



Bank of Finland

BoF Economics Review

1 • 2018

The great illusion of digital currencies

Aleksi Grym, Bank of Finland

Abstract

This paper is an analysis of digital currencies, including cryptocurrencies, and their potential as monetary instruments. The analysis shows that the concept of a digital currency is a fallacy. Currency, in the form of coins and banknotes, can be viewed as a physical representation of a monetary unit of account. Currency cannot be digitised, as this would inevitably mean creating a financial record keeping system based on accounts. Cryptocurrencies are not currencies at all but accounting systems for non-existent assets. Central bank digital currency would practically mean bank accounts at the central bank. Whether the general public should have access to such accounts, and whether monetary transactions should be allowed to be made anonymously or privately, are questions of policy and unrelated to cryptocurrencies or their underlying technology.

BoF Economics Review consists of analytical studies on monetary policy, financial markets and macroeconomic developments. Articles are published in Finnish, Swedish or English. Previous knowledge of the topic may be required from the reader.

The opinions expressed in this article are those of the author(s) and do not necessarily reflect the views of the Bank of Finland.

Editors: Juha Kilponen, Esa Jokivuolle, Karlo Kauko, Paavo Miettinen and Juuso Vanhala

1. Introduction

Recent advances in digital technology have spurred a transformation in the global financial industry. Consumer behaviour with regards to payments and other financial activities is changing, and service providers including banks have been challenged by new market entrants. Among the many innovations in this area, digital currencies have become of keen interest for both the general public as well as financial institutions.

A famous example of this class of innovations is Bitcoin, which has also been the template for other so called cryptocurrencies. The public interest in Bitcoin has been initially stimulated by stories of its potential to become a new global form of money. Acting as monetary authorities in their respective countries, central banks around the world have taken note of this phenomenon and started to investigate the plausibility of the many assertions regarding Bitcoin and digital currencies in general.

As of today, the fundamental nature of digital currencies remains surprisingly elusive. On the one hand, it shows how poorly understood the concept of money itself still is today. On the other hand, it may be reflecting how the world wide web and social media have muddled our sense of fact and fiction. There is also the challenge that the expertise required to understand a sophisticated innovation in computer science, such as Bitcoin, is quite different from the expertise required to understand how some of the fundamental features of our economy, such as money, work.

This paper is an attempt at de-muddling our understanding of digital currencies and of money in general. I argue that the concept of digital currency is essentially a fallacy. My argument rests on the observation that digital currencies are actually account based ledger systems and not significantly different from other financial record keeping technology. They include some specific innovative features relating to cryptography and distributed computing, but these are implementation details which are unrelated to the fundamental characteristics of money.

2. Previous research on digital currencies

I will use the terms *digital currencies* and *cryptocurrencies* interchangeably.¹ I see cryptocurrencies as a special case of digital currencies. The term "cryptocurrency" came about with Bitcoin, as it was the first to utilise cryptographic digital signatures to validate transactions.

Cryptocurrencies are the class of digital currencies that has grown immensely in recent years, and that growth is probably the main reason for the recent surge in research and public debate on the nature of digital currencies. Although digital currency is a more general concept than cryptocurrency, I am not aware of digital currencies other than cryptocurrencies that would have any real significance in the world today. It is nonetheless important to generalise the analysis to digital currencies, because these could, at least in principle, include digital currencies issued by central banks.

There are many good descriptions of the history of Bitcoin and how the Bitcoin system works, and I will therefore not repeat them here.² In what follows, I briefly review some of the academic literature on cryptocurrencies.

Yermack (2013) is the only paper I know of which directly addresses the question of whether cryptocurrencies are money, and it is also one of the earliest academic papers on cryptocurrencies. The paper concludes that cryptocurrencies do not perform the functions of money to such a degree that they could be considered monetary instruments.

¹ For a more detailed conceptual analysis, see e.g. ECB (2012) or Bech & Garratt (2017).

² For a technical description of cryptocurrencies, see e.g. Nakamoto (2008) or Badev & Chen (2014).

Some of the earliest studies on cryptocurrencies were conducted by central banks. ECB (2012) provides an overview of virtual currencies, such as those used within gaming environments, and considers cryptocurrencies one subclass among them. ECB (2015) is a follow-up study which provides a more detailed descriptive analysis, and concludes that cryptocurrencies do not constitute money or currency. Badev & Chen (2014) is the earliest publication by the Federal Reserve Board on the topic. The paper avoids defining Bitcoin, but provides a thorough analysis on its technical architecture and its transaction patterns. Ali et al. (2014) is the first publication by the Bank of England on the topic and provides a conceptual overview of cryptocurrencies. The paper refers to cryptocurrencies as money and as currency, but also points out some key differences between cryptocurrencies and real money.

Bitcoin has a well-functioning secondary market. Baek & Elbeck (2014) analyse the market price of Bitcoin and conclude that Bitcoin is best described as a speculative investment vehicle. Cheung et al. (2015) also analyse the market price of Bitcoin and conclude that its price trajectory features bubbles. Cheah & Fry (2015) also study the price trajectory of Bitcoin. They conclude that the price of Bitcoin exhibits bubbles and that its fundamental value is zero. Balci et al. (2017) investigates whether trading volumes can predict market returns for Bitcoin. Their results are mixed. Urquhart (2016) tests whether the market for Bitcoin is efficient and finds that it is not. Nadarajah & Chu (2017) build on the work of Urquhart (2016) and find some evidence of market efficiency. Katsiampa (2017) seeks to find the best econometric model for describing the volatility of the price of Bitcoin. Bouri et al. (2017) explore the ability of Bitcoin to function as a hedging instrument and find some evidence for this.

Glaser et al. (2014) have studied the Bitcoin user community and find strong evidence that the demand for Bitcoin is primarily driven by its use as a speculative investment instrument rather than a currency. Similar findings have been reported by Baek & Elbeck (2014), Katsiampa (2017), and Dwyer (2015). Yelowitz & Wilson (2015) apply a different methodology and find evidence that interest in Bitcoin is associated with interest in computer programming and illegal activity. Foley et al. (2018) investigate Bitcoin transactions and find that a large portion of transactions and users are related to illegal activity.

Böhme et al. (2015) provide a descriptive analysis of the Bitcoin system, its market, and its governance structure. The paper compares the supply of Bitcoin to the supply of money and refers to Bitcoin as a currency, but does not explain the choice of terminology. Dwyer (2015) and Selgin (2015) also analyse various broader aspects of the Bitcoin system. Both assume that Bitcoin is a currency without providing further explanation for that assumption. Huberman et al. (2017) study the economic incentive structure of the Bitcoin network and find that congestion is necessary for its continuous operation. They describe Bitcoin as a system of accounts.

