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Central bank digital currency – implications for liquidity management and monetary policy

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Summary

The paper discusses potential effects of a central bank digital currency (CBDC) on liquidity and monetary policy. CBDC could benefit the payment system but could also pose macroeconomic/financial challenges if demand for CBDC becomes high. High CBDC demand can affect banks' balance sheets, funding costs and the money and credit creation process, as well as the central bank's balance sheet and risk, and the implementation of liquidity and monetary policy. This may entail a substantial shock to the financial system as it functions today. These macroeconomic/financial costs are discussed in the literature. Much of the discussion focuses on how CBDC can be designed to contribute to a more efficient payment system, while avoiding or at least reducing the macroeconomic/financial drawbacks substantially. Proposed solutions include limiting the amount of CBDC that can be held, a multi-interest rate system for CBDC, a system where CBDC can be lost and where the central bank issues CBDC only in exchange for government securities. The benefits and costs of the first two in particular are discussed in this paper. We believe that both limits on CBDC holdings and multi-interest rates can help curb CBDC demand, but at the same time they will reduce the applicability of CBDC.

We focus only on the relationship between CBDC and liquidity management and monetary policy and do not attempt to make a full assessment of whether CBDC should be introduced. This is a larger question that requires striking a balance: potential benefits of CBDC must be weighed against potential costs, in particular the macroeconomic/financial challenges discussed in this paper. The overall conclusion is that CBDC should not primarily be thought of as a monetary policy instrument and that liquidity management, given a well-designed CBDC, will be manageable. Detailed conclusion is as follows:

Liquidity management

The paper is based on the current liquidity management system and describes the quota system in greater detail. As for liquidity policy, the assessments are as follows:

- CBDC is an autonomous factor that influences banks' need for reserves. In the event of increased demand for CBDC, Norges Bank must provide loans to banks.
- Volatile demand for CBDC will make structural liquidity forecasts more uncertain and subject to unpredictable shifts. More fine-tuning operations may be required.
- Liquidity management will probably become more unpredictable but is nevertheless considered manageable. It is assumed that a CBDC will be designed with a view to substantially reducing the macroeconomic/financial costs discussed in this paper, and the more this is done, the smaller the consequences will be for Norges Bank's liquidity management.

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Monetary policy

- The effect on monetary policy depends on demand for CBDC, both how high it will be and how interest rate sensitive it will be. This will in turn depend on how CBDC is designed and is excessively difficult to assess in advance.
- The introduction of a CBDC with no interest rate may narrow monetary policy space by reducing the pass-through from the policy rate to banks' retail rates and increasing the effective lower bound for the policy rate.
- CBDC should be designed so that it can bear interest rates. An adjustable interest rate on CBDC mitigates the risk that monetary policy space will be reduced. A two-tiered interest rate system, as Norges Bank already uses to manage liquidity in the banking system, can be a good alternative.
- In principle, CBDC can be designed so that the interest rate can act as a monetary policy instrument. But the benefits of doing so are most likely limited compared with the risk this would pose to the financial system. If the CBDC rate is to be used to steer aggregate demand in the economy, it cannot simultaneously be used to regulate CBDC demand. It is therefore difficult to envisage how a CBDC can be employed as a monetary policy instrument without at the same time accepting an increased risk of the macroeconomic costs materialising.

1. Introduction - Background

Central bank digital currency (CBDC) implies that the public[2] can hold a digital monetary claim on the central bank, which appears on the liabilities side of the central bank's balance sheet. Today, the only claim on the central bank that can be held by the public is physical cash: notes and coins. CBDC will be a new kind of money. In this paper, we discuss how CBDC can influence Norges Bank's liquidity management and monetary policy. In the paper, we shed light on how CBDC can affect banks' balance sheets, funding costs and credit behaviour, as well as the central bank's balance sheet and risk.

The same unit of account (currency) can be represented by several different types of money. How does CBDC fit into the "money landscape"? Today we have three forms of the krone (Chart 1). The most widely used is the public's deposits in banks, which amount to about NOK 3000 billion. This is privately issued money that banks create when they provide loans to the public and which is destroyed when the public repays loans to banks. Then there is cash (notes and coins) issued by the central bank. This is central bank money that can be held by the public and amounts to approximately NOK 40 billion. We also have central bank reserves, or reserves. Reserves are banks' overnight deposits in the central bank and the means of settlement between banks (reserves are discussed in more detail in Section 2). Reserves are digital central bank money but are not referred to as CBDC as they cannot be held by the public. CBDC is a fourth type of krone that can be issued by the central bank.[3] As in most central bank literature and in accordance with Norges Bank's CBDC project, this paper focuses on retail CBDC held by the public.[4] CBDC and central bank reserves are thus two

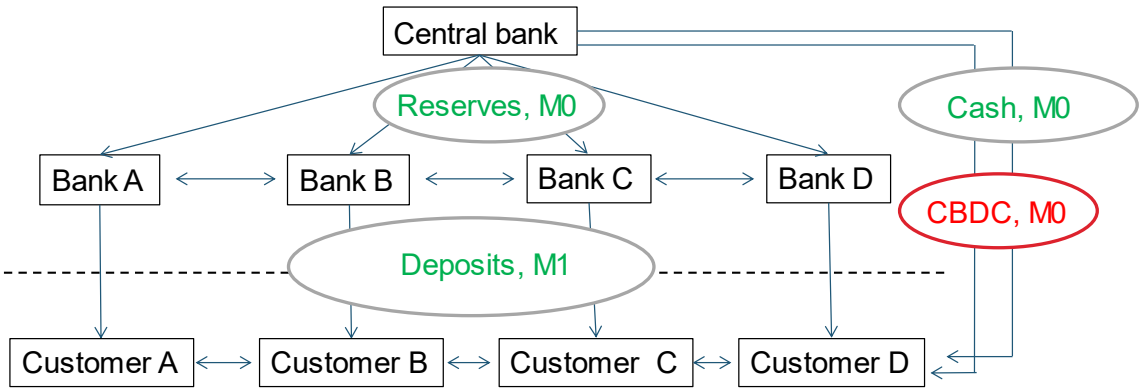
[2] The general public comprises to households, non-financial enterprises and financial enterprises that are not banks.

