 2015; Case and Shiller, 2003; Tu and Meredith, 2015), it appears Bitcoin does indeed suffer from a hazard of great expectations to its future price. Historically, this has been an unsustainable position for such assets. While the collapse of cryptocurrency prices could be severe (as during the technology bubble of 1997–2001), the resulting market will be healthier and more grounded in rational economic value. The market will also determine which of the emerging cryptocurrencies possess the greatest value in the future blockchain economy. Bitcoin's true valuation lies between its basest role as black market tender and the possibility of becoming a globally-recognized alternative currency.

The diffusion of Bitcoin can be modelled by the sigmoidal Richards function. Combined with the finding that the diffusion of the Euro traced out an r-shaped curve rather than a sigmoidal curve, these results suggest that Bitcoin is diffusing like a technology-based product rather than like a currency.

The diffusions of the security SPY and the cryptocurrency Ether were shown to trace out r-shaped curves, suggested that Bitcoin also differs from them in its elemental nature. There has been some disagreement over whether Bitcoin is a security (Michaels, 2018). The present study suggests that Bitcoin does not diffuse like a security, or at least not like SPY. The question of whether Ether or Bitcoin is a commodity remains unresolved and will require more extensive analyses of more diffusion data. Crude oil appeared sigmoidal but could not be fit by the Richards model, and corn did not appear sigmoidal but could be fit.

Since Bitcoin's behavior more closely resembles a technology-based product, an emerging asset class, or a bubble event, then it is correct that existing currency and security laws and regulations should not be applicable to it. If it is deemed desirable to apply laws to it such as the

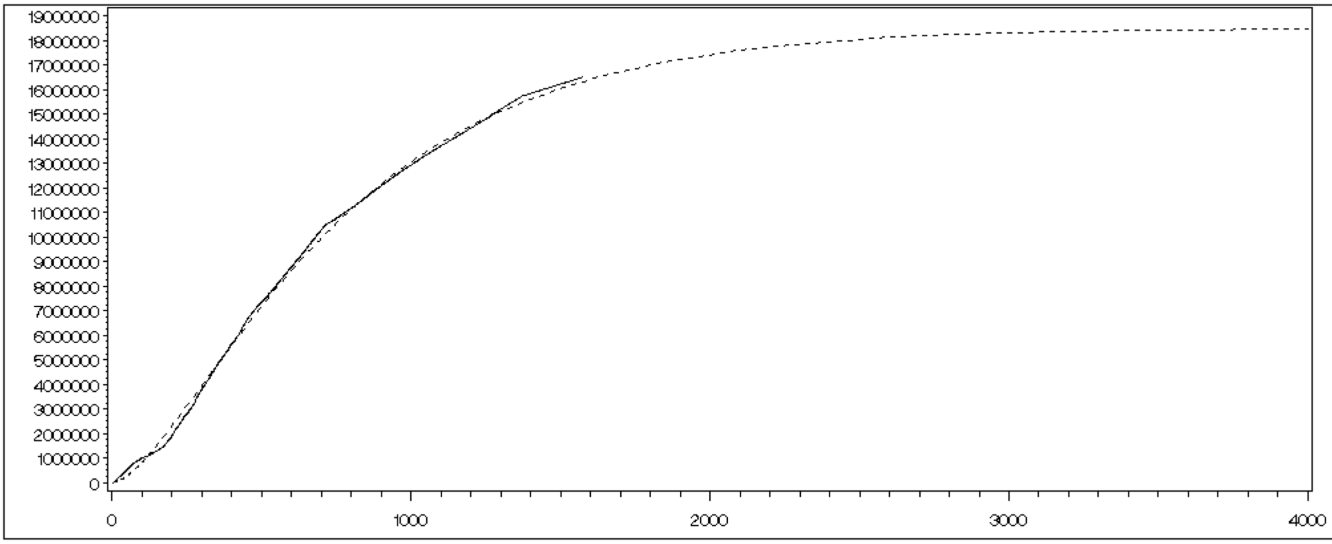


Fig. 3. Total number of Bitcoins that have already been mined. Solid line shows data (Gervais et al., 2014), day 1 to 1573. Dashed line shows model, days 1 to 4000.