Heilman & Rauchs (2017) provide rich empirical data on the industry that has sprung up around cryptocurrencies. It is a highly descriptive study which avoids making assumptions and assertions that aren't supported by evidence. One of the many findings in the paper is that cryptocurrencies are primarily used as a speculative investment instrument.

3. Again, what is money?

3.1. Neoclassical definitions of money

The economic literature is rich in definitions and discussions on the nature of money. Many writers have tried to formulate a definition which would stand the test of time and would apply to all the different forms that money has taken over the course of millennia. It is inescapable, however, that any such definition will only reflect the realities known up to that point in time.

Kiyotaki & Wright (1989) have developed a widely cited economic model where money emerges endogenously as a medium exchange. Their definition of money follows a long and pervasive tradition in the economic literature according to which money, usually interpreted as a physical good, exists to facilitate trade and to make barter exchange more efficient. Based on that premise, Kiyotaki & Wright (1989) define money, and clarify the difference between commodity and fiat money, as follows:

“When a commodity is accepted in trade not to be consumed or used in production, but to be used to facilitate further trade, it becomes a medium of exchange and is called commodity money. If an object with no intrinsic value becomes a medium of exchange, it is called fiat money.”

What is common to most definitions in the literature is that money is defined based on what it does and not what it is. This could mean that anything can be money, as long as it is used in a certain way. In addition to functioning as a medium of exchange, money is widely seen as also having the functions of store of value and unit of account.

Store of value implies that money is an asset.³ It should retain its approximate value over time so that its owner can get a similar utility from it at any later date. Keynes (1936) and Samuelson (1958) emphasise this intertemporal nature of money. According to their view, money is used to preserve purchasing power across time, to exchange present goods for future goods.

Medium of exchange means something which is accepted in exchange solely for the reason that it can be later traded for other goods and services. A medium of exchange is necessarily also a store of value, but not vice versa.⁴ An object which is easily transported, durable, divisible, easily recognised and assayed, has the potential to become a medium of exchange. Historical examples include stones, cereal, metal objects, animal skins and shells.⁵

Medium of exchange is sometimes confused with *means of payment*. Yang (2007) demonstrates the difference between the two concepts. While a medium of exchange refers to an asset which people regularly exchange for other goods and services, means of payment refers to generally accepted methods for the delivery of money. The difference is that a medium of exchange is in itself an asset of value, while a means of payment is not. Yang (2007) exemplifies this by noting that banknotes are a medium of exchange, while cheques are not. Both, however, are means of payment. According to this view, cash is the only asset which is both a medium of exchange and a means of payment.

Unit of account can be defined as a general metric for value. Doepke & Schneider (2017) define it as the good in which the value of future payments is specified. Unit of account literally implies that it is the metric used in bookkeeping. Prices can be quoted in many units, but only one of them is the unit of account for the producer of that good or service. This follows from the fact that the producer has to pay for inputs, including wages and salaries, and pay out taxes and dividends. There is therefore an inherent connection between accounting units and prices. Money as a unit of account is reflecting the ratio at which various goods can be traded

³ See Yang (2007).

⁴ See Ostroy & Starr (1988).

⁵ See e.g. Graeber (2011).

into other goods. Doepke & Schneider (2017) show that it is optimal to use the same unit of account on both sides of the balance sheet in order to mitigate risks.

McLeay et al. (2014) and Ali et al. (2014) describe the functions of money as hierarchical. According to their view, not every store of value is a medium of exchange, and not every medium of exchange is a unit of account, but every unit of account is a medium of exchange, and every medium of exchange is a store of value. While this is an intuitive idea, neither paper presents any empirical support for it. Graeber (2011) shows that the idea may have little or no historical basis.

3.2. Liquidity and currency

Liquidity is a property of any good or asset and refers to the ease of selling it. A highly liquid asset can be exchanged into other goods and services easily and at a low cost. Many definitions of money, including those by Jevons (1875), Menger (1892), Brunner & Meltzer (1971), express the idea that the most liquid good in the economy is used as money. Keynes (1936), Diamond & Dybvig (1983), among others, use liquidity as a synonym for money. Starr (2003) has developed a general equilibrium model where out of many goods in the economy the one that is most liquid, defined as having the lowest transaction costs, becomes the generally accepted medium of exchange. Ostroy & Starr (1988) summarise the idea as follows:

“What distinguishes money from other stores of value is its liquidity, and what underlies the liquidity of money is the fact that it is the common medium through which other commodities are exchanged.”

Currency refers to money in circulation, in other words, it is physical money which is passed on from one owner to another without going through intermediaries. It is also widely used and generally accepted as payment and to settle debts within a certain geographic or economic community. This definition implies that money is a broader concept than currency, and that currency is a special case of money. Practically speaking, currency is synonymous to coins and banknotes.⁶

According to the theory presented by Menger (1892), and many others since, money emerged out of existing stores of value as the one that was most liquid and was able to facilitate transactions, thereby making the exchange of goods and services more efficient. There are two reasons for this efficiency gain. First, using a medium of exchange reduces the number of transactions required to arrive at an optimal allocation of resources. Second, using a single unit of account reduces the information and transaction costs in those transactions. These can be explained as follows.

In an economy with N agents, there are $N(N-1)/2$ possible trading opportunities between any two agents. This number reduces to $N-1$ interactions when money is used. This is the efficiency argument for a medium of exchange. In an economy with n commodities and no money, there are $n(n-1)/2$ different exchange ratios for different commodity pairs. This number reduces to $n-1$ prices when money is used. This is the efficiency argument for a unit of account. If these were two different objects, there would exist one more exchange ratio, the one between the medium of exchange and the unit of account. If the same object functions as both, this exchange ratio disappears and efficiency is further improved.

3.3. Money as a unit of account

What is apparent in many of the neoclassical definitions of money is the emphasis on physical currency. This is in contrast to the fact that the greatest part of money today, and possibly

⁶ For a more detailed discussion on the meaning of currency, see e.g. McLeay (2014).

throughout history, has been in the form of account balances on financial ledgers, i.e. scriptural money.⁷

It would be easy to conjecture that a widely used medium of exchange also becomes used as a unit of account.⁸ This is because the value of any good or asset is ultimately tested by selling it. It is also more efficient to use the same asset as both a medium of exchange and as a unit of account.⁹ Graeber (2011) shows, however, that money has actually evolved the other way around. Money first appeared as an accounting unit for the purpose of record keeping. Goods were valued and priced in these units, and only later did some of those goods become used as mediums of exchange.

