



Central bank digital currency

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Abstract

Central banks have traditionally issued cash to the general public. With digitalisation, banknotes are becoming a technically outdated payment instrument, and some central banks have explored the possibility of central bank-issued electronic money applicable to retail payments. Electronic central bank money would offer the public the possibility to hold central bank money in a potentially cashless future. In its present form, blockchain technology would probably not be a suitable solution, since it is unable to process a sufficiently large number of transactions. Electronic central bank money would potentially have significant implications for other areas of central bank policy, which should be meticulously analysed.

JEL codes: G21, E58, E42

We would like to thank Juha Kilponen, Tuomas Välimäki, Jarmo Kontulainen and Esa Jokivuolle for valuable comments. The opinions expressed in this paper are those of the authors and do not necessarily reflect the views of the Bank of Finland or the Eurosystem. This article was originally published in Finnish under the title "Digitaalinen keskuspankkiraha", BoF Economics Review 4/2017.

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

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

1. What is central bank money?

Nowadays there are two forms of money issued by central banks, i.e. central bank money: cash and reserve deposits held with the central bank, where the depositor is usually a commercial bank. No currency area in the world is known to have issued any other type of central bank money, such as electronic scriptural money used by the general public. Both types of money are entered as liabilities on the central bank's balance sheet. Most money is, however, scriptural currency created as a result of lending by deposit banks and could, in practice, be fully converted into central bank money.

The current forms of central bank money were established in Finland following the founding of the Bank of Finland, in the early years of Finnish autonomy, some 200 years ago. They still reflect the technical solutions of the era. Both banknote production and ledger technology have developed since then, but the nature of money has remained unchanged. As a result of technological advances, it may now be possible to also create other, digital forms of central bank money.¹

Central bank money is held by the general public only in the form of banknotes. It is also held by credit institutions and government in the form of reserve deposits. In the euro area, reserve deposits are located in the Eurosystem's TARGET2 system. The central bank's counterparties have the right to exchange reserve deposits for banknotes and vice versa. Credit institutions forward banknotes to customers, i.e. ordinary citizens, companies and entities.

The euro cash used in Finland is sovereign (fiat) money, which under EU legislation is legal tender throughout the euro area. About 90% of the cash in Finland is distributed to the general public via ATMs. Banks usually pay bilaterally netted debts to each other in central bank money, i.e. in deposits with the central bank. From the perspective of the general public, currently only cash payments are settled in central bank money. Cash accounts for over 10% of the euro area monetary aggregate M2, which includes transaction accounts and deposits with agreed maturity.

New central bank money is always created via central bank accounts and based on monetary policy decisions. The central bank creates new money in the central bank accounts via open market operations or refinancing operations. Deposits at commercial, savings and cooperative banks are commercial bank money. Credit institutions create commercial bank money by granting loans to the public. The bank granting a loan records a deposit on the customer's account and on its receivables a loan of the same amount.

The deposit recorded on the customer's account is a valid payment instrument, for example as a credit transfer. The majority of consumer credit granted in Finland is in the form of housing loans. The majority of payment transactions by the general public are executed with commercial bank money created in the banking system, by transferring money between deposit accounts, e.g. when purchases in a shop are paid with a debit or credit card.

There is no empirical evidence on the technology and economic impacts of central bank digital currency and there is scarcely any academic research on the topic. Moreover, there is no legislation or international standards on central bank digital currency (CBDC). We present considerations that should be taken into account in the possible issuance of CBDC. This paper presents a review of the available literature, which includes scarcely any real research papers. This paper also presents some considerations on the proposals presented in the literature, focusing on both technical and economic issues.

¹ Camera (2017).

2. What would central bank digital currency be like?

In this examination, central bank digital currency refers to money that meets the following criteria:

- The central bank issues it in digital form.
- Anyone has the right to hold it. It is not a privilege reserved to e.g. credit institutions.
- It is the same currency as banknotes and central bank deposits. The conversion rate of banknotes and zero-interest bearing digital cash would always be one-to-one, and at least some economic entities, e.g. banks, could convert it freely into other types of central bank money.
- It can be used as a payment instrument in retail payments.
- When two parties engage in a transaction, there is no third party – at least not a private one – that verifies or executes the payment as a central counterparty. The same principle applies to banknote payments.

