

Fiat Money, Cryptocurrencies and the Pure Theory of Money

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Abstract: This paper attempts to account for the rising value of cryptocurrencies using basic concepts of monetary theory. A positive value of fiat money is itself problematic inasmuch as that value apparently depends entirely on its expected resale value. A current value entirely dependent on expected future resale value seems inconsistent with backward induction. While fiat money can avoid the backward-induction problem if it is made acceptable in payment of taxes, acceptability for tax payments is unavailable to cryptocurrencies. Is the rising value of bitcoin and other cryptocurrencies a bubble? The paper argues that network effects may be an alternative mechanism for avoiding the logic of backward induction. Because users of any good subject to substantial network effects incur costs by switching to an incompatible alternative to the good currently used, users of a bitcoin for certain transactions may be locked into continued use of bitcoin despite an expectation that its future value will eventually go to zero. Thus, even if bitcoin and other cryptocurrencies are bubble phenomena, network effects may lock existing users of bitcoin into continued use of bitcoin for those transactions for which bitcoins provide superior transactional services to those provided by conventional currencies. Nevertheless, the prospects for bitcoin's expansion beyond its current niche uses are dim, because its architecture implies that a significant expansion in the demand for its transactional services would lead to rapid appreciation that is incompatible with service as a medium of exchange.

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I Introduction

My primary aim in this paper is to account for the value of bitcoins and other cryptocurrencies, using the basic concepts and doctrines of the economic theory of money. These concepts and doctrines are by no means entirely settled or uncontroversial, but I shall attempt to apply them to best of my understanding, while noting possible alternative understandings and interpretations of those concepts and doctrines. Although I shall be applying some advanced theoretical concepts, my argument will be informal and intuitive rather than rigorously abstract and deductive.

The theoretical problem that this paper aims to illuminate is how a pure medium of exchange -- an instrument or asset that provides no service other than to be held in the expectation that it will be readily accepted by others whenever offered in exchange -- can command and maintain a positive value. This problem has been discussed in various ways and I will take two such approaches as my starting point: (1) the backward-looking regression theorem of von Mises ([1913] 1934) and (2) the forward-looking (despite its name) backward-induction principle of von Neumann and Morgenstern (1944). The second approach seems to imply that a pure medium of exchange cannot have a positive equilibrium value, which implies that bitcoin and cryptocurrencies are a bubble phenomenon. [Two competing explanations have been advanced: (1) that money has evolved from real commodities that provide valuable services that give them value and independent from their medium-of-exchange function (Menger 1890), and (2) that money is a creature of the state which imparts value to money by accepting it as payment for the tax liabilities it imposes on those subject to its jurisdiction.] This paper will therefore focus on how a positive equilibrium value for bitcoin or other cryptocurrencies might be rationalized.

To do so, I will consider another key characteristic of a medium of exchange: the demand of any individual for any medium of exchange increases as the demand of other individuals for that medium of exchange increases. This interdependence of individual demands for a medium of exchange is called a network effect. It is precisely this network effect that enables a medium of exchange to discharge its primary function: to be accepted routinely when offered in exchange for other goods, assets or services. But one consequence of network effects is that users of a good characterized by network will incur a cost if they switch to an alternative product. The switching cost tends to lock users of such a good into its continued use. Switching costs and their resulting lock-in effect may provide some resistance to the backward-induction reasoning the implies that a pure medium of exchange cannot have a positive equilibrium value.

However, in accounting for the value of a pure medium of exchange, we must still overcome a bootstrapping problem: how can a medium of exchange provide the service of acceptance in exchange if it does not have a resale value apart from its medium-of-exchange function? Where does such acceptance come from and what ensures its durability? Is the willingness to accept a medium of exchange and the demand to hold that medium of exchange on

which it is predicated simply a will of the wisp? This is a question that a theory of cryptocurrencies, unlike conventional monetary theories, cannot avoid.

Bootstrapping is a problem not only cryptocurrencies; it is a problem for fiat currencies. So, before addressing the problem for cryptocurrencies, I will first consider, in Section II, how the problem has been addressed for fiat currencies, explaining why past attempts to account for the value of fiat money as a carryover from the value of commodity monies do not effectively counter the backward-induction principle. Although applied to a fiat currency, the underlying assumptions of the backward-induction argument are not satisfied, the argument at least suggests that a positive value for fiat money is fragile and potentially unstable. In section III, I explore an alternative, and more credible, explanation for a durable and stable positive value of fiat money: acceptability in discharging tax liabilities. Because cryptocurrencies are not acceptable in discharging tax liabilities, the question is raised in section IV how cryptocurrencies can overcome the bootstrapping problem discussed in section II. Providing no service other than acceptance in exchange and not being acceptable in discharging tax liabilities, bitcoin seems very much subject the backward induction argument, which strongly suggests that the huge appreciation of bitcoin and other cryptocurrencies is a bubble phenomenon, not unlike the tulipmania of seventeenth century Holland. In section V, I argue that, if there is a class of transactions for which cryptocurrencies provide transactional services superior to those provided by conventional currencies, the combination of network effects and lock-in may circumvent the bootstrapping problem. In section VI, I consider whether network effects and lock in can enable bitcoin to retain positive value despite the tendency of backward induction to cause a collapse of its value. In section VII, I apply this analysis to bitcoin and other cryptocurrencies, but noting that even if network effects and do enable bitcoin to remain a viable niche currency for a narrow class of transactions, the potential effectiveness of bitcoin as a medium of exchange has been undermined by rapid appreciation, because the bitcoin architecture allows the quantity of bitcoins to expand in response to growing demand without further bitcoin appreciation. This architectural defect means that bitcoin is now held primarily in anticipation of further appreciation, thereby rendering bitcoin unsuitable to serve as a medium of exchange. In section VIII, I explore whether an alternative cryptocurrency designed to maintain a stable value might be better suited than bitcoin to expand its user-base and fulfill the ambitions of cryptocurrency enthusiasts to displace fiat currencies in general, and the dollar in particular, as the dominant media of exchange. I conclude in section IX.

II Accounting for the Value of Fiat Money

In the economics [column](#) he used to write for the *New York Times*, Hal Varian (2004) once posed the question “Why Is that Dollar in Your Wallet Worth Anything?” The first answer he considered is the one that most people probably believe: the government makes the dollar worth something by declaring it legal tender. The problem with that answer, Varian observed, is that legal tender laws notwithstanding, nothing prevents those preferring to use another medium of exchange from executing transactions or discharging with a different asset (e.g., gold or silver) or a different currency (e.g., Swiss franc). If people preferred to execute transactions with another medium of exchange, legal tender laws would not prevent them from agreeing to do so.

And if everyone preferred to execute transaction with something other than the dollar, the value of the dollar would plummet, despite its legal-tender status.

Varian then proposed an alternative explanation, suggesting that people accept fiat money as a social convention. In other words, the expectation that people will accept payment in dollars creates mutually reinforcing expectations, what we now call a network effect, thereby inducing convergence on a common expectation. Writing in the aftermath of the US invasion of Iraq, Varian cited the experience of Kurdistan, which, upon gaining de facto autonomy from Iraq after the first Gulf war, continued using the old Iraqi dinar as its local currency even after Saddam Hussein introduced a new currency that became the legal currency in the parts of Iraq that remained under Saddam's control until his overthrow.