One could therefore argue that money is always scriptural, and that money is inherently a unit of account. Currency, in the form of coins, banknotes or other physical objects, can be seen as a physical manifestation of the unit of account. Physical currency would then be just another way to keep accounts, a more tangible form of bookkeeping. Out of the three basic functions for money, therefore, it is the unit of account that is arguably the most fundamental.¹⁰

Diagram 1 illustrates the three basic elements of financial record keeping: accounts, transactions, and a unit of account. In the case of scriptural money, accounts are held in books or on computers at a bank.¹¹ An account entry is a record of some asset. An account entry without a corresponding asset would be meaningless. Each account has a balance which is expressed in the unit of account. Transactions are recorded in a journal, and account balances adjusted accordingly.

In the case of physical currency, accounts are maintained individually by each person. A purse or a wallet is effectively a cash account. The contents of such a purse is the balance of that account. A transaction takes place when some units of account, i.e. currency, are physically transferred from one purse to another. The balances on each account adjust accordingly. There is thus no conceptual difference between a bank account and a cash purse, as they consist of the same elements.

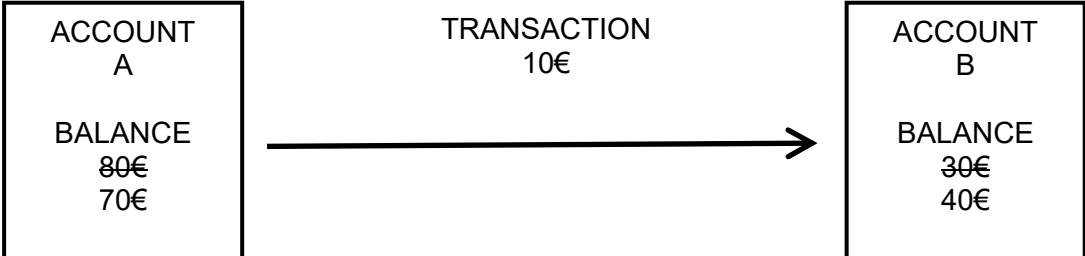


Diagram 1

The handling of physical objects to keep accounts is simple and intuitive and therefore still widely used today. This is consistent with empirical research on the use of cash recently conducted by Esselink & Hernandez (2017). They find that the main reason why cash is the preferred payment instrument among consumers in the Eurozone is that "it gives a clear overview of expenses". In other words, cash has an accounting function in addition to a payment function. It is the combination of these two functions that makes cash so compelling.

⁷ The percentage of currency out of the monetary aggregate M1 is approximately 14% for the euro and 40% for the US dollar. For a detailed analysis of how the total money supply breaks down in modern economies, see McLeay (2014).

⁸ See e.g. Jevons (1875), Menger (1892), Brunner & Meltzer (1971).

⁹ See Brunner & Meltzer (1971).

¹⁰ There are not many examples in recent history where an entirely new currency was created. One such rare case is the euro. Before it was issued as a currency available to the general public, it only existed as a unit of account.

¹¹ See Greenspan (2016) for a more detailed technical analysis of ledgers.

The theory of money as a unit of account is not new, but it has not been the dominant narrative in the economic literature. Kocherlakota (1998) is one of the few papers which builds on the idea. It presents a theoretical model where currency primarily functions as a financial record keeping device. The paper demonstrates that any resource allocation which can be attained using a medium of exchange can also be attained using financial record keeping.

3.4. A brief remark on money creation and price stability

Money in today's world is created by the banking system as a whole. One can distinguish between central bank money and commercial bank money. The former generally exists in two forms, cash and reserve accounts. Both types of central bank money are liabilities on the balance sheet of a central bank. Reserves can only be held by commercial banks at the central bank, while cash can be held by any person or entity. The central bank can create new money by lending to commercial banks, or by purchasing assets from them. Commercial banks can create new money through lending to households and businesses. Money as credit has been the subject of debate for more than a century. Whether or not all money should be viewed as credit is not the subject of this paper. I refer to Innes (1914), Skaggs (1998), Wray (2014), or McLeay (2014) for discussions on the topic.¹²

Cash can further exist in two different forms, coins and banknotes. These have become equivalent, but they have different historical origins. Early deposit banks took coins as deposits and made account entries to record those deposits. Banknotes were effectively receipts for the deposits, and later started circulating as currency in place of the deposited coins.¹³ When a modern bank issues money in the form of an account entry, it commits to exchanging that money into banknotes. Modern banknotes are not redeemable for any specific asset, but they are generally accepted as payment for goods or services.

When new money is created in the form of loans, whether by central banks or commercial banks, it is largely backed by collateral. Therefore, money is not created "out of thin air" but rather as a result of liquidity transformation. Less liquid assets, such as rent yielding real estate, dividend yielding equity, or interest yielding bonds, are pledged as collateral against monetary loans. Gaffney (2009) provides a thorough analysis of this mechanism.

Even though modern fiat money is not backed by any specific underlying asset, such as gold, it is backed by what central banks call *price stability*, often pursued by a policy of *inflation targeting*.¹⁴ Price stability means stability in the general price level, not any one price in particular. Price stability as a policy goal effectively means that money retains its value relative to all goods and services. Since under price stability the value of money is guaranteed relative to all goods and services, it is arguably a stronger form of backing than backing against a single commodity. Whether or not a central bank is able to deliver on that guarantee is a separate question, but it is worth pointing out that a similar credibility concern applies regardless of whether the monetary system is based on price stability or a commodity standard.

4. Can such a thing as digital currency exist?

4.1. A closer look at cryptocurrencies

In light of recent developments in digital technology, the theory of money as a unit of account is the one that best fits the entire span of historical evidence, starting from the prehistoric era to the present day. In what follows, I examine digital currencies in this context and argue that

¹² Historical evidence seems to suggest that money first appeared as a unit of account, before it appeared as a medium of exchange. This is consistent with both the credit theory of money as well as the arguments presented in this paper, although the two are not directly related. See Graeber (2011) for more details.

¹³ See e.g. Quinn & Roberds (2014).

¹⁴ Bernanke & Mishkin (1997) introduced the concept as a monetary policy framework. Bordes & Clerc (2007) have analysed the policy in a European and Angeriz and Arestis (2007) in a British context.

the concept of digital currency is questionable. When currency is viewed as a physical representation of a monetary unit of account, then turning that currency into digital form simply means using the same unit of account in financial records.