This paper focuses on the need for and possibilities of digital currency that is similar to cash, based on the current ongoing debate. This payment instrument could be used for purposes completely different from retail trade, which is the main use for cash.

For the new payment instrument to be a substitute for cash, it should share many of its properties. Cash, in its current form, has many characteristics that users may find important but cannot be found in current electronic payment instruments. These features include anonymity, immediate finality and transaction clearing without third parties. To be able to examine the characteristics of the various payment instruments and the need for such instruments in future, we must first classify and analyse the structural characteristics of the payment instruments. Only then can we systematically analyse what characteristics digital cash issued by central banks should have.

As the first criterion, we examine real time settlement. One of the benefits of cash is that as soon as the authenticity of a banknote or coin is established and the banknote or coin is accepted, the execution of the payment transaction is validated as such. It is important because immediate settlement minimises counterparty risk and funds are transferred to the payee in real time. Payment validation is, in principle, also independent of electronic systems, even though retailers' point-of-sale terminals record cash and card payments into the same system. In card payments, the payment terminal checks availability of funds (validation of funds) for the required payment. The actual settlement takes place only in batch runs between banks, typically overnight. The new instant payment systems provide real-time settlement of payment, in a couple of seconds. This type of system has been launched at least in the Nordic countries (in Finland, the system 'Siirto' was introduced in spring 2017) and in the United Kingdom. These systems also enable person-to-person payments in real time, in the same way as cash payments.

Another natural characteristic of cash is anonymity of payment. In many payment situations identification of the parties to the payment transaction is neither necessary nor important. However, a payment transaction rarely requires anonymity. Cash payment machines, parking metres and most retail payments operate without identification, in cash. In Bank of Finland surveys, only a few consumers (some 2% of respondents) cited anonymity as a criterion for selecting a payment method. For example in Germany, anonymity of payment is of significantly larger importance to the consumer. In a recent euro area payments survey, 13% of consumers cited anonymity as an important reason for using cash in retail payments.² In electronic payment methods, the user is usually identified via their bank account. With loyalty cards, the payer's identity may also be revealed to the merchant.

² ECB (2017).

The third factor distinguishing between payment methods is whether the payment instrument itself is also an asset. Cash is a liquid asset, and it is often used in saving 'for a rainy day'. Card payments, credit transfers and direct debits are not assets as such; they only provide access to the payment system where settlement takes place. Like card payments, credit transfers and instant payments, in turn, are only tools for controlling and using the consumer's purchasing power which is deposited on bank accounts, in the electronic systems of deposit banks.

In the case of cash, anonymity, immediate settlement and independence of central counterparties are all based on the fact that cash is a bearer instrument, i.e. the person who is physically in possession of the banknotes and coins is legally their owner. In addition, banknotes and coins include all the information required for authentication and settlement finality. In practice, settlement means entering the transaction into a ledger, and in the case of cash payments, it also involves transferring the payment instrument to its next owner. In the case of scriptural money, all transactions and balances are recorded in the account bank on an ongoing basis. In the case of cash, there is no central authority responsible for bookkeeping; each holder of cash essentially keeps their own records. In such a situation, the ledger is distributed.

The digital implementation of a bearer instrument does not fully correspond with cash money. For a digital currency to fulfil the criteria of a bearer instrument, it should be convertible into a sequence of number, the holding of which would be necessary and adequate verification of ownership. For example in the case of Bitcoin and other cryptocurrencies, this type of sequence of number that is a sign of ownership is called a private key. The distributed ledger of the Bitcoin system, in turn, includes real-time information on the amount of purchasing power owned by the holders of each private key. To make this type of a system independent of a central authority, the amount of purchasing power held by each private key is recorded in a distributed ledger, instead of a centralised ledger.³

Another important characteristic of money is that it cannot be counterfeited. In the case of cash, non-counterfeitability is tangibly based on security features that can be seen and felt. Banknotes also have several machine-readable optical and electromagnetic security features that ensure that they are checked for authenticity in a mechanical sorting process. In electronic recordkeeping, non-counterfeitability of money is based on verified transaction records and double-entry bookkeeping. In the case of Bitcoin, non-counterfeitability is based on the openness and transparency of the distributed ledger (blockchain). For both cash and Bitcoin, production is technically so difficult that counterfeiting would be very expensive.

