# A digital euro and the future of cash

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*What is the discussion about a digital euro – and, more generally, digital central bank currencies – all about? We are focusing here on the future of cash. For strategic reasons, central banks are seeking to provide a credible and viable public anchor for digital money given that the future might be shaped more strongly by new private issuers of money. The technological structures and business model-driven incentives of the new players, which are associated with the internet economy and thrive on network effects, might lead to a concentration of significant market power in payments. Ultimately, this might even result in a fragmented monetary system and jeopardize universal access to public money. From a central bank's perspective, the crucial question is therefore not so much about replacing cash with new payment technologies but about finding ways to ensure that the monetary system will continue to work in the public interest in a digital future. Cash will, and should, play a role also in a future monetary system. By creating a digital euro, central banks in the euro area aim to adapt cash in such a way that it meets the needs of the digital age.*

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Both the work and discussion on a digital euro are often perceived in the public as driven by a desire to ultimately replace cash. Yet, the European Central Bank (ECB) has stressed on many occasions that this is incorrect. Plus, the ECB has emphasized that any potential future model of a digital euro will only complement, and not substitute, existing means of payment, in particular cash. Yet, since banknotes and coins cannot be used for digital payments, there is a lingering perception that they are an outdated technology that will sooner or later have to be replaced. The root cause seems to be a superficial understanding of the modern monetary system and of the factors driving the debate on central bank digital currencies (CBDCs).

We argue that the discussion about a digital euro is not about replacing cash but a strategic discussion of how money can function in the public interest in a digital age. It is a debate about how to ensure universal access to central bank money for all citizens and how central banks should react to new, technology-driven issuers of private money in the platform-centered internet economy. Rather than a project to replace cash, a digital euro would therefore be the Eurosystem's response to challenges arising from new entrants into the market for digital payments.

The monetary and payment systems have been working so well that in our daily activities we rarely give much thought to the details of the architecture these systems are based on. In our daily lives, EUR 1 is EUR 1, no matter whether we pay by cash, debit card, credit card or other digital tools. We therefore begin our discussion in section 1 with a comprehensive overview of the architecture of the

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modern monetary system and the precise role that cash has in it. In section 2, we explore how the entry of new private issuers of money or money-like instruments has created the need for central banks to engage in the discussion on new forms of digital central bank money in the first place. In section 3, we explain why central banks consider it necessary to ponder whether they should develop a new digital form of central bank money for the public. In this context, papers and reports spell out various arguments for such a move, but replacing cash is not among them.

Arguments why it might be a good idea to develop a public alternative to privately issued money are bound to be very abstract. In section 4, we therefore try to discuss implementation options and their various issues and trade-offs in a broad, yet sufficiently detailed way. We aim to give readers an idea of what it would mean for them if such a public payment instrument became available. In section 5, we summarize some positive and normative arguments why we believe that cash will and should play a role also in a future monetary system that is likely to provide new forms of public and private digital money. Section 6 concludes.

## 1 The role of cash in the current monetary system

Both as consumers and producers of goods and services, citizens in Austria are used to having permanent access to a smoothly functioning payment system to pay their bills and transfer money. This is also true for people living in the euro area, the European Union (EU) or in developed countries around the world. People predominantly make larger-value payments digitally by using cards, bank transactions, smartphones or other digital devices, while they tend to use cash for smaller-value transactions. There seems to be a long-term trend away from cash toward digital payments, but in the EU at large cash still plays a significant role as a preferred means of payment.[2] From the perspective of payment system users, EUR 1 is EUR 1 no matter whether this amount is paid in cash or digitally. From this point of view, it is perhaps difficult to make sense of the discussion on a future digital euro. Without additional information or context, many people might think this discussion is a first step in a general attempt to replace cash. But this is not the case. To the contrary, the debate is zeroing in on the problem how to guarantee universal access to central bank money in a world that has an increasing need for digital payments. As a consequence of digital transformation, online communication, collaboration, banking and shopping have become ubiquitous in our everyday lives.[3] To better understand and assess this claim, let us take a brief look at how the modern monetary system works and which role it assigns to cash.

In a modern economy, citizens, businesses and public institutions use two forms of money, broadly speaking: state or public money and private money.[4] State money is issued by a central bank acting as an agent of the state. It is therefore usually referred to as central bank money. This form of money exists both in digital form – as entries in central bank accounts – and as banknotes and coins. Private

[2] *See the contribution by Schautzer and Stix in this issue.*

[3] *See Cochoy et al. (2017) for a detailed discussion of the effects of digital transformation on consumers.*

[4] *For an excellent overview of how the modern monetary system works, see Weber (2018) or the classic by Holme-Robertson (1924).*

money has been traditionally issued by commercial banks and exists as digital entries in bank accounts, i.e. in a database.[5]

Central bank money is issued digitally as deposits to selected commercial banks, which are supervised, regulated and subject to some form of deposit insurance. So, this form of money, technically referred to as central bank reserve accounts, has been digital since computer technology allowed for industrial-strength use of digital databases. Central bank money is also issued physically in the form of banknotes and coins. Only in this form is central bank money currently available to the public at large. Given its physical nature, it cannot be used for digital payments.