I will below describe the functional principles of cryptocurrencies and use Bitcoin as a representative example. There are over a thousand other cryptocurrencies in existence today, but Bitcoin is by far the largest and most popular, and it is also the template for most of the rest. It is helpful to follow the thinking of Nakamoto (2008), and to work out step by step how one would arrive at a cryptocurrency system given its objectives.¹⁵

The goal of Nakamoto was to create a new type of payment system that would allow sending money online from one party to another without using intermediaries. The payment system would be similar to cash in the sense that payments would be direct, anonymous, and irreversible. Nakamoto attempted to do this by introducing the concept of *digital coins*. It is a confusing choice of terminology, since in reality there is nothing resembling coins in the Bitcoin system.¹⁶ Instead, at the core of the Bitcoin system are *transactions*. A transaction is a data entry with three pieces of information: a sender, a recipient, and an amount being transferred.¹⁷ The sender and the recipient are identified by account numbers which in Bitcoin are represented by *public keys*.¹⁸ The amount transferred is expressed using a fungible unit of account. This unit of account was supposed to represent money.

Bitcoin keeps record of transactions in strict chronological order. In Bitcoin, this record is called a *blockchain*. This is equivalent to a *journal* in traditional accounting terminology. The essential record keeping mechanism, therefore, including the concept of a transaction and a fungible unit of account, is no different from ledger books that have been used for hundreds of years or more.

Typically, the task of financial record keeping would be that of a bank. For Nakamoto, however, the objective was to avoid banks. Bitcoin is therefore implemented as a peer-to-peer network. This means that there is an unspecified number of volunteers who jointly perform the task of an accountant. In Bitcoin, these accountants are called, confusingly, *miners*. For each transaction, one of the miners is randomly chosen as the one who records the transaction in the ledger.¹⁹ As a reward, the miner is allowed to retain a transaction fee, paid by the sender.²⁰

Nakamoto's solution of randomly assigning an unidentified intermediary is sometimes erroneously interpreted as using no intermediary at all. But an intermediary is always used, and all transactions are necessarily recorded in a single ledger. For all intents and purposes, that ledger is a centralised ledger. The fact that there are multiple synchronised copies of it, distributed across a network, is irrelevant, as each one has the same data. The basic principle of operating a ledger to record account balances and transactions is therefore no different from what a bank would do. The idea of withholding a transaction fee is also no different from how banks would be rewarded for processing payments.

¹⁵ I am conscious of the fact that the identity of Nakamoto is unknown, and instead of one person could refer to a group of people.

¹⁶ Nakamoto defines a digital coin as a chain of digital signatures. The idea is that all the information needed to validate a transaction is atomically contained within the transaction. This is an innovative way to build a ledger, but it but doesn't remove the need for one.

¹⁷ Bitcoin transactions also carry as information the digital signatures of the transacting parties, but that is not important in the present context.

¹⁸ For a detailed description of public key cryptography and its use in Bitcoin, see Nakamoto (2008) or Badev & Chen (2014).

¹⁹ The randomisation process in Bitcoin is one where all the miners use computing power to solve a mathematical problem. Whoever finds the answer first gets to add the next transactions to the ledger. To an outside observer, the process is indistinguishable from random selection.

²⁰ In Bitcoin, miners actually receive both a transfer fee plus a predetermined additional reward, but this does not fundamentally change the incentive structure of the system. In any event, miners receive a reward if and only if they manage to record a valid transaction.

A challenge for Nakamoto's system was how to ensure that miners don't enter fraudulent transactions into the ledger. This is what Nakamoto referred to as the double-spending problem.²¹ Double-spending is normally avoided by using a single trusted record keeper, and by having public institutions oversee the conduct of that record keeper. Nakamoto solved the problem by making the ledger public, and by using cryptography and algorithms, the details of which are widely documented and not necessary repeating here, to make entering fraudulent transactions very expensive.

Another puzzle for Nakamoto was how to enable the system to transfer ownership of money instead of arbitrary units, considering that banks had been specifically excluded from the system. Nakamoto never managed to solve that problem, because it cannot be solved. If banks are not involved, then the system cannot possibly transfer money. Money as an account entry means a commitment by a bank to convert that account entry into something else, whether this is coins, banknotes, or general purchasing power. When there is no bank or other entity making such a commitment, or when the account entry does not refer to any actual deposited asset, the account entry is meaningless.

Nakamoto described the role of banks as purely one of processing transactions, but that is an incomplete view, as it omits the role of the banks as also providing the liquidity for the payment system. In order to recreate a fully functional payment system it is therefore not enough to solve the double-spending problem. One also has to solve the question of where the liquidity for the payment system comes from. If there was a bank that would provide the liquidity for the Bitcoin system, then money could be used as its unit of account.²² But then the purpose of setting it up as a peer-to-peer network would become moot, since the bank could itself maintain the ledger and act as the record keeper. The system would be indistinguishable from a core banking system. It would consist of:

- A set of accounts
- A unit of account
- A ledger (or, strictly speaking, a journal) where all transactions are recorded

The only difference between a cryptocurrency system and a traditional ledger system is that in a cryptocurrency system the ledger is distributed across a network of computers, while a traditional bank maintains the ledger in a centralised computer system. There is, however, no practical difference in what the systems do.²³

In Bitcoin, account holders are not required to identify themselves, but this does not change how the system functions. Any core banking system is also based on account numbers, and could in principle operate on an anonymous basis. It is a legal but not a technical requirement that account holders need to be identified.²⁴

In summary, digital currency is not currency at all, but a system of accounts. This should not be surprising considering that a computer is fundamentally a recordkeeping device similar to a ledger. Perhaps it is not even theoretically possible to process financial transactions in any other way. Unlike cash, digital currency does not pass from one owner to another without going through intermediaries.²⁵ The fact that Bitcoin runs on a peer-to-peer network does not mean

²¹ Dwyer (2015) notes that for a currency to have value, it must not be double-spent. While this is true for a currency, it is also true for any other asset, and therefore not a sufficient condition for something to become a currency.

²² The bank could be either a central bank or a commercial bank.

²³ For a more detailed analysis of the differences between the Bitcoin ledger and traditional centralised ledgers, see Greenspan (2016).

²⁴ There is a strong argument why anonymous ownership of an intangible asset such as scriptural money is problematic: it is difficult to prove and legally defend ownership if the owner's identity is unknown. Ownership of currency, and other physical objects, can be demonstrated by physical control. Ownership of intangible assets, however, cannot be proven unless the identities of the owners have been recorded somehow. In the case of bank accounts, identities are mapped to account numbers.

²⁵ In Bitcoin, every transaction involves a miner as an intermediary.

that *transactions* on that network would be peer-to-peer. They are not. The data which comprises a transaction is transmitted from the sender to the ledger, not from the sender to the recipient.