Varian's column elicited a [response](#) from Frank Shostak (2004) which made a powerful objection to Varian's explanation of the value of fiat money.

To say that the value of money is on account of social convention is to say very little. In fact, what Varian has told us is that money has value because it is accepted, and why is it accepted? Because it is accepted! Obviously, this is not a good explanation of why money has value.

To bolster his thesis Varian suggests that the value of the dollar is a result of the "network effect." According to him, "Just as a fax machine is valuable to you only if lots of other people you correspond with also have fax machines, a currency is valuable to you only if a lot of people you transact with are willing to accept it as payment."

Instead, to explain why anyone would accept fiat money in the first place, Shostak invoked what is known as the Regression Theorem proposed by Ludwig von Mises ([1913] 1934). According to Mises, the demand for any money, i.e., an asset demanded solely because it is accepted in exchange, not for any direct service that it provides, is contingent on its having had a positive value prior to its acceptance in exchange. The Regression Theorem therefore claims that the demand for every medium of exchange can be traced to a time when the value of the asset was not a medium of exchange and its value stemmed from its real (i.e., non-monetary) uses.¹

But if so, how can we account for the value of a fiat money that does not, has not, and never did, provide any real services from which its value as a medium of exchange could have been derived? More problematic than the failure of the Regression Theorem to provide a valid deductive argument for a historical conjecture about the origins of fiat money is that the Regression Theorem fails to address an even more serious problem in accounting for the value of fiat money, the problem raised by Varian and for which he struggled to find an answer: why does a fiat money, regardless of how it might once have become valuable, retain that value? The Regression Theorem, as its name attests, is backward-looking. But economic problems, as Austrian economists are usually quick to point out, are prospective, not retrospective. Whether a fiat money once had value is irrelevant explaining why, and how, it retains its value.

¹ Davidson and Block (2015) make a similar point concerning the conventional interpretation of the Regression

Why should a fiat money not be able to retain value? As I observed above, for a pure medium of exchange, a fiat money, to have value, it must be widely expected that it will be accepted in exchange by someone else. Without that expectation, a fiat money would lose its value; no one would accept in exchange.

Consider the following thought experiment. The world will not last forever. At some point before the world comes to its end, the end will be foreseen. When the end is foreseen, no one any longer would willingly accept a pure medium of exchange, a medium of exchange ceasing to have value when there is no one to accept it. Who would want to be the last one to accept a medium of exchange? The certain expectation that money will lose its value would cause the value of money to fall to zero -- immediately. This type of reasoning, known as backward induction, telescopes the anticipated loss of value back to the present.

To be sure, the backward-induction argument rarely convinces anyone that fiat money can't retain value. The main reason that it is unpersuasive is that the end of the world, even if it is regarded as a certainty, appears so remote, opaque and conjectural that no one feels confident in drawing any definitive inference about a sudden loss in the value of fiat money.

But my interpretation of the backward-induction argument is that it implies that the value of a fiat money is a kind of bubble. Although the bubble may be maintained, contrary to the strict logic of the backward-induction argument, for a considerable length of time, there is a positive probability that the bubble will burst at any moment. A positive value for fiat money may be no less a bubble than tulips were in seventeenth-century Holland,² or houses in twenty-first-century America. People may continue to accept money under a false expectation that they will always be able to find another person willing to accept it. But at some point, an expectation that was once held confidently may be disappointed.

Even if a positive value for fiat money is not impossible, that positive value may be an unstable quasi-equilibrium. Network effects may also have an effect on the existence and stability of an equilibrium, but before considering the role of network effects, I first want to discuss an explanation, not mentioned by Varian, for the continuing positive value of fiat money: the acceptability of fiat money as payment for tax liabilities.

III The Value of Fiat Money and Tax Liability

In the previous section, I argued that conventional explanations for the positive value of fiat moneys -- legal tender and social convention -- are not fully satisfactory. Although not necessarily inconsistent with the pure logic of choice, a positive value for fiat money seems, at a minimum, to be a fragile and unstable equilibrium, given the potentially volatile expectations on which it depends and the eventual worthlessness of a pure medium of exchange looming beyond

² Earl Thompson (2007) argued that the tulip bubble, almost universally considered the result of popular delusion, was in fact a rational response to a short period in which prices in futures contracts were legally, and temporarily, converted into options exercise prices. I neither endorse nor contest Thompson's claim here; I merely cite the tulip price increase and decline as a familiar example of price behavior thought to be characteristic of a bubble phenomenon.

the horizon. Is it possible to ground the value of fiat money on a more solid foundation than just uncertainty about when the world will come to an end?

In fact the acceptability of inconvertible fiat money as payment of tax liabilities has long been an explicit assumption made by economic theorists in accounting for the value of fiat money. Although he generally viewed money as either a precious metal or a financial instrument, convertible into a precious metal, Adam Smith (1776), without extended discussion, made the matter of fact assumption that a government could impart value to its inconvertible fiat money by accepting that money in payment for tax liabilities owed to itself.³

A more detailed and sophisticated affirmation of the role played by the acceptability of fiat money in payment of taxes was provided by one of the leading early neoclassical economists, P. H. Wicksteed. Wicksteed (1910) analyzed the conditions under which the government may impart value to inconvertible fiat notes that provide no service other than general acceptability in exchange. Wicksteed began by supposing that the government declares those notes to be legal tender whereby monetary obligations incurred in terms of some already acceptable medium of exchange (gold, in Wicksteed's account) may be legally discharged. Such a fiat money could have value, because by enabling people to discharge debts using the newly issued fiat currency, the newly issued currency would be as valuable to them as the value of the debts they would otherwise have to discharge with gold. However, insofar as creditors would anticipate that the debts owed them could be discharged with fiat money, they would begin to specify that their contractual obligations would thenceforward only be satisfied by payment in actual gold rather than fiat money. Thus, if a fiat money is declared legal tender for debts already incurred, it might temporarily have a value approaching the value of the commodity in terms of which debts were contracted. But that value would likely diminish as newly written private contracts began specifying that debts could be discharged only using a specified commodity or instrument.

Wicksteed then considered what happens if the government not only makes fiat money legal tender, but announces that the legal liabilities incurred by the public to the government (in particular tax liabilities) could thenceforth be discharged by remittances of the fiat money issued by the government. Once fiat money is accepted in payment of tax liabilities, the government creates a continuous demand for fiat money, because the tax liabilities imposed by government recur at scheduled times during the year. In making its fiat money acceptable for the discharge of the tax liabilities that it imposes, a government can maintain the value of those notes at par with a pre-existing gold currency by appropriately limiting the quantity of notes issued.