Legally, central bank money is a liability of the central bank. It is, however, not redeemable against assets held by the central bank. When we pay with cash, we ultimately pay with central bank money as it happens to be the final domestic means of payment. Central bank money also serves as a settlement asset among banks for payments made by their customers through transfers between bank accounts. The value of central bank money is managed through the central bank's monetary policy, which consists in the legally enshrined promise and mandate to keep the purchasing power of central bank money stable relative to a broad basket of goods and services. The main responsibility and policy goal of a central bank is therefore to fulfill this mandate and keep the promise of price stability by means of its monetary policy.[6]

Bank deposits, which are private money, are issued by commercial banks to all citizens with a bank account. Most payments in a modern economy – about 95% – are made by digital transfers between bank accounts. Bank deposits can be accessed via debit cards, credit cards and other, mostly digital, payment instruments. Account owners may use such instruments to instruct their bank to carry out transactions on their behalf.

In contrast to state money, private money is a liability of a commercial bank. It is a promise obliging the commercial bank which has issued the deposit to convert the private money at par – this means 1 to 1 – into central bank money anytime on demand unless the account has certain covenants attached which restrict immediate conversion. Unlike central bank money, commercial bank money has some credit and liquidity risks, although these risks are contained by various policy instruments such as bank licensing, supervision, regulation, deposit insurance and access for banks to refinancing facilities at the central bank.

Under normal circumstances central bank money and deposits are interchangeable, i.e. EUR 1 in a bank account can be exchanged for EUR 1 in cash. Ultimately, the quality of central bank money is superior to that of a bank deposit, however, because central bank money does not depend on the solvency of a private issuer. Central bank money rests on a unique legal framework, the power of the state to

[5] *The traditional unique role of commercial banks as issuers of private money has recently been enlarged by new institutions outside the traditional banking system, such as internet firms and crypto asset issuers. We will discuss these new players and their role in the modern monetary system in section 2. Historically, there have also been periods, mainly in the 19th century, when commercial banks also issued their own banknotes. This practice ended with the regulation that invested central banks with the monopoly to issue banknotes.*

[6] *See Article 127 of the consolidated version of the Treaty on the Functioning of the European Union (TFEU) at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A12016E127.*

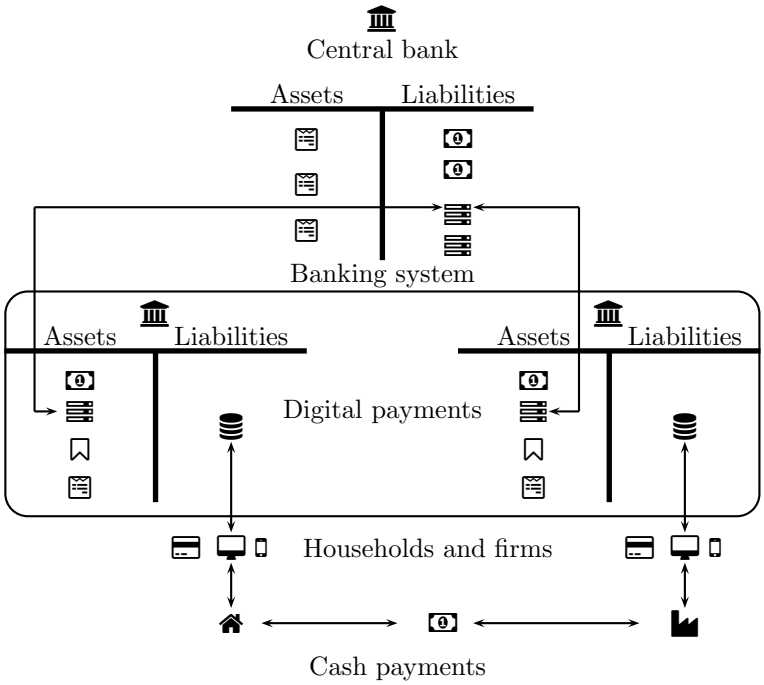
collect taxes and its status as legal tender[7]. The ultimate asset for settling payments between banks, it defines the unit of account.

Experts and many nonexperts know that deposits carry some credit risk. Yet, the prudential measures aimed at minimizing this risk are generally considered to be very credible. For this reason, we expect that EUR 1 is EUR 1 no matter whether we pay in cash or by bank transfer, debit card or another means involving a bank account. The private banking system is highly integrated with the central bank and the monetary system at large in operational, legal and regulatory terms. As a result, the vast majority of people accepts private money issued by banks, considers it legitimate and does not see a need for a digital payment system directly in central bank money.[8]

Figure 1 summarizes this section in a schematic illustration showing the different layers of the modern monetary system: the central bank at the top, the banking system (here represented by two banks) and households and firms as well as the different forms of money (digital, cash). Due to the hierarchical structure, this system is often referred to as a two-tier system. The central bank issues money in electronic form to selected commercial banks as reserve accounts (stack symbols) and as banknotes and coins (banknote symbols). In exchange for this money, the central bank receives high-quality securities (contract file symbols on the asset side

Figure 1

**The modern monetary system**




*Source: Authors' compilation.*

[7] *Legal tender is a notion of EU law enshrined in Article 128(1) TFEU. Means of payment cannot generally be refused in the settlement of a debt in the same currency unit. They must be accepted at full face value, with the effect of repaying the debt.*

[8] *While legitimacy has always been a bone of contention and led to various reform ideas and initiatives, only few people engaged in this discussion in the past (Weber, 2018).*

of its balance sheet) from the commercial banks. Commercial banks create deposits (database symbols) through extending credit to households and firms (flag symbols) and can make digital transfers among each other via the central bank. At the bottom of the monetary hierarchy, households (house symbol) and firms (industry symbol) may pay physically with central bank cash or by instructing their commercial bank to transfer deposits between accounts while using different devices (card, computer and smartphone symbols). Cash and reserves are the ultimate settlement assets on which all other financial promises are based.

