Cryptocurrencies: They aren't money but the technology is here to stay

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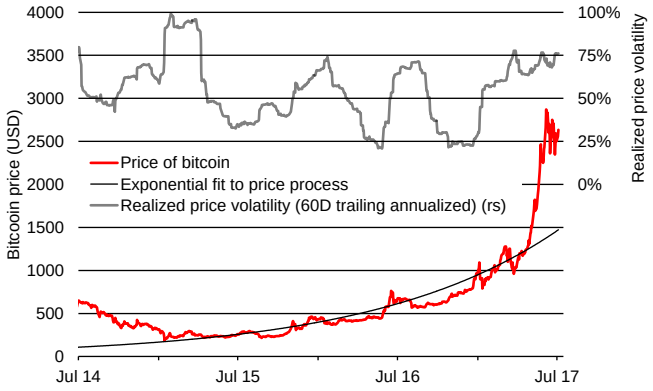
- The recent amazing rate of price appreciation of bitcoin and the related extreme price volatility is not a new phenomenon. However, this topic has received renewed attention recently as prices of cryptocurrencies have surged to fresh peak levels and as the cumulative market capitalization of hundreds of global cryptocurrencies reached USD 100bn for the first time.
- We offer a short introduction to the technology and infrastructure behind Bitcoin and similar cryptocurrency networks. This is meant to serve as a starting point to understanding and assessing cryptocurrencies and distributed-ledger technology – also known as blockchain – more generally. The technological innovation that came with Bitcoin in 2009 is likely here to stay, although the concept needs to develop in order to be more widely adopted in the financial sector and society.
- From an economist's point of view, the important aspects of cryptocurrencies include their status as a form of money, their impact on financial stability, their potential to disrupt the financial sector and the question of whether financial regulation must be amended. Despite the enormous growth of these currencies cumulative market capitalization, present cryptocurrencies lack important and necessary properties of money. However, the evolution of cryptocurrencies continues, and central banks have also started experimenting with modifications of their concept.

1. Bitcoin and cryptocurrencies

In 2Q17, the price of many virtual currencies surged to unprecedented levels. Although this triggered a series of media reports, the financial community may have not yet fully grasped the concept behind these currencies. Due to its dominance in terms of market capitalization and being the first cryptocurrency, Bitcoin is presently the most widely known virtual currency. Increased media coverage of late stems from the staggering price appreciation of bitcoin, particularly in 2Q17, when the price of the cryptocurrency increased by about 140% qoq. Fascination surrounding such a skyrocketing asset price is usually accompanied by the realization that the price volatility of Bitcoin has been very high (chart 1). While the volatility of fiat money exchange rates can be substantial, the volatility of bitcoin's price in USD is much larger. This fact and its elevated rate of price growth are not recent phenomena. Between late-June 2015 and late-March 2017, bitcoin's price increased by 220%. Bitcoin's realized price volatility is estimated to have been around 75% recently and has frequently been higher than 50% in the past three years (chart 1).

CHART 1: THREE-YEAR PRICE HISTORY OF BITCOIN*



*The exponential fit to the three-year price time-series represents an annualized continuous growth rate of about 86%.