Table 3a
Richards model parameters for the data sets of the total number of Bitcoins.

Parameter	Estimate	Approx. Std. Error	Approx. 95% Confidence limits	
M	0.6000	0.0171	0.5665	0.6335
W	18,000,000	41,994.1	17,917,617	18,082,383
T	18,500 (observation 201, August 26, 2010)	20.22	18,460.3	18,539.7
K	0.001000	0.000013	0.000975	0.001020

Table 3b
Richards model goodness-of-fit for the total number of Bitcoins.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > *F*
Model	4	2.07E+017	5.18E+016	603,870	<0.0001
Error	1308	1.12E+014	8.575E10		

Bank Secrecy Act, then it will be necessary to revise those laws. Such revision would be unprecedented as there are currently no technologies or asset classes that are regulated as currencies. To avoid such an overly broad and likely controversial measure, it is advisable rather that such revision be narrowly tailored to encompass only currency-like cryptocurrencies such as Ether, to the exclusion of asset class-like cryptocurrencies such as Bitcoin.

6. Conclusion

While Bitcoin resembled some emerging market currencies in its long and sustained appreciation, the magnitude of Bitcoin's appreciation has been unprecedented. Contrary to its common classification as a commodity, Bitcoin remains most closely related to option indices and inversely correlated to major currencies. Bitcoin's rapid asset appreciation has exceeded the most prominently-studied historical bubbles of the last three hundred years, posing substantial hazards in the near

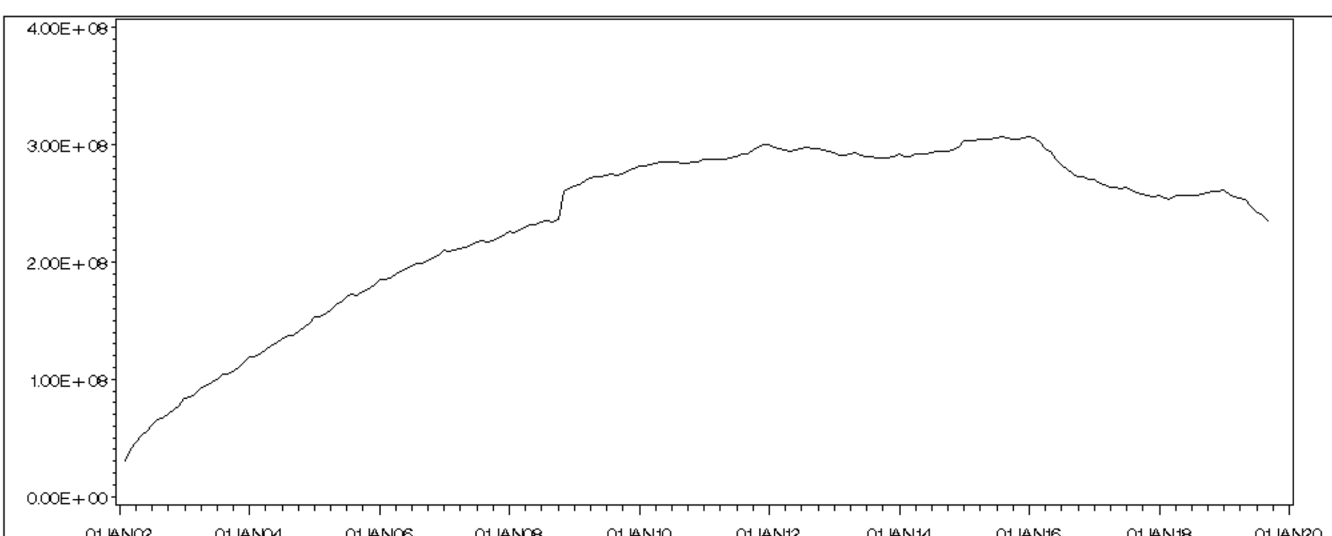


Fig. 4. Diffusion (net circulation) of the Euro.