[3] The general public's deposits in banks are referred to as M1, while banks' deposits in the central bank and notes/coins in circulation (whether held by banks or the general public) are referred to as the base money, M0. A potential CBDC will also be part of M0.

[4] Norges Bank's CBDC project has gone through several phases (see Norges Bank 2018, 2019, 2021a, 2023).

different types of digital money, both on the liabilities side of the central bank's balance sheet. The significance of this distinction will become clearer later in the paper.[5]

Chart 1. Four types of money: Central bank reserves, cash, bank deposits and CBDC



The literature usually discusses two types of CBDC, account-based CBDC and token-based CBDC. With account based CBDC, the value recorded in an account belongs to an identifiable account holder. This may be in the form of the public having accounts in the central bank directly, or via an intermediary - a financial institution. In legal terms, it will be the public that has the claim on the central bank.

Token-based CBDC signifies that the value is represented on a unit - in a "token". A token can be register-based or only stored on a physical device. With a register-based token, a registry will continuously record the transactions. Users have CBDC at their disposal through a user interface, such as a mobile application, which communicates with the registry via cryptographic keys. Even if the mobile phone is lost, you do not lose the money as long as you have the cryptographic keys. A token stored only on a physical device, which is not register-based, means that the value is stored directly in the token, so that the money is lost if the token is lost. For the public, a register-based token solution will have much in common with an account-based solution. In both cases, there is little risk that the money will be lost. Users will probably in both cases perceive their cash holdings as an account without having to deal with the underlying infrastructure. Regarding implications for liquidity management and monetary policy, this applies to both register-based token solutions and account-based solutions.

[5] In the literature, CBDC held by the public is referred to as "retail", while CBDC, which can also be held by financial corporations for settlement purposes, is referred to as "wholesale". Wholesale CBDC and central bank reserves will then be closely related and may be identical but need not to be, depending on how conditions for holding wholesale CBDC and central bank reserves are designed. Like other central banks, Norges Bank focuses on retail CBDC, and wholesale CBDC is not discussed in this paper.

The literature focuses on how CBDC can (i) provide a more efficient payment system and ensure satisfactory competition in the markets for means of payment and instruments, (ii) be a contingency solution independent of the existing payment system, (iii) ensure public access to credit risk-free money, (iv) replace declining cash use and (v) ensure suitable legal tender (cf. Norges Bank 2018, 2019). In addition, focus is placed on whether, in a world of low and falling cash use, CBDC can (or must) ensure confidence in our money and the singleness of money.

The literature also emphasises that the infrastructure for CBDC should offer the possibility to function as a platform for third-party providers, who should be able to innovate and build services on top of the CBDC platform. This can be, for example, payment applications, solutions based on so-called smart contracts and offline solutions. The work on CBDC at Norges Bank, as in other central banks, is also based on a precautionary motivation: Norges Bank wants to be prepared to introduce a CBDC if the monetary and payment system evolves in a different direction than we can foresee today. The introduction of a CBDC can act as a measure to prevent money and payment functions from being transferred to new arenas and infrastructures that could weaken the efficiency and security of the payment system in Norway.

Depending on the design, CBDC may have adverse consequences for the financial system, including the central bank's liquidity management, monetary policy and financial stability. Challenges may arise in particular when demand for CBDC becomes high. Demand for CBDC can be expected to be high if CBDC is well suited as a store of value. This form of CBDC can affect banks' balance sheets, funding costs and money and credit creation process, as well as the central bank's balance sheet and risk and the implementation of liquidity and monetary policy. This may entail a substantial shock to the financial system as it functions today. These challenges are discussed in the literature. Much of the discussion zeroes in on how CBDC can be designed to contribute to a more efficient payment system, while at the same time avoiding or at least reducing the macroeconomic and financial disadvantages considerably. The proposals entail making CBDC more suitable as a means of payment and less suitable as a store of value.

The notion of CBDC emerged about 10 years ago and has in recent years been the subject of much discussion, research and study, both in academic circles and among central banks. There are widely diverging and diametrically opposing views on CBDC. Some express scepticism, for example: *Monetary policy and digital currencies: Much ado about nothing?* (Pfister, 2017), *Central bank digital currencies risk becoming a gigantic flop* (Bofinger and Haas 2021)[6], *CBDC: A solution in search of a problem?* (Waller, 2021), and *Central bank digital currencies: A solution in search of a problem?* (House of Lords, 2021).

On the other hand, others express great positivity and believe that CBDC is almost essential to the existence of the present financial system. For example, Rice (2021) says: ... *CBDCs are seen by some as a superhero or superheroine solution; that is, as an opportunity to address all of the pain points in payments. Superheroes and heroines have fantastic abilities. They are full of possibilities. They come in many shapes and sizes: some are gifted with flight (like Captain Marvel), some with telekinesis (Wanda Maximoff), and others with super strength (Wonder Woman) ...*

[6] Bofinger and Haas (2021) draw on Bofinger and Haas (2020) who are critical of the introduction of a CBDC from a microeconomic perspective.