One of the key required features of a payment instrument is confidence in the acceptability and continuity of the instrument. In the euro area, only euro cash has the status of legal tender, but the scriptural money of commercial banks is fully convertible into cash. According to recommendations adopted by the European Commission in 2010, euro cash must be accepted for its full face value for payment of debt, without surcharge. Some euro area countries have, however, set limits on the size of payment, with the aim of preventing such things as the grey economy 'selling under the counter', as it were. The continuity and acceptability of cryptocurrencies as payment instruments are not as certain as with currencies issued by central banks. Cryptocurrencies have also been more vulnerable to fraud and stealing of funds, e.g. if a private key is lost or in connection with hacking.

Money always involves the issue of stability of value. Key national central banks have inflation targets that have an impact on the value of their currency over time. The inflation target applies particularly to cash money, because account deposits are often subject to an interest rate which, at least in principle, is higher than the rate of inflation.

³ Dwyer (2015) examines in detail the technical aspects of Bitcoin.

Moreover, cash is not dependent on technology or equipment; in other words, anyone can use cash, irrespective of the size or colour of their wallet. Digital money as an intangible phenomenon can never be fully independent of technology or devices, even though this should be the ultimate goal.

Next, we present a classification of some of the current payment instruments (Chart 1). There are three commonly used methods of payment: cash, credit transfers and card payments. Of these, only cash payments are available to all and settled in central bank money. Credit transfers between deposit accounts are executed in commercial bank money. If a credit transfer takes place between two different banks, the netted fund transfers are settled on central bank accounts in central bank money. Card payments are executed in commercial bank money, because the card holder pays the debt to the card issuer typically as an intra-bank credit transfer. The share of cash in payment transactions has decreased significantly in the past 15 years, whereas the number of card payments has increased more or less correspondingly. The new form of central bank money would be located in the upper left box of Chart 1, together with traditional banknotes.

Chart 1. Forms of payment

	Central bank money	Non-central bank money
Anonymous Immediate settlement Distributed ledger	Cash	Cryptocurrencies
Non-anonymous Time-restricted settlement Centralised ledger	Central bank accounts	Credit transfers Card payments

Source: Bank of Finland.

Digital cash would thus not be in the form of deposits in the central bank's account system; it would be located in the counterparties' own systems. In theory, households and companies could be offered deposit accounts in the central bank⁴, but this alternative would not introduce any new technical features into the monetary system, and it is therefore excluded from our examination for now. In contrast, a system based on a distributed ledger could be interpreted as digital cash.

There are a number of ways to implement central bank digital currency. The central bank could provide a system in which the digital currency is stored, transferred and authenticated. Another possibility is to create a standard for digital currency in which the private sector would be responsible for creating the storage and transaction applications. The third alternative is to limit the central bank's role to the creation of money in respect to balance sheet and debt relationships. The private sector would be responsible for the technical arrangements. A private entity would open an account with the central bank, and the funds on the account

⁴ In Finland, this has been proposed by Lainà (2015).

would be earmarked as funds of the holders of payment instruments issued by a private issuer. The amount of funds on the account should be equivalent to the amount of payment instrument issued by the service provider. A private entity would issue certificates of ownership in deposits with the central bank, which would be used as payment instruments⁵. The arrangement could also be compared to a bank deposit, which is subject to a 100% reserve requirement. To ensure neutral treatment of the different payment instruments, the central bank should impose on the providers of digital money conditions that do not give banknotes or digital money an artificial cost advantage or other competitive advantage. This type of arrangement in which the deposit is made with a commercial bank has been discussed in research papers.⁶

If the objective is to create a form of central bank digital currency the characteristics of which resemble cash, the key characteristics are anonymity, immediate settlement, the possibility to make retail payments, and a distributed ledger system. The objective of the creators of Bitcoin has been to create these characteristics in digital form. No-one has succeeded in creating them before, and Bitcoin is currently the only relevant alternative.⁷ Blockchain technology, developed in the wake of Bitcoin, is a new innovation which enables these features, in principle. At the moment, however, it would seem that blockchain technology, or other similar distributed ledger technology (DLT) systems, are not particularly suitable for retail payments.

Compared with current retail payment systems, e.g. card payment and credit transfer systems, blockchain technology is considerably slower and less efficient. This is highlighted when the system is completely decentralised, i.e. it operates as a peer-to-peer network. Efficiency can be improved by partially centralising the system, but then the system would lose some of its other, specifically desired features.