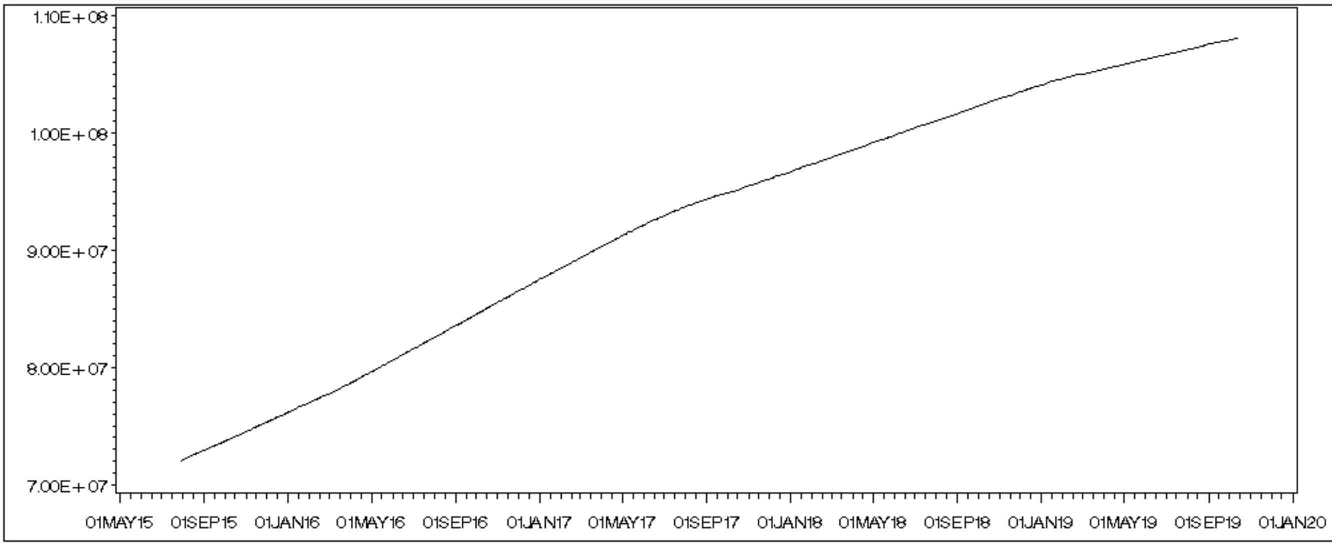


Fig. 5. Diffusion of Ether.