Cash is likely to play a role even in the modern payment environment that will increasingly depend on digital payments. This will be due both to some of its unique features and benefits for users and to its key legal role in financial contracts.

Several features of cash that are unique from the user perspective are not easy or perhaps not feasible to implement digitally (Bundesministerium für Wirtschaft und Energie, 2017). Cash allows for simplicity and immediate finality in payments. Payments are made by a simple physical transfer of banknotes or coins. No signatures, no further bookkeeping of the payment in a register or no internet availability are necessary. Persons not knowing each other may simultaneously exchange a good or service for physical cash. Such exchanges require little personal trust, and they would not take place were it not for this form of payment. Digital payments depend on digital transaction registers as well as some form of intermediation or transfer infrastructure. In fact, electronic payments involve many different parties to ensure the alignment of payment messages and funds. Cash is uniquely robust and resilient due to its independence from electronic devices. Many consumers use cash because it provides them with a simple and effective way to keep track of their expenses (Bagnal et al., 2016). Cash payments protect consumers from abuse of their payment information. They leave no trace about what consumers paid for. For instance, if persons wanted to be tested for an HIV infection and to keep this information private, they could pay for such tests with cash. Besides, payment information collected on individuals could be abused to manipulate their behavior. If such data were sold for advertising without consumers' consent, they could also be abused for commercial purposes. On the other hand, another unique feature of cash worth mentioning is that physical proximity is necessary for making or receiving payments, which could be regarded as a disadvantage from a user perspective.

Overall, demand for cash is unlikely to disappear completely. The user advantages of cash combined, including device and internet independence in exchanges, cannot be fully replicated digitally. Even if demand for cash as a means of payment will decrease in the long run, its unique advantages will remain attractive for users.

While playing a minor role in terms of transaction volumes, cash nevertheless is key to the current monetary system (Bundesministerium für Wirtschaft und Energie, 2017). This key role comes from the function cash has in financial contracts, in particular debt contracts. Debt contracts legally oblige the debtor to provide certain amounts of money, which is usually specified as cash. For instance, deposits held at a commercial bank are debt contracts which oblige banks to pay back (parts of) the deposits as cash on demand. This special role of cash, or central bank money more generally, is attributable to the fact that, in our monetary system, central bank money is the final settlement asset in the current hierarchy of payment instruments. A legal obligation to provide cash to settle a debt only makes sense in a world where the asset on which the obligation is based is available to both contracting parties.

Of course, it would be possible in theory to reinterpret the notion of an obligation to deliver cash and consider other titles, such as deposits at the central bank, that must be delivered. One could even define the legal tender notion, which in many jurisdictions refers to cash, as referring to this other form of money, contrary to widespread current practice.[9] In this case, many new and tricky issues arise, which are not straightforward to address and are difficult to solve. If – contrary to current practice – in a new monetary arrangement all natural and legal persons had direct access to the central bank's balance sheet, this would probably concentrate the payment system at the central bank. This would create problems of transaction data protection and governance as well as new infrastructure requirements which would prove very challenging in practice or might even indirectly threaten central bank independence (Chaum et al., 2021).

## 2 New players in the market for privately issued money

More recently, banks have experienced new competition from other private issuers of money. Among these private issuers, crypto assets like bitcoin and ethereum have received the most public attention and have also fueled debates on the future of money and the monetary system. However, such debates, often led with exuberant enthusiasm, idealism and quasi-religious fervor, quickly revealed that crypto assets are unlikely to succeed as privately issued money. They are not expected to supersede conventional money in its current form for various reasons. They are not generally accepted as payment for goods and services, are highly volatile, have technical scaling problems, waste enormous amounts of energy and – perhaps most importantly – lack a responsible and accountable issuer. For central banks and governments, crypto markets have so far been more of a potential challenge to financial stability given their enormous growth and progressive interlinkages with the traditional financial system. Crypto assets also pose challenges for fighting money laundering, financing of terrorism and online crime (see e.g. FSB, 2022).

Another form of privately issued digital money that is relatively new are so-called stablecoins. Stablecoins are crypto assets whose issuers attempt to stabilize the value either by algorithmically controlling the supply or by backing the stablecoins by other assets or currencies. This is only a very rough classification; for a more detailed description, see Clark et al. (2021). While algorithmic stablecoins have been a failure in practice so far, asset- or currency-backed stablecoins have been more successful. Backing their financial promises with certain asset classes, stablecoin issuers closely resemble banks in economic terms but have yet to be integrated in the same legal and regulatory framework as banks. As pointed out by Chaum et al. (2021), unlike crypto assets, stablecoins, especially if properly regulated, have a better chance to succeed as a new form of private money.