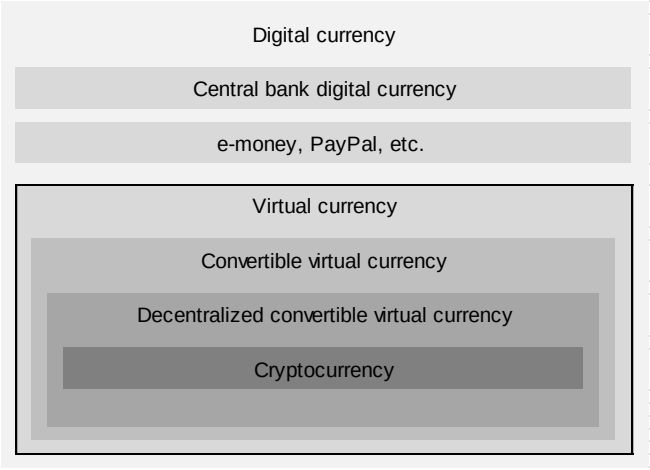
Source: Bloomberg, UniCredit Research

Investors who have read about such asset performance might wonder what kind of asset bitcoin and cryptocurrencies actually are. They constitute a particular form of a **virtual currency** (see taxonomy depicted in figure 1). Virtual currencies are electronic representations of value, issued by private entities and denominated in their own unit of account. Virtual currencies are distinguished from the more general concept of **digital currencies** by the fact that they are not denominated in legal tender and are not issued by central banks. Airline miles and similar bonus points are examples of virtual currencies. They are administered by a central authority and not denominated in a fiat currency. Airline miles are also sometimes an example for a **convertible virtual currency** (at least in one direction), as airlines might offer them to clients in exchange for legal tender. The Linden Dollar is another example of a virtual currency. It is used in the online virtual world "Second Life" as a means of payment. Second Life and Linden Dollars have been administered and operated by the US company Linden Lab since 2003. Linden Dollars are fully convertible; they can be bought and sold in exchange for legal tender.

Cryptocurrencies have several independent features that distinguish them from the broader concept of virtual currencies. In contrast to the two examples mentioned above, cryptocurrencies do not rely on a central authority to function. They are, by definition, convertible into legal tender and they use technology from cryptography to solve several issues that arise in a decentralized virtual-currency system, such as the double-spending problem (Narayanan et al., 2016).

As a side note, concepts for central bank digital currencies – which are not virtual currencies as they would be issued by these monetary institutions – are being considered by many major central banks but they are not yet in place.

FIGURE 1: TAXONOMY OF VIRTUAL CURRENCIES



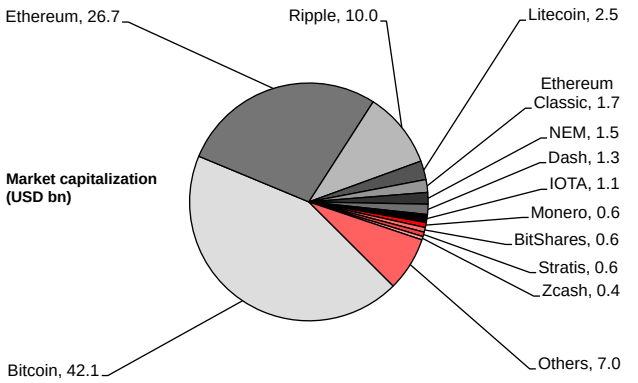
Source: He et al. (2016), UniCredit Research

Bitcoin was the first cryptocurrency. Its emergence in 2008 marks the invention of the concept of a cryptocurrency. The Bitcoin system started to operate in January 2009 after a software engineer (or a group of software engineers) under the pseudonym Satoshi Nakamoto posted the Bitcoin system's specifications to a cryptography discussion forum a few months before (Nakamoto, 2008). Although it has been subject to several software changes since 2009, the same global Bitcoin system, which uses bitcoin as a unit of account, is still running today. It is a public and globally distributed network of internet nodes that have chosen to run and use the Bitcoin network.[1]

In the past eight years, Bitcoin has not only grown constantly in terms of market capitalization but hundreds of modifications of this first cryptocurrency network have been proposed and implemented under new names and with varying technical tweaks. In terms of market capitalization, Bitcoin, Ethereum, Ripple, Litecoin and Ethereum Classic are the five most important global cryptocurrencies. They have a current cumulative market capitalization of USD 83bn. Chart 2 shows the distribution of the market capitalization of the 200 most important cryptocurrencies listed on the website coinmarketcap.com. But there are many hundreds more, according to the website cryptocompare.com, with increasingly negligible capitalization and tradability. In 2Q17, the cumulative market capitalization of all cryptocurrencies exceeded USD 100bn for the first time.

While the above-mentioned price increase for bitcoin significantly contributed to this development, the rapid price increase of other cryptocurrencies was even more important. The share of cryptocurrency market capitalization of bitcoin has been about 80% for a long time. It declined to about 44% in early July 2017.