Coeuré (2021) writes: … A well-designed CBDC will be a safe and neutral means of payment and settlement asset, serving as a common interoperable platform around which the new payment ecosystem can organise. It will enable an open finance architecture that is integrated while welcoming competition and innovation. And it will preserve democratic control of the currency …
… A CBDC's goal is ultimately to preserve the best elements of our current systems while still allowing a safe space for tomorrow's innovation. To do so, central banks have to act while the current system is still in place – and to act now …

Most central banks view CBDC as an opportunity, with advantages and disadvantages, and are studying this carefully with a view to possible introduction. Over time, sentiment in central banking circles has tended to shift from somewhat hesitant to more optimistic, not least because new motives for introducing a CBDC have come to the fore. In the beginning, low and falling cash use was probably an important motive: CBDC should replace cash so that the public still has access to central bank money. Gradually, the introduction of new forms of money such as stablecoins created outside the traditional banking system seems to have motivated central banks to escalate their study of CBDC. The initiative in 2019 by Facebook and other companies to establish a new stablecoin called Libra was probably important here, although it was not implemented as originally intended.

In a consultation paper from 2023 the Bank of England placed emphasis on the need for CBDC: … *Our primary motivations for the digital pound are the availability of central bank money as an anchor for confidence and safety in money, and promoting innovation, choice, and efficiency in payments … … the Bank and HM Treasury judge there is likely to be a future need for, and benefits from, the digital pound …* Bank of England (2023).

The Bank of England envisages CBDC as a settlement instrument with properties similar to cash, without an interest rate but with an upper limit on the amount of CBDC the public can hold.[7] CBDC is being introduced to strengthen the "monetary anchor" and to better facilitate a more efficient payment system and is not seen as a monetary policy instrument. Apart from that, it may be noted that the views of the Bank of England (2023) may seem to differ from those of the House of Lords (2022) cf. quote above.[8] The extent to which the views of the Bank of England differ from much of the academic CBDC literature is also remarkable (and liberating). As discussed in Box D further down in the paper, the conclusions of some academic CBDC studies are based on fairly strict assumptions. This may signify that the conclusions of such studies do not necessarily apply in general terms and are of limited value as guidelines in practice.

The European Central Bank (ECB) has also initiated a large project (ECB 2020, 2022a, 2022b, 2022c, 2022d, 2023a). ECB highlights a number of advantages linked to CBDC. The arguments are essentially in concordance with arguments advanced by the Bank of England, *… preserving the role of public money as the monetary anchor for the payment system … … digital euro would be a public good and foster innovation …* ECB (2022b).

Danmarks Nationalbank (2023), in a consultation response to the European Commissions legislative proposals on a digital euro, is more reluctant, … *From a Danish perspective, it is not clear how a Danish retail CBDC will create significant added value compared with the*

[7] The motive for an upper limit is to reduce demand for CBDC and is discussed in more detail in Section 4.
[8] For a critique of the views of the House of Lords (2022), reference is also made to Positive Money (2022): *CBDC: A Solution in search of a fair hearing?*

existing solutions in Denmark. Denmark has a well-functioning financial infrastructure with efficient payment solutions. Moreover, issuing central bank money in digital form to citizens and businesses involves a number of operational, economic, legal and financial risks … (in Danish only, our translation).

If one were to attempt to find some common denominators in what might be called the "practical-oriented central bank literature" on CBDC, the following might be appropriate: With regard to the traditional functions of money, it is emphasised that CBDC should primarily serve as a means of payment and to a lesser extent as a store of value. Another key issue is that CBDC must be designed to contribute to a more efficient payment system without causing damage to the financial system.[9] In the practical-oriented central bank literature, there is also fairly strong agreement that the motivation for CBDC should not be to have an additional monetary policy instrument, although it is not ruled out that CBDC may be assigned such a role in the future. It should be noted, however, that many *academic studies* reveal that CBDC can fulfil the purpose of a monetary policy instrument. How CBDC can be used as a monetary policy instrument depends, however, on the given model employed to analyse the issue. In fact, it is not entirely unambiguous in the academic literature whether a higher interest rate on CBDC produces a contractionary or expansionary effect on the economy. Admittedly, most academic studies argue that a higher interest rate on CBDC has a contractionary effect similar to that of an increase in the central bank's ordinary policy rate. However, Kumhof et. al. (2023) argue that this claim is false and that an interest rate increase on CBDC produces an expansionary effect on the economy (and vice versa for a cut in the interest rate on CBDC). The conclusion depends, of course, on the theoretical model design on which the conclusion is based.

The rest of the paper is structured as follows: In the next section, we examine the role of banks and the central bank in the financial system. In Section 3, we show how CBDC may produce adverse financial effects, including how CBDC can affect banks' balance sheets, funding costs and behaviour in the credit creation process, as well as the central bank's balance sheet and risk. Among other things, we discuss two assertions that often (somewhat uncritically) appears in the literature. First, the literature sometimes gives the impression that banks as a group can meet increased demand for CBDC by replacing deposit funding with market funding, and that banks therefore do not need central bank funding. This is not correct. Facing increased demand for CBDC, banks must reduce their deposits in the central bank, and as a group, banks can only do so by borrowing reserves from the central bank if reserves in the banking system are limited. Second, and related to the first issue, the literature emphasizes that banks' deposit funding can be replaced by central bank funding when high demand for CBDC results in banks losing deposit funding. Admittedly, the assertion is correct but may have profound consequences for the central bank's balance sheet and risk and the central bank's footprint in the financial system. This is discussed in a separate box. In line with the international literature, Section 4 discusses how a CBDC can be designed to minimise the risk of instability in the financial system.