Cryptocurrencies such as Bitcoin are often referred to as digital tokens. Such a description may seem intuitive, but it is fundamentally false. No tokens actually exist. A cryptocurrency system merely keeps record of *imaginary* token ownership. An account balance in a cryptocurrency system makes it look *as if* the account holder had a claim to tokens, but since no tokens exist in reality, the claim is ineffective.

4.2 Does Bitcoin have intrinsic value?

The fact that the Bitcoin network is incapable of transferring money created two problems for Nakamoto. On the one hand, the system fails in its ultimate goal, namely to replace cash. On the other hand, a peer-to-peer network relies on miners providing computing resources in exchange for transfer fees. If the transfers do not consist of money, then neither do the fees, and if the miners don't receive a pecuniary reward, then they have no incentive to operate the network. This might seem like an existential problem, but the network did manage to materialise, and even grow to substantial proportions. How was that possible? I explain it as follows using basic economic concepts.

Consider a planner, i.e. Nakamoto, who wants to set up a decentralised peer-to-peer ledger, i.e. Bitcoin. The planner wants the system to operate independently of anyone, and therefore invites miners to join and operate the network in exchange for transfer fees. But the only fees the planner can offer are Bitcoin units which have no value. As a solution, the planner suggests that the miners sell for actual money the units they receive as rewards. But who would buy them? Initially, nobody has an incentive to pay anything for them. To solve this problem, the planner suggests to the miners that if they *advertise* their mining rewards, then perhaps this will generate demand and people will want to buy them.

This is more or less what happened. Advertising may not have been explicitly suggested by Nakamoto, and it didn't need to be a coordinated effort, but anyone who ended up owning Bitcoin units nevertheless had an incentive to advertise them in order to create a secondary market. The advertising message was initially the story of a new global currency. Whether the story was realistic or not was not important, as long as it generated demand. As soon as Bitcoin units had willing buyers, it became worthwhile to operate the network, since the mining rewards had become saleable goods. There would be a positive return on investment both to advertising Bitcoin and to expanding the computing resources of the miners. These investments have since grown to massive proportions. As of today, so much computing power has been invested into the Bitcoin network that its energy consumption exceeds that of many countries.²⁶ Advertising was initially, perhaps inadvertently, done by almost anyone enthusiastic enough about the topic using websites, discussion boards, social media posts, online videos, white papers, and media interviews. Eventually it became a more deliberate activity which utilised books, films, and other major marketing channels.²⁷

Although Bitcoin started out as an intrinsically worthless unit of account, it has gained genuine demand, which is evident in a persistent non-zero market price. It is important to emphasise, however, that this demand has not turned Bitcoin units into money.

It is difficult to generalise why people are buying Bitcoin. Evidently Bitcoin is used for criminal activity.²⁸ It has also become a brand that some consumers feel drawn to, and may give a

²⁶ See e.g. Rogers (2017).

²⁷ To date, there are over 2,000 book titles about Bitcoin on Amazon. Google search can find over 265 million web pages and 381,000 PDF documents about Bitcoin. SlideShare has over 16,000 presentations about Bitcoin. YouTube has over 4 million videos and IMDB identifies over 200 films or TV productions about Bitcoin.

²⁸ Foley et al. (2018) estimate that 44% of all Bitcoin transactions and 25% of the user base are related to illegal activity.

sense of belonging to a community.²⁹ For others, it may give a feeling of security against state oppression, either real or imagined. It seems that many are drawn to Bitcoin because of the thrill of trading. Because these can be genuine satisfiable needs, it would not be entirely accurate to say Bitcoin doesn't have intrinsic value. Many goods and services such as toys, fashion, art, club memberships, or firearms, are bought because they provide their owners with intangible value which may be difficult for others to comprehend.

It is also evident that much of the attraction for Bitcoin is related to personal financial gains. Bitcoin is widely advertised as an investment which can give its owner large financial rewards. The rapid increase in the market price of Bitcoin may have reinforced this message, thereby encouraging further demand and creating a market bubble. Since Bitcoin is not a financial security and does not yield any return in itself, any hopes of financial gains are hinging on the continuing rise in its market price. It is clear that such an indefinite rise is not possible, as it would require an ever increasing number of new buyers entering the market.

4.3. Could Bitcoin become a real currency?

There are many people who seem to believe the Bitcoin story and in its potential to become a real currency. Without doubt, Nakamoto has been successful in incentivising miners to operate the network. But as I have shown in this paper, they are not operating a payment system, but a ledger with a meaningless unit of account.

In what follows, I will conduct two thought experiments in order to assess whether a cryptocurrency like Bitcoin could theoretically become a real currency. The first is a scenario where an existing currency, say the euro, is issued in the form of cryptocurrency alongside bank accounts and cash. The second scenario explores the idea of making an existing cryptocurrency, say Bitcoin, the only legal tender in an economy.

[Scenario 1: Euro-denominated cryptocurrency](#)

Suppose a euro-denominated cryptocurrency would be issued and become legal tender alongside existing bank accounts and cash. In practice, this would require that either a central bank or a commercial bank would commit to converting the cryptocurrency into other forms of the euro. Without such a commitment, the value of the cryptocurrency could not be kept at parity with cash and account money. Therefore, the issuing bank needs to have complete control of the supply of the cryptocurrency. In other words, the cryptocurrency would be supplied on demand in exchange for other forms of money, the same way as cash is supplied today. If that were the case, then obviously no new cryptocurrency would be created through mining, and the purpose of miners would become questionable. There would be no need for the energy-intensive mining process of the Bitcoin system, since the issuing bank could simply take over the processing of transactions and maintain the ledger. It is difficult to find any reason why that process should be decentralised, or why the ledger should be public. The security and privacy concerns of an open, public ledger would be significant, while there would be no apparent benefit.

As a result, cryptocurrency accounts would look like ordinary bank accounts, and the issuing bank would find it difficult to justify why it should keep both types of accounts. There is no evidence that cryptocurrency technology would bring efficiency gains, cost advantages, or any added value for either the account holders or the bank. It would be an unnecessary burden for banks to maintain two types of bank accounts based on disparate technologies.

²⁹ See Pepall & Reiff (2016) for an economic model where advertising creates a desire for the consumer to belong to a community.

Scenario 2: Bitcoin economy

For this scenario, let us assume Bitcoin would become legal tender by decree in some country or jurisdiction. It would be the only monetary unit of account in the economy, and any previous currency, along with the central bank issuing it, would be abolished. It is clear that this scenario is highly unlikely, but since it is a scenario that has been debated in the public, it is worthwhile analysing in detail.