CHART 2: MARKET CAP OF CRYPTOCURRENCIES (USD BN)*



*as of 3 July 2017. Source: coinmarketcap.com, UniCredit Research

In this publication, we explain the technological basics of cryptocurrencies, using Bitcoin as an example. While other cryptocurrency systems deviate from Bitcoin in many interesting and important aspects, they usually share a form of technology that was pioneered by Bitcoin: cryptographic **blockchains** and **distributed ledger technology** (DLT).

The more general discussion of DLT and its future implications for finance, the economy and society is beyond the scope of this publication. DLT could have implications far beyond the emergence of cryptocurrencies. It challenges the role that intermediaries play in many aspects of today's societies. Regarding DLT, The Centre for Cryptocurrency Research and Engineering of Imperial College London has claimed the following (link): "What is on offer is the ability to support a general notion of trustless, verifiable decentralized ownership and the ability to transfer and process information in a decentralized but programmable way. It is hard to begin to comprehend the significance of this development but suffice to say it has the potential to fundamentally change the way human society deals with contracts, identity, patents, copyright, votes, and more."

2. The basics of Bitcoin and blockchains

In the following, we discuss the functionality of cryptocurrencies by looking at the Bitcoin network as an example and making appropriate simplifications to identify basic concepts.

[1] While the *Wall Street Journal* and the *Oxford English Dictionary* advocate the use of the lowercase term "bitcoin" for both meanings, we make an explicit distinction in this publication to highlight the difference. Uppercase Bitcoin represents the decentralized system and lowercase bitcoin the unit of account.

Let us first assume that bitcoins already exist as an electronic currency in the Bitcoin network. The purpose of the network is to enable **payments** between owners of bitcoin, i.e. rapid global transfers of value denominated in bitcoin. Such payments are initiated by transferring data directly between two parties that intend to exchange bitcoins. As such a data transfer is possible via the internet and within seconds (preferably via encrypted transfer channels), the Bitcoin network allows bitcoins to be rapidly transferred globally. However, the internet is not the only useful data-transfer conduit that can be used to initiate payments. Local data transfers, for example, between two mobile phones represent technical alternatives. As such, the Bitcoin network is an electronic payment system that uses the internet and potentially other means of electronic communication to transfer value denominated in bitcoin.

TABLE 1: ELECTRONIC PAYMENT SYSTEMS AND PROPOSALS*

ACC	Agora	AIMP
Allopass	b-money	BankNet
Bitbit	Bitgold	Bitpass
C-SET	CAFÉ	Checkfree
ClickandBuy	ClickShare	CommerceNet
CommercePOINT	CommerceSTAGE	Cybank
CyberCash	CyberCents	CyberCoin
CyberGold	DigiGold	Digital Silk Road
e-Comm	E-Gold	Ecash
eCharge	eCoin	Edd
eVend	FirstVirtual	FSTC Electronic Check
Geldkarte	Globe Left	Hashcash
HINDE	iBill	IKP
IMB-MP	InterCoin	Ipin
Javien	Karma	LotteryTickets
Lucre	MagicMoney	Mandate
MicroMint	Micromoney	MilliCent
Mini-Pay	Minitix	MobileMoney
Mojo	Mollie	Mondex
MPTP	Net900	NetBill
NetCard	NetCash	NetCheque
NetFare	No3rd	One Click Charge
PayMe	PayNet	PayPal
PaySafeCard	PayTrust	PayWord
Peppercoin	PhoneTicks	Playspan
Polling	Proton	Redi-Charge
S/PAY	Sandia Lab E-Cash	Secure Courier
Semopo	SET	SET2Go
SubScrip	Trivnet	TUB
Twitpay	VeriFone	VisaCash
Wallie	WayZPay	WorldPay
X-Pay		

*This list of electronic payment systems, published in (Narayanan et al., 2016), does not include cryptocurrencies. It is not complete and lists technology that was available before Bitcoin was invented. It includes e-cash and credit-card-based technologies. Some systems are academic proposals, while others were deployed and tested. Some are still in wide use today.