These new entrants into the market raise a question of strategic importance: how can we ensure that in a future where more and more payments become digital, citizens will still have universal access to central bank money and will not entirely depend on private money issuers to make digital payments?

[9] *Note that the notion of legal tender is not uniformly defined across jurisdictions. Legal tender often refers to cash, but sometimes central bank deposits are included, as for example in Switzerland. Including deposits of commercial banks at the central bank, however, differs substantially from granting general access to the central bank balance sheet to the general public.*

Why should we raise this strategic question in the face of new suppliers of privately issued forms of money? Here, it is important to see the nexus between stablecoin issuers and so-called big techs, the giant global internet firms of the digital age. The core of their business models consists in collecting, repackaging and reselling user data acquired in their platform-based business lines of messaging, social media, internet search technology, e-commerce and computing. These firms have a huge incentive to enter the payment market and the market for privately issued money, because adding payment information to their existing user data would make these data much more informative and therefore valuable. After all, they would generate data on consumers' willingness to pay for goods and services at the individual level. Stablecoin models are a technology that can be easily combined with a platform business.

Economists refer to the core feature of such business models as "network effect." A network effect implies that a good or service becomes more useful to everybody if more people use it. Payment technologies typically show such effects, which is natural. After all, a payment instrument is useful if it is widely accepted in exchange for goods and services, and it helps of course if many people use this payment instrument. Network effects run the risk of concentrating market power, pushing up transactions costs as well as impeding competition and innovation, which could even result in a breakdown of universal access to digital payments (BIS, 2021).

Such a concentration of market power also indirectly entails the risk of mass surveillance and privacy intrusions. It also poses a serious threat to the right to informational self-determination and puts citizens at risk from data exploitation by payment service providers.

In such a situation, properly designed digital central bank money that is accessible to all citizens may offer individuals a choice of a digital payment instrument that protects their data and their privacy. It could provide a neutral payment infrastructure that supports competition, efficiency and innovation. And it could sustain universal access to central bank money even in a future where people depend more and more on digital payments and physical cash becomes a fallback payment solution.

In this context, it may be easier to understand that the discussion about developing a new form of digital central bank money is not about replacing cash but about ensuring universal access to central bank money in a future dominated by digital payments.

## 3 Arguments for a central bank-issued digital means of payment

According to Auer et al. (2020) and Auer and Böhme (2021) as well as other international sources[10], central banks around the world have stepped up their research and development of a general central bank digital currency, or CBDC. After some preparatory work in 2020, the ECB (2020, 2021a, 2021b) launched a project-investigating phase to analyze and solve issues with respect to a digital euro to be able to decide soon whether an actual development phase should be started. Global trends in technology as well as country- or currency-specific circumstances are often reported as the main motivations to look deeper into the CBDC question.

[10] *See, for example, the website https://cbdctracker.org/.*

These motivations by themselves would, however, be rather general and inconclusive for launching projects of this scale that are likely to have huge structural repercussions for the financial system. So, let us look more closely at the arguments given by central banks and in the public policy discussion.

The strategic argument of preserving universal access to central bank money for citizens even in a world increasingly shaped by digital payments and private issuers of money was elaborated in detail by the BIS in its annual economic report 2021. This argument was also featured in the report of the ECB's High-Level Task Force on a digital euro (ECB, 2020). It has been restated in various forms in the public debate and in recent policy reports, e.g. in Brunnermeier and Landau (2022).

The BIS (2021) starts from the role of the public sector to enable and sustain a monetary system that can function in the public interest. According to the BIS, this encompasses the ability to maintain a competitive structure in payment services, high-quality governance structures as well as the guarantee of basic rights such as data protection, informational self-determination and universal access to central bank money.

In the view of the BIS, these tasks are potentially challenged by the entry of big techs into the market for payments. These companies are the backbone of the platform economy that thrives on network effects: the more people use a particular platform, the more attractive this platform is to others to join irrespective of whether the platform specializes in search technology, messaging, social media, computing or e-commerce. Not only do these network effects create a very valuable, but rarely directly visible, complementary business of commercializing the user data gained in the platform activities, but they also lead to a concentration of market power and political power, which inhibits competition, efficiency and innovation (see e.g. Zhuboff, 2019). Entrenched market power can exacerbate and sustain already high costs in payment services even though the cost of communication devices and bandwidth has been declining.

This argument is also made by Brunnermeier and Payne (2022) and Brunnermeier and Landau (2022). They stress that the structural logic of the platform economy tends to create and develop complementarities between different activities and fosters economic incentives to create a closed system and erect technical barriers. As a shared form of currency on the platform would strengthen these complementarities and links, platforms have a strong incentive to develop new digital forms of money. This can lead to an excessive fragmentation of the monetary system and entails the danger that the monetary system is weakened for lack of a stable, universally accessible anchor of value that is currently provided by central bank money.