Based on how money has historically evolved, one can hypothesise the likely long-term evolution for the Bitcoin economy.³⁰ Initially, Bitcoin would represent the entire monetary base of the economy and currency in circulation, similar to early coinage. Because that monetary base would be scarce, much of it would be deposited into banks as reserves, the same way as coins were deposited into early deposit banks.³¹ Banknotes backed by those reserves would be issued and used as currency. It is efficient for reserves to converge into one bank, and this would effectively become a central bank. A growing economy would need an increasing amount of cash for transactions, and this would lead to fractional reserve banking. Eventually, Bitcoin backing would be suspended, and monetary policy would become based on inflation targeting instead. Money would become fiat, Bitcoin a pure commodity, and there would no longer be any connection between the two.

This stylised sequence of events highlights the importance of unit of account as the most fundamental function of money. What started out as high-powered currency, ended up vaulted as reserves, and eventually replaced by banknotes and account money. In the end, all that remained of the original monetary base was the unit of account.

The advertised Bitcoin story includes the idea that a fixed, limited supply of Bitcoin units is enough to ensure its non-inflationary value.³² But the supply of Bitcoin is limited only to the extent that it replaces base currency in the form of coins. As our thought experiment shows, the total supply of money would be extended by banknotes and bank lending. The Bitcoin story doesn't specify how this additional supply would be controlled. Banknotes are the dominant payment instrument throughout the world today, and although their use may have declined in some countries, they are by and large not showing signs of becoming unpopular.³³ While Bitcoin may have been invented to replace coinage, coins are not the same as banknotes. There is no reason to think that there wouldn't be demand for banknotes, and the means to supply them, also in a Bitcoin economy.

To summarise, Scenario 1 shows that creating cryptocurrencies does not make sense for any bank, because a convertible cryptocurrency would be indistinguishable from ordinary bank accounts. Scenario 2 is not plausible either, because it would effectively mean replacing an existing monetary unit with a new unit, and then rebuilding all the institutions required to govern it. There is nothing to suggest that the hypothesised set-up would be an improvement compared to the monetary institutions we have today.

As of today, and contrary to how Bitcoin is advertised, cryptocurrency is not used anywhere as a unit of account for pricing, invoicing, accounting, wages, taxes, or any of the ways that monetary units are used. Neither is it widely used as a payment method, except for a small number of online stores, many of which trade in illegal goods.³⁴ In the few exceptional cases where merchants accept Bitcoin as payments, it usually represents a negligible percentage of their

³⁰ See e.g. Quinn & Roberds (2014) for a historical analysis on the emergence of fiat money in Amsterdam, or Kynaston (2017) for a comprehensive history of the Bank of England. A similar line of reasoning to the one presented here has been previously suggested by Ali et al. (2014).

³¹ Private keys would be deposited, and the blockchain would be used as a settlement system. See Schnabel & Shin (2018) for a description of early deposit banks.

³² Actually, the supply of Bitcoin is not only limited, it is steadily decreasing over time, as access to Bitcoin accounts can be lost. According to Roberts & Rapp (2017), up to 23% of existing Bitcoin units have been lost forever. This means that the supply of Bitcoin approaches zero over the long term.

³³ See e.g. De Putter (2016) or Esselink & Hernandez (2017).

³⁴ See e.g. Hendrickson et al. (2016)

total turnover. What is more, the merchant typically sells the Bitcoin immediately so that they actually never receive the Bitcoin.³⁵ It is therefore quite clear that the public has not adopted Bitcoin as a medium of exchange, nor as a unit of account, anywhere in the world. There is also no indication that this situation would be about to change in any significant way. The advertised story about Bitcoin as a currency is and remains fiction.

4.4. Central bank digital currency

The emergence of cryptocurrencies has prompted many to ask whether central banks should issue digital currencies. The question has received particular attention in the Nordic countries, where cash is used less compared to most other parts of the world.³⁶ The central banks of each Sweden, Finland, and Denmark have recently published discussion papers on the topic.

A central bank digital currency would be a claim on the central bank, and hence a safe asset, and convertible into other forms of central bank money. Sveriges Riksbank (2017) emphasise its potential role as a small-value payment instrument, similar to cash, which should be available at all times, possibly even offline. Danmarks Nationalbank (2017) point out that it would constitute a risk-free asset, but are doubtful whether it would bear any technical similarities to cryptocurrencies. Grym et al. (2017) consider universal access, suitability for small payments, and privacy to be relevant features.

Bech & Garratt (2017) develop a taxonomy for various forms of money, and theorise the existence of a central bank issued cryptocurrency. Their analysis shows that anonymity of transactions, as a consequence of using a peer-to-peer network, would be the key distinguishing feature of a central bank cryptocurrency compared to other forms of central bank money. A similar conclusion can be drawn from Danezis & Meiklejohn (2015) who present a technical model for a central bank issued cryptocurrency. In their model, the infrastructure for a central bank cryptocurrency would be operated as a network, but there would be otherwise no difference to other forms of central bank money.

The taxonomy by Bech & Garratt (2017) breaks down different forms of money based on four dimensions. The first is whether a form of money is widely available, or only accessible to a limited group of counterparties. The second dimension is whether money is digital or physical. Thirdly, money can be either issued by a central bank or a commercial entity. As the final dimension, Bech & Garratt (2017) make a distinction between peer-to-peer or token-based, and account-based money. Using this taxonomy, all conceivable forms of money can be listed. One can therefore imagine the existence of, say, a token-based, digital, widely available form of money issued by a central bank. This is what is often meant by a central bank digital currency. The problem with this definition is that no tokens actually exist in a digital environment. The dimension of token-based versus account-based is therefore the same dimension as physical versus digital. An account-based money is always digital, and vice versa, and a token-based money is always physical, and vice versa. The number of dimensions in Bech & Garratt (2017) therefore actually reduces to three.

In light of the analysis presented in this paper, and consistent with the cited literature, central bank digital currency would constitute central bank accounts for the general public. The cash-like properties referred to in the literature narrow down to two features:

- Anonymity and/or privacy
- Decentralised settlement

Anonymity and privacy of financial transactions may or may not be desired properties for a payment instrument, depending on one's point of view. Anonymity means the possibility to

³⁵ There are no reliable statistics on merchant acceptance of Bitcoin, which in itself can be seen as evidence of very low acceptance. Some investigation into Bitcoin acceptance is provided by Gandel (2017).

³⁶ See e.g. Esselink & Hernandez (2017) or Sveriges Riksbank (2017).

make a transaction without identifying oneself. Privacy means the possibility to make a transaction without anyone except the transacting parties knowing about it.³⁷ Cash transactions are currently the only type of monetary transaction that can be made both privately and anonymously. It is questionable whether anonymity actually matters to most people. Esselink & Hernandez (2017) have shown that anonymity is not important to users of cash in the Eurozone. Privacy may be more important than anonymity in most situations.

