

Complementing Money Functions: Central Bank Digital Currencies and Currency Competition*

Jörg J. Dötsch  – Tamás Ginter 

Central bank digital currencies (CBDCs) are currently one of the most vital issues in monetary policy worldwide. While several aspects of the emergence of digital currencies have been addressed in the respective literature, little focus has been directed to one important underlying parameter: the new role of technology in the digital age, which complements the traditional money functions and hence may exert an effect on currency competition. In this paper, we first provide an overview of money functions, currency competition and digital money. We then state that with the emergence of CBDCs, technology has become a new and important functional parameter born by the CBDC itself. We conclude that while technological competition has arisen as a factor of currency competition, stability remains its most decisive factor.

Journal of Economic Literature (JEL) codes: E42, E58, O33

Keywords: CBDC, digitalisation, currency competition

1. Introduction

Interest in digital currencies – be they state-controlled or private – has emerged widely in economic research throughout the past decade. A broad range of studies has addressed, amongst other things, the effect of the emergence of privately-issued digital currencies on monetary policy and financial stability (Bordo – Levin 2017; Nelson 2017), potential technological advancements and the development of new solutions (Auer – Boehme 2020; Maulana et al. 2019), and undesirable implications, such as the use for fraudulent and illegal activities (Gilbert – Loi 2018). Several aspects of the emergence of digital currencies have been addressed in the respective literature. The focus is primarily on the new steering possibilities for central banks in the field of monetary policy. In addition, problems of data protection on the one hand and questions of consumer behaviour, ranging from payment preferences to financial inclusion, on the other hand are discussed.

* The papers in this issue contain the views of the authors which are not necessarily the same as the official views of the Magyar Nemzeti Bank.

Jörg J. Dötsch: *Andrássy Universität Budapest, Associate Professor. Email: joerg.doetsch@andrassyuni.hu*
Tamás Ginter: *Andrássy Universität Budapest, PhD Student. Email: tamas.ginter@andrassyuni.hu*

The first version of the English manuscript was received on 18 September 2023.

DOI: <https://doi.org/10.33893/FER.23.1.50>

It is worth noting that privately-issued digital currencies – “cryptocurrencies” – are actually not *money* in the narrower sense. Nevertheless, it cannot be denied that they raise very specific questions of monetary policy, which is subject to new conditions in the digital age. This is all the more remarkable as the introduction of central bank digital currencies (CBDCs) is currently one of the most vital global issues in monetary policy. However, we believe that an adequate assessment of the role of CBDCs is only possible if one takes into account the increased complexity in the context of currency competition, which is partly due to the existence of digital currencies. This is the subject of our paper.

We proceed as follows. Since this is a fundamental question, we first discuss the most important characteristics of money and its possible forms and then present the role of the money functions. In the second step, we provide a short description of the key characteristics of digital money and tackle the most relevant aspects of recent technological advancements. Then, in the third step, we link the two aforementioned subjects (i.e. money functions and digital currencies) and provide a theoretical framework for the description of the new type of complementation of money functions and what it means in the context of the emergence of central bank digital currencies.

In this perspective of ours, we claim that in conjunction with the development of and emerging competition between (central bank) digital currencies, the list of money functions must be *complemented* with *that of technological competition*. Technology itself does not represent a new money function of its own kind. But digital technology is a new, indispensable factor in the competition among currencies. And within this, focusing on the functionality of money, it is a competitive advantage of a CBDC in its direct competition with cryptocurrencies.¹ While currency competition is a widely discussed phenomenon in the relevant literature (see e.g. *Eichengreen 2005* and *Endres 2009*), technological competition has never before been treated as part of currency competition. Taking this approach, we make a contribution not only to the pertinent body of research, but also offer a perspective to stakeholders interested in the development of (central bank) digital currencies.

¹ While it is debatable (and is debated in this paper, as well) whether cryptocurrencies are currencies at all, we use the term “cryptocurrency” (and not, e.g. crypto asset) not because they are currencies in the stricter sense, but they are most commonly referred to as cryptocurrencies in the relevant literature.

2. Preliminary considerations on the medial character of money

2.1. Money functions and their preconditions

The role of money is commonly described in terms of a minimum of three and sometimes up to six (e.g. *Flynn 2018*) different money functions. For our purposes, we rely on the regularly used, following three functions conceptualised by *Menger (1892)* and *Jevons (1876)* according to which money is

- (1) a *means of exchange*,
- (2) a *measure of value* or *unit of account* (*numéraire*),
- (3) a *store of value*.

Fiedler et al. (2019:37) point out that money “(...) constitutes a category of its own as it is neither an object of consumption (it does not directly satisfy human need) nor a means of production (the usefulness of money to allow for increasingly complex production process does not depend on its quantity).”

Prima facie, these functions seem self-evident. For traditional currencies, these functions are interrelated and inseparable, so that it would be futile to draw up a sequence with regard to importance. They are always *bundled*. Insofar as we are dealing with a medium of interaction, general acceptance would of course be a fundamental prerequisite for the functions to come into effect at all. Of course, conversely, acceptance necessarily breaks down in the event that only one of the functions does not work properly: this is a gateway for currency competition, as we will show later in a more differentiated way. However, it is neither sensible to isolate the functions from each other in every case nor can they be separated from certain preconditions. A few basic remarks on this.

In order to serve as *numéraire*, the medium must be *divisible*. To be able to be used everywhere it must be *transportable*, in whatever form. To be able to be used anytime and to serve as a store of value it must be *durable*. And, at least, it must be *free of manipulation* so that the partners in a transaction are not exposed to risks for the benefit of third parties. Money must be scarce *per se*, otherwise it couldn't be a measure of scarcity over time. Since *all* of these preconditions are always important for the functioning of the medium of money, they can be summarised under the postulate of a *stable money value*.²

² There is a wealth of academic discussion surrounding the demand for a stable monetary value, which cannot be fully reproduced here. It is important to note that the monetary functions mentioned cannot operate as intended if the value of money is not stable. *Friedrich August von Hayek (1999:239)* most notably addressed this issue from the perspective of private currency competition: “(...) a private institution which must issue money in competition with others can only remain in business if it provides the people with a stable money which it can trust. The slightest suspicion that the issuer was abusing his position when issuing money would lead to a depreciation of its value and would at once drive him out of business.” With regard to public issuers, the same principle applies; they must earn their credibility over time. Considering the institutional context and the role of central banks, *Friedman (2002:38)* further emphasises that it is their responsibility to “(...) provide a stable monetary framework for a free economy”.

These preconditions are important always and everywhere and it is no coincidence that have they been discussed for almost as long as money exists (see e.g. *Crespo 2021:459*). This discussion “(...) is part of a long historical interaction between technology and society” (*Söderberg 2018:2*). If we consider digital technology as a “general purpose technology” (*Bresnahan – Trajtenberg 1995*), this discussion is indeed very urgent today. As we will see, this is about more than the just fact that money today no longer needs to be coined to be durable: The requirements for it have become more abstract and complex. This leads us to the important aspects of the technology and architecture of monetary systems.

2.2. Technology and architecture of monetary systems

Monetary systems are institutional solutions of how money is created and its value is protected. Both tasks are interconnected. *Fiedler et al. (2019:11)* expediently distinguish two basic components of monetary systems: their *technology* and their *architecture*. In simplified terms, the architecture refers to which institutions can issue which kind of money under which conditions and in what form it comes into circulation. The technology refers to the aspect of the practical realisation, how a medium is created or declared to serve as money. According to this, traditionally there are three basic types.