The BIS (2021) also takes issue with lacking universal access and data governance in a digital payment market where big techs hold entrenched market power. The BIS sees CBDC initiatives as a strategic policy tool to meet this new challenge. Creating an open payment platform promotes competition and innovation, which channels network effects into a virtuous circle of competition and innovation in payments instead of getting trapped in a vicious circle of market power, inefficiency, mass surveillance and lack of innovation.

Universal access and a uniform currency are of vital importance for central banks also for the effective conduct of monetary policy. The fact that the euro is

the only standard of value for all people in the euro area is the basis for an effective and functional monetary system and monetary policy. As pointed out by Brunnermeier and Landau (2022), "a uniform currency and the control of the unit of account are jointly necessary to ensure the implementation of monetary policy and preserve monetary sovereignty."

This strategic view on CBDC developments as articulated by the BIS and echoed in many reports and policy papers of central banks is one of the arguments supporting central banks' increased efforts to come up with their own versions of digital central bank money. Ultimately, the debate is about which institution in the economy should have the power and the means to conduct monetary policy.

Besides these strategic arguments, business or efficiency arguments advocate the development of CBDCs. A case in point is fostering innovation and competition in payments. For instance, focusing on the US payment system, Duffie (2021) claims that US banks can provide a low-cost payment system but have not done so. His focus therefore is on the private banking system as an issue of inefficiencies and not on big techs' market power or on cash. In Duffie's perspective, this inefficiency in the US system drives the power and energy of new entrants like big techs and other private issuers of money. The argument that the central bank should develop a CBDC to increase pressure on private banks to offer better payment services is less frequently voiced in the public discussion. It also has some country-specific features. The situation in the USA does not seem to be directly comparable to the payment system in the euro area although inefficiencies could perhaps also be identified there. One example is the rollout of the Single Euro Payments Area (SEPA), an EU initiative to unify standards for digital payments in the euro area and to tackle the fragmentation of the European payment system that had previously relied on different national standards. The adoption of SEPA schemes proceeded slowly because voluntary migration was perceived as expensive and risky for first movers, as they had to keep the old and the new system running in parallel. Therefore, EU legislation was necessary to set end dates for completing the migration of credit transfers and direct debits to the harmonized SEPA standards. Today, some parallels can be drawn between SEPA and the sluggish implementation of instant payments in the EU, which might again necessitate a legislative intervention. Again, early adopters face higher costs for running an additional payment infrastructure. Also, the shift from deferred net settlement to prefunded settlement in central bank money is less favorable for banks from a liquidity management perspective unless all banks move from SEPA credit transfers to SEPA instant payments.

When existing digital payments are compared to cash from a cost perspective, there seems to be no clear-cut answer. A report for the German ministry of economic affairs[11] claims that in Germany cash payments have been cheaper for users than card payments. Credit card payments seem to be the most expensive form of digital payments across Europe.

Various reports have pointed to the high costs and apparent inefficiency in international payments. Hopes are expressed that CBDCs might make these payments cheaper and faster. However, no clear evidence is available on the precise mechanism how this could be achieved. It seems that a deeper understanding of the

[11] *Bundesministerium für Wirtschaft und Energie (2017).*

root causes of existing inefficiencies has yet to be developed. Furthermore, Auer et al. (2021) point to various coordination challenges that might arise in establishing interoperability of CBDC systems around the globe.

Finally, CBDCs are sometimes also regarded as an instrument that might improve financial inclusion. Such hopes – justified or not – certainly do not apply universally. Especially in the highly developed countries, it is rare that somebody is excluded from participating in the financial system or from receiving or making payments because a CBDC is not yet available. On the contrary, now it seems difficult to beat cash in terms of inclusiveness. Cash is particularly easy to use and is available to everybody in society, including people without access to electronic devices, such as children, poor or older people. However, this situation might change in the future if the use of cash in a more digitally dominated world is further declining. In the future, the economic opportunities of a person who participates in the payment system while having only access to cash might be severely restricted.

Overall, it seems that the arguments voiced in favor of developing CBDCs are mainly based on strategic considerations, either as a counterbalance of the public sector against big techs' current and potential future market power, or as an instrument to increase competitive pressure on banks and credit card firms to offer cheaper payment services, or as an instrument to improve financial inclusion.

None of these arguments for developing a CBDC makes a case for replacing cash. In fact, competition for a potential new digital currency comes from big techs and other private issuers of money like players in the global platform industry. In contrast to public perception, in which the debate about a digital euro is often framed as an initiative or even a "war" against cash, replacing cash does not figure across the public sector and in any official reports on the various projects around the globe. Instead, in their pursuit of CBDCs, central banks are motivated by declining user demand for cash that is driven by digital transformation. This general trend raises concerns that the private sector might come to hold entrenched power in digital payments in the future.

## 4 Three ways in which a digital euro could be implemented

Implementation of CBDCs is still in its infancy. What is more, unclear and ambiguous terminology often obscures, rather than clarifies, the issues yet to be resolved. Reports often take recourse to the institutional features of the modern monetary system by referring to forms of money existing as physical objects – like cash – or money as an entry in ledgers – like deposits at commercial banks or reserve accounts at the central bank.[12] The often invoked terminology of "token-based systems" and "account-based systems" rarely helps clarify implementation issues, as has been pointed out by Lee et al. (2021).