The power, then, of Governments to make their issues do exchange work depends on their power to make a note of a certain face value do a definite amount of exchange work; and this they can effect by giving it a definite primary value to certain persons, and then keeping the issue within the corresponding limits. (p. 622)

³ "A requirement that certain taxes should be paid in particular paper money might give that paper a certain value even if it was irredeemable." (Smith 1776, p. 312)

But difficulties in gauging the extent of the public's demand for the fiat currency relative to convertible gold currency could cause the fiat currency to circulate at either a premium or a discount relative to the gold currency. Moreover, doubts about the viability of the government and the reliability of its promise to accept the fiat currency it has issued to discharge the tax liabilities it has imposed could lead to fluctuations in the value of the fiat currency independent of any change in the outstanding quantity of the currency held by the public.

[T]he history of paper money abounds in instances of sudden changes, within the country itself, in the value of paper money, caused by reports unfavourable to the Government's credit. The value of the currency was lowered in these cases by a doubt as to whether the Government would be permanently stable and would be in a position to honour its drafts, that is to say, whether, this day three months, the persons who have the power to take my goods for public purposes will accept a draft of the present Government in lieu of payment. (p.623)

Writing nearly 40 years after Wicksteed, Abba Lerner (1947) also emphasized the role of the acceptability of fiat money to discharge tax liabilities as the necessary condition for fiat money to maintain a positive value. It was only after national governments increased tax burdens sufficiently, Lerner argued, that fiat moneys could replace gold as the dominant monetary standard without causing an inflationary spiral. Subsequently, Earl Thompson (1976) and Charles Goodhart (1998) also identified the acceptability of fiat money in discharging tax liability as the necessary condition for fiat money to maintain a reasonably stable positive value.⁴

By making its fiat money acceptable for discharging tax liabilities that it imposes, a government creates a recurring real source of demand for its money independent of its use as a means of exchange in private transactions. The creation of a non-monetary source of demand for fiat money immunizes fiat money against the backward-induction argument that the foreseeable loss of value by the fiat money, which would otherwise imply an immediate loss of its value. So as long as a sufficient number of people expect to have a tax liability that they must discharge, the value of fiat money cannot go to zero.⁵

Nor does the fact that people hold money for reasons other than paying taxes prove that acceptability of fiat money to discharge tax liability is not necessary for a fiat money to have positive exchange value. The monetary services provided by a fiat money increase the demand to hold money, just as, under the gold standard, the monetary services provided by gold increased the value of gold.

⁴ Another source is the German economist G. F. Knapp (1924 [1905]). His doctrine was dubbed by Keynes (1930) as chartalism, which received dismissive reviews from many orthodox economists, notably Mises (1934 [1912]). Offering few specifics, Mises heaped scorn on Knapp's work, unjustly accusing Knapp of ignorance or misunderstanding of economic theory.

⁵ However, should the survival of a government become doubtful, thereby reducing the likelihood that discharge of tax liabilities to the government will be required, the non-monetary demand for the money starts to fall, likely causing its value in exchange to fall as well. A classic example of this phenomenon is the Confederate hyperinflation that began in late 1864 as the approaching military defeat of Confederate came into increasingly clear view.

Why does the acceptability of fiat money for discharging tax liability ensure that fiat money has a positive value even at non-peak tax collection periods? Given that the periodic (e.g., quarterly) peak tax collection periods are known and foreseen in advance, the value of fiat money at peak collection periods can be anticipated; with the value at peak periods anticipated, the value at non-peak periods will have an equilibrium value contingent on the expected value at the peak period. Explaining the value of fiat money in terms of its value at peak tax periods would seem to imply that the fiat money would fall immediately after each peak tax period and before beginning to appreciate toward the expected value at the next non-peak periods. But this implication holds only if there is no monetary demand for fiat money. If there is monetary demand for fiat money, the value of fiat money is not entirely solely from its value in discharging tax liability. Insofar as the value of fiat money derives from its use as a medium of exchange as well as its use in discharging tax liability in which case it would not necessarily follow that there would be any tendency for the value of a fiat money to appreciate between peak tax periods and to fall immediately after each peak tax period.⁶

IV Are Bitcoins Special or Just Another Fiat Currency?

Having argued that the acceptability of fiat currencies as payment for tax liability is one factor, and perhaps the critical one, in explaining why fiat moneys have historically been able to retain a reasonably stable value over long periods of time, I can now return to the starting point of this discussion, which is whether bitcoins and other cryptocurrencies are potentially able to provide credible competition to fiat currencies issued directly by governments or by government-sponsored entities like central banks. Neither fiat currencies nor cryptocurrencies provide those holding them any tangible real service other than their expected resale value. The lack of any external source of value raises a question about the rationality of the expectation of a positive, let alone a stable, resale value for such assets. For an asset held only because of future expected resale value, such doubts seem especially problematic.

In section II, I argued that, the backward-induction argument, at least superficially, implies that the rational expected value of such an asset is zero. Although there is reason to believe that the backward-induction argument is based on an assumption -- that the final period can be foreseen -- that is not satisfied in fact, the argument is not necessarily rendered irrelevant and may well draw attention to an inherent instability and fragility in the value of any cryptocurrency.

Although fiat currencies are also implicated by the logic of the backward-induction argument, we saw in the previous section that their acceptability in discharging tax liabilities, especially when governments imposing tax liabilities that are a substantial share of the total income of the population under the jurisdiction of the government issuing the currency, provides a source of demand independent of medium of exchange function performed by fiat currencies, thereby providing an sort of anchor to the value of fiat currencies analogous to the non-monetary demand for commodities that serve as money. Because issuers of cryptocurrencies have no taxing power, the stabilizing anchor that underpins the value of fiat currencies is unavailable to

⁶ Thompson (1976) neglected to consider the monetary demand for a fiat money in arguing that there would be a tendency for deflation between peak tax-collection periods.

cryptocurrencies, so the risk of a catastrophic collapse in the value of cryptocurrencies seems far greater for cryptocurrencies than for fiat currencies. The experience of bitcoins illustrates the instability of value.

Starting in 2012 at a value close to zero, bitcoin remained at a price close to zero for almost a year before beginning a startling rise in value up to nearly \$20,000 in December 2013, before falling precipitously to a value of about \$2500, a loss of value of 85 percent. Subsequently, the price of bitcoin has fluctuated in a range of between \$4000 and \$12000, and as of this writing has just risen above \$13,000 for the first time in five years. Bitcoin can hardly be said to serve as a stable store of value, and bitcoin holders, are almost certainly doing so primarily in the expectation of reaping capital gains rather than for the supposedly secure and anonymous transactions services bitcoin provides through the underlying blockchain technology.

The initial rise and fall of bitcoins bears at least a superficial resemblance to the tulip mania in Holland in the seventeenth century. See Figures 1 and 2. At its peak, the price of tulips was about 20 times its initial value. The increase in the price of bitcoins, at least 100-fold in a corresponding period of explosive price increase, dwarfs the rise in tulip prices. However, after its initial – and relatively modest -- rise and subsequent fall, the price of tulips never experienced, another comparable price increase. To gauge the magnitude of the bitcoin bubble, compare the Figure 1 and Figure 2 this one constructed by Earl Thompson (2007) from actual prices in tulip contracts during the Dutch tulip mania of 1636-37. The price of tulips in February 1637 was about 10 times higher than they were in November 1636. The price of bitcoins in , the tulips were barely more than a blip. The price peak bitcoin briefly reached in December 2017 was more than 20 times higher than the price in January 2017. Tulips lost about 25% of their value in five days after the price peak. Bitcoins lost 40% of their value in the five days after the price peak.