- (1) Media used as money can have a value as a commodity and work as “commodity money”. Obviously, this can be precious metal,³ but depending on the economic situation, it could also be anything else (see, classically, *Folz 1970:40*). The individual actors in the economy can thus decide whether they derive utility from the *function* of a medium as money or from its *material value* (*Köhler 2019:24*).
- (2) Money can be created as a *declared equivalent* for a good or service. Accordingly, money can be created by a central bank, which, for example, ties the money to an underlying good with a stable market value, e.g. precious metal. If it sells the corresponding precious metal, the money is accordingly withdrawn from the economic cycle again (see *Köhler 2019:24*). Since money was usually linked to precious metals in this way of money creation, it is also referred to as *metallism* (see e.g. *Cesarano 2014*).
- (3) Money can be created by *granting credit*. Here, the creation of money is not preceded by a barter transaction as in the second system. Such a currency, in which the medium in the narrower sense has almost no material value anymore,

³ The fact that gold is the most common form of “commodity money” should not lead to the misconception that gold is so particularly suitable for the production of physical money because it is also so highly valued as a commodity in other forms. In addition to the technological requirements in the narrower sense, the actual cause is rather functional, namely that although gold is available in sufficient quantities, it is one thing above all: scarce.

is accordingly the antithesis of the first system, while the second system occupies an intermediate position. The medium of this system is fiat money.

Ultimately, money functions based on the trust that users can receive real value or service in exchange. Money serves as both a claim and a promise in all transactions, but ultimately, these claims and promises are resolved through the central bank, which controls the supply of money.

In developed economies, the third system is usual. It is based on the *economic* argument that it is the most elastic with regard to the dynamics of the economy.⁴ On the other hand, there is a *political* and consistently unspoken argument: people in charge are used to being interested in increasing the money supply for political purposes, and this is easiest with fiat money. Expansion of the money supply carries the risk of inflation.⁵ In this context, therefore, very important balancing problems arise that cannot be discussed in this framework. This problem is not only as old as money, it stays with all kinds of money as long as there is no answer to Juvenal: “*Quis custodiet ipsos custodes?*”⁶ But this is, again, not our topic.

However, fiat money is only accessible in two forms: either in the form of cash, i.e. token-based, or in the form of reserves. As far as *access* to money is concerned, the architecture of our recent monetary system is two-tiered. The reserves are only accessible to commercial banks. Commercial banks therefore play, in a sense, a role as an intermediary that can provide accounts to non-banks, i.e. citizens and businesses. Non-banks accordingly have claims on commercial banks in the form of these accounts denominated in a currency. Here, the money is correspondingly account-based, i.e. the money can be clearly assigned to an owner by a third party – the intermediary, a commercial bank (see *Brunnermeier et al. 2019:5*). For the purposes of our contribution, we do not separately treat central bank money in the form of cash on the one hand and the money available in the accounts of commercial banks on the other. In view of the functionality of money focused on here, this would not make much sense. However, it should be noted that central banks that are publicly considering the introduction of CBDCs do emphasise its quality as central bank money.

⁴ It is important to note that the flexibility provided to politics by a fiat money system, which allows for the cushioning of short-term economic problems through monetary means, can lead to an “inflationary bias”. This bias has always resulted in inflation, which ultimately leads to the destabilisation and destruction of the money’s functions, ever since the existence of fiat currencies. See *Bernholz (2015:18)*.

⁵ This statement is contradicted by modern monetary theorists, see e.g. *Mitchell et al. (2016)*. However, we do not address the questions related to MMT in this paper.

⁶ In English: “Who guards the guardians?”. Basically, one of the crucial questions for institutional economics. See for example *Hurwicz (2008)*.

3. Digital currencies

3.1. Context

Why is it necessary to create ‘digital money’ at all? Aren’t the existing currencies and monetary systems already sufficient? Numerous aspects play a role here. One is the demonstrably gradually diminishing role of cash in transactions in modern economies (*Harasim 2016*). Apparently, more and more payments are being made electronically, i.e. also digitally. In this context, many publications mention a transition to a “cashless society” as a background (e.g. *Fiedler et al. 2019:9*). In the discourse of monetary theory, one also speaks of “trends of dematerialisation and informatisation of money” (*Nishibe 2020:314*).

There are very different causes for this. For example, the successively lower significance of cash may have *cultural* causes such as the willingness to accept innovations, which we assume to be more pronounced e.g. in China than in Europe. The possibility to reduce transaction costs in the sense of time and fees is an economic argument.⁷ Indirect network externalities with regard to the spread of digital currencies may play a role on certain social platforms that use their own currency as a form of community money (see e.g. *Brühl 2020*). In addition, digital currencies may serve as a store of value instead of a central bank currency. They are hence used as an asset, a “crypto-asset”, which is “(...) a digital representation of value or rights which may be transferred and stored electronically, using distributed ledger technology or similar technology” (*European Commission 2020:34*; see e.g. *Khan – Hakami 2021:22*). Of course, this kind of use is partly speculative (see e.g. *Khan – Hakami 2021:22*).

These phenomena are basically nothing new and, as *Fiedler et al. (2019:11)* point out, electronic payments, transfers, etc. have hardly affected the architecture of the monetary system so far. However, the volume speculated within the form of crypto-assets should also not obscure the fact that cryptocurrencies call themselves currencies, but cannot fulfil the functions briefly outlined above like central bank money. Or can they? The next section focusses on the differences between crypto- and traditional currencies.

3.2. Differences compared to central bank money

It should be noted that there is no uniform definition for the phenomenon of digital currencies (*Söderberg 2018:1*). This somewhat loose term encompasses various forms and it is to be expected that other forms will appear (*IMF 2021:5*). The European Central Bank (ECB) defines the term “cryptocurrency” as “(...)

⁷ Referring to his research on Bitcoin, *Stroukal (2018:41)* emphasises that the immediate transaction costs are indeed low, but he also considers “hidden costs”, concretely “direct transaction fees, bounties paid to miners, and increased risk”.

a type of unregulated, digital money, which is issued and usually controlled by its developers, and used and accepted among the members of a specific virtual community” (ECB 2012). This is also followed by Söderberg (2018:1), who speaks of “(...) digital units that are created and transferred between the users through the use of cryptography”.⁸ There are now more than 10,000 of these unregulated phenomena on the market,⁹ and the variety of variants is remarkable. There are eMoney, stablecoins, crypto-assets, tokenised bank deposits, tokenised financial assets and others, and thus it is a “rich landscape” (Halaburda et al. 2022:107) of different forms not all of which are covered by the definition of crypto-assets. For the purposes of our considerations, we will leave it at this: there is a wealth of media in the digital sphere that can at least partially fulfil monetary functions and which – sometimes more, sometimes less justifiably – are generally referred to as “digital currencies”.

Regarding the *technological* side of the monetary systems, so far central bank money is only available to citizens as cash; undertakings and citizens hold their accounts at commercial banks, which are supplied with central bank money by the central bank. Citizens and businesses can carry out transactions only through the network of these private intermediaries. For our question, which is orientated towards functional aspects of money, it is initially not analytically necessary to distinguish between the central bank money available to citizens in the narrower sense – i.e. cash – and the claims on the accounts of financial intermediaries. The latter are also denominated in the units of a corresponding central bank currency. It is due to the architecture of the monetary system that a distinction can be made between ‘real’ central bank money and claims expressed in central bank money units. We will return to this later.

With regard to the architecture of the monetary system, the background of cryptocurrencies is correspondingly different, as the level of commercial banks is eliminated and transfers among the participants of a community are possible directly as a peer-to-peer procedure. This is generally faster and also cheaper (IMF 2021:5). This means that cryptocurrencies also move outside of the usually nationally determined currency areas and are in principle global: instead of a local community, they are a “virtual community of interest” (Nishibe 2020:315). Cryptocurrencies “(...) can be distributed much more widely, including across devices and borders” (IMF 2021:6). They can be monetised, but they only exist digitally and are not realised physically.

⁸ The technical side of the cryptographic process in the narrower sense is not our topic. Most crypto-assets are based on the blockchain, but not all are (such as Iota). In the context being considered here, the technology itself – distributed ledger technology – is essentially unimportant because, in theory, any medium that satisfies certain functional characteristics can be classified as money.

⁹ It is important to bear in mind that this number has grown with astonishing dynamism so far. Söderberg (2018) still mentioned about only 1,500.

The technological background is provided by decentralised networks. The founder of bitcoin, known under the pseudonym Satoshi Nakamoto, is often quoted as saying that cryptocurrencies are “(...) a new electronic cash system that uses a peer-to-peer network to prevent double-spending (...)” that is “(...) completely decentralised with no server or central authority” (quoted after Luther – Smith 2020:433).