In this paper we do not provide an overview of the CBDC literature (we refer to other reliable review articles), but in Section 5 we address a widespread argument that CBDC is necessary to ensure confidence in our money and the singleness of money. We especially focus on one

[9] Monnet (2023), Niepelt (2023) and Monnet og Niepelt (2023) argue that the more a CBDC is designed to prevent being used as a store of value and to reduce CBDC demand, the less user-friendly a CBDC will be. This is more discussed in Chapter 4.

point that is often highlighted, but which we believe is not particularly well discussed in the literature: That singleness of money and public confidence in the monetary system presupposes the public has access to money issued by the central bank. This assertion is crucial, since the logical consequence is that the central bank *must* introduce a CBDC if physical cash eventually becomes a thing of the past and vanishes. We therefore raise the question of whether CBDC is necessary to ensure confidence in our money and singleness of money in a cashless situation, or whether regulation and the central bank's role as bankers' bank (including singleness (i.e., uniformity of value) between bank deposits and central bank reserves) are sufficient to achieve this. In our view, the conclusion on this point is less obvious than the literature might suggest.

Against this background, Section 6 discusses how a CBDC may influence Norges Bank's liquidity management, i.e., how a CBDC may influence the manner in which the central bank manages central bank reserves in order to implement monetary policy. CBDC will exist as a new type of autonomous factor on the central bank's balance sheet, which comes as an addition to the government's account (which is also an autonomous factor). Our assessment is that liquidity management will be more unpredictable, but still manageable. It is assumed that CBDC is designed with a view to substantially reducing macroeconomic and financial costs discussed in this paper, and the more extensively this is done, the smaller the consequences for Norges Bank's liquidity management will be. In a separate box, we discuss how a CBDC may affect banks' liquidity coverage ratio (LCR). In a separate appendix, we provide an account of Norges Bank's current liquidity management system, the quota system.

Section 7 discusses the relationship between CBDC and monetary policy, how a CBDC can influence monetary policy and whether CBDC provides new opportunities in the implementation of monetary policy. We demonstrate that a potential interest rate on CBDC cannot be used simultaneously to steer demand for CBDC and as a monetary policy instrument. CBDC can also influence the effective lower bound (ELB) on interest rates, as it may be easier for the public to convert bank deposits to CBDC than bank deposits to cash. The key conclusion, as mentioned above and in accordance with the international practical-oriented central-bank literature, is that CBDC should not primarily be considered as an additional monetary policy instrument. The paper contains many boxes placed at the end of each section.

2. The role of banks and the central bank in the financial system

Banks play a key role in today's financial system and have two fundamental functions in particular: They provide credit to economic agents and facilitate payments between them. Other institutions can also provide credit, but banks are in a special position because they are the only ones that can create money and hence their own funding. When banks grant customers a loan, customers are given a bank deposit.[10] Central to banks' provision of credit is maturity transformation: The loans often have long maturities, while deposits can be drawn on immediately. Since deposits are banks' debt, a customer payment that involves the transfer of a deposit from one bank to another must be related to the transfer of an asset. These assets are central bank reserves, banks' unrestricted deposits in the central bank overnight. It is electronic money issued by the central bank that acts as a means of settlement between banks. When banks create deposits by providing loans, they expose themselves to liquidity risk because banks that lose customer deposits must transfer central bank reserves from their

[10] Purely technically – from accounting principles - banks can create an unlimited amount of money and credit. Nevertheless, a number of factors impose restrictions on banks' lending, including assessments related to profitability and risk and regulatory requirements.

account in the central bank to the receiving bank's account in the central bank. Banks can reduce liquidity risk by adjusting the liabilities side on their balance sheets. They can replace deposit funding with longer-term market funding or offer customers longer-term deposits. This reduces banks' immediate need for central bank reserves and liquidity risk for the banks.

This is apparent on banks' balance sheets (Chart 2). On the asset side, banks have loans to the general public (credit), securities and deposits in the central bank. On the liabilities side, banks have deposits from the general public (unrestricted deposits and deposits with longer-term maturities), funding in the form of debt securities, loans from the central bank and equity. On the asset side, the central bank has securities and loans to banks, while on the liabilities side it has deposits from banks, deposits from the government, notes/coins and equity. CBDC would also be stated on the central bank's liabilities side.

Chart 2. Balance sheet of the banking sector and central bank (extract)

The banking sector			Central bank	
Assets	Liabilities		Assets	Liabilities
Loans to the public	Deposits from the public - Unrestricted deposits (M1)		Securities	Deposits from banks (Reserves, M0)
Securities	- Time deposits		Loans to banks	Government's account
Deposits in the central bank (Reserves, M0)	Debt securities			Notes/coins (M0)
	Loans from the central bank			Deposits from the public: CBDC (M0)
	Equity			Equity

As mentioned above, banks' unrestricted overnight deposits in the central bank are referred to as central bank reserves, or simply reserves (also referred to as bank liquidity). Reserves serve as a means of settlement between banks: When a bank deposit is transferred from a customer in bank A to a customer in bank B, reserves are transferred from bank A's account in the central bank to bank B's account in the central bank.[11] The total amount of reserves in the banking system is influenced by autonomous factors on the liabilities side of the central bank's balance sheet, in Norway primarily transactions via the government's account.[12] Depending on the liquidity management system and the target for reserves in the banking system, the central bank will counteract the effect of autonomous factors through market operations. Norges Bank employs a quota system for liquidity management: Each bank receives interest on a certain amount of reserves overnight at the policy rate, while deposits above the quota bear interest at a lower rate, the reserve rate. The liquidity management system (and alternative liquidity management systems) and Norges Bank's principles for liquidity management are discussed in further detail in a separate appendix. In the first instance, it is sufficient to know that in the quota system the amount of reserves is relatively "small", i.e., banks possess limited deposits in the central bank overnight.[13]

[11] A bank is willing to take over customer deposits from other banks (debt) because it also receives an equal amount of central bank reserves (a claim on the central bank). Thus, banks' customers can use their deposits as a means of payment to customers of other banks.