Source: Narayanan et al. (2016), UniCredit Research

Bitcoin does not represent the first attempt to engineer a cryptographic technology to enable direct payments between two counterparties that communicate via the internet. Concepts for an electronic representation of cash date back to the 1980s. Since the 1990s, when the internet as a global communication conduit grew from a niche technology to the most important global communication network, many different cryptographic electronic payment systems have been conceived and implemented. Bitcoin technology is based on many aspects of these predecessors. To demonstrate that Bitcoin did not emerge entirely out of the blue, Table 1 shows how many different technologies had been proposed or even implemented before Bitcoin was introduced.

There are two important differences between these earlier attempts and Bitcoin: **1.** Bitcoin does not directly facilitate the transfer of legal tender as it uses its own unit of account. **2.** In contrast to all other earlier cryptographic payment systems, Bitcoin does not need a central authority to function. It is a pure dynamic peer-to-peer network that administers the global public distributed ledger of bitcoin transactions.

To claim **ownership of bitcoins**, a Bitcoin wallet is required. Ownership of a certain amount of bitcoins is linked to a pair of cryptographic keys, a private key and a public key. Both keys consist of two unreadable alphanumeric character strings. This technique, called **public-key cryptography**, has been widely used in electronic communications and information technology for decades. With regard to the Bitcoin network, the public key also serves as an account number and is referred to as the **Bitcoin address** (more precisely, a Bitcoin address is a so-called hash-value of that public key). Bitcoins are exchanged between Bitcoin addresses. The private key is the crucial piece of secret information that proves ownership of some address and its bitcoin balance. Only the knowledge of the private key allows one to initiate bitcoin payments to some other Bitcoin address. If the private key is lost or stolen, ownership of the related bitcoins is lost or stolen. There is no other evidence of ownership of bitcoins in the Bitcoin network aside from being in possession of the relevant private cryptographic key. A **Bitcoin wallet** allows one to safely store a key pair or a collection of key pairs.

In order to initiate bitcoin transactions and receive confirmation, electronic communication via internet with the global peer-to-peer Bitcoin network is necessary. For that purpose, related open source or proprietary **software** can be run on many different internet nodes (large-scale computing facilities, personal computers, mobile phones, web servers, etc.). By communicating with the Bitcoin network, a node becomes part of it. There are two different types of Bitcoin software: full clients and lightweight clients. Full clients include a full copy of the Bitcoin ledger, the complete history of all bitcoin transactions since January 2009.

This ledger is a temporally ordered sequence of blocks (the **blockchain**), which contain bitcoin transaction data and additional information. The Bitcoin global public blockchain, which contains all payment transactions ever made since 2009, had grown to a size of 100 gigabytes by December 2016. On average, every ten minutes, a new block with new transactions is added to the end of the existing blockchain. Full Bitcoin clients need to permanently update their copy of the global blockchain. Any bitcoin transaction that has been included in the global blockchain becomes a **confirmed transaction**. Lightweight Bitcoin clients do not have a copy of that ledger but are able to communicate with the Bitcoin network and initiate transactions. An electronic **Bitcoin wallet** can be understood as a (lightweight) Bitcoin client software with the additional ability to safely store one's own private keys and related Bitcoin addresses. However, other forms of wallets exist.

Although the structure described above represents anything but a technological revolution, the actual novelty pioneered by Bitcoin is the mechanism that allows the network to achieve consensus on the next block that will be added to the blockchain. Achieving consensus among distributed database nodes in a computer network is a computer-science problem that had been studied many years before the advent of Bitcoin. It is known as the distributed-consensus problem. Its classical predecessors include the Byzantine Generals Problem, in which generals commanding separate divisions and communicating by messenger try to devise a joint plan of action (Narayanan et al., 2016). Mathematical proof shows that this is impossible if one-third or more of the generals are traitors.

Distributed consensus is almost impossible to achieve in many situations, but Bitcoin succeeded in this by simultaneously introducing two elements, which were novel in 2008, into the blockchain-extension protocol: providing incentives (enabled as the system has its own unit of account) and using randomization. In this publication, we can only offer a brief outline of the mechanism and refer readers who want to delve deeper into this topic to a recent book by Narayanan et al. (2016).