Cryptocurrencies are not legal tender and therefore lack an important stabiliser mechanism for acceptance. Media that are declared a public means of payment thus have a critical mass *per se*, in which corresponding network externalities unfold.¹⁰ Cryptocurrencies may appear in connection with existing communities, but the use there is then already restricted by the scope of this community, and possibly also within it. Brunnermeier *et al.* (2019:19) accordingly mention “digital currency areas”, which only exist within a corresponding, non-state network. The respective cryptocurrencies thus gain their stability exclusively from the quality of this network: First of all, exclusively through acceptance as a medium of exchange by a critical mass of participants *for whom the volatility risk plays a relatively minor role* in relation to central bank currencies. They are decoupled from state power and they are also decoupled from the economic performance of a currency area. These communities thus work differently from traditional currency areas in the sense of Mundell (1961). It can therefore be said that they are generally more volatile than central bank currencies. The less they are backed by real values or pegged to central bank currencies, and the more volatile they are, the more they have a “(...) dynamic instability problem: it may suddenly lose its transaction value if people believe that in the future, others will not accept it in exchange” (Brunnermeier *et al.* 2019:24).

While central banks can in principle create fiat money in unlimited quantities,¹¹ the possible quantity of cryptocurrencies produced through so-called “mining” can be technically limited due to the very mathematical procedure, the encryption technology, which defines them and precludes counterfeiting at the same time. This endogenous, ‘technical scarcity’ is a remarkable parallel to metallism in money creation (see Sanderson 2015; Cesarano 2014). Söderberg (2018:2) therefore speaks of “digital metallism” with reference to Maurer *et al.* (2013).

With regard to any cashless operation, the security of money in a central bank currency system – e.g. securing ownership of accounts, clearing procedures, banking secrecy, etc. – is left to the intermediaries, while the counterfeit-proofing of cash and the stability of the currency itself is provided by the promise of a central bank.¹²

¹⁰ This stability is internalised by cryptocurrencies that are backed by (possibly several) central bank currencies. They absorb their stability and are called, very obviously, stablecoins.

¹¹ This is a technical possibility, but there are practical limits to it. The practical limit can only be denied on the assumption that there is no connection between the money supply and the value of money (see footnote 5).

¹² Of course, the relevant intermediaries are not completely left to their own devices. In developed economies, they are *de facto* subject to corresponding bodies of public control, and misconduct would also be penalised by the market, at least as long as there is relevant competition.

A cryptocurrency offers greater security against access by third parties, including the state itself: private “wallets”, in which the quantities of units of the respective cryptocurrency, each with defined property rights, are stored instead of accounts in commercial banks.¹³

Not least because of these aforementioned functional differences compared to central bank money, there is also a significant difference in terms of the performance of crypto-assets. Their value relative to central bank currencies generally fluctuates considerably. The aspect of relative performance draws the attention to competition. The following section is dedicated to this.

3.3. Cryptocurrencies and currency competition

Currency competition is a widely studied field. Without being able to go into this in depth here (for an overview, see e.g. *Cohen 2015*, also *Karau 2022*; *Mayer – Bofinger 2023*), we focus on the complementation of functionality in this context. Just a few remarks to clarify the background must suffice.

Competitive relationships between currencies can develop due to the fact that currencies represent complex solutions to problems (see e.g. *Gerba – Rubio 2019*). Each individual monetary function can be understood as a partial solution. Hence, we assume that for example for the store of value function, a currency will be favoured that is relatively more likely to fulfil this function (see below). In principle, currencies fulfil all three functions, which are interdependent, as long as they are *stable*. In addition to the fact that the means of exchange used within a currency area is prescribed in principle, the stability of a currency is, of course, influenced by a large number of factors that go beyond its sheer functionality. For example, the size and performance of the respective economic area or trading habits, however justified and enforced.

However, competition always arises for currencies as soon as money owners decide in which currency they want to hold their money. Whenever it comes to “holding”, the function of the “store of value” becomes dominant and the respective owners will ask themselves which medium serves this goal best. This *can* be a (central bank) currency – which is why one or more foreign currencies are usually a component of the portfolio in asset management – but it does not have to be. However, currently, crypto-assets come into focus with this problem.

¹³ At first glance, such wallets appear to be more secure against access by third parties. This may be true for many users, but there are also counterexamples. In March 2023, for example, the US government confiscated bitcoins (see *Redman 2023*). These wallets are therefore not completely “watertight”. However, if the argument put forward by most central banks and numerous experts in this discussion that many criminal activities are carried out with cryptocurrencies is to be taken seriously, the possibilities of state observation and intervention will have to be assessed as relatively limited.

The fact that crypto-assets known in everyday language as “cryptocurrencies” are not actually money in the stricter sense does not mean that this new phenomenon does not influence currency competition under the conditions of digitalisation. According to *Brunnermeier et al. (2019)*, digitalisation leads to a differentiation of monetary competition with regard to different monetary functions.

How this differentiation unfolds can be explained with reference to Gresham’s Law: If two different types of money are in circulation – in the classic case silver coins and gold coins – which have the same denomination and can be exchanged one-to-one, the currency that is considered to be a poorer store of value will stay in circulation as medium of exchange, while the other, which is considered to be a better store of value, is then hoarded accordingly (see e.g. *Horváth 2022:543*). Accordingly, because one type of money is not competitive in the long term with regard to one certain money function, a crowding-out effect occurs.

While the crowding-out effect in the example with cash unfolds due to a preference with regard to the expected relatively better fulfilment of the *store of value* function, the situation becomes much more complex under digital conditions. This is because, in principle, relative preferences for certain functions can come into play wherever exchange is not carried out using cash. Digital money *or* central bank money may be preferred *for certain functions* and, hence digital currencies “(...) *could threaten individual countries’ monetary sovereignty by displacing domestic currencies*” (*Auer et al. 2021:9*).

Specifically, what functions might these be? If, as established above, on the one hand, there are necessary preconditions for any medium to serve as money (see *section 2.1*) and, on the other hand, private digital currencies can neither be enforced by the state nor is their value linked to the economic performance of a currency area,¹⁴ then, from a functional perspective, we assume three drivers for a preferential use to remain (for similar arguments, see e.g. *Mayer – Bofinger 2023*):

- (1) The scope of indirect network effects as a (self-enforcing) prerequisite for general acceptance. These are a crucial prerequisite for anything to be able to function as a *medium of exchange* at all.
- (2) The relative weight of the assumption/expectation that a medium is relatively better suited as a *store of value*.
- (3) Technical possibilities that digitalisation offers – beyond the previous possibilities of cashless payment and savings.

¹⁴ As mentioned above, stablecoins occupy an intermediate position in this respect. For the purposes of our considerations, we make no further distinctions in this regard.

Following the example of Gresham's Law, a crypto-asset could potentially be considered as an alternative to inflationary central bank currencies.¹⁵ Even in this perspective, if only means of payment denominated in central bank currencies are *money* in the stricter sense, a competitive relationship still unfolds. It is not exactly the same situation as a competitive relationship between (a minimum of two) central bank currencies, one of which is relatively more stable and the other relatively more inflationary. Nevertheless, the effect on the relatively weaker medium is the same. And as long as certain crypto-assets are also used as a medium of exchange within certain communities and can be converted into central bank money if necessary, the process described here is also more similar to currency competition than other forms of asset inflation.

Of course, crypto-assets and central bank currencies start from a very different basis. The unfolding of indirect network effects is partly inhibited by the sheer fact of public issuance. Although cryptocurrencies are global *per se*, they are fragmented by different spaces of public regulation and other technical obstacles. In this respect, a complex regulatory problem arises with regard to the important question of convertibility, which sets corresponding limits to the success of cryptocurrencies in one or the other functional area. Other barriers that are relevant for traditional currencies, such as exchange costs, are eroded by the possibilities of digital technology, at least as long as we are talking about use in the digital realm, i.e. non-cash. Exchange costs would be in principle lower, because the exchange of digital currencies not only takes place without time expenditure, but also lacks a third party to whom fees might have to be paid (see Brunnermeier *et al.* 2019:11).