We thus organize our discussion around concrete technologies rather than abstract and potentially confusing concepts. Let us start with the most familiar concept from the current system, the concept of a deposit account.

[12] *By the way, these two forms of money predate the modern monetary system by a few centuries and have been in use since the late Middle Ages and the Renaissance period in Europe.*

### 4.1 Deposit accounts held directly or indirectly at the central bank

From an implementation perspective, the straightforward option would be that the central bank opens its balance sheet not only to selected commercial banks with whom it does business and jointly runs the payment system, but also to all citizens by allowing them to open accounts directly with the central bank – in the same way as is now possible with commercial bank accounts. This pure and perhaps excessively centralized form would significantly change the central bank's operations. For one thing, the ECB would face the challenge to run about 500 million new customer accounts on its systems in addition to the current payment infrastructure. For another, this option would also entail many new functions for the ECB currently performed by commercial banks, most importantly customer identification (the implementation of so-called KYC or "know your customer" rules) as well as compliance with anti-money laundering legislation (so-called AML rules). It would mean operating customer front ends and services and most likely investing in the energy and communication technology infrastructures to ensure the availability and robustness of the payment infrastructure. The payment system would be excessively concentrated with the central bank, and massive information concentration would ensue as well. Such changes would significantly transform the political economy role of the central bank by giving it a much larger public footprint. While citizens view central banks now mainly as bureaucratic institutions responsible for price stability and financial stability, this would bring central banks in the focus as institutions that could directly intervene in the distribution of money, in transfers and other operations that are now usually seen as being in the realm of fiscal authorities.

This extreme approach does not figure in the discussion, however. Most central banks considering digital central bank money are discussing an implementation option which would assign the servicing and maintenance of customer accounts as well as the implementation of KYC and AML compliance rules to third parties or to commercial banks.

Auer and Böhme (2021) provide an overview of how such systems of accounts could be organized in principle and discuss models where central bank accounts would be held by citizens only indirectly via intermediaries. Specifically, they discuss (1) a model where commercial banks handle customer onboarding and compliance as well as the retail payment infrastructure, with the central bank periodically recording retail balances (hybrid CBDC), or (2) an architecture, in which intermediaries onboard clients, handle KYC and AML policies and run the retail payment infrastructure, with the central bank handling wholesale payments in the background (fully intermediated CBDC). Similar architectures can be found in the report of the ECB (2020) on a digital euro.

While maintaining customer accounts and the underlying IT infrastructure is a time-tested activity, account models have two problems, which limit their attractiveness as a model for implementing a CBDC.

The first concern is data concentration at the central bank. A CBDC model that involves a system of directly or indirectly held customer accounts and allows citizens to directly access the central bank's balance sheet concentrates a huge amount of data at the central bank or makes these data indirectly accessible to the central bank, as pointed out by Chaum et al. (2021). A payment system based on an infrastructure of accounts must associate ledger entries with some form of

identity, transaction histories of individual accounts and a list of credits and debits per account. Otherwise, it is not possible to ensure transaction legitimacy, i.e. the legitimate change of entries in the ledger of accounts.

Technological tools may protect the privacy of transaction data against abuse and vis-à-vis other parties, but they do not guarantee transaction data privacy to the users of the digital currency. While the technology allows to protect user data, in such a system the users cannot themselves control and guarantee transaction privacy as informational self-determination would require (see e.g. D'Aligny et al., 2022). An account infrastructure, even if established with the best of intentions and measures of prudence, practically makes mass surveillance and the imposition of sanctions against individual account holders relatively cheap. Because the transaction data of an account system are centrally held, it is technically easy to enforce sanctions or surveillance measures. The very nature of data centralization, as pointed out by Chaum et al. (2021), would open a new avenue to exert pressure on central banks. This might undermine central bank independence and central banks' effectiveness in fulfilling their mandate to guarantee price stability through conducting monetary policy.

Note that hybrid systems as discussed in Auer and Böhme (2021) could provide a counterweight to such data centralization. But such systems come with other problems. For instance, in a hybrid system the central bank would be forced to honor claims it has no records of. This makes the central bank completely dependent on trusting in the integrity and reliability of the records held by third parties.

The second concern is competition with commercial banks. CBDCs implemented as a system of accounts would give customers the opportunity to hold their account at a commercial bank or at the central bank. This would have implications for financial stability (see e.g. Bindseil et al., 2021). The easy and practically frictionless alternative of a credit risk-free opportunity to deposit and store money could trigger a run and lead to outflows from commercial banks to the central bank at the slightest hint of financial uncertainty. Since banks play a major role in the euro area for financing households and firms, concerns that a CBDC for all might undermine banks' business model have been gaining relative weight.

A digital euro implemented in this way might also lead to a structural shift away from bank deposits into the CBDC. This would reduce funding and intensify competition for deposits. Higher interest rates might, in turn, reduce bank profitability and thus banks' credit intermediation capacity.

The discussion among experts about the significance of these concerns is not yet conclusive. Some take a more pessimistic view, and others a more benign one.[13] The financial stability arguments are, however, taken seriously so that policy measures have already been proposed which should help the central bank stabilize flows between the central bank and commercial bank deposits. The proposals contain either quantity measures limiting possible CBDC holdings or price measures which would allow to penalize holdings that are considered excessive through negative interest rates on CBDC stocks above a certain threshold (Bindseil et al., 2021). Given the huge heterogeneity among the potential users of a future digital currency and the differences between private and corporate users, it will be difficult to enforce flow controls via transparent rules.