[12] Reserves are also influenced by demand for notes and coins. When banks buy notes/coins from the central bank, they draw on their deposits in the central bank so that reserves are reduced.

[13] For a more detailed discussion of these monetary factors, see Bernhardsen, Kloster and Syrstad (2016). They discuss the relationship between the various monetary aggregates that arise on banks' and central banks' balance sheets (including credit, bank deposits M1 and central bank reserves M0), how money is created and destroyed, and how central bank reserves and bank deposits are affected when the central bank purchases securities and provides loans to banks, etc.

It is not desirable that banks adapt their balance sheets in order to eliminate all liquidity risk. The entire economic system in which banks create money and credit – the maturity transformation process - is based on banks assuming liquidity risk. Therefore, banks have access to accounts in the central bank and the central bank's facilities. This acts as a buffer for banks' liquidity risk in the maturity transformation process. Banks that must transfer central bank reserves to other banks, can borrow reserves from the central bank. In addition, the central bank can act as lender of last resort and, if necessary, provide banks with extraordinary reserves (other than those generated by day-to-day liquidity management). This acts as a liquidity insurance for banks.[14] In addition, the authorities provide a guarantee for bank deposits up to a certain size.

These factors underpin public confidence in bank deposits but may at the same time lead to moral hazard: They may weaken banks' incentives to manage liquidity risk through market adjustments and may result in excessive liquidity risk for banks. The authorities therefore impose a number of regulatory requirements on banks that force banks to manage certain credit and liquidity risk. The regulatory requirements – liquidity and capital requirements – place restrictions on banks' balance sheets and the possibility to issue money and credit.[15]

In the sections below, we will discuss in further detail how a CBDC can affect this model.

3. Macroeconomic/Financial challenges posed by CBDC

As mentioned in the introduction, the literature often discusses two types of CBDC, account-based CBDC and token-based CBDC. Both an account-based solution and a register-based token solution can be designed so that CBDC may be used as a store of value to a significant extent, resulting in high demand. This may lead to macroeconomic/financial challenges related to liquidity management, monetary policy and financial stability. It is appropriate to discuss this in the context of an account-based solution, but the arguments apply to a register-based token solution as well. We assume that the account-based solution implies that the public can hold CBDC directly in the central bank without any intermediary (but this is not a key prerequisite here). We also take the quota system currently used by Norges Bank in liquidity management as given, hence banks' amount of reserves is relatively small (the quota system is discussed in further detail in a separate appendix).

Our starting point is a bank customer who transfers his own bank deposit to his own CBDC account in the central bank. On the bank's balance sheet, deposits from the general public and deposits in the central bank are equally reduced, provided that the bank possesses sufficient reserves in its central bank account. The bank's deposits in the central bank are reduced because reserves must be transferred from the bank's account in the central bank to the customer's CBDC account in the central bank: reserves become CBDC.[16] On the central bank's balance sheet, bank deposits are reduced, while deposits from the general public (CBDC) increase. This is illustrated by the red arrows in the upper panel in Chart 3.[17]

[14] See Norges Bank (2021b) and Søvik (2020) for further discussion on liquidity insurance.
[15] For a brief discussion of the regulatory requirements, see Norges Bank (2015).
[16] This is analogous to how banks settle transactions between themselves when deposits are moved between banks: banks that lose customer deposits have reduced debt and must transfer reserves (assets) to the banks that receive customer deposits (cf. Section 2).
[17] The public can also exchange cash (notes/coins) for CBDC. On the liabilities side of the central bank's balance sheet, notes/coins are then reduced, while CBDC increase.

But suppose that the bank lacks sufficient reserves to accommodate demand for CBDC. This may be a reasonable assumption given the current quota system, in which banks detain limited deposits in the central bank. If the bank is unable to borrow reserves from other banks, it must borrow additional reserves from the central bank. The borrowed reserves are transferred to the customer's CBDC account (reserves become CBDC). As a result, the bank has changed the composition of its balance sheet: customer deposits have been replaced by central bank funding. On the central bank's balance sheet, both deposits from the general public (CBDC) and lending to banks increase. Reserves remain unchanged. These transactions are illustrated by the green arrows in the lower panel in Chart 3.[18]

Chart 3. The balance sheet of a bank (banking sector) and the central bank

	Bank			Central bank	
	Assets	Liabilities		Assets	Liabilities
Ample reserves in the banking system	Deposits in the central bank (reserves) ↓	Deposits from the public ↓ Loans in the central bank		Loans to banks	Deposits from banks (reserves) ↓ Deposits from the public: CBDC ↑
Scarce reserves in the banking system	Deposits in the central bank (reserves)	Deposits from the public ↓ Loans in the central bank ↑		Loans to banks ↑	Deposits from banks (reserves) Deposits from the public: CBDC ↑