With regard to the *store of value* function, there is thus a potential effect of the existence of cryptocurrencies that is not dissimilar to international currency competition. The volume of claims expressed in cryptocurrency measured in units of a central bank currency alone should make this clear.¹⁶ At first glance, however, other functions seem to remain unaffected, such as the fact that a cryptocurrency would in some way be better suited as a medium of exchange than "real" central bank money, i.e. cash, or – for the sake of completeness – claims expressed in central bank money units at the corresponding intermediaries. However, the aforementioned effects and the potential of digital technology seem to be given such weight by central banks that they have invested heavily in considerations for the creation of central bank digital currencies.

¹⁵ In this case, this means that the less secure it is considered to be in the long term to hold values in a central bank currency because it is inflating or there is a corresponding *expectation* of inflation, the more likely it is that the central bank money will no longer be used as a store of value but will be invested in corresponding assets; the relatively less valuable medium will then continue to circulate. This logic is just as inherent to money as the phenomenon of asset inflation mentioned here is an empirical commonplace.

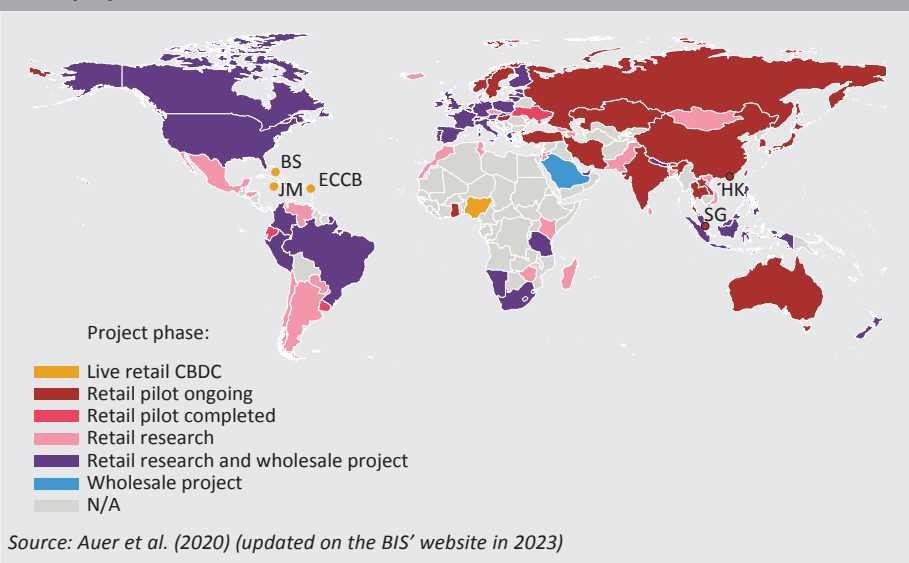
¹⁶ Of course, it is another matter whether crypto-assets will fulfil their function as a store of value, not least because they are undoubtedly more volatile in the short term compared to central bank money. As Brunnermeier *et al.* (2019, 24) put it, they have a "dynamic instability problem", which they attribute in particular to the problem of acceptance. Accordingly, it would not be inaccurate to categorise them as an object of speculation. However, it is not possible to make a clear distinction, because not only can central bank money also be used for speculation but depending on the term, any storage of value has a speculative character. See also the previous footnote.

4. Central bank digital currencies

4.1. Preliminary considerations

Regarding the architecture of the monetary system, CBDCs would enable private households or businesses to gain *direct* access to a central bank account – similar to what was previously the case only for commercial banks. “CBDCs can be defined as a form of digital money, denominated in the national unit of account, which is a direct liability of the central bank” (Auer et al. 2021:3, referring to Group of central banks 2020). It would be “(...) an electronic form of central bank money that can be exchanged in a decentralised manner known as peer-to-peer, meaning that transactions occur directly between the payer and the payee without the need for a central intermediary” (Bech – Garratt 2017:56).¹⁷ The European Central Bank describes its idea of a digital euro as “(...) an electronic equivalent to cash. And it would complement banknotes and coins, giving people an additional choice about how to pay” (ECB 2023).¹⁸ There has been quite an intense debate on this for almost half a decade (see Auer et al. 2021; Agur et al. 2022; Panetta 2021a, 2021b, 2021c) and according to Boar – Wehrli (2021) by 2020, 86 per cent of central banks had already conducted research in CBDCs and more than 50 central banks had already published their results by that time.

Figure 1
CBDC projects around the world



¹⁷ Bech and Garratt (2017) use the term “central bank cryptocurrencies” because of the underlying technology, but this makes no difference.

¹⁸ In principle, this idea is actually not new; Auer et al. (2021:4) also refer to the proposal by Tobin (1987).

This allows for variations which affect both the technology and architecture of the monetary system. CBDCs could be token-based or account-based, and there are conceptions for *wholesale* or *retail* variations. The technological basis could be distributed ledger technology or the existing technological infrastructure (see *Auer et al. 2021:3*). However, the perhaps most important aspect regarding the architecture of the monetary system is that the role of commercial banks would then only be optional.¹⁹ This constellation would induce commercial banks “(...) to make their deposits more attractive and increases the costs of funds for commercial banks” (*Auer et al. 2021:15*).²⁰ By adding a new form to the existing forms of central bank money the central bank’s reserves would be merged with CBDC, “(...) *(b)ase money is extended beyond cash and reserves to a third aggregate state – unless reserves are simply merged with CBDC units by granting unrestricted access to reserve accounts*” (*Fiedler et al. 2019:17*).

What would be the essential difference compared to the aforementioned crypto-assets? What advantages would a CBDC offer? The motives seem to be different or are stressed differently in different jurisdictions (*Auer et al. 2021:7*). The main difference would of course be the issuer itself. A unit of a CBDC would be a claim against a central bank, ‘backed’ by the state or states forming the respective currency area. It would accordingly be denominated in the respective national currency and could serve as a numéraire. It would be a legal tender that, unlike private cryptocurrencies, can be used everywhere for payment. *Prima facie*, therefore, there would – apart from the change in the architecture of the monetary system – be no difference at all to the previous central bank money *in terms of the functions* that money must be able to fulfil. It would be only the technology that makes a difference. So what is the point?

4.2. Motives

Central banks emphasise the advantages of CBDCs: on the operational side, faster payment processes, and even goals such as “financial inclusion” (*ECB 2022*). The European Central Bank hopes that a digital euro “(...) *could foster financial innovation and improve the overall efficiency of the payments system*” (*ibid.*).

On the one hand, it is an open question whether these aspects are a problem at all. On the other hand, arguments are also put forward, such as the need for central banking technology to keep pace with changes in the modes of payment because “(...) *retail payments are (...) undergoing a disruptive transformation*” (*ibid.*). The ECB thus alludes to point (3) of preferential use mentioned in the previous chapter.

¹⁹ In fact, most central bank projects currently leave the commercial banks in their role. However, even just the technological potential for a shift in the architecture of the monetary system of this magnitude is a new dimension.

²⁰ This summarised with reference to *Andolfatto (2021)*, *Keister – Sanches (2021)* and *Chiu – Koepl (2019)*.

The central bank would like to respond “to the increasing demand for safe and trusted electronic payments” (ECB 2022).

The ECB thus attests a problem of trust with regard to the existing technical payment solutions. And although the demand for “trusted payments” is already increasing, the ECB fears that the only central bank money available for non-banks, cash, “(...) could (in a digital world) become marginalised as a means of payment” (ibid.). Correspondingly, it envisages the digital euro as an “(...) anchor of stability for the payment and monetary systems” (ibid.). This metaphor is probably intended to address points (1) and also (2) mentioned in section 3.3.