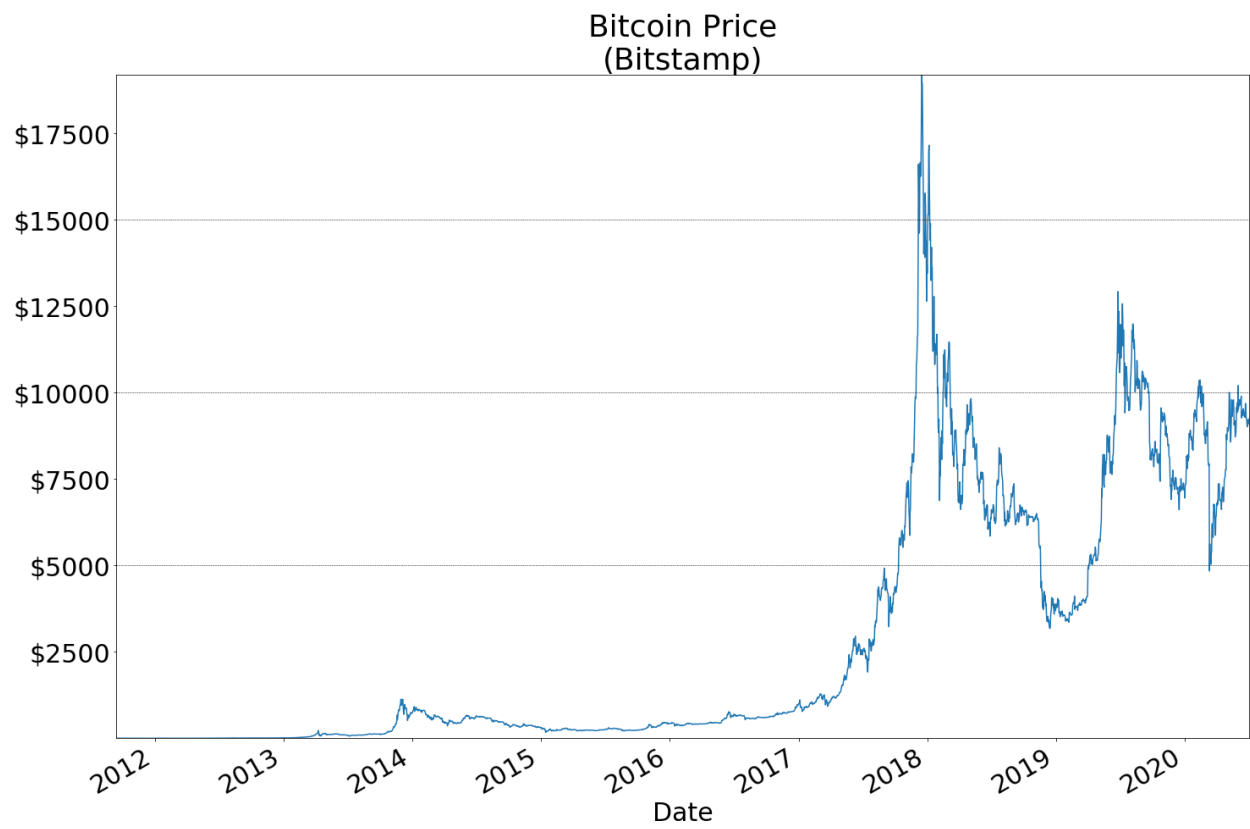
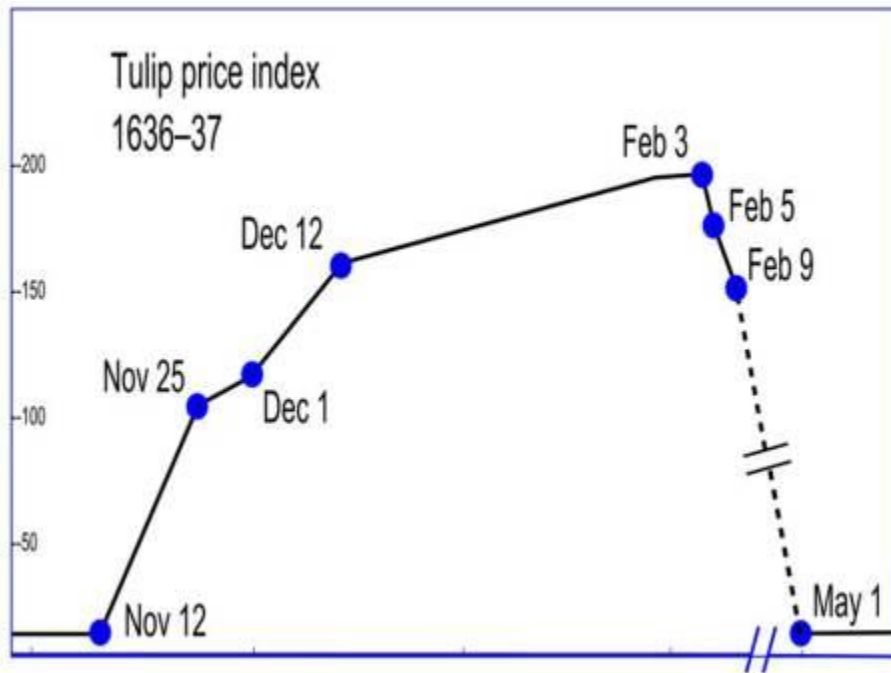


Figure 1



Source: Thompson (2007)

My concern is not so much to explain the resilience of the bitcoin phenomenon as to understand its implications. The price of bitcoin having recovered a substantial portion of earlier losses, one may assume that there are those who believe that there will be a sufficient increase in the demand for bitcoin to cause a future price increase. Because the value embodied in bitcoin could be derived only from its use as a medium of exchange, one cannot help but ask what would be the source of the expected demand to use bitcoin as a medium of exchange?