Loans in the central bank are only offered against adequate collateral, and if demand for CBDC is high, it may be necessary for the central bank to expand the set of approved collateral and perhaps include securities with higher credit risk. This is because the central bank has to accommodate high demand for CBDC by providing loans to banks. Conversely, uniformity of value between CBDC and deposit money may be lost (excess demand for CBDC may make CBDC worth more than deposit money). If the central bank does not accommodate the increased demand for reserves through market operations, it could also lead to increased use of the central bank's standing overnight lending facility and to upward pressure on the overnight rate. This may imply that monetary policy is not implemented as intended. As a result, the literature has identified several macroeconomic/financial challenges if the public has the possibility to hold unlimited deposits in the central bank:

- The credit risk on the central bank's balance sheet may increase. Increased credit risk must ultimately be borne by taxpayers and should be a decision made by elected officials. The Central Bank Act does indeed state that the central bank shall require adequate collateral for credit, but it is up to the central bank to determine the quality of various collateral and associated haircut rates, etc.[19] Potential consequences of CBDC for collateral and risk for Norges Bank's balance sheet, including the possibility of reducing this by haircuts, are discussed in a separate box, *see Box A. Demand for CBDC and banks' collateral for loans from Norges Bank.*

[18] In practice, the following is conceivable: Throughout the day, the public transfers bank deposits to CBDC. Banks must accommodate this by drawing on intraday loans from the central bank. The borrowed intraday reserves are transferred continuously to the public's CBDC accounts throughout the day. Towards the end of the day, banks have a negative balance in the central bank that must be covered by a loan, in the current system an F-loan (The F-loan replaces the intraday loan). This is analogous to how payments into the government's account affect banks' and central banks' balance sheets and how banks are offered F-loans in the event of decreasing structural liquidity. This is discussed in further detail in Section 6.

[19] Cf. Central Bank Act, Section 3-1 (5).

- Greater uncertainty may arise as to the composition of banks' liabilities and funding costs. Banks can adjust their behaviour in response to the introduction of a CBDC:
    - Customer deposits lost by banks as a result of CBDC demand must always be replaced by central bank funding given that banks lack sufficient reserves to accommodate the CBDC demand. Loss of deposit funding and need for reserves as a result of increased CBDC demand cannot be replaced by increased market funding ex post after demand for CBDC has materialised. The literature is not always entirely accurate on this point. One sometimes gets the impression that banks (the banking system in aggregate) can replace loss in customer deposits and loss of reserves with market funding. This is false, see *Box B. Loss of deposit funding due to increased demand for CBDC cannot be replaced by market funding.* However, banks can seek to be better equipped to meet increased demand for CBDC ex ante by increasing the share of long-term funding, either by issuing bonds or by attracting term deposits from customers. The effect of this is that banks lock in more funding for a given period, so that it cannot disappear into CBDC. This may increase banks' funding costs, which is likely to be passed on to higher lending rates.[20]
    - Uncertainty related to funding costs and interest margins may influence banks' lending behaviour. Banks may become less willing to extend credit to the public.
    - Overall, there is reason to believe that banks will not express indifference when dealing with CBDC, should it be introduced. If banks are at risk of losing a substantial portion of their deposits to CBDC, they can respond by increasing their deposit rates. That, in turn, will help curb public demand for CBDC. It is impossible to know in advance how much CBDC the public will hold in a new equilibrium. There are several examples in the literature showing attempts made to estimate the effect of CBDC on, inter alia, bank deposit rates. Bindseil (2020) and Alstadheim and Søvik (2021) provide several illustrative examples and argue that the effect on banks' deposit rates will be moderate, assuming that demand for CBDC is not too high, *... Banks' funding costs and hence lending rates will probably increase somewhat with the introduction of a CBDC. We have looked at some simple scenarios where different shares of banks' deposits are replaced by a CBDC, and we find modest direct effects on the costs of some deposits being moved out of banks. The impact may be substantially greater if competition from CBDC increases...* (Alstadheim and Søvik, 2020).

- In the literature, some have suggested that the central bank can supply reserves to banks ex ante, before demand for CBDC has materialised, as an alternative to lending to banks ex post. We find this to be unsuitable in Norway, and it ultimately has limited impact on the risk assumed by the central bank, see *Box C. Should the central bank supply reserves to banks ex ante as an alternative to lending ex post to banks?*

[20] Higher lending rates will, in isolation, imply a tightening of monetary policy. The central bank can counter this by reducing the policy rate (a fall in the neutral interest rate), but since a limit exists to how low the policy rate can be set, this will reduce leeway in monetary policy.

These potential macroeconomic consequences of a CBDC are referred to in the literature as "disintermediation", or a disruption of the banking system.[21, 22] A number of studies downplay the significance of these concerns and refer to the so-called "equivalence result". This is based on the central bank replacing banks' deposit funding to an unlimited extent on the same terms as the lost deposit funding. If the equivalence result holds, several of the macroeconomic/financial challenges associated with CBDC will be eliminated. Banks' funding costs and provision of credit will then remain unaffected by the general public's transfer of bank deposits to CBDC. However, the assumption that the central bank replaces banks' deposit funding with loans on the same terms is highly critical and unrealistic. This means that the central bank's (and taxpayers') risk increases substantially and that the central bank assumes a completely new role in the financial system. The equivalence result, as well as some literature related to this, are discussed in a separate box, see *Box D. The academic CBDC literature, including the equivalence/neutrality result*.