At the same time, a digital euro “(...) would also strengthen the monetary sovereignty of the Euro area and foster competition and efficiency in the European payment sector” (ibid.). The first part of the sentence is probably most closely related to point (1) mentioned in section 3.3, but only makes sense if we assume that there is competition with other media of payment. If this were not the case, then the ECB would be talking about its own sovereignty as an institution. This also confirms its statement that a digital euro “(...) would preserve the role of central bank money as a stabilising force of the payments system” (ibid. p.2). The argument behind the assumption that a digital euro would foster competition in the European payment does not need concern us here.

Chen et al. (2022, see below) provide an international an empirically backed overview of the numerous motives. Reviewing the relevant Hungarian literature, a fivefold categorisation of the motives for introducing CBDCs unfolds.

First, the introduction of central bank digital currencies is viewed as an enhancement of monetary sovereignty (*Fáykiss – Szombati 2021; Horváth 2022*), or, in other words, the strategic autonomy of a currency area (*Terták – Kovács 2022*). The emergence of cryptocurrencies and numerous FinTech and BigTech companies (typically resident in the United States) allowed the US dollar to gain power in such transactions (see *Fáykiss et al. 2021*), and thus CBDCs are supposed to prevent the dollarisation of the respective national (or in the case of the euro, supranational) currencies (see also *Kóczyán 2022*).

Second, another international aspect of the introduction of CBDC would be the increased efficiency of international payments by enhanced interoperability, providing gains for both companies and individuals transacting across borders (see *Boros – Horváth 2022; Müller – Kerényi 2022; Terták – Kovács 2022*).

Third, the introduction of CBDC would provide more and new scope for monetary policy (*Fáykiss – Szombati 2021*) and could potentially increase the efficiency of monetary policy (*Müller – Kerényi 2022*), allowing for direct monetary transmission in case of interest-bearing CBDCs (*Kóczyán 2022*; see more on that in section 4.4).

Fourth, literature suggests efficiency gains in the banking sector, as CBDC introduction is supposed to enhance competition among financial institutions (Kóczyán 2022; Kóczyán et al. 2022). This enhanced competition is nevertheless a significant risk for commercial banks' business models, and also elevates the long-term risk of bank runs (Müller – Kerényi 2022).

Fifth, fellow authors suggest that CBDC innovations should become 'sticky' by boosting financial and technological innovations in the private sector (Kóczyán 2022; Kóczyán et al. 2022; Müller – Kerényi 2022).

In their paper, Fiedler et al. (2019:9) have assembled the above arguments to some extent as "(...) higher revenue, efficiency of the payment system, traceability of illegal transactions, surveillance, upholding the public monopoly of money, countering competition" (Fiedler et al 2019:9).

With regard to currency competition to be countered, it is then only the "efficiency of the payment system" which goes beyond the actual parameters of currency competition in the traditional sense. However, competition no longer takes place in the same way as in pre-digital times. Would the efficiency – to leave the critical aspect of network effects for these considerations aside for now – that would be achieved through technology increase the competitiveness of the CBDC and hence of the respective currency?

4.3. Currency competition through functional complementation

The emergence of (central bank) digital currencies thus provides an incentive to reconsider the set of functions money can have as described above. The categorisation, for example by Flynn (2018), provides a set of functions that is attributed to money itself (let it take the form of coins, banknotes, bits or bytes) and is interchangeably carried by the physical entities or digital signs or tokens that one calls money. However, with the introduction of CBDCs, a new, hitherto unexplored dimension of monetary functionality arises: namely, that of *technological* competition. What does this mean?

While currency competition is not a new phenomenon (see e.g. Eichengreen 2005), before the digital revolution, this kind of competition was *not* based on the technological or other physical characteristics of money – we are not talking here about precious metal currencies, but about modern fiat money systems – (coins, banknotes, scriptural money) itself. Quite the contrary: the decisive factors of currency competition were, among other things, as mentioned above, the general economic performance of the currency area, the set of characteristics of the respective money suppliers, i.e. the architecture of the money system, and the choice of the exchange rate regime (Endres 2009). One should state here that a claim against a central bank expressed in monetary units is always 'backed'

by a state. It is hence the interplay between the competitive performance of an economy, the reliability of monetary and economic policy and the sustainability or realism of fiscal policy which influence the relative advantage of one currency to another. In any form of fiat money system, the physical form of money, i.e. its technology in the narrower sense, did not play a role.

However, with the technological progress in past decades, the set of factors of competition now include *the technology itself* that lies behind the functioning of the respective CBDC. This technology may become a factor of interstate currency competition on the one hand and of competition with crypto-assets as well. This does not create a new monetary function, but it does add a new technological dimension to the existing ones. First and foremost, this concerns the function of a medium of exchange. Only if we take this complement seriously does the European Central Bank's argument make sense that it is aiming for "financial innovation" (ECB 2022) and wants to improve "the overall efficiency of the payments system" (ibid.). Relatively cheaper, faster or safer transactions will make a currency more attractive.

But whatever the role of commercial banks in a monetary system with CBDCs may be, a CBDC would compete with any forms of payment that are not made with "real but digital" central bank money, even within one currency area. The extent to which a CBDC could then actually serve "the increasing demand for safe and trusted electronic payments" (ibid.) better than the current intermediaries can is an open and initially technological question. Another question is to what extent a CBDC would be favoured in international transactions due to its technological advantages – such as guaranteed anonymity, speed of transactions, access to a central bank money account, etc. – and thus influence international currency competition, including competition with "digital currencies". This is a theoretical option, but it does exist: and it is a novelty on this scale.

One might say that a kind of *technological competition* would become a decisive parameter of CBDCs with respect to the functionality of money.²¹ This characteristic lies in the technological realisation and the technological design of the CBDC itself, and it is partly independent from the traditional factors of currency competition. And this is an unprecedented phenomenon: never before has money itself carried such a function. We are still at a very early phase of the development of CBDCs and so far no universally usable CBDCs have been introduced. However, when developing CBDCs, central banks should bear in mind that this development will

²¹ If a CBDC offers no functional advantages, introducing one requires other aspects of justification. Waller (2021:6) has drawn attention to this problem with reference to the US banking system: "I remain sceptical that a Federal Reserve CBDC would solve any major problem confronting the U.S. payment system". The problems he addresses are easily transferable to other currency areas. We cannot go into the relevant opportunities, risks and trade-offs here, as this would neither benefit nor detract from the focus of this contribution.

irreversibly supplement the set of functions of money known before. The following section attempts to segment the areas of impact of this new type of competition.

4.4. Areas of CBDC competition

In what manner technology serves as a new complement to money functions can be derived from the technological *design* of a CBDC. *Chen et al. (2022)* identify six key aspects of CBDC design: (1) the degree of interoperability, (2) the degree of central bank involvement in the operation of a CBDC (which we do not address in this paper as it does not influence (technological) currency competition by any means), (3) if the CBDC bears interest, (4) potential constraints on transaction amount, (5) data governance policy, and (6) underlying technology. In the following, we describe how the relevant aspects contribute to the pre-existing factors of currency competition.

(1) Interoperability

Interoperability is a core issue of the digital economy (see e.g. *Kerber – Schweitzer 2017:40*). In our focus, in simple terms it can be summarised as the ease of the flows between CBDCs and other payment systems (*BIS 2021*). It comes across both on a domestic level (i.e. flows between domestic payment systems) and on an international one (i.e. cross-border flows between international payment systems; *Chen et al. 2022*). The more interoperable a CBDC (both on the national and the international levels), the higher the incentive for its widespread use. This aspect is the actual core of technological currency competition. Its economic significance lies in the potential for lowering transaction costs (in the sense of transaction cost theory) for the users of such a currency. As relevant research has shown, it is useful in this respect to distinguish between the competitive effects potentially unfolding between *wholesale* and *retail* CBDCs.

The extent to which the use of retail CBDC would be more convenient for the end consumer than cash, as *Kóczyán et al. (2022:9)* assume, would first have to be proven in practice, especially since this aspect represents only one of a series of factors determining the respective preference, which first have to be determined empirically. *Boros – Horváth (2022:511)* have pointed out that “(...) the instant payment systems already in use efficiently satisfy customer needs”. Moreover, in view of the relatively small amount of cash in relation to the amount of fiat money or the central bank money as a whole (M0 according to Fed), it would be questionable to what extent this competitive element would really be decisive in the sense of currency competition.