[13] *See Brunnermeier and Niepelt (2019) for an optimistic view and Pichler et al. (2018) for a more skeptical view.*

### 4.2 Blockchain technology

Many reports on CBDCs have suggested that ideas from the world of crypto assets might provide interesting design elements. What could provide a "cash-like" digital alternative to a more traditional system of directly or indirectly held customer accounts is a combination of the decentralized control features of blockchains and a transaction register based on pseudonymous identities.

The design of the bitcoin system and the blockchain featuring decentralized control of the transaction ledger is an interesting concept. It lends itself for a situation where no central party exists that would keep and update transaction records or where the transaction parties cannot agree on such a central party because all potential players are assumed to be malicious or untrustworthy. Such a situation does, however, not reflect the state central banks and the current monetary system are in.

If a CBDC works in collaboration with intermediaries, they would be a supervised, vetted and licensed circle of institutions. In such a system, it is sufficient that malicious behavior can be detected, and illegitimate transactions can be recovered. The uncontested role of the central bank as an institution in the modern monetary system would also make it unnecessary to distribute the central bank's ledger with a blockchain. It would be of no benefit but increase transaction costs instead.

Auer and Böhme (2021) point out a second important reason why the crypto asset model will not be the answer to a CBDC implementation. The way in which access to crypto asset systems is implemented would be not practical for a CBDC. In bitcoin, transactions are authorized by digital signatures alone. The security of assets in such a system hinges therefore entirely on the security of the secrecy of private keys. According to Auer and Böhme (2021), "[...] if 20 years of research in usable security teaches us a single lesson, then it is that 'Johnny can't encrypt' (Whitten and Tygar, 1999); precisely because end users cannot manage private keys! Given that proficient cryptocurrency users keep losing fortunes due to lost and stolen keys (e.g. Abramova et al., 2021), there is simply no case for making people's direct claims on the central bank – their money under the mattress – contingent on the use of cryptography without any safety net."

Such arguments might sound confusing to readers who have read about various industrial-strength enterprise projects built on blockchain technology enabled by systems like Corda, Hyperledger or Quora. But, as Auer and Böhme (2021) point out, a closer look often reveals that these systems are run in configurations that resemble redundant but centrally controlled database systems rather than bitcoin.

Since crypto asset technology addresses issues that do not arise for a central bank in a modern monetary system and since there are critical security issues in the way transactions are authorized, blockchain is unlikely to be the answer for implementing a CBDC.

### 4.3 Digital bearer instruments: digital cash and its modern implementation

An early concept of digital money proposed by the computer scientist and cryptographer David Chaum (1983) is the model of digital cash. For reasons we cannot trace with confidence, this model fell somewhat into oblivion but was taken up and further developed by the so-called GNU Taler project, a software project led by

the computer scientists Christian Grothoff and Florian Dold (2019) and run by a team of developers and researchers.[14]

Building on digital cash and its principles, this model pulls this old technology toward the current technology frontier. It strongly focuses on transaction data privacy. The technology was presented in a working paper of the Swiss National Bank (Chaum et al., 2021) as a potential model of how a CBDC could be implemented. It provides an interesting model for a digital form of central bank money that would functionally be closer to cash than to directly or indirectly held customer accounts.

The GNU Taler system provides a model of a digital bearer instrument that exists locally in a wallet very much like physical banknotes. The local storage property is, however, achieved in a full online mode, with no offline functionality. The competitive niche of such an instrument would therefore not be physical cash but other digital payment solutions, be it traditional ones like credit cards or new ones like stablecoins. So let us briefly describe its main features.

Implemented as a CBDC,[15] GNU Taler would be issued by the central bank and distributed to commercial banks, just like banknotes. Issuance is central and no distributed ledger is involved in issuing, distributing and paying. The central bank does not directly interact with customers in this model, and the only information that remains with the central bank is a list of spent coins.

Customers withdraw the digital coins at their commercial bank that oversees KYC and AML compliance. The coins are kept in electronic wallets, which could be on a smartphone or on other electronic devices, from where they can be spent at a merchant. Transaction data privacy vis-à-vis the bank as well as the merchant is guaranteed via time- and industry-tested cryptographic techniques.[16] The coin income on the merchant side is, however, transparent, and therefore taxable. The coins earned by the merchant are deposited at the merchant's bank, which is again responsible for the KYC and AML procedures. Double spending is controlled by checking the coins against the spent coins list database at the central bank. This is the big picture of the GNU Taler circulation.

Transaction privacy is achieved using so-called blind signatures. The blind signature protocol prevents both the central bank and the commercial bank from tracing purchases made with the digital coins back to the customer. The customers blind their coins with a local cryptographic procedure on their own devices before having them digitally signed by the central bank. The hidden numeric value representing the coin then functions as a public key with an associated private key known to the owner of the coin. The central bank's signature on the coin's public key gives value to the coin. The central bank signs the coin with its own private key. A merchant or another payee can use the central bank's corresponding public key to verify the central bank's signature and thus the coin's authenticity.