In a blockchain system, payment transactions are settled randomly by any of the participants in the network, and information on settlement is distributed to all the parties in the network. At the same time, the ledgers of all the participants are reconciled. This process is not only slow but also expensive, because in the absence of a central authority, fraud is prevented by making it so expensive that it is simply not worth trying to distribute counterfeit transactions into the network. The reliability of the network is thus based on economic incentives, and they in turn require expensive settlement of transactions.

Another problem is the uncertainty about settlement finality that is caused by the distributed ledger system. In a decentralised peer-to-peer network like Bitcoin, in which payment transactions are settled in different parts of the network and ledgers are reconciled on an ongoing basis, there is never definite certainty that any of the reconciliations in the payment chain are final.

Based on current knowledge, it would thus be more advisable to implement central bank digital currency, and also other retail payment systems, using some other technology, e.g. a centralised ledger.

⁵ Scottish and Northern Ireland banknotes are based on this type of arrangement. The banknotes are issued by a commercial bank, which must hold at least the same amount of earmarked central bank money, either as deposits with the Bank of England or Bank of England banknotes. See http://www.acbi.org.uk/media/sni_notes_factsheet_nov12_copy1.pdf, point 3.

⁶ Bossone (2017).

⁷ There are hundreds of other cryptocurrencies, but in terms of the considerations presented in this paper, they do not differ fundamentally from Bitcoin.

3. The benefits of central bank digital currency

'Central bank digital currency' is a broad concept. The areas of application can range from real-time securities settlement to blockchain-based digital cash to private citizens mainly for retail trade purposes. A payment instrument used in retail trade can only become widespread if both consumers and retailers have a positive attitude towards it.

The main reasons for digital cash relate to payment needs, and the possibilities offered by digital cash have also been discussed in connection with the zero lower bound on interest rates.⁸

Several central banks have shown interest in the matter. For example Cecilia Skingsley, Deputy Governor of Sveriges Riksbank, suggested in her speech of November 2016 that the Riksbank should issue digital currency – e-krona – in Sweden.⁹ Later the Riksbank issued a more detailed report on the subject.¹⁰

With payments shifting increasingly online, and with mobile devices, there are signs that there would be a demand for CBDC among consumers. Credit card companies, for example, offer payment methods applicable in online shopping, but not all consumers have a credit card. Some consumers also perceive online card payments as unsecure. Bank transfer systems operate fast mainly within one currency area. It is not possible to use central bank money in online payments, but there might be a need for payments in central bank money.

The current retail payment systems are almost solely based on private bank-offered instruments for using an account, such as credit transfers, card payments and cash withdrawals. This is appropriate because consumers' purchasing power is primarily stored in bank accounts. Wages and capital income are paid directly into bank accounts, from which people typically make first their regular payments (rents, housing corporation maintenance charges, electricity bills, loan repayments etc.) as SEPA payments. Other consumption expenditures are normally paid either via card or cash. Cash is primarily obtained from ATMs. Occasionally, larger sums or large banknotes are withdrawn over the counter. Less frequently, if necessary, cash is withdrawn at the checkout counter in shops in connection with purchases.

Because of the regulatory obligation to pay wages and other earnings into a bank account, and because consumers pay consumption expenditures from their bank accounts, retail banks' central role in the provision and settlement of retail payments is secured at present. This also pertains to their role as lenders, since bank lending and borrowers' loan repayments concentrate on the same bank accounts. Therefore, in the current system, banks play a key role in households' and companies' economic affairs. However, one could ask whether the current arrangement between banks and income earners will also be optimal in the future, and whether it is the best possible solution to use the banking system in the organisation of payments.

CBDC could also have implications for financial stability. Banks have played a pivotal role in society for example because payments are at the centre of economic activity and exchange. Public support measures for the banking system in connection with financial crises have often been necessary for ensuring, inter alia, the smooth operation of the payment system. Financial crises typically stem from banks' risk-taking and other economic actors' overindebtedness. Borrowing always involves three parties: the bank that grants the credit, the borrower that needs the credit for a certain transaction and the authorities that strive to maintain stability and regulate the availability of funding. Of these, banks are in a special position.

⁸ See e.g. Haldane, A (2015) How low can you go? Bank of England speeches.