The literature is fairly unanimous in that CBDC must be designed so that the aforementioned negative consequences are avoided or significantly reduced. This is evident in the work of a group of central banks organised by the BIS, which points out that the following principles must be met in the event of the introduction of a CBDC[23]:

... The principles emphasise that: (i) a central bank should not compromise monetary or financial stability by issuing a CBDC; (ii) a CBDC would need to coexist with and complement existing forms of money; and (iii) a CBDC should promote innovation and efficiency. The possible adverse impact of a CBDC on bank funding and financial intermediation, including the potential for destabilizing runs into central bank money, has been a concern of central banks. Any decision to launch a CBDC would depend on an informed judgment that these risks can be managed, likely through some combination of safeguards incorporated in the design of a CBDC and financial system policies more generally ... (Our underlining)

The same group points out in September 2021 that:[24]

... In October 2020, this group set out three common foundational principles for considering issuing a central bank digital currency (CBDC). ... The first of these principles was "do no harm" – this does not mean "have no impact", but rather that new forms of money supplied by the central bank should continue supporting the fulfilment of public policy objectives and should not impede and ideally enhance, a central bank's ability to carry out its mandate for monetary and financial stability. This principle arose from a recognition that while a CBDC has the potential to provide benefits to the operation and resilience of the financial system

[21] ECB (2020), chapter 3, provides an excellent discussion of this issue.
[22] CBDC can be viewed as a "leak" from the banking system. The starting point for this rationale is that when deposit-taking banks create deposit money as a liability, this liability remains in the banking system as long as the central bank limits the right to hold an account at the central bank to deposit-taking banks. If, on the other hand, the central bank broadens access to others than deposit-taking banks, this also allows banks' liabilities to be moved from banks' aggregate balance sheet to the central bank. Then, non-bank counterparties will hold deposits at the central bank, while the offsetting item on the central bank's balance sheet will be loans to banks that replace the banks' deposit money/deposits. If the deposit money moved from the banking system is substantial, the central bank's balance sheet risk may increase. CBDC is one such possible leak. Other examples may be so-called full-reserve banks and different types of shadow banks if the latter are permitted to hold accounts in the central bank (see Norges Bank (2021b) for further discussion).
[23] See Group of central banks (2020). The group consists of central banks from Canada, the euro area, Japan, Sweden, Switzerland, the UK and the US in addition to BIS.
[24] See Group of central banks (2021).

(particularly regarding payment services), a CBDC could also affect existing financial market structures and business models, which may pose risks to financial stability as the financial system evolves, particularly via the potential disintermediation of banks … (Our underlining)

These points are also reflected in Norges Bank's analyses of CBDC so far, stating that[25]

… A premise underlying this work is that the existence and scope of a CBDC must not impair the ability of banks and other financial institutions to provide credit …

This premise is fully in line with groups of central banks' principles and implies that CBDC must be designed in such a way that the macroeconomic/financial consequences discussed above are avoided. The literature emphasises that CBDC should be designed primarily as a means of payment, and not as a store of value, ... *For the central banks contributing to this report, the common motivation for exploring a general purpose CBDC is its use as a means of payment ...* [26]. It is assumed that demand for CBDC will then not be so high that the macroeconomic/financial disadvantages occur. Various designs of CBDC with this in mind are discussed in Section 4 below.

Box A. Demand for CBDC and banks' collateral for loans from Norges Bank

When the public converts from bank deposits to CBDC, banks must reduce their holdings of central bank reserves (reserves become CBDC). If banks do not possess sufficient reserves, they must borrow from the central bank. This is only done against collateral, and if demand for CBDC becomes high, banks may encounter problems in providing sufficiently approved collateral (cf. Section 3).

The general public's deposits in transaction accounts (M1) in Norwegian banks (including branches of foreign banks) are currently around NOK 3 000 billion. It is almost impossible to estimate how high demand for CBDC might be but let us assume that the public wants to transfer 10 percent of deposits in transaction accounts to CBDC, i.e., NOK 300 billion. By comparison, the amount of outstanding notes and coins lies just beneath NOK 40 billion. CBDC is likely to be more suitable than cash as a store of value, and demand for CBDC may be substantially higher than demand for cash. In times of financial turbulence, particularly if confidence in the banking system should deteriorate, demand for CBDC may increase markedly.

Today, banks have deposited collateral in Norges Bank worth NOK 400-420 billion. Increased demand for CBDC equivalent to NOK 300 billion will to a large extent lay claim of this collateral. This comes in addition to the need for collateral when other factors contribute to withdrawing reserves from the banking system, resulting in low structural liquidity. In periods, Norges Bank currently has outstanding F-loans of NOK 100 billion. Should the central bank also need to supply the banking system with additional reserves in times of financial turbulence, such as during the coronavirus crisis in 2020, banks will have to provide additional collateral.[27]

Central banks can normally accept collateral with somewhat higher credit risk by applying higher haircuts so that banks can borrow reserves for a smaller share of the collateral's estimated

[25] See Norges Bank (2018, 2019, 2021a).
[26] See Group of central banks (2020).
[27] For an overview of Norges Bank's measures during the coronavirus crisis, see Norges Bank's response to coronavirus (COVID-19) (norges-bank.no)

value. Furthermore, banks can pledge a larger portion of their assets than today. For most banks, lending to the public, including residential mortgages, is the largest item on the asset side. That banks, to this extent, have to pledge a larger share of their assets - often with a higher haircut rate - seems to have an uncertain effect on the economy. This suggests that CBDC should be designed to limit demand. This will help to avoid or significantly reduce the above-mentioned macroeconomic/financial challenges, including the risk on the central bank's balance sheet.