Once the network has implicitly agreed on a common blockchain, it then has to reach consensus on the next block that will be added to the chain. Broadcasting new, unconfirmed transactions to the Bitcoin network is disturbed by technical imperfections, such as delays and loss of data. Hence, the different Bitcoin network nodes usually have very different sets of new, unconfirmed transactions. However, the network still needs to agree on a new block. Some network nodes, called **miners,** actively participate in the process to reach consensus on the new block. Each of these miners takes the respective set of unconfirmed transactions that it has heard of, checks it against the existing blockchain and, using cryptography, verifies that that these transactions are valid. It then compiles (a candidate for) a new block to be added to the block chain.

As several thousand or more miners might have assembled such a candidate for the next block – and these individual blocks will usually all be different – the Bitcoin network picks one of them more or less randomly.

The mechanism used to randomly select one block among the virtually endless number of new-block candidates also serves an additional purpose. In the Bitcoin blockchain, a new block should be added to the blockchain only every ten minutes (on average). Hence, the miners are not only asked, according to the Bitcoin protocol, to compile a valid candidate for the next blockchain block but are also required to solve a complex computational problem known as a hash problem, which involves the computation of millions of so-called hash values. The time needed to find a solution to that problem depends on both computing power (and hence electricity and hardware-investment costs) and pure chance. Once a miner posts a new block together with a solution to this computational problem, the other miners will likely end their attempts to solve their computational problem – once they have quickly checked that the posted new block and the attached solution are valid, to prevent fraud. The mining community then accepts the new block, turns its attention to the subsequent block and considers again all unconfirmed transactions that have not yet managed to get into the blockchain. By using this method, no central authority is needed to achieve distributed consensus, as each miner decides individually what the currently valid blockchain is. Miners can remain essentially anonymous. The Bitcoin network protocol includes a mechanism to periodically adjust the computational complexity of the hash problem, to ensure that a change in the collective computing power of the Bitcoin network does not alter the length of the time interval needed, on average, to establish a new block. The target value for this time interval is 10 minutes.

The lucky miner whose block is added to the blockchain receives the block reward, an amount of newly created bitcoins (currently 12.5 bitcoins) as well as any voluntary transaction fees. Thus, the process of amending the blockchain is called **bitcoin mining**.

The amount of bitcoins in the system increases as a result of mining, but the block reward is halved every 210,000 blocks (which is reached about every four years). The first bitcoins were created in January 2009 by mining the first (empty) block, giving Satoshi Nakamoto the first block reward of 50 bitcoins. A short calculation (try) verifies that the total number of bitcoins that can ever exist is 21mn (limited eventual supply of bitcoins). By 2040, this amount will have essentially been reached. The economic incentive to maintain the Bitcoin network after that will then likely rely on transaction fees, which are voluntary presently. As long as the internet exists, and at least a few miners are active somewhere on the globe, the Bitcoin network will continue to live. It is here to stay.

Users of the Bitcoin network are not required to be miners, as ownership of bitcoin and the ability to initiate bitcoin payments are not linked to the ability to participate in mining. Most users will use the convertibility of bitcoin into legal tender to buy or sell bitcoin via exchanges or similar services. See the text in the box below for further details on how to become a user of Bitcoin.

Using Bitcoin in practice

Using Bitcoin starts with setting up a wallet, typically in the form of an online wallet or in the form of a mobile phone app (like Mycelium or Blockchain.info). Several service providers offer online wallets, which are websites to generate Bitcoin addresses and related private keys, to store this information and use this cryptographic data to initiate bitcoin transactions. While access to such wallets is password-protected, private keys to access bitcoins are stored remotely on webservers. Mobile phone apps that store such information only on the local device exist as alternatives. A recent survey-based study by Cambridge University estimates the global number of cryptocurrency wallets to be between 2.9mn and 5.8mn (Hileman and Rauchs, 2017) .