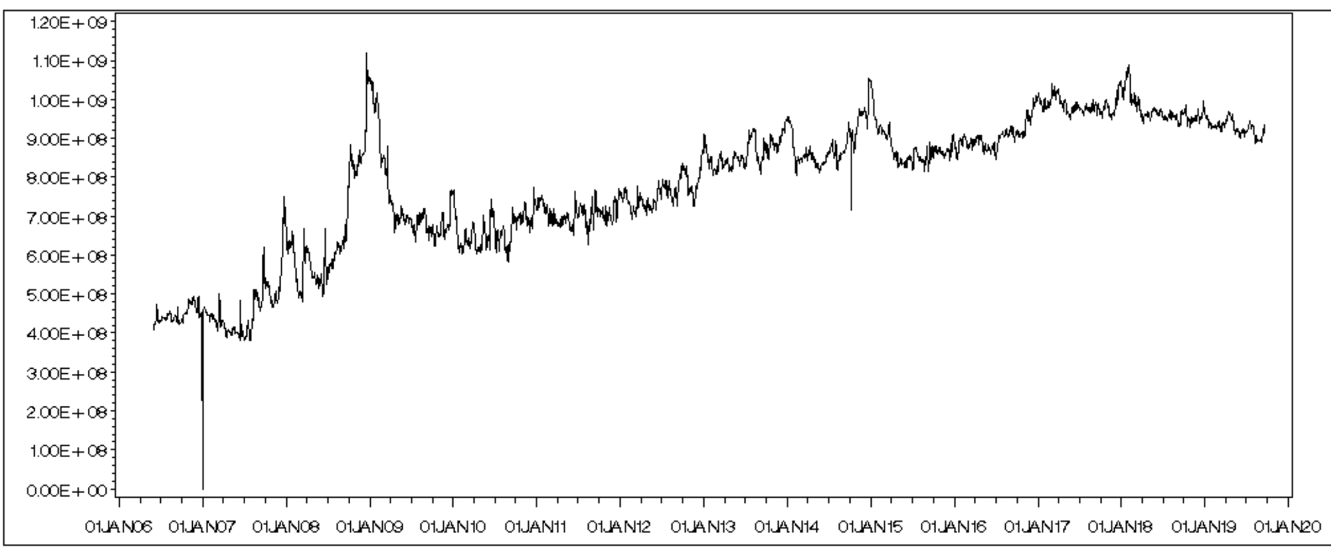


Fig. 6. Diffusion of SPY Shares Outstanding.

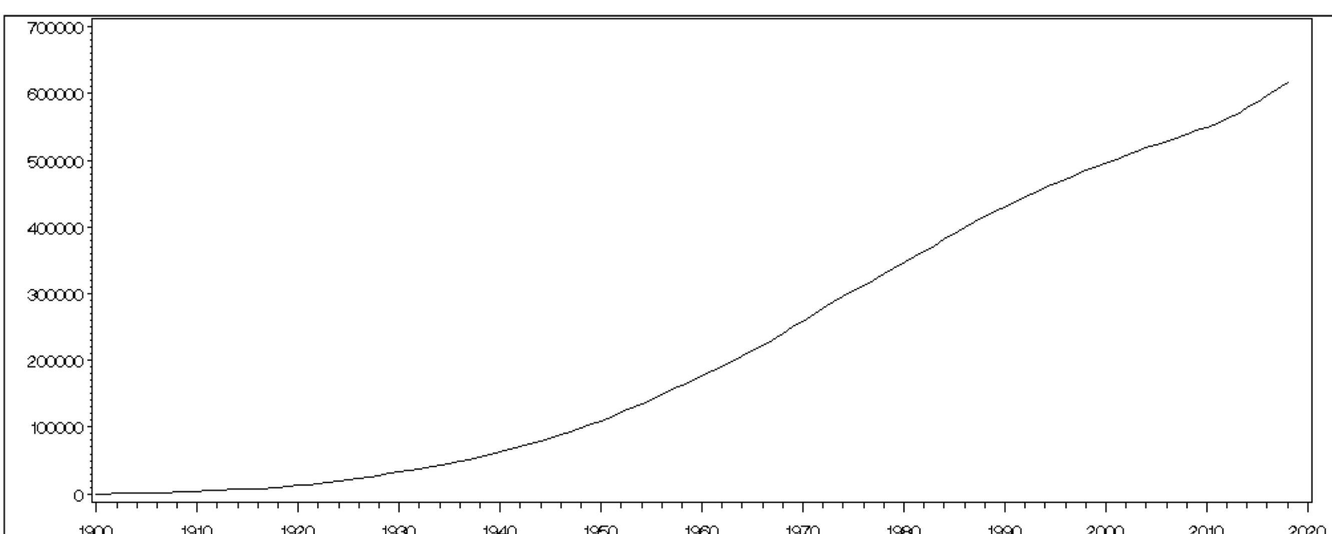


Fig. 7. Diffusion of Crude Oil in the U.S.