The current demand to use bitcoins as a medium of exchange, largely confined to transactions requiring anonymity that are more safely mediated with bitcoins than with other media of exchange, seems very limited. The observed fluctuations in the value of bitcoins seem too large to be accounted for by fluctuations in the number of transactions actually being mediated by bitcoin. I have seen no evidence that bitcoin has displaced any media of exchange in executing any but a very minute percentage of all transactions.⁷

So the question is how many transactions would have to be mediated by bitcoin to justify anything like its current price? I make no attempt to calculate that number, but it seems doubtful that the current price of bitcoin is compatible with any realistic estimate of the number of

⁷ The average number of bitcoin transactions per day in the first quarter of 2016 was 2.02 million. In the fourth quarter of 2017 the number reached 3.17 million and in the first quarter of 2019 the number reached 3.83 million. But since then, the daily number has been slightly less than 3 million from the fourth quarter of 2019 through the second quarter of 2020. <https://www.statista.com/statistics/730806/daily-number-of-bitcoin-transactions/#:~:text=At%20the%20end%20of%20the,Bitcoin%20transactions%20recorded%20daily%20worldwide.>

transactions that bitcoin could ever mediate. And if, as I am going to argue, the extravagant hopes of bitcoin backers and promoters were somehow realized, and bitcoin did gain wide adoption as a medium of exchange, the increased demand to use bitcoin to mediate transactions might well cause further upward pressure on the price of bitcoin, owing to the extremely high cost of increasing the quantity of bitcoins that has been designed into the underlying bitcoin architecture. But, as I shall explain below, increasing use of any currency is inconsistent with a rapid increase in its value. The underlying architecture of bitcoin therefore precludes it from ever being widely adopted as a medium of exchange. To understand this inherent defect, it will be necessary, in the next section, to delve further into the nature of the network effects characteristic of any medium of exchange.

The dysfunctional bitcoin architecture is sometimes justified on the grounds that it is the upper bound imposed on the total number of bitcoins that underpins confidence in its value, thereby enhancing and stabilizing that value. But a constraint on supply is not what imparts value to an asset; it is the demand to hold the asset that imparts value. No upper bound on the total stock of an asset for which there is no demand can make the asset valuable. If an asset is useful because of the valuable services it provides or if it is a claim on a stream of payments, the asset will have value; imposing a limit on its quantity is pointless.⁸ If the supplier of the asset wants to guarantee purchasers that it will not later sell the asset for a lower price than previous buyers had paid, the supplier could simply offer a price guarantee (or a put option) rather than impose a quantity constraint that would force any increase in demand for the asset to result in an increase in the asset price (Coase 1972). Imposing such a quantity constraint on an asset designed to serve as a medium of exchange is to ensure *ab initio* that asset will never be widely adopted to serve as a medium of exchange.⁹

V Network Effects Revisited

If we observe that, despite large swings in value over the past five years, bitcoin retains a positive value, now over 60 percent of its all-time high reached in December 2017, does that mean that bitcoin truly does have a positive value, or does it mean that a bubble can persist indefinitely? There seem to be only two ways to explain this anomalous state of affairs: either I have overlooked some material fact about bitcoin that might impart a positive value to them, or there is a problem with the theory of valuation that I am using.

I don't believe that my basic approach is inconsistent with the positive value that the bitcoin has maintained for several years. However, that approach does require some adjustment

⁸ Bitcoin provides a unique service as a medium of exchange, unavailable to those using fiat money, in facilitating anonymity for transactions, payment via bitcoin being more difficult to trace than electronic payments via conventional media of exchange. That is a good reason for people to want to use bitcoins in certain kinds of transactions. However, the difficulty of tracing transactions via bitcoin does not explain why bitcoins have a positive value in the first place, only an argument why, if they do have a positive value, the demand for them might be greater than it would have been if not for that advantage. Without an independent explanation for the positive value of bitcoin, a positive value of bitcoin cannot be bootstrapped by citing the difficulty of tracing bitcoin transactions.

⁹ One reader has suggested that the quantity constraint contributes to incentive compatibility by ensuring that holders of bitcoin do not form expectations that the value of bitcoin fall to zero as a result of overissue as suggested by Luther (2018). But this argument fails to take account of the inherent incompatibility between a fixed supply of a medium of exchange and a constant value.

to account for the large role that network effects play in the demand for money. Because the willingness of people to accept and hold a medium of exchange increases rapidly as the total number of people willing to accept and hold that medium of exchange increases, the backward-induction argument becomes less straightforward than I had earlier made it out to be.

The network externality affecting the demand for a particular money means that your demand for that money increases its usefulness to me and that my demand for that money increases its usefulness to you. But network effects have another critical consequence: as increasing numbers of people use a particular money for an increasing number of their transactions, those using that money to mediate their transactions become increasingly locked in to its continued use, because as long as those with whom they are transacting use that money it will be difficult for them to switch from that money to an alternative money.

If you and I are actual or potential trading partners, your demand for the particular money that we both use in transacting adds to the cost I would incur by switching from the common medium of exchange that we now use to a different medium of exchange. So, even if backward induction and the expectation that the medium of exchange that we now use will lose its value at some future date encourages us both to stop using the medium of exchange that we now use, the network externality and the lock-in effect encourages, or even compels, us to continue using the medium of exchange that we both use. The net effect is unclear, but the more transactions and the more trading partners are implicated in switching from one medium of exchange to another, the more tightly we will be locked into continued use of the medium of exchange that we both use, notwithstanding our expectation that it will eventually lose its value.

At a minimum, these two opposing forces – one encouraging abandonment of the currently-used medium of exchange and the other locking traders into its continued use -- suggests that even if the equilibrium value of a fiat money or a crypto-currency is positive, the equilibrium value may be unstable. A sufficient change in expectations may cause a drop in demand for the money beyond the threshold or tipping point at which the decline in demand and value becomes self-reinforcing and cumulative.

Because currency instability derives from subjective expectations and because changes in expectations can be self-fulfilling or self-reinforcing, that instability is difficult, if not impossible, to control or contain. To be sure, the larger the network and the greater the lock-in to the existing medium of exchange, the more stable is the equilibrium value of the currency and the less vulnerable it is to sudden change. But even a widely used medium of exchange may be subject to instability and a tipping point if people begin migrating to another medium of exchange. For a truly dominant currency, like the US dollar, whose dominance is perhaps more overwhelming than that of gold during the heyday of the international gold standard, there is little likelihood of a sudden shift to another currency standard, absent some cataclysmic event, like the outbreak of world war in August 1914.

How does this discussion relate to bitcoin? I have described three potentially opposing forces bearing on the value of a pure medium of exchange. On one side there is backward induction, which tends to drive the value of a pure medium of exchange to zero once its future loss of value becomes clear enough that it is no longer accepted in exchange. Against backward

induction, at least for a fiat currency issued or sponsored by a government with the power to levy and collect taxes, the value of the fiat currency can be maintained, despite the logic of backward induction, because acceptability in payment of taxes by the government creates a demand for a fiat currency as long as the issuing government is expected to remain in power and to impose tax liabilities that can be discharged by the currency it issues. And finally, aside from acceptability in discharging tax payments, the switching cost borne by current users of a currency in switching to another currency increases as the number of people using that currency increases.

For bitcoin and other cryptocurrencies, which are not accepted in discharging tax liabilities, only the network effect locking existing users of a currency into its continued use that can support a continuing positive quasi-equilibrium value. The question, then, is whether the network effects generated by bitcoin or other cryptocurrencies are large enough to maintain their value above zero for an extended period of time?

I will try to offer two tentative answers to that question in the next section. I offer two answers, because the underlying architecture of bitcoins render it inherently unsuitable as a medium of exchange. If I am right in regarding bitcoin as unsuitable to serve as a medium of exchange, a different kind of cryptocurrency, based on an alternative architecture might have a better chance than bitcoin to establish itself as an alternative medium of exchange, though, under almost any conceivable set of circumstances, the chances that any cryptocurrency could expand its reach beyond a niche of regular users seems to me very low.