Several methods can be used to load a freshly created wallet with bitcoins. Cryptocurrency exchanges are available to buy and sell Bitcoin in exchange for hard currencies. Bank account direct debit, credit cards and other forms of payment can be used to pay for a transfer of bitcoins to a specified Bitcoin address. Bitcoin ATMs now also exist. These take bank notes and load, for example, a phone-based wallet with bitcoins. To enable this, a mobile phone is used to display a quick-response code (QR code) to a camera in the ATM. The QR code encodes the Bitcoin address where the bitcoins should go. After the ATM initiates a bitcoin payment to the provided address – by broadcasting the transaction to the Bitcoin network – the mobile phone app also receives the (still-unconfirmed) transaction from the network. It takes miners several minutes to add the transaction to the blockchain. The delay between initiation and confirmation of a payment is much shorter for other cryptocurrencies, such as Ethereum.

The owner of the wallet is then able to use some of his or her newly purchased bitcoins to buy goods or services. In May, Abigail Johnson, the CEO of Fidelity, an asset manager, announced, for example, that she had introduced the means for employees to pay for meals in the cafeteria with bitcoin. Should a bitcoin owner want to buy a drink from a Bitcoin-enabled coffee machine, a phone-based wallet would scan a QR code displayed on the machine to receive the Bitcoin address where the bitcoins should be sent and the amount sought by the machine. The wallet app would then initiate a payment transaction (using the private key safely stored in the mobile phone wallet) and broadcast it to the Bitcoin network.

The coffee machine, also connected to the internet, would receive from the Bitcoin network the information that a payment has been initiated and provide the drink.

The payment would become part of the blockchain several minutes later, once a miner has successfully compiled a new block that includes the transaction for the drink. Similarly, payments for online services or for purchases of goods from web-based stores can be made. Certain Bitcoin ATMs are also able to disburse fiat currency in exchange for bitcoin. Technical alternatives to QR-code scanning – such as near-field communication, which is also used by Apple Pay – exist.

Nowadays, buying bitcoins and making bitcoin payments is easy for everyone with an internet-enabled mobile phone. While the number of merchants accepting bitcoin payments reportedly reached more than 150,000 worldwide in 2015 (including PayPal, Microsoft and Dell), acceptance of bitcoins on Main Street and by online stores remains the exception. Currently, the maximum average number of Bitcoin transactions possible is only about seven per second. Therefore, it is not conceivable that Bitcoin payments will become mainstream on Main Street. We are not aware of the existence of bitcoin-accepting merchants that also set prices in bitcoin. Instead, prices are usually quoted in fiat currency and converted into bitcoin for the purpose of payment only. Given the large bitcoin-price volatility, merchants likely exchange bitcoins into their accounting currency rapidly, using a suitable service provider.

3. Is Bitcoin money?

Denationalization of money has been a topic long before decentralized electronic currencies were studied. Historically, private fiat money even preceded today's fiat currencies (He et al., 2016), which are legal tender and usually governed by independent central banks that control money supply. Some stakeholders like to regard cryptocurrencies as private denationalized money. However, the question of whether according to economic theory today's cryptocurrencies can even be regarded as money is open for discussion. While cryptocurrencies share some of the properties of money, we think that they are not money.

We follow the rationale of related publications of the BoE (Ali et al., 2014) and the IMF (He et al., 2016) in explaining why Bitcoin is not money. While today's fiat money mostly exists in the form of bank deposits and, to a lesser extent, in the form of coins and notes, cryptocurrencies are not a claim on any individual or any institution. At the same time, they are intangible assets, unlike physical commodities. The BoE therefore calls cryptocurrencies (and digital currencies more generally) **digital commodities**. This marks an important difference between cryptocurrencies and national currencies.

However, this difference does not exclude the fact that cryptocurrencies can be used like money, which can be understood in terms of the role it plays in society (the point of view of economists) and in terms of its legal and regulatory status. Economic theory identifies three purposes that something that claims to be money must serve: **1.** It must be a **store of value** (today's purchasing power can be transferred to some future date). **2.** It must be a **medium of exchange** (payments can be made with it in a wide variety of contexts). **3.** It must be a **unit of account** (prices for goods and services are quoted, negotiated and agreed in it).