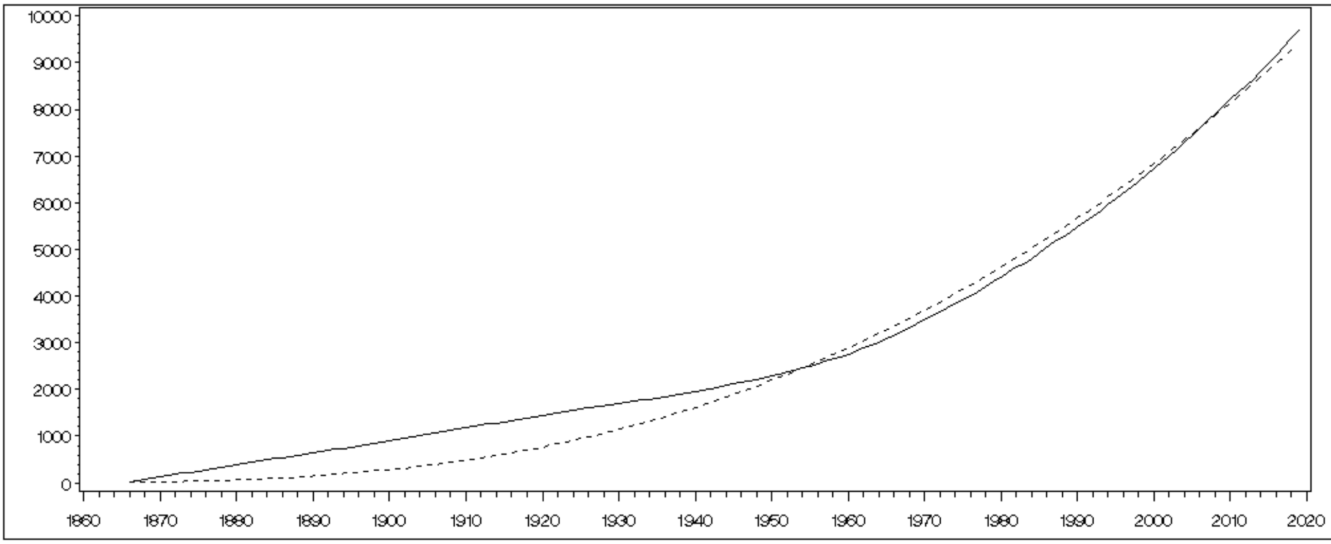


Fig. 8. Diffusion of Corn in the U.S. Solid line is data and dashed line is the Richards model.

Table 4a
Richards model parameters for the diffusion of corn in the U.S.

Parameter	Estimate	Approx. Std. Error	Approx. 95% Confidence limits	
M	0.7000	0.2804	0.1459	1.2541
W	320,000	1,661,097	−2,962,170	3,602,170
T	2300	931.7	459	4141
K	0.002500	0.007220	−0.011800	0.016800

Table 4b
Richards model goodness-of-fit for the diffusion of corn in the U.S.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > *F*
Model	4	2.37E+009	5.93E+008	3874.63	<0.0001
Error	150	2.29E+007	152,960		

future for investors and technologists alike.

The present study contributes to the theory of currencies, in part by clarifying what is not a currency. It contributes to the theory of cryptocurrencies by empirically classifying the behavior of a leading cryptocurrency. It contributes to the theory of technology by applying technology diffusion theory to a hybrid techno-financial instrument.

We have many unanswered questions about Bitcoin that present future avenues for research. Valuation models for cryptocurrencies are nearly absent from the literature, and their development would help clarify many of the valuation fundamentals that remain unknown. In our research, we found that lower Bitcoin Betas and higher Sharpe Ratios corresponded with the beginning of Bitcoin's rapid recognition as a viable investment commodity in 2017. Identifying and predicting these characteristics would be useful for investors during the transition period from a closely-held niche technology to highly-valued asset class. We are just beginning to grasp the implications of blockchain technology and cryptocurrency. Significant work must be accomplished before the potential of these technologies is realized.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.techfore.2019.119877.

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