VI Network Effects and Bitcoin

In the previous section I argued that bitcoins and other cryptocurrencies, providing no service other than their anticipated future resale value to their holders, are at risk of losing their resale value. Despite their vulnerability to extreme loss of value, bitcoin and other cryptocurrencies may avoid such an outcome by gaining sufficient early acceptance as a media of exchange. Acceptance as a medium of exchange triggers network effects that increase demand for the medium of exchange and promotes lock-in among existing users. If sufficiently strong, that lock-in may support continued use of the medium of exchange, thereby preventing what would otherwise be an inevitable loss of value.

Despite a seemingly predictable future loss of value, bitcoin has gained acceptance as a medium of exchange by providing medium-of-exchange services not provided by other currencies, even the dominant currency: the dollar. Bitcoin has also attracted a coterie of libertarian and anarchist ideologues who, on principle, prefer using a non-governmentally supplied medium of exchange, though it is far from clear how widely such ideologues actually use bitcoin in transactions that are not the type for which bitcoin actually enjoys a competitive advantage.

Promoters of bitcoin extol the blockchain technology that is designed to render trading with bitcoins anonymous and secure. But the decentralized character of bitcoin transactions slows down, and increases the cost of, transacting with bitcoins. In fact, most users cannot easily access the blockchain directly, relying instead on bitcoin accounts managed by intermediaries who access the blockchain on their behalf. There are recurring reports of hacking into the bitcoin

accounts managed by intermediaries to effectuate fraudulent transactions, casting doubt on the purported security and anonymity of bitcoins.¹⁰

For discussion purposes, let me stipulate that bitcoin does provide enhanced privacy and anonymity in performing transactions, which, for some transactions, more than compensates for the added cost of transacting with bitcoins or other blockchain-based cryptocurrencies. But the number of transactions for which bitcoins or cryptocurrencies might be preferred by transactors is a tiny fraction of the total number of transactions mediated by conventional currencies. Still, a plausible argument could be made that a niche market for a medium of exchange designed for secure anonymous transactions would suffice to make a secure and anonymous medium of exchange viable. But a niche currency is a shaky platform upon which to challenge the dominant international currency entrenched by extreme network effects and high switching costs.¹¹

It is therefore seems implausible to imagine that its base of illegal transactions and transactions of a small subculture of political extremists could ever provide bitcoin with a transaction volume comparable to that currently mediated even by the fiat currency of a small economy, say, the Uruguayan peso.¹² Nevertheless, the advantages of using bitcoin to mediate illegal exchanges enable bitcoin to provide a service that cannot be duplicated by any established fiat currency, enabling bitcoin to maintain a positive value notwithstanding a likely loss of value at some point in the indefinite future.

The small size of the potential market accessible to bitcoin casts doubt on whether other cryptocurrencies can be viable. If a niche market characterized by network effects, it is unlikely that more than one supplier could be viable. As the first, and still the largest, cryptocurrency, bitcoin will not be easily displaced as the primary cryptocurrency, the hype surrounding the surge in initial cryptocurrency offerings notwithstanding. However, the structural defect mentioned above does create a potential market opportunity for an alternative differentiated cryptocurrency to displace bitcoin as the leading cryptocurrency.

In the previous section, I drew attention to the defect in the bitcoin architecture that, by imposing increasing costs on the creation of additional bitcoins as the total quantity created

¹⁰ If bitcoin did gain wide acceptance among a broad range of users, economies of scale might support the emergence of efficient, transparent and trustworthy intermediaries to manage personal bitcoin accounts. But the inherent limitations of bitcoin militate against the expansion of its usage and acceptance necessary for such intermediaries to emerge.

¹¹ One reader has suggested that the success of Ripple in competing with SWIFT in executing international transfers shows that cryptocurrencies using blockchain technology can effectively compete with fiat currencies in providing transaction services. But the limited success of Ripple in competition with SWIFT actually highlights the limitations of blockchain. Blockchain capacity is not sufficient to allow Ripple to handle all international bank transfers, and the cost of holding XRP, the volatile cryptocurrency used in making transfers on the Ripple blockchain, adds to the transactions costs of using Ripple. SWIFT, a monopolistic supplier of international bank transfer services, has responded to Ripple by speeding up and reducing the cost its services.

¹² It has been suggested that there is also a demand by other blockchain users for bitcoins to be used as collateral in mediating blockchain transactions using other cryptocurrencies such as the ether. However, recent statistics indicated that the amount of bitcoin collateral held by ether is less than a half of one percent of total bitcoin capitalization. Another suggested source of potential demand for bitcoins is that people in unstable regimes are likely to demand bitcoins despite the high cost of transacting with bitcoins because of the instability of their own currencies. However, residents in countries with unstable regimes in power already use dollars as their primary alternative to their local regimes and bitcoins are unlikely to replace dollars as the main alternative to unstable domestic currencies.

approaches a fixed upper bound, undermines its potential for expansion. The architectural defect stems from a misguided ideological commitment to making an inflationary increase in the total quantity of bitcoins impossible.

The problem with this architecture is that insofar as bitcoin attracts new users that hold, and execute transactions with, bitcoins, the consequent increase in the demand to hold bitcoins causes the price of bitcoin would increase. The early growth in the use of bitcoin did indeed cause an increase in both its price and the total outstanding quantity. But the rising price of the bitcoin, which fueled expectations of further price increases, had an unanticipated effect; to undermine the usefulness of bitcoin as a medium of exchange.

It may seem paradoxical that a rapid increases in the value of an asset – or more precisely the expectation of a rapid increase in its value – impairs its suitability to serve as a medium of exchange, but the tendency for any asset being used as a currency to disappear from circulation as a result of an expectation of a rapid increase in its value has long been recognized in the literature on money. The phenomenon has both a name (Gresham’s Law) and a pithy epigram (bad money drives out the good) attached to it.