It cannot be claimed that any of the three properties listed above is entirely met by today's cryptocurrencies. While the USD-price of many cryptocurrencies has increased enormously in the past few years, the extreme volatility of the exchange rate of these currencies versus legal tender casts doubt on the ability of cryptocurrencies to be a reliable **store of value**. Most cryptocurrencies incorporate strict rules for their creation, and these rules limit eventual total supply. But these limits also create problems. In normal times, to keep inflation low and stable the total amount of money in the economy should rise with the size of the economy. But the number of bitcoins is limited by some other, random, formula. And, if for whatever reason the Bitcoin system was manipulated to create as many bitcoins as he/ she wanted, it would devalue the bitcoin.

We have described the innovative properties of Bitcoin to make payments in great detail above. Rapid global cross-border payments using cryptocurrencies are feasible, and this might therefore suggest that cryptocurrencies represent at least a proper **medium of exchange**. While the advantages of making transactions cannot be disputed, cryptocurrencies are not a widely accepted payment method today and would currently not be able to serve this purpose – even if economies wanted to adopt cryptocurrencies as a more broadly used medium of exchange. The maximum number of Bitcoin transactions per second is orders of magnitude less than what established fiat currency systems can process (Meiklejohn and Danezis, 2015), although future cryptocurrency systems might improve upon that parameter. Given the strong price appreciation of bitcoin, there is a substantial deflation of prices for goods and services denoted in bitcoin. An analysis of Bitcoin transaction data also suggests that most wallets make very few transactions. This implies that many owners of bitcoin hold it because they anticipate that the bitcoin price will further increase.

Finally, we are not aware of cryptocurrencies being used as an independent **unit of account**. Even if merchants accept bitcoin payments, they typically price their goods and services in legal tender and use the prevailing bitcoin exchange rate to determine the bitcoin amount sought. While it cannot be ruled out that individual business transactions are also negotiated and agreed outright in bitcoin (or some other cryptocurrency), this must be regarded as the exception. It goes without saying that bitcoin or other cryptocurrencies are not used as a medium of exchange across a variety of transactions between many people and businesses. The BoE emphasizes that operating as a unit of account is perhaps the most important feature of money. Bitcoin and other cryptocurrencies fulfil this role, if at all, at most for a rather small group of persons globally.

Regarding the legal and regulatory status of cryptocurrencies as money, they are not legal tender. While sovereign governments have the power to regulate their country's monetary system, most of them have not interfered heavily in the development of cryptocurrencies in the past eight years (He et al.; 2016). Governments have struck a balance between the necessity to regulate and allowing the potential of new technology to unfold. While a range of existing laws are already applicable to cryptocurrencies, some countries have adopted regulations (or amended existing regulations) with regard to specific crimes (like money laundering), or they have clarified the taxation of cryptocurrency dealings.

4. Financial stability and banking-sector implications

Many developed markets' central banks not only have a mandate to execute monetary policy but also a mandate to safeguard the stability of a country's (or currency union's) monetary and financial systems. The total amount of money in circulation that is denominated in G10 currencies is still vastly larger than the market capitalization of cryptocurrencies. This is one of the reasons why cryptocurrencies' significance for financial stability and inflation was still regarded as insignificant by IMF staff (He et al., 2016), when they said that "concerns about financial stability, or the implications for monetary policy, are less immediate". Instead, IMF staff see immediate and pressing concerns surrounding financial integrity, consumer protection, tax evasion and the regulation of capital movements, as cryptocurrencies have emerged very much in the absence of effective regulation, although governments have started to take action (see above).

One of the steps taken by some governments to safeguard financial stability is to restrict the ability of regulated financial institutions to deal with cryptocurrencies. A limited link to the financial system ensures that systemic risks to financial stability emerging from cryptocurrencies are not likely to occur currently. As the volume of transactions executed via cryptocurrency networks is still marginal – for example, when compared to major credit card payment platforms – cryptocurrencies do not (yet) represent a systemically important payment network.