By contrast, it seems much more plausible that the technological advantage of a CBDC becomes relevant in a wholesale variant by enabling direct payments between banks in different countries (see for example *Boros – Horváth 2022:511*) and thus

a considerable reduction of previously unavoidable transaction costs (see *World Bank 2022*) can be achieved.

(2) Interest bearing

Jurisdictions where interest bearing (retail) CBDCs are issued have a comparative advantage vis-à-vis those issuing a CBDC that does not bear interest. This is actually not a form of technological competition, but the use of a traditional monetary policy instrument *that goes beyond the concept of a CBDC as a digital complement to cash*. Admittedly, this option raises a number of important questions that go beyond the aspect of technology addressed here.²²

(3) Constraints and data governance policy

We treat these two factors combined (while *Chen et al. 2022* discuss these separately). From the perspective of currency competition, both factors represent a *trade-off between efficiency and safety*. Constraints on the transaction amounts contain a dilemma in themselves: while the aspects of ease and efficiency indicate that no constraints should apply (as these would cause a disadvantage vis-à-vis cash transactions), the aim of preventing illegal and illicit transactions speaks in favour of quantitative restrictions. Quantity restrictions are not only common when withdrawing cash, but also, for example, in transactions with physical gold for private individuals.

Now, the option of quantity restrictions would of course be economically rational from the point of view of monetary policy, insofar as it could counter inflationary developments (i.e. savings could not be spent if inflation was expected). Ultimately, it is the aforementioned economic facts that influence the extent to which such quantitative restrictions play a role at all. If the monetary policy of a currency zone is stable in conjunction with the other factors mentioned, then there is no reason to limit quantities. If not, users could expect such restrictions. However, those who really care about the anonymity of their transactions will find a way to choose another payment method anyway, starting from the scale that is to be pursued at all. However, the aforementioned trade-off does not even have to occur, if the respective economy is competitive, if the monetary and economic policy are reliable and if fiscal policy is sustainable.

Similarly, a trade-off arises between granting users' anonymity and limiting illegal activities. While the outcome is yet unclear and the debate on CBDC-related privacy matters is still ongoing (see e.g. *Darbha – Arora 2020; Jabbar et al. 2023*), these aspects will contribute to the competition between central bank digital currencies.

²² Of course, the focus is primarily on the effects on the activities of commercial banks. There is a broad discussion on this, but it does not provide a uniform picture.

It should not be forgotten in this discussion that any data protection is always an object of politics and therefore never carved into stone, nor that anonymising and keeping anonymous any data is an extremely challenging technological problem. Anonymous data can also be re-identified (*OECD 2020:10*, with reference to *PCAST 2014*). This is also a very challenging technological problem, but its role in the context of technological monetary competition also depends heavily on political preconditions.

(4) Technology (DLT/CLT²³)

The technology on which a CBDC is based is by definition the most relevant factor of technological currency competition. As both central banks and private actors are actively researching this matter (see e.g. *Mori – Pizzamiglio 2023*; *Chen et al. 2022*), in this paper, we would rather not try to predict the emerging consensus on the technology (distributed or central ledger technology) that will become the most widely used. Ultimately, this is not about technological problems in the narrower sense: just as a contribution on the problems of a gold currency will probably focus less on casting technology. The question is to what extent the technological basis actually enables the additional technological parameters of currency competition, i.e. in the numbering here, above all (1) and (3). Whatever technology it will be, it will remain in the hands of a central bank for a CBDC and thus be inextricably linked to the aforementioned problems of the economy and politics of a currency area.

5. Conclusions

To what extent would a CBDC change currency competition? As we have shown, the new technology represents an additional parameter in competition. It is a new complement to monetary functions. This aspect is new in the history of fiat money, in which the technological properties of the concrete medium of money were basically irrelevant as long as all functional requirements could be fulfilled. In this respect, digital technology *adds a new functional dimension* and increases the complexity of competition.

Currency competition *per se* has been a widely accepted and researched phenomenon: so far, however, the *stability* of money was the key factor when assessing the value of competing currencies. Acceptance of a currency primarily depended on its stability, as both devaluation and revaluation affect certain groups negatively (*Hayek 1976*), while generally, unexpected and considerable fluctuations in the value of a currency increases transaction costs no less. This aspect of currency competition will exist as long as currencies exist, and will not become less relevant. Technological competition as a factor of (international) currency competition

²³ DLT: distributed ledger technology, CLT: central ledger technology

complements to the aspect of stability rather than substituting it (but with the possibility of influencing pre-digital factors of currency competition).

The technology becomes relevant primarily with regard to its potential to reduce transaction costs, for example through higher speed in payment transactions, in whatever way this is realised technologically. However, the fact that the digital version of a central bank currency can be used at all and thus become a competitive medium is linked first and foremost to its interoperability. In this context, it must be emphasised that a competitive effect through the new technology will primarily be able to enfold with the wholesale variant of CBDCs and, initially, hardly at all with a retail variant of CBDCs. However, for even if one CBDC is much more interoperable and easier to use and can thus be paid around the globe much more quickly, this does not mean that the other conditions that have always been relevant for a stable, i.e. *competitive* money would weigh less.

In this respect, the technological parameter is actually the relevant competitive factor, but it is ambivalent. Because no matter how much one may trust the corresponding data governance policy, data protection is and remains the subject of politics. Public pronouncements are one thing, the other is the extent to which they are believed and to which extent promises are kept. Last but not least, it is precisely the non-governmentality *and* anonymity of the private crypto-assets that is trusted by investors – even if this aspect is a trade-off to stability, the core of currency competition.²⁴ In other words, it does not seem economically plausible that the technological superiority of one CBDC alone would sap the purchasing power of another currency, as long as the latter better fulfils the basic – traditional and pre-digital – requirements for stable money.

However, the complementing of money functions is thus remarkable in that it increases the complexity of currency competition, but at the same time increases the possibilities of political (governmental) spillovers. In this respect, it remains an open question whether digitalisation does indeed enhance the competitiveness of a currency. Especially, as central bank currencies – may they be digital or not – face competition from private digital money to a decisive degree not because of the technology, but due to their fulfilment of certain monetary functions. Thus, while technological competition has indeed arisen as a factor of currency competition, other factors such as stability and privacy still matter and might even matter as much or more.

²⁴ While this aspect is out of the scope of this paper, we highly encourage further research on these aspects, the link between the development of CBDCs and data protection and privacy issues. This is a question particularly worth analysing as anonymity is why cryptocurrencies are attractive to many investors and thus an aspect that can on the long run also become an element of currency competition.

References

- Agur, I. – Ari, A. – Dell’Ariccia, G. (2022): *Designing central bank digital currencies*. Journal of Monetary Economics 125, January, 62–79. <https://doi.org/10.1016/j.jmoneco.2021.05.002>
- Andolfatto, D. (2021): *Some Thoughts on Central Bank Digital Currency*. Cato Journal, 41(2): 343–351. <https://doi.org/10.36009/CJ.41.2.12>
- Auer, R. – Boehme, R. (2020): *The technology of retail central bank digital currency*. BIS Quarterly Review, March 2020: 85–100. https://www.bis.org/publ/qtrpdf/r_qt2003j.htm
- Auer, R. – Cornelli, G. – Frost, J. (2020): *Rise of the central bank digital currencies: drivers, approaches and technologies*. BIS Working Paper No. 880. <https://www.bis.org/publ/work880.htm>
- Auer, R. – Frost, J. – Gambacorta, L. – Monnet, C. – Rice, T. – Shin, H.S. (2021): *Central bank digital currencies: motives, economic implications and the research frontier*. BIS Working Paper No 976. <https://www.bis.org/publ/work976.pdf>
- Bech, M.L. – Garratt, R. (2017): *Central bank cryptocurrencies*. BIS Quarterly Review, September: 55–70. https://www.bis.org/publ/qtrpdf/r_qt1709f.htm
- Bernholz, P. (2015): *Monetary regimes and inflation: history, economic and political relationships*. Cheltenham: Edward Elgar Publishing. <https://doi.org/10.4337/9781784717636>
- BIS (2021): *Central bank digital currencies: system design and interoperability*. https://www.bis.org/publ/othp42_system_design.pdf
- Boar, C. – Wehrli, A. (2021): *Ready, steady, go? Results of the third BIS survey on central bank digital currency*. BIS Papers No. 114, Bank for International Settlements. <https://www.bis.org/publ/bppdf/bispap114.pdf>
- Bordo, M.D. – Levin, A.T. (2017): *Central Bank Digital Currency and the Future of Monetary Policy*. NBER Working Paper No. 23711, National Bureau of Economic Research. <https://doi.org/10.3386/w23711>
- Boros, E. – Horváth, M. (2022): *Central Bank Digital Currency: the Next Money Revolution? Central Bank Digital Currencies in the Dimension of Geopolitics*. Public Finance Quarterly, 2022(4): 506–521. https://doi.org/10.35551/PFQ_2022_4_2
- Bresnahan, T.F. – Trajtenberg, M. (1995): *General purpose technologies ‘Engines of growth’?* Journal of Econometrics, 65 (1): 83–108. [https://doi.org/10.1016/0304-4076\(94\)01598-T](https://doi.org/10.1016/0304-4076(94)01598-T)