Already commented on by Aristophanes in one of his plays, the phenomenon was a commonplace in early writings on metallic coinage. It typically occurs when two moneys – one of them having more valuable material content than the other – circulate concurrently. For example, if a coinage consists of both full-bodied and clipped coins with equal face value, people hoard the more valuable full-bodied coins, offering only the clipped coins in exchange. Similarly, if some denominations of the same currency are gold coins and others are silver coins, so that the relative values of the coins are legally fixed, a substantial shift in the relative market values of silver and gold causes the relatively undervalued (i.e., the “good”) coins to be hoarded, disappearing from circulation, leaving only the relatively overvalued (“bad”) coins in circulation. I note in passing that a fixed exchange rate between the two coins or currencies is not, as has often been suggested, necessary for Gresham’s Law to operate when the rate of appreciation of one of the currencies is sufficiently rapid.¹³ The fixed exchange rate that equates the values of two assets is what creates the expectation of rapid adjustment of the relative value of the two assets should the fixed exchange rate be changed, leading to the disappearance from circulation of the asset expected to appreciate.¹⁴

If I can use dollars with a stable or even purchasing to obtain the goods and services that I seek, why would I instead use an asset that I expect to appreciate rapidly to buy the same goods

¹³ The maximum rate of expected appreciation consistent with continued use of an asset as a medium of exchange is given by the Fisher equation:

$$i = r + \pi^e,$$

where i is the nominal rate of interest, r , is the real rate of interest and π^e is the expected rate of deflation. At the zero lower bound on the nominal rate of interest, we have $r = -\pi^e$, which says that expected rate of deflation (the expected rate of appreciation of money) cannot exceed the real rate of interest in equilibrium. An expected rate of deflation faster than the real rate of interest causes money to be hoarded and to disappear from circulation. If another money is available for use of a medium of exchange, that other money will be adopted instead of the currently used medium of exchange, replacing it in exchange, driving it out of circulation. See Glasner 2018

¹⁴ One might argue that Gresham’s Law is a disequilibrium phenomenon and that once the value of Bitcoin reaches an appropriate level its value will stabilize and from that point forward will provide transactional services like any other medium of exchange. But a monetary-regime transition is a disequilibrium phenomenon and is unlikely to be smooth or predictable.

and services I can use dollars to obtain? Unless the planned transaction was considerably more costly to execute using the alternative medium of exchange than with the appreciating asset, say, because it provided a transaction service so valuable that is not provided by the alternative, to make it worthwhile to forego the expected appreciation, it would make no sense to use the appreciating asset to mediate the transaction.

The rapid appreciation of bitcoin since 2013 and continued expectations of future appreciation undermine its suitability to serve as a medium of exchange, except for the narrow class of transactions for which it is especially well-suited. Insofar as the demand for bitcoins is driven by expectations of further appreciation, those expectations are what discourage people from using bitcoin as a medium of exchange. But the architecture of bitcoin makes further appreciation of the bitcoin inevitable if the demand to use bitcoin as a medium of exchange were ever to increase. That is the fatal antinomy designed into the architecture of bitcoin.

VII A Stable Cryptocurrency?

Recognizing the internal contradiction inherent in bitcoin, some innovators have tried to launch stable cryptocurrencies whose value would not fluctuate or appreciate thereby undermining its functionality as a medium of exchange. Some cryptocurrencies have been pegged to a commodity, e.g., gold, silver or oil, some have been pegged to an existing currency, e.g., the dollar, and others to an abstract measure of value, e.g., a commodity-price index or a broader price index. I need only consider the case of a cryptocurrency pegged to the dollar, the dollar being not only the currency used in the largest economy in the world, but also the dominant international currency in terms of which all internationally traded commodities are valued.

The most interesting and ambitious such attempt, which laid out an algorithm for stabilization of the value of the cryptocurrency is the Basecoin. An initial prospectus, soliciting investors to capitalize the venture and describing the algorithm, was issued in 2017 and raised \$133 million from investors. However, the proposed coin, renamed the Basis, was never launched, and the funds raised from investors were refunded.

The prospectus proposed a peg of \$1 per Basis, with profits accruing to investors by way of the anticipated increase in the demand for Basecoins, thereby eliciting the issue of sufficient new Basecoins to maintain the \$1 peg with the new issues distributed to investors in proportion to their equity shares. In the event of a decline in the value of the Basis below the \$1 peg, the protocol required selling claims to units of the Basis at the current discounted price which would be redeemable in the order in which they had been sold once the Basis parity with the dollar was restored. The funds raised by selling Basis options could then be used to buy Basis units, reducing the outstanding quantity and raising their value.

More fundamentally, the Basis managers would have to use the invested capital to intervene in the open market and purchase Basis units as needed to maintain the \$1 peg of the Basis. If the public had sufficient demand to hold the Basis, investors would earn seignorage on the difference between the \$1 value of each additional unit and the capitalized cost of maintaining that unit while held by the public. If the demand of the public to hold Basis units declined, investors would be required to disburse their invested capital to support the peg. The

market price of the Basis would provide a reliable signal about the relationship between the quantity of Basis units demanded and the stock of Basis units held by the public, a price below the peg indicating an excess supply and a price above the peg indicating an excess demand.

The viability of the Basis would therefore depend on whether the demand for the crypto-transactional services provided by the Basis would generate enough seignorage for investors to earn at least a competitive return on their investment. Whether the Basis would generate a competitive return to investors would hinge on what services, not provided as well or better by the dollar or other fiat currencies, the Basis could provide.¹⁵

Many promoters of bitcoins or other cryptocurrencies cite Hayek's (1978) work on competing currencies as a paradigm for the success of cryptocurrencies. But comparisons between modern cryptocurrencies and Hayek's idea for private currency competition with government fiat currencies are inapt for several reasons.

First, Hayek argued that private currencies competing with fiat currencies would succeed by offering the public currencies more stable in value than existing fiat currencies. But when Hayek argued for competing currencies annual inflation rates in the United States and most other advanced economies were well above 5% and often above 10%; public consternation with inflation was among the chief political issues of the time. High inflation is no longer a major issue, and it has not been a significant issue for at least three decades.

Moreover, Hayek's theoretical argument was that, contrary to widespread opinion, private creators of money (i.e., banks) have no inherent tendency to overissue and therefore require no external constraint to prevent inflationary overissue. Against the prevailing contrary view, Hayek maintained that private issuers of competing currencies would instead maximize their profits by trying to satisfy the public's preference for a currency with a stable value.

But Hayek's argument (based on the insight that banks compete with each other to make their moneys more attractive for the public to hold and to transact with than competing moneys offered by other suppliers) failed to consider how network externalities cause convergence on a single monetary standard. That tendency implies that unconstrained competition does not necessarily lead to convergence on the optimal standard given that the costs of switching from an

¹⁵ In addition to straightforward costs of accessing the blockchain, most blockchain transactions are conducted on behalf of transactors by specialist intermediaries that manage their accounts. Account holders bear non-negligible risks that their accounts will be frozen owing to lost passwords or compromised by the malfeasance of intermediaries. Only frequent and knowledgeable traders specializing in crypto-transactions, bitcoin account holders are often those who earn their livings by providing various services exchanged on the dark web, and therefore find it advantageous to invest the resources necessary to make active trading using cryptocurrencies worthwhile.

The underlying blockchain technology through which cryptocurrencies mediate transactions maintains the anonymity and untraceability of the transactions recorded on the centralized ledger of the blockchain. But the centralized ledger is actually unwieldy and cumbersome, substantially raising the cost of transacting with cryptocurrencies above the cost of transacting with dollars and other fiat currencies. Unless the parties to a transaction have a specific reason to mask their identity, transacting with a cryptocurrency is more costly than transacting by conventional means. Indeed, most transactors incur added costs in accessing the blockchain and therefore rely on costly accounts provided by Blockchain specialists who execute transactions on their behalf.

existing standard to a better standard may well exceed the benefit from replacing the inferior standard with a better one. Network effects tend to lock in an existing standard, rendering inoperative the competition between standards that Hayek thought would lead to convergence on the optimal standard.