Box B. Loss of deposit funding due to increased demand for CBDC cannot be replaced by market funding

The literature sometimes gives the impression that banks as a group can meet increased demand for CBDC by replacing deposit funding with market funding, and that banks therefore do not need central bank funding. The argument seems to be that when the public transfers deposits from banks to CBDC, banks can solve their need for liquidity (reserves) by issuing more debt. In a new equilibrium, it is then assumed that customer deposits have been reduced, while market funding has increased. This argument is incorrect when we look at the banking system as a whole. A confusion is made between an "ex post" and an "ex ante" argument. Ex post, after demand for CBDC has materialised, banks must reduce their deposits in the central bank, and as a group, banks can only do so by borrowing reserves from the central bank, if there were not enough reserves in the banking system at the outset. When the public transfers bank deposits to CBDC, additional debt is incurred on the central bank: CBDC figures on the liabilities side of the central bank. The central bank requires compensation, and this requirement comes in the form of banks having to reduce their deposits in the central bank. And if banks do not have sufficient reserves, they must borrow from the central bank. Ex post, losses of customer deposits to CBDC cannot be replaced by market funding, only by central bank funding.

However, before demand for CBDC has materialised, banks can ex ante reduce liquidity risk by lowering the share of deposit funding and increasing the share of longer-maturity funding (debt or term-deposits). This reduces liquidity risk because customer deposits account for a smaller share of funding (this is precisely how banks manage their own liquidity risk). And the lower banks' initial customer funding, the smaller the potential for demand for CBDC, and the less liquidity risk CBDC poses for banks. But ex post, after demand for CBDC has materialised, banks will have to reduce their deposits in the central bank.

The arguments above do not apply to individual banks. A single bank that loses customer deposits to CBDC can obtain reserves at the expense of other banks, for example by borrowing in the money market or by issuing debt securities. If the buyer of the debt securities has an account in another bank, the bank will receive an increase in deposits in the central bank as payment for the debt securities sold. But banks as a whole cannot procure reserves in this manner. When banks as a group need additional reserves, reserves can only come from the central bank.

An analogy can be drawn here to a situation involving a run on banks, where the public withdraws bank deposits for cash. If banks run out of cash, banks must get more cash from the central bank on behalf of their customers. Banks pay for cash by drawing on their deposits in the central bank. If banks do not have sufficient reserves, they must borrow reserves from the central bank. If the central bank does not lend reserves to banks, for example because the central bank would then be exposed to higher credit risk, the public's demand for cash will not be accommodated. This could undermine the uniformity of value (singleness) between bank deposits and cash: Demand for cash is so high that the public is willing to pay more than one krone in bank deposits to get one krone in cash.

Box C. Should the central bank supply reserves to banks ex ante as an alternative to lending ex post to banks?

In Section 3, we pointed out that the central bank must lend to banks (ex post) in the event of high demand for CBDC, so that banks' deposit funding is replaced by central bank funding. One alternative could be to supply reserves to banks ex ante before demand for CBDC is known. This is discussed in the literature. However, whether the central bank supplies reserves ex post, after demand for CBDC is known, or ex ante, before demand for CBDC has materialised, has no significance for the risk on the central bank's balance sheet (assuming that the amount of reserves supplied is the same). Moreover, supplying reserves ex ante will probably complicate Norges Bank's liquidity management, cf. the discussion on liquidity management in Section 6.

The central bank can purchase securities or foreign exchange to supply reserves to banks. With regard to securities purchases, the starting point might be that the central bank - in order to limit credit risk - only purchases securities that are approved as collateral for loans. However, even if purchases are limited to eligible collateral, this may affect prices and risk premiums in relevant markets. Purchases of government securities, which have zero credit risk, can be particularly problematic, as the government securities market is small and one desires to avoid that the central bank influence government yields, which otherwise give the market a risk-free yield curve. If one purchases securities beyond that which is approved in the safety regulations, the risk on the central bank's balance sheet increases. Foreign exchange purchases are also problematic, as they can result in monetary policy consequences by influencing the krone exchange rate. Norges Bank can supply reserves to banks by lending to banks. But loans require collateral. With regard to risk on the central bank's balance sheet, it does not make a difference whether reserves are supplied ex post, after demand for CBDC has materialised, or ex ante, before demand for CBDC is known. Increased central bank reserves on the central bank's liabilities side will have to be matched by an element on the asset side, be it securities, currency or loans to banks (against eligible collateral).

The situation may be somewhat different if there are substantial reserves in the banking system at the outset, as is the case in some countries in which the central bank to a large extent has purchased securities (quantitative easing and credit easing). During the financial crisis in 2008/2009 and thereafter, up until today, some central banks purchased securities so that reserves in the banking system have grown substantially. These decisions were made in the interest of monetary policy and financial stability. To the extent that this has increased the risk on central banks' balance sheets, these are decisions that have already been taken, and any increased risk tolerance has been part of the central banks' assessment. If demand for CBDC increases, banks can then draw on existing reserves without changing the risk on the central bank's balance sheet. A transfer from reserves to CBDC will then take place on the central bank's liabilities side, without affecting the asset side.[28, 29] However, with little reserves in the banking system at the outset, the central bank must assess the risk it assumes against potential

[28] Fraschini et al (2022) discuss in more detail how high demand for CBDC may affect the economy differently depending on whether the monetary policy situation is "normal" or QE influenced with high reserves in the banking system. With substantial surplus reserves in the banking system as a result of QE, banks can draw on these in the event of increased demand for CBDC. However, the authors point out that problems may then arise when the QE measures are to be reversed, if, as a result of a CBDC, reserves in the banking system are scarce.

[29] Abad, Nuño