- Brunnermeier, M.K. – James, H. – Landau, J.-P. (2019): *The Digitalization of Money*. NBER Working Paper No. 26300, National Bureau of Economic Research. <https://doi.org/10.3386/w26300>
- Brühl, V. (2020): *Libra: a differentiated view on Facebook's virtual currency project*. *Intereconomics*, 55, 54–61. <https://doi.org/10.1007/s10272-020-0869-1>
- Cesarano, F. (2014): *The Puzzle of Metallism: Searching for the Nature of Money*. *History of Political Economy*, 46(2): 177–210. <https://doi.org/10.1215/00182702-2647468>
- Chen, S. – Goel, T. – Qiu, H. – Shim, I. (2022): *CBDCs in emerging market economies*. BIS Papers No. 123, Bank for International Settlements, pp. 1–22. <https://www.bis.org/publ/bppdf/bispap123.pdf>
- Chiu, J. – Koepl, T. (2019): *The Economics of Cryptocurrencies – Bitcoin and Beyond*. Staff Working Paper 2019–40, Bank of Canada. <https://www.philadelphiafed.org/-/media/frbp/assets/working-papers/2021/wp21-37.pdf>
- Cohen, B. (2015): *Currency Power: Understanding Monetary Rivalry*. Princeton, N.J.: Princeton University Press. <https://doi.org/10.2307/j.ctt1wf4dgb>
- Crespo, R.F. (2021): *On money as a conventional sign: revisiting Aristotle's conception of money*. *Journal of Institutional Economics*, 17(3): 459–471. <https://doi.org/10.1017/S1744137420000570>
- Darbha, S., – Arora, R. (2020): *Privacy in CBDC technology*. Staff Analytical Note 2020–9, Bank of Canada. <https://doi.org/10.34989/san-2020-9>
- Eichengreen, B. (2005): *Sterling's Past, Dollar's Future: Historical Perspectives on Reserve Currency Competition*. NBER Working Paper No. 11336, National Bureau of Economic Research, Cambridge. <https://doi.org/10.3386/w11336>
- Endres, A.M. (2009): *Currency Competition: A Hayekian Perspective on International Monetary Integration*. *Journal of Money, Credit and Banking*, 41(6): 1251–1263. <https://doi.org/10.1111/j.1538-4616.2009.00255.x>
- ECB (2022): *The case for a digital euro: key objectives and design considerations*. European Central Bank, July. https://www.ecb.europa.eu/pub/pdf/other/key_objectives_digital_euro~f11592d6fb.en.pdf. Downloaded: 31 August 2023.
- ECB (2023): *Digital Euro*. European Central Bank. https://www.ecb.europa.eu/paym/digital_euro/html/index.en.html. Downloaded: 30 January 2023.
- European Commission (2020): *Proposal for a regulation of the European Parliament and of the Council on Markets in Crypto-assets, and amending Directive (EU) 2019/1937*. Brussels, 24. September. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020PC0593>

- Fáykiss, P. – Horváth, B.I. – Horváth, G. – Kiss-Mihály, N. – Nyikes, Á. – Szombati, A. (2021): *Transformation of Money in the Digital Age*. Civic Review, 17(Special Issue): 124–140. <https://doi.org/10.24307/psz.2021.0009>
- Fáykiss, P. – Szombati, A. (2021): *The conceptual framework of central bank digital currencies*. In: Banai, Á. – Nagy, B. (eds.): *At the dawn of a new age – Money in the 21st century*. Magyar Nemzeti Bank, pp. 95–134. <https://www.mnb.hu/en/publications/mnb-book-series/at-the-dawn-of-a-new-age-money-in-the-21st-century>
- Fiedler, S. – Gern, K.-J. – Stolzenburg, U. (2019): *The impact of digitalisation on the monetary system*. In: European Parliament: *The Future of Money*. Compilation of papers. Study requested by the ECON committee. Monetary dialogue, December, 5–29. [https://www.europarl.europa.eu/RegData/etudes/STUD/2019/642364/IPOL_STU\(2019\)642364_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/STUD/2019/642364/IPOL_STU(2019)642364_EN.pdf)
- Flynn, D. (2018): *Six monetary functions over five millennia: A price theory of monies*. In: van der Spek, R.J. – van Leeuwen, B.: *Money, Currency and Crisis*. In Search of Trust, 2000 BC to 2000 AD. New York: Routledge, pp. 13–36. <https://doi.org/10.4324/9781315210711-2>
- Folz, W. (1970): *Das geldtheoretische und geldpolitische Werk Walter Euckens*. Berlin: Duncker und Humblot.
- Friedman, M. (2002): *Capitalism and Freedom*. Chicago: University of Chicago Press.
- Gerba, E. – Rubio, M. (2019): *Virtual Money: How Much do Cryptocurrencies Alter the Fundamental Functions of Money?* In: European Parliament: *The Future of Money*. Compilation of papers. Study requested by the ECON committee. Monetary dialogue, December, pp. 30–60. [https://www.europarl.europa.eu/RegData/etudes/STUD/2019/642364/IPOL_STU\(2019\)642364_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/STUD/2019/642364/IPOL_STU(2019)642364_EN.pdf)
- Gilbert, S. – Loi, H. (2018): *Digital Currency Risk*. *International Journal of Economics and Finance*, 10(2): 108–123. <https://doi.org/10.5539/ijef.v10n2p108>
- Halaburda, H. – Sarvary, M. – Haeringer, G. (2022): *Beyond Bitcoin: Economics of Digital Currencies and Blockchain Technologies*. Cham.
- Harasim, J. (2016): *Europe: The Shift from Cash to Non-Cash Transactions*. In: Górká, J. (ed.): *Transforming payment systems in Europe*. London: Palgrave Macmillan UK, pp. 28–69. https://doi.org/10.1057/9781137541215_2
- Hayek, F.A. von (1976): *Choice in Currency. A way to stop inflation*. London: The Institute of Economic Affairs.
- Hayek, F.A. von (1999): *The Future Unit of Value*, In: Kresge, S. (ed.): *Good Money Part II: The Standard*. The Collected Works of F.A. Hayek, Volume 6. Chicago: University of Chicago Press, pp. 238–252.