Aside from that gap in his argument, Hayek did not explain how a bank could launch a new standard given the prior acceptance of another standard.¹⁶ To use a terminology suggested by Nick Rowe, there are two kinds of money creators (banks): alpha banks and beta banks. Alpha banks issue monetary instruments that define the monetary standard. Under the gold standard, gold is the alpha money; all banks operating on the gold standard are beta banks relative to gold. Under the classical gold standard, the Bank of England served as an alpha bank, Bank of England notes and deposits constituting the reserves of beta banks in Great Britain and even in other countries that adopted the gold standard by making their own currencies exchangeable at par with the pound sterling issued by the Bank of England.

Taking account neither of the network externality nor Rowe's distinction between alpha and beta banks, Hayek attributed the lack of alternative monetary standards that compete with the standards established by existing fiat currencies to legal restrictions that prohibit the creation of non-government alternatives. But the legal restrictions on private commercial banks are not what foreclose private banks from creating alternative monetary standards. Private banks are beta banks that create inside money convertible into the outside (alpha) fiat money issued by governments.

Promoters of bitcoin and other cryptocurrencies imagine that bitcoin or perhaps some other cryptocurrency could somehow become an outside alpha money that could displace the dollar as a dominant currency. That aspiration is belied by the fact that bitcoins are held in the expectation that it will appreciate rapidly. As explained above, rapid expected appreciation disqualifies an asset from being widely used as a medium of exchange, because its wide use in that capacity would entail a vicious downward deflationary cycle. That understanding, at least on an intuitive level, inspired a search for a stable cryptocurrency. But the only possible stable cryptocurrency is one pegged to the dollar or another stable (alpha) currency.

While one attempt to create a stable cryptocurrency pegged to the dollar was abandoned before the currency was even launched, another crypto currency, the Tether, purports to be pegged to the dollar. But there is no transparency on the mechanism by which that peg is maintained, and there are recurring allegations of misconduct by Bitfinex, a cryptocurrency exchange with which Tether is closely related, and has been the object of criminal investigation by the office of the Attorney General of New York.¹⁷

That no such currency stable currency pegged in a transparent way to the dollar exists suggests to me that the potential accessible market for a crypto-currency offering crypto-transactions services is too small to support a profitable and transparent stable crypto-currency. Because the demand for Tether and other cryptocurrencies using blockchain creates a further derived demand for bitcoin, it seems unlikely bitcoin's initial advantage in the cryptocurrency

¹⁶ On this point, too, Hayek's error stemmed from his failure to take into account the network externality that leads people to transact with and hold the same medium of exchange that other people are already using. Why would a bank invest in creating a new standard in terms of which to denominate its deposits or even to issue banknotes?

¹⁷ <https://en.wikipedia.org/wiki/Bitfinex>

space will be competed away by new entrants even if they provide, what may be in principle, a lower-cost alternative to bitcoin. Instead, it seems that bitcoin will survive largely as a speculative asset sustained by the optimistic hopes for appreciation and the limited crypto-transactions services it provides to a relatively small clientele of transactors trading illicit goods and services on the dark web. That bitcoin or any other cryptocurrency will expand its market beyond this narrow clientele supplemented by an even smaller group of extreme libertarians whose aspirations to launch an alternative monetary system free of government control seems no more likely to be realized than the hopes of these ideologues of nominating a Presidential candidate capable of winning more than two percent of the popular vote.

VIII Conclusion

Bitcoins and cryptocurrencies pose a challenge to traditional theories of the value of money, and, indeed, to traditional theories of asset value. Traditional theories of asset value are based on some notion of the expected income or service stream associated with the asset. The challenge of purely monetary assets is that the income or service streams are entirely derived from the expectation of a resale value. So the question that any theory of the value of a cryptocurrency must address is how to maintain the resale value of a cryptocurrency if ultimately it provides no use either as a commodity or can discharge tax liability that holders owe to the issuer of the cryptocurrency.

If neither of these sources of value inhere in a cryptocurrency, one seems to left with only two possible explanations, which are not necessarily inconsistent: either cryptocurrencies are a pure bubble that can persist owing to uncertainty about when the final period at which exchanges will cease is destined to occur, or that a sufficiently widespread demand for a currency, even if it is based on an unsustainable expectation of future resale value, locks existing users into continued use of cryptocurrency notwithstanding the unsustainability of the expectation of future resale value.

I concede that the resolution of the underlying paradox surrounding the existence of cryptocurrencies is not fully satisfactory, but if I am correct the unsatisfactory nature of the explanation will be mirrored in the disappointment of the expectations of promoters of cryptocurrencies that their creations will somehow displace existing fiat currencies and usher in new monetary regime liberating us all from the shackles of the state monopoly over money.

REFERENCES

- Coase, R. H. 1972. "Durability and Monopoly." *Journal of Law and Economics* 15(1):143-49.
- Davidson, L. and W. Block. 2015. "Bitcoin, the Regression Theorem and the Emergence of a New Medium of Exchange." *Quarterly Journal of Austrian Economics* 18(3):311-38.
- Glasner, D. 2018. "The Fisher Effect and the Financial Crisis of 2008." Mercatus Research Paper, September 2018, Available at SSRN: <https://ssrn.com/abstract=3247795> or <http://dx.doi.org/10.2139/ssrn.3247795>
- Goodhart, C. A. E. 1998. "The two concepts of money: implications for the analysis of optimal currency areas," *European Journal of Political Economy* 14(3):407-32.
- Hayek, F. A. 1978. *Denationalization of Money*, 2nd edition. London: Institute of Economic Affairs.
- Knapp, G. F. [1905] 1924. *The State Theory of Money*. London: Macmillan.
- Lerner, A. (1947). "Money as a Creature of the State." *American Economic Review* 37(2):312-17.
- Luther, W. J. 2018. "Is Bitcoin Intrinsically Worthless?" *The Journal of Private Enterprise* 33(1):31-45.
- Mises, L. von. [1913] 1934. *The Theory of Money and Credit*. London: Jonathan Cape.
- Neumann, J. von and O. Morgenstern. (1944) *The Theory of Games and Economic Behavior*. Princeton: Princeton University Press.
- Rowe, Nick. 2014. "Alpha banks, beta banks, fixed exchange rates, market shares, and the money multiplier." https://worthwhile.typepad.com/worthwhile_canadian_initi/2014/03/alpha-banks-beta-banks-fixed-exchange-rates-market-shares-and-the-money-multiplier.html
- Shostak, F. 2004. "How Does Money Acquire its Value?" <https://mises.org/library/how-does-money-acquire-its-value>
- Thompson, E. A. 1976. "A Reformulation of Macroeconomic Theory." Unpublished manuscript. <http://www.econ.ucla.edu/workingpapers/wp091.pdf>
- Thompson, E. A. 2007. "Tulip Mania: Fact or Artifact." *Public Choice* 130:99-114.
- Varian, H. 2004. "Why Is that Dollar in your Wallet Worth Anything?" *New York Times Sunday Business Section*.