The information accessible to central banks is the total amount of coins withdrawn and the total amount of coins spent. Commercial banks learn how many

[14] *https://taler.net/en/index.html*.

[15] *We use the qualification "as a CBDC" because the system could certainly also be used by private issuers. Issuing a CBDC would be one possible use case of GNU Taler.*

[16] *These are technically modern versions of cryptographic hash functions (invented in 1989), blind signatures (invented in 1983), Schnorr signatures (invented in 1989), Diffie-Hellman key exchange (invented in 1976), cut-and-choose zero-knowledge proofs (invented in 1985). See Dold (2019) for details and the respective references.*

coins a customer has withdrawn but not how many – and where – coins have been spent.

As with crypto assets, transactions are authorized by cryptographic keys alone, which are under the user's self-custody and can thus be lost or stolen. Like a lost wallet filled with cash, digital cash that has been lost or stolen because the cryptographic private keys have come into unauthorized hands cannot be recovered or regained.

A technological challenge posed by digital bearer instruments is how to prevent double spending. After all, digital objects are usually easy to copy. The GNU Taler system takes an approach to this problem which does not deal with copy prevention but assures within the system that each coin can be spent only once. Once a coin has been spent, the number of the coin – but no transaction history – goes to the central bank, which keeps a list of spent coins. When payees receive coins, the system helps them consult the list to verify that the coins have not already been spent before. If the coin was spent before, the payment would be invalid.

In such a system, the transaction data privacy problem is solved by giving users full control of transaction data privacy by locally using the blind signature scheme on their own devices. Unlike in a system of directly or indirectly held customer accounts, users do not have to entrust any third party with transaction data privacy.

In this system, excessive flows between commercial bank accounts and this form of a CBDC are less of a concern compared with a system of customer accounts. Given the self-custody of the CBDC in the Taler system, transferring money into the Taler wallet is not risk free since users must safeguard their wallets against both physical and digital threats. So, the system has a built-in self-regulation against excessive flows of funds. While transaction limits could be legally imposed in principle, it is not possible to impose holding limits, since there are no (customer) accounts. But as such limits have many problems on their own, as discussed in the subsection on accounts, this could be considered an advantage rather than a disadvantage. Of course, as with real bank runs, where customers scramble to convert their deposits into cash, such a run could occur here as well amid big uncertainty and solvency concerns via a commercial bank, perhaps facilitated by the digital and thus less friction-prone process of conversion.

Overall, a system envisaged in GNU Taler could be a useful blueprint for a CBDC implementation that would reap the benefits of a digital economy without disrupting the architecture of the monetary system and without necessitating massive new infrastructure investment and operations. Its efficiency and cost effectiveness combined with its usability would make it a viable competitor for privately issued digital assets in the platform economy. Since it is envisioned as an online-only system (Grothoff and Dold, 2021), it would by design not compete with cash, which would then remain the only form of central bank money that can be used without digital devices.

## 5 Cash is set to play a role also in the payment landscape of the future

We have stressed throughout this paper that the discussion about the digital euro centers on how to assure (1) universal access to central bank money, (2) a coherent and unfragmented monetary system and (3) an innovative and competitive environment for payment services in an increasingly digital economy dominated by huge platform businesses. It is not about abolishing cash. The recent pressure on cash

seems to come from the user side as digital forms of payment are becoming more popular. As we have argued in section 2, the demand for cash is unlikely to decline to zero, even in the longer term, because cash offers unique features to users. And cash is also unlikely to be abolished soon due to its unique legal function in contract law; in the current legal system most financial promises are based on cash.

Documents published by central banks, in particular the report on a digital euro issued by the ECB (2020), argue that a digital euro would complement existing payment solutions and would not substitute either bank deposits or cash. Even in a monetary and financial system where payments are increasingly digital and even when a digital central bank currency would be available, cash would still be an indispensable element in the universe of payment instruments. This will guarantee robustness by providing a physical device-independent opportunity to make payments. Overall, these arguments support both a positive and normative conclusion about the future of cash in a world where the payment landscape could be augmented by new private as well as public digital payment solutions. In a nutshell, cash will and should play a role in this future landscape.

## 6 Conclusions

Throughout history, technological change has also fostered change in payment technologies and instruments and the monetary system in general. In this day and age, digital transformation and the internet economy have created huge incentives for new private issuers of money to enter the market for payments. In other words, the incumbent issuers of private money, i.e. commercial banks, as well as central banks might face stiff competition. Since the dominant new players are mainly associated with the internet economy, which thrives on network effects, the danger of future market concentration and fragmentation in the market for digital payments is looming. This poses a strategic challenge to central banks. The all-important question is therefore: can central banks develop a new form of public digital money that (1) safeguards universal access to payments and the monetary system, (2) fosters competition and innovation, (3) protects the privacy of personal data and (4) supports effective monetary policy? This is the challenge that central banks around the world have risen to by launching new projects on central bank digital currencies, including the ECB's digital euro project. Introducing a digital euro does not aim to replace euro cash as a technologically outdated means of payment. Cash will and should have a role to play even in a future monetary system with a changed payment landscape, in which digital forms of money will have a more prominent role than they have today.

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