⁹ <http://www.riksbank.se/sv/Press-och-publicerat/Tal/2016/Skingsley-Borde-Riksbanken-ge-ut-e-kronor/>.

¹⁰ Riksbank (2017).

Central bank-issued digital cash would offer a new alternative to payments, but this could have implications for the stability of banks' deposit stocks and thereby also for bank funding.

From the perspective of an individual user, new central bank money should offer something that current electronic or physical forms of money do not.

Technology is not an obstacle, but it is not a determining factor when discussing CBDC, either. Therefore, the functional and technical characteristics of CBDC should be determined on the basis of the rationale for the need for CBDC. From the perspective of payments, CBDC could be implemented for example as a digital payment scheme comparable to e-money, which would be directed at consumers and trade. It could also be implemented as a central bank money directed at the financial sector, which would enable real-time securities trading and be connected with blockchain technology-based management of holdings. If CBDC were to be implemented by making central bank accounts available to the public, this would involve the above-mentioned potential implications for bank funding and therefore also for financial stability, for example. These implications should be meticulously analysed.

4. Potential problems and unintended effects

The new money or payment instrument to be launched does not automatically become popular. Private entities have tried to issue electronic money. For example, in Finland a chip-based Avant money card was launched in the 1990s. Customers could load e-money onto the card, and it was accepted as a form of payment in telephone booths and some vending machines and shops. The Avant card was a scheme run by Toimiraha Oy, a company initially owned by the Bank of Finland. The company was sold to commercial banks and renamed Automatia Rahakortit Oy. The value loaded on the card was legally electronic money, and it was based on commercial bank money. The popularity of this payment instrument remained low, and the number of users was not large enough to achieve critical mass.¹¹ A key factor restricting its popularity was the fact that customers were charged a fee for loading and unloading money, and this did not please consumers and retailers who were accustomed to free-of-charge cash withdrawals at ATMs. The Avant card's popularity was also hampered by the incomplete electrification of the payment environment. Its role remained insignificant, and it was abandoned in 2006 when the lower limit for debit card purchases was abolished.¹² Similar chip-based electronic wallets have failed also in other countries, for example Canada.¹³ Of the euro area countries, only in the Netherlands a prepaid wallet is still widely used. In addition, the products provided by international card companies created a payment environment of developing and expanding features (speed, ease of use, safety, extensive acquirer network) against which local e-wallets could not compete.

The failure of stored-value cards has often been explained by problems related to network effects. For retailers, it was not worth investing in devices required by the payment instruments as the popularity of these cards was limited, and for consumers it was not worth acquiring these cards as they were accepted in only a few places. This is, however, not a sufficient explanation. Many other two-sided markets have faced a similar dilemma.¹⁴ In two-sided markets, two different types of target groups must adopt the same product in order for the product

¹¹ Jyrkönen – Paunonen (2003) p. 11. See also Helsingin Sanomat 29 September 1995 and Helsingin Sanomat 12 July 1999 (in Finnish only).

¹² Taloussanomat 10 April 2006 (in Finnish only).

¹³ See Plouffe et al (2000).

¹⁴ For a presentation of the theory of two-sided markets, see Rochet – Tirole (2003).

to succeed.¹⁵ A possible explanation is that, basically, there was no real need for the stored-value card, due to its failure to break through – in contrast to many other network commodities in a two-sided market.

Technically, it would be possible to extend the functionality of ATMs and online banks to handle digital cash. The new form of money would offer an alternative to bank deposits, and therefore the stock of low interest-bearing deposits by private customers as a source of bank funding could become more unstable. At the end of 2016, the deposits of Finnish households totalled over EUR 85 billion, and the average interest rate on these deposits was below 0.2%. If the new form of money was to widely replace deposits on household and corporate balance sheets, banks could offer higher interest rates on accounts or additional services to attract deposits back. Alternatively, banks would have to resort to more large-scale borrowing from somewhere else. If deposits of the public were to flow to the central bank balance sheet in the form of digital cash, this would result in a financial surplus for the central bank and, correspondingly, commercial banks would be faced with a financial deficit. In such a case, the central bank would need to increase its financing to commercial banks. Since central banks provide liquidity against collateral, commercial banks would need more securities as collateral. This could increase e.g. securitisation of bank loans.