- Horváth, G. (2022): *Monetary Sovereignty and Central Bank Digital Currency*. Public Finance Quarterly, 2022(4): 539–552. https://doi.org/10.35551/PFQ_2022_4_4
- Hurwicz, L. (2008): *But Who Will Guard the Guardians?* The American Economic Review, 98(3): 577–585. <https://doi.org/10.1257/aer.98.3.577>
- IMF (2021): *The Rise of Public and Private Digital Money: A Strategy to Continue Delivering on The IMF's Mandate*. Policy Paper No. 2021/055, International Monetary Fund. <https://doi.org/10.5089/9781513592039.007>
- Jabbar, A. – Geebren, A. – Hussain, Z. – Dani, S. – Ul-Durar, S. (2023): *Investigating individual privacy within CBDC: A privacy calculus perspective*. Research in International Business and Finance, 64, 101826. <https://doi.org/10.1016/j.ribaf.2022.101826>
- Jevons, W.S. (1876): *Money and the Mechanism of Exchange*. New York: D. Appleton and Co.
- Karau, S. (2022): *Central Bank Digital Currency Competition and the Impossible Trinity*. Finance Research Letters, 54, 103723. <https://doi.org/10.1016/j.frl.2023.103723>
- Keister, T. – Sanches, D. (2021): *Should central banks issue digital currency?* Working Paper 21–37. <https://doi.org/10.21799/frbp.wp.2021.37>
- Khan, R. – Hakami, T.A. (2021): *Cryptocurrency: usability perspective versus volatility threat*. Journal of Money and Business, 2(1): 6–28. <https://doi.org/10.1108/JMB-11-2021-0051>
- Kerber, W. – Schweitzer, H. (2017): *Interoperability in the Digital Economy*. Journal of Intellectual Property, Information Technology and E-Commerce Law (JIPITEC), 8(1): 39–58. <https://www.jipitec.eu/issues/jipitec-8-1-2017/4531>
- Kóczyán, B. (2022): *Potential Advantages of Retail Central Bank Digital Currency*. Financial and Economic Review, 21(3): 149–158. <https://en-hitelintezetiszemle.mnb.hu/letoltes/fer-21-3-fa1-koczian.pdf>
- Kóczyán, B. – Kollarik, A. – Kiss, L. – Simon, P. (2022): *Central Bank Digital Currency: A New Instrument of Monetary Policy*. Public Finance Quarterly, 2022(4): 522–538. https://doi.org/10.35551/PFQ_2022_4_3
- Köhler, E.A. (2019): *Die Geldordnungstheorie der Freiburger Schule*, Ordo, 70(1): 21–49. <https://doi.org/10.1515/ordo-2020-0005>
- Luther, W.J. – Smith, S.S. (2020): *Is Bitcoin a decentralized payment mechanism?* Journal of Institutional Economics, 16(4): 433–444. <https://doi.org/10.1017/S1744137420000107>
- Maulana, A. – Purtri, D.P. – Yulia (2019): *Development of digital currency technology*. IOP Conf. Series: Journal of Physics: Conference Series, 1175, 012205. <https://doi.org/10.1088/1742-6596/1175/1/012205>

- Maurer, B. – Nelms, T. – Schwartz, L. (2013): *“When perhaps the real problem is money itself!”: the practical materiality of Bitcoin*. *Social Semiotics*, 23(2): 261–277. <https://doi.org/10.1080/10350330.2013.777594>
- Mayer, F. – Bofinger, P. (2023): *Cryptocurrency competition: An empirical test of Hayek’s vision of private monies*. WEP-Würzburg Economic Paper No. 103. <https://www.uni-wuerzburg.de/fileadmin/12000000/Downloadpool/WEP/wep103.pdf>
- Menger, K. (1892): *On the Origin of Money*. *The Economic Journal*, 2(6): 239–255. <https://doi.org/10.2307/2956146>
- Mitchell, W. – Wray, L.R. – Watts, M. (2016): *Modern Monetary Theory and Practice: An Introductory Text*. Centre of Full Employment and Equity (CofFEE), The University of Newcastle.
- Mori, G. – Pizzamiglio, F. (2023): *CBDC – Exploring a New Digital World*. Iason Research Paper No. 55. https://www.iasonltd.com/doc/rps/2023/cbdc_exploring_a_new_digital_world.pdf
- Mundell, R.A. (1961): *A Theory of Optimum Currency Areas*. *The American Economic Review* 51(4): 657–665.
- Müller, J. – Kerényi, Á. (2022): *The Rise of Central Bank Digital Currencies*. *Financial and Economic Review*, 21(3): 122–148. <https://doi.org/10.33893/FER.21.3.122>
- Nelson, B. (2017): *Financial Stability and Monetary Policy Issues Associated with Digital Currencies. Remarks at Fintech – the Impact on Consumers, Banking, and Regulatory Policy*. https://www.philadelphiafed.org/-/media/frbp/assets/events/2017/consumer-finance/fintech-2017/day-2/7_slides_nelson.pdf. Downloaded: 5 September 2023.
- Nishibe, M. (2020): *The present and future of digital-community currencies: RAMICS 2019 in Hida–Takayama keynote speech*. *Evolutionary and Institutional Economics Review*, 17: 327–343. <https://doi.org/10.1007/s40844-020-00177-y>
- OECD (2020): *Consumer Data Rights and Competition – Background Note by the Secretariat*. OECD, 10–12 June. [https://one.oecd.org/document/DAF/COMP\(2020\)1/en/pdf](https://one.oecd.org/document/DAF/COMP(2020)1/en/pdf)
- Panetta, F. (2021a): *“Hic sunt leones” – open research questions on the international dimension of central bank digital currencies*. Speech at the European Central Bank Research Association (CEBRA) conference on international aspects of digital currencies and fintech, Frankfurt am Main, 19 October. <https://www.bis.org/review/r211118c.pdf>. Downloaded: 10 June 2023.

- Panetta, F. (2021b): *Central bank digital currencies: a monetary anchor for digital innovation*. Speech at the Elcano Royal Institute, Madrid, 5 November. <https://www.ecb.europa.eu/press/key/date/2021/html/ecb.sp211105~08781cb638.en.html>. Downloaded: 10 June 2023.
- Panetta, F. (2021c): *Designing a digital euro for the retail payments landscape of tomorrow*. Speech at the ECON Committee of the European Parliament, European Central Bank. <https://www.ecb.europa.eu/press/key/date/2021/html/ecb.sp211118~b36013b7c5.en.html>. Downloaded: 10 June 2023.
- PCAST (2014): *Big Data and Privacy Working Group*. Washington, D.C. https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_big_data_and_privacy_-_may_2014.pdf
- Redman, J. (2023): *US Government Remains a Top Bitcoin Holder With Seized Stash Valued at \$5.6 Billion*. Bitcoin.com, News. <https://news.bitcoin.com/us-government-remains-a-top-bitcoin-holder-with-seized-stash-valued-at-5-6-billion/>. Downloaded: 7 December 2023.
- Sanderson, H. (2015): *Digital currencies: A gold standard for bitcoin*. Financial Times, 15 May. <https://www.ft.com/content/38d02382-f809-11e4-962b-00144feab7de>
- Söderberg, G. (2018): *Are Bitcoin another crypto-assets money?* Sveriges Riksbank. Economic Commentaries No. 5, 14 March. <https://www.riksbank.se/globalassets/media/rapporter/ekonomiska-kommentarer/engelska/2018/are-bitcoin-and-other-crypto-assets-money.pdf>
- Stroukal, D. (2018): Can Bitcoin become money? Its money functions and regression theorem. *International Journal of Business and Management*, 6(1): 36–53. <https://doi.org/10.20472/BM.2018.6.1.004>
- Terták, E. – Kovács, L. (2022): *The Motives for Issuing Central Bank Digital Currency and the Challenges of Introduction Thereof*. *Public Finance Quarterly*, 2022(4): 491–505. https://doi.org/10.35551/PFQ_2022_4_1
- Tobin, J. (1987): *The case for preserving regulatory distinctions*. Proceedings of the Economic Policy Symposium, Jackson Hole, Federal Reserve Bank of Kansas City, pp. 167–183.
- Waller, C.J. (2021): *CBDC – A Solution in Search of a Problem?* Speech, American Enterprise Institute, Washington, D.C., 5 August, BIS central bankers’ speeches. <https://www.bis.org/review/r210806a.pdf>. Downloaded: 12 December 2023.
- World Bank (2022): *An analysis of trends in cost of remittance services*. *Remittance Prices Worldwide Quarterly*, Issue 41 (March). https://remittanceprices.worldbank.org/sites/default/files/rpw_main_report_and_annex_q122_final.pdf