There have been disruptive events within cryptocurrency networks and associated infrastructure in the past – such as the bankruptcy of Bitcoin exchange Mt. Gox in 2014 and the split of Ethereum into Ethereum and Ethereum Classic in 2016 – but no contagion to the financial system was observed. Scenarios in which cryptocurrencies become relevant to financial stability or monetary policy in some countries are speculative, as they need to anticipate a proliferation of their use and a surge of their cumulative market capitalization, and this appears unrealistic today.

Presumably more relevant than such scenarios with regard to the impact of cryptocurrencies on the banking sector are attempts by existing financial institutions to embrace the new concepts associated with cryptocurrencies and to modify them. Variants of cryptocurrencies that overcome some of the obstacles that prevent the use of cryptographic electronic currency as a form of legal tender have been assessed. A proposal inspired by the research agenda of the BoE tries to combine the payment technology of cryptocurrencies with the ability of a central bank to control the distributed ledger (Meiklejohn and Danezis, 2015; MIT Technology Review, 2016). Thus, a central bank would be in the position to control the supply of the electronic currency and select the "mintettes" (the analogue of Bitcoin miners) that process the distributed ledger. The mintettes could, for example, be commercial banks, as a central bank may not be comfortable with making large investments in information technology. The computational cost of such a system to process transactions would be much lower than that, for example, of Bitcoin – while it would also improve the scalability with regard to the feasible speed and frequency of transaction processing and maintain the advantage of instant electronic payments that current cryptocurrencies offer.

More generally, DLT is being explored by financial institutions and financial-service providers for many purposes beyond that of making payments and serving as currency. These include security and derivative processing. A technology based on the Ripple cryptocurrency network and used by many major global banks is already being used to facilitate real-time cross-border payments in fiat currency (link).

5. Privacy and crime

Sources of news and the media associate Bitcoin and cryptocurrencies with crime and illegal activities, which is also the focus of existing regulation in that area. While the Bitcoin blockchain is a public ledger, and all bitcoin transactions are therefore publicly and permanently traceable, there is no general method to identify the owner of a Bitcoin address with a real-world identity. However, as soon as an address is, for example, involved in a transaction on a cryptocurrency exchange, or when bitcoins are bought using credit cards or other fiat-money payment methods, individuals or institutions can, in principle, be linked to a Bitcoin address.

All transactions using this address (past, present and future) can then be linked to that real-world identity. Merchants accepting bitcoin would usually not like to conduct their businesses in such a publicly fully transparent manor. Techniques exist to improve anonymity in Bitcoin, like using new random Bitcoin addresses for every new transaction (Narayanan et al., 2016). While such techniques have been shown to be imperfect, they have the potential to obscure bitcoin flows. In that sense, and from the point of view of the anonymity of payments, Bitcoin as a currency system more resembles coins and notes issued in fiat currency than money in account.

Given the pseudonymity of bitcoin ownership, the system has a high potential to be used for illegal activity, such as for the purchase of illegal goods, money laundering, tax evasion, circumvention of the regulation of capital movements and for financing terrorism or crime. Therefore, Bitcoin and cryptocurrencies more generally are frequently associated with negative effects on society. It seems that further development of cryptocurrencies need to strike a balance between a need for privacy, which is required by individuals and businesses, and the need for society to be able to effectively fight crime.

6. Conclusion

The global cumulative market capitalization of tradable cryptocurrencies recently hit USD 100bn. Thus, questions regarding the economic significance of cryptocurrencies have resurfaced. To pave the way for a discussion of the economics associated with this topic, this publication delves into how Bitcoin – the first and still the most-important cryptocurrency network – technically works. We argued that today's cryptocurrencies are missing important features of money. While financial-stability risks have yet to emerge as a result of cryptocurrencies, risks related to financial integrity, consumer protection, tax evasion and the regulation of capital movements have been partly addressed by sovereign governments to date. The future implications of blockchain technology go beyond currencies and are difficult to comprehend today. The technology continues to evolve rapidly. We highlighted as an example that major central banks are currently considering variants of cryptocurrencies as an electronic form of legal tender.

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