Privacy was one of the stated objectives for Nakamoto (2008). Bitcoin transfers are made to and from addresses which are essentially random account numbers with no identifying information. The Bitcoin ledger is public, but it is difficult to identify the beneficiary for each account number. This means that Bitcoin does not provide perfect anonymity, but it allows for a moderate degree of privacy.

The normative question of whether, or to what degree, banking services and payments should be private is outside the scope of this paper. It is noteworthy, however, that legislation and international treaties have developed in the direction of less privacy, whereas digital currencies seem to be striving towards more privacy. It is also important to note that ownership of an intangible asset is difficult to demonstrate, and legally defend, unless the identity of the owner is reliably known.

Whether there are significant benefits in decentralising a payments infrastructure any further from how it is operating today is doubtful. The concept has been explored to some extent, for example by Leinonen et al. (2002), but it has raised little enthusiasm before the emergence of cryptocurrencies. In any event, the technology to build decentralised payment systems has been available for far longer than cryptocurrencies have.³⁸ The Bitcoin system has been built in a decentralised way for no reason other than to enable privacy. There is, however, an evident trade-off between efficiency and privacy, and the Bitcoin system is far slower and more costly to operate than any existing payment system.³⁹ Moreover, as Catalini et al. (2016) and Böhme (2015) have pointed out, it is questionable whether the Bitcoin system manages to remain decentralised, as the power to govern the network is increasingly converging into the hands of a small number of large stakeholders.

5. Conclusions

The story of Bitcoin becoming an actual monetary unit is based on the false perception that money could exist in a single form, such as coins, and without institutional backing. In reality, however, currency exists as both coins and banknotes, and has circulated alongside various forms of scriptural money throughout history. Replacing coins with a digital version does not mean other forms of money would go out of existence. What is more, currency can be seen as just another form of scriptural money, a kind of financial record-keeping device comparable to an account book. Money, at its essence, is a unit of account.

The concept of digital currency is therefore a fallacy, as currency cannot be digitised. When money is digital, it takes the form of account balances. Contrary to common perception, cryptocurrencies do not enable direct peer-to-peer transfers without intermediaries. Cryptocurrency systems use intermediaries, so called miners, who maintain a ledger. The fact that miners are unidentified and randomly selected for each transaction does not mean intermediaries are not used. Cryptocurrencies, therefore, are essentially accounting systems for non-existent assets.

³⁷ Bech & Garratt (2017) refer to privacy as *third-party anonymity* and anonymity as *counterparty anonymity*.

³⁸ See Leinonen (2016).

³⁹ See e.g. Bordo & Levin (2017)

References

- Ali, R. – Barrdear, J. – Clews, R. – Southgate, J. (2014) "The economics of digital currencies", *Quarterly Bulletin*, Q3/2014, Bank of England.
- Angeriz, A. – Arestis, P. (2007) "Monetary policy in the UK", *Cambridge Journal of Economics*, Vol. 31, No. 6.
- Badev, A. – Chen, M. (2014) "Bitcoin: Technical Background and Data Analysis", *Finance and Economics Discussion Series*, 2014-104, Federal Reserve Board.
- Baek, C. – Elbeck, M. (2014) "Bitcoins as an investment or speculative vehicle? A first look", *Applied Economics Letters*, Vol. 22, No. 1.
- Balcilar, M. – Bouri, E. – Gupta, R., Roubaud, D. (2017) "Can volume predict Bitcoin returns and volatility? A quantiles-based approach", *Economic Modelling*, Vol. 64.
- Bech, M. – Garratt, R. (2017) "Central bank cryptocurrencies", *BIS Quarterly Review*, September 2017, Bank for International Settlements.
- Bernanke, B.S. – Mishkin, F.S. (1997) "Inflation Targeting: A New Framework for Monetary Policy?", *Journal of Economic Perspectives*, Vol. 11, No. 2.
- Böhme, R. – Christin, N. – Edelman, B. – Moore, T. (2015) "Bitcoin: Economics, Technology, and Governance", *Journal of Economic Perspectives*, Vol. 29, No. 2.
- Bordes, C. – Clerc, L. (2007) "Price stability and the ECB's monetary policy strategy", *Journal of Economic Surveys*, Vol. 21, No. 2.
- Bordo, M.D. – Levin, A.T. (2017) "Central Bank Digital Currency and the Future of Monetary Policy", *Hoover Institution Economics Working Papers*, No. 17104, August 2017.
- Bouri, E. – Jalkh, N. – Molnár, P. – Roubaud, D. (2017) "Bitcoin for energy commodities before and after the December 2013 crash: diversifier, hedge or safe haven?", *Applied Economics*, Vol. 49, No. 50.
- Brunner, K. – Meltzer, A.H. (1971) "The Uses of Money: Money in the Theory of an Exchange Economy", *American Economic Review*, Vol. 61, No. 5.
- Camera, G. (2017) "A perspective on electronic alternatives to traditional currencies", *Sveriges Riksbank Economic Review*, 2017:1, Sveriges Riksbank.
- Catalini, C. – Gans, J.S. (2016) "Some simple economics of the blockchain", *NBER Working Paper Series*, Working Paper 22952, National Bureau of Economic Research.
- Cheah, E-T. – Fry, J. (2015) "Speculative bubbles in Bitcoin markets? An empirical investigation into the fundamental value of Bitcoin", *Economic Letters*, Vol. 130.
- Cheung, A. – Roca, E. – Su, J-J. (2015) "Crypto-currency bubbles: an application of the Phillips–Shi–Yu (2013) methodology on Mt. Gox bitcoin prices", *Applied Economics*, Vol. 47, No. 23.
- Danezis, G. – Meiklejohn, S. (2015) "Centrally Banked Cryptocurrencies", *Internet Society*.
- Danmarks Nationalbank (2017) "Central bank digital currency in Denmark?", *Analysis*, No. 28, Danmarks Nationalbank.