Another potential problem could be the impact of CBDC on the risk of bank runs.¹⁶ Digital cash and bank deposits would likely be closer substitutes than banknotes and deposits. Therefore, bank customers might switch from deposits to central bank money for more minor reasons than before. In principle, bank runs could also occur at times when bank offices are closed. The higher risk of bank runs should be taken into account e.g. in bank liquidity regulations: retail deposits would no longer be as reliable and stable a form of funding as has customarily been the case. On the other hand, it must be noted that modern deposit guarantee schemes have effectively prevented bank runs.

It is extremely difficult to estimate the macroeconomic implications of digital cash without historical experience. Similar types of payment instruments developed by the private sector are not very common, implying that we have no experience to assess the macroeconomic or other broader effects. Therefore, no actual conclusions can yet be drawn. However, we can propose some hypotheses, the realisation of which must be monitored, should CBDC someday be issued somewhere in the world.

If digital cash were to compete with traditional cash, customers' marginal propensity to consume could increase slightly. Studies in behavioural economics have shown that consumers spend less when they use traditional cash as opposed to account money.¹⁷ Digital cash would be as abstract as a bank account balance, and therefore it could have similar psychological effects. Easy access to credit blurs budget constraints and increases the risk of payment defaults. Of course, digital cash would be determined as cash without the possibility for credit, in which case the central bank would not need to worry about the credit risk.

CBDC could also increase dollarization, i.e. situations in which residents widely use some foreign currency other than their national legal tender. As a rule, an economy does not gain from dollarization. Instead, dollarization amplifies cyclical fluctuations and reins in economic growth.¹⁸ Financial dollarization typically results from high inflation or other factors which have undermined the credibility of the domestic currency, while legal barriers to the use of foreign

¹⁵ For example, the CD player broke through even though initially it was not worth selling CDs as no-one had a CD player, while no-one considered it worth their while to buy a CD player because there were no suitable records available. However, the new digital technology included other benefits, for example interference-free and noise-free sound reproduction, durability and improved practicality. A car is useless without petrol, but it is not worth establishing a petrol station if no-one has a car. But petrol-engine cars gained in popularity nevertheless.

¹⁶ Riksbank (2017), p. 28.

¹⁷ See e.g. Mercantati – Li (2014).

¹⁸ See e.g. Levy Yeyati (2006).

currency reduce dollarization. The relatively limited evidence available shows that the same factors also contribute to an increase in the use of foreign banknotes.¹⁹ If a form of central bank money exists that can be transmitted across borders at a low cost and stored in digital format, it is easier for private sector actors to start using some currency other than their own national legal tender. Nobody would have to carry cash from one country to another, and the absence of currency supply, for example, would not pose a problem. In many cases, using and holding currency would be equally easy, irrespective of one's place of residence. A lesser loss of confidence in legal tender could lead to a partial or complete abandonment of the domestic currency.

Because of network effects, everyone should primarily use the currency that is most common in their own operating environment. One of the natural environments to use CBDC is the Internet. The Internet has no geographical position, and money circulating on the Internet has no natural currency areas in the traditional geographical sense. Dollarization may begin in online shopping and spread later from the Internet to other activities. If residents of a country make a considerable share of their transactions online, and in foreign currency, they may be more willing to use the same currency also in other situations to avoid the use of two parallel currencies. This could pose a problem particularly for small currency areas and emerging economies.

5. Towards electronic central bank money

Banknotes and coins are a way to make central bank money available to the general public. Cash has its advantages and is primarily suitable for face-to-face exchange, which is notably declining. The increased prominence of the Internet as a trading platform emphasises the need to discuss new alternatives. Lately, there have also been suggestions to restrict the use of cash e.g. by removing the largest-value banknotes from circulation or limiting the maximum value of cash payments to reduce the grey and criminal economy.

All in all, making an electronic form of cash available to the public might well be a potential future objective. However, the introduction of electronic central bank money could have significant implications for the operation of the financial system and, for example, the stability of credit institutions' funding. These implications should be meticulously analysed.

Some central banks have explored the possibilities to issue money in electronic form. It is still unclear what kind of technical solution would be feasible. Blockchain technology made known by Bitcoin would hardly be applicable to retail payments, at least in its current form. A more probable solution would be an arrangement based on a more centralised ledger, with many of the characteristics of traditional cash.

¹⁹ See e.g. Lendele – Kamanda Kimonda-Mbinga (2005).

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