- De Putter, E. (2016) "Cashless society – really?", *Journal of Payments Strategy & Systems*, Vol. 10, No. 3.
- Diamond, D.W. – Dybvig, P.H. (1983) "Bank Runs, Deposit Insurance, and Liquidity", *Journal of Political Economy*, Vol. 91, No. 3.
- Doepke, M. – Schneider, M. (2017) "Money as a unit of account", *NBER Working Paper Series*, Working Paper 19537, National Bureau of Economic Research.
- Dwyer, G.P. (2015) "The economics of Bitcoin and similar private digital currencies", *Journal of Financial Stability*, Vol. 17.
- ECB (2012) "Virtual currency schemes", October 2012, European Central Bank.
- ECB (2015) "Virtual currency schemes – a further analysis", February 2015, European Central Bank.
- Esselink, H – Hernandez, L. (2017) "The use of cash by households in the euro area", Occasional Paper Series, No. 201, European Central Bank.
- Foley, S. – Karlsen, J.R. – Putnins, T.J. (2018) "Sex, drugs, and bitcoin: How much illegal activity is financed through cryptocurrencies?", <https://ssrn.com/abstract=3102645>
- Gaffney, M. (2009) "Money, Credit, and Crisis", *American Journal of Economics and Sociology*, Vol. 68, No. 4.
- Gandel (2017) "Bitcoin Is Hot, But Good Luck Using It", *Bloomberg Gadfly*, December 1, 2017, <https://www.bloomberg.com/gadfly/articles/2017-12-01/bitcoin-is-hot-until-you-actually-try-to-spend-some>
- Glaser, F. – Zimmermann, K. – Haferkorn, M. – Weber, M.C. – Siering, M. (2014) "Bitcoin – asset or currency? Revealing users' hidden intentions", *Twenty Second European Conference on Information Systems*, Tel Aviv 2014.
- Graeber, D. (2011) *Debt: The First 5,000 Years*, Melville House.
- Greenspan, G. (2016) "Payment and exchange transactions in shared ledgers", *Journal of Payments Strategy & Systems*, Vol. 10, No. 2.
- Grym, A. – Heikkinen, P. – Kauko, K. – Takala, K. (2017) "Central bank digital currency", *BoF Economics Review*, No. 5, Bank of Finland.
- Heilman, G. – Rauchs, M. (2017) "Global cryptocurrency benchmarking study", Cambridge Centre for Alternative Finance, University of Cambridge Judge Business School.
- Hendrickson, J.R. – Hogan, T.L. – Luther, W.J. (2016) "The political economy of Bitcoin", *Economic Inquiry*, Vol. 54, No. 2.
- Huberman, G. – Leshno, J.D. – Moallemi, C. (2017) "Monopoly without a monopolist: an economic analysis of the bitcoin payment system", *Bank of Finland Research Discussion Papers*, No. 27/2017, Bank of Finland.
- Innes, A.M. (1914) "The credit theory of money", *Banking Law Journal*, Vol. 31.
- Jevons, W.S. (1875) *Money and the Mechanism of Exchange*, D. Appleton and Company.

- Katsiampa, P. (2017) "Volatility estimation for Bitcoin: A comparison of GARCH models", *Economics Letters*, Vol. 158.
- Keynes, J.M. (1936) *The General Theory of Employment, Interest, and Money*, Palgrave Macmillan.
- Kiyotaki, N. – Wright, R. (1989) "On money as a medium of exchange", *Journal of Political Economy*, Vol. 97, No. 4.
- Kocherlakota, N.R. (1989) "Money is memory", *Journal of Economic Theory*, Vol. 81.
- Kynaston, D. (2017) *Till Time's Last Sand: A History of the Bank of England 1694-2013*, Bloomsbury Publishing.
- Leinonen, H. – Lumiala, V-M. – Sarlin, R. (2002) "Settlement in modern network-based payment infrastructures – description and prototype of the E-Settlement model", *Bank of Finland Discussion Papers*, Vol. 23/2002, Bank of Finland.
- Leinonen, H. (2016) "Decentralised Blockchain and Centralised Real-Time Payment Ledgers: Development Trends and Basic Requirements" in Górká, J. (ed.) (2016) *Transforming Payment Systems in Europe*, Palgrave Macmillan.
- McLeay, M. – Radia, A. – Thomas, R. (2014) "Money in the modern economy: an introduction", *Quarterly Bulletin*, Q1/2014, Bank of England.
- Menger, C. (1892) "On The Origins of Money", *Economic Journal*, Vol. 2.
- Nadarajah, S. – Chu, J. (2017) "On the inefficiency of Bitcoin", *Economics Letters*, Vol. 150.
- Nakamoto, S. (2008) "Bitcoin: A Peer-to-Peer Electronic Cash System", www.bitcoin.org.
- Ostroy, J.M. – Starr, R.M. (1988) "The Transaction Role of Money", *UCLA Economics Working Papers*, No. 505, UCLA Department of Economics.
- Pepall, L. – Reiff, J. (2016) "The "Veblen" effect, targeted advertising and consumer welfare", *Economics Letters*, Vol. 145.
- Quinn, S. – Roberds, W. (2014) "How Amsterdam got fiat money", *Journal of Monetary Economics*, Vol. 66.
- Roberts, J.J. – Rapp, N. (2017) "Exclusive: Nearly 4 Million Bitcoins Lost Forever, New Study Says", *Fortune*, November 25, 2017, <http://fortune.com/2017/11/25/lost-bitcoins>
- Rogers, A. (2017) "The hard math behind Bitcoin's global warming problem", *WIRED*, December 15, 2017, <https://www.wired.com/story/bitcoin-global-warming>.
- Samuelsson, P.A. (1958) "An Exact Consumption-Loan Model of Interest with or without the Social Contrivance of Money", *Journal of Political Economy*, Vol. 66, No. 6.
- Schnabel, I. – Shin, H.S. (2018) "Money and trust: lessons from the 1620s for money in the digital age", *BIS Working Papers*, No. 698, Bank for International Settlements.
- Selgin, G. (2015) "Synthetic commodity money", *Journal of Financial Stability*, Vol. 17.
- Skaggs, N.T. (1998) "Debt as the Basis of Currency: The Monetary Economics of Trust", *American Journal of Economics and Sociology*, Vol. 57, No. 4.

Starr, R.M. (2003) "Why Is There Money? Endogenous Derivation of 'Money' as the Most Liquid Asset: A Class of Examples", *Economic Theory*, Vol. 21, No. 2/3.

Sveriges Riksbank (2017) "The Riksbank's e-krona project Report 1", September 2017, Sveriges Riksbank.

Urquhart, A. (2016) "The inefficiency of Bitcoin", *Economics Letters*, Vol. 148.

Wray, L.R. (2014) "From the State Theory of Money to Modern Money Theory: An Alternative to Economic Orthodoxy", *Working Paper*, No. 792, Levy Economics Institute of Bard College.

Yang, B.Z. (2007) "What is (not) money? Medium of exchange \neq means of payment", *American Economist*, Vol. 51, No. 2.

Yelowitz, A. – Wilson, M. (2015) "Characteristics of Bitcoin users: an analysis of Google search data", *Applied Economics Letters*, Vol. 22, No. 13.

Yermack, D. (2013) "Is Bitcoin a real currency? An economic appraisal", *NBER Working Paper Series*, Working Paper 19747, National Bureau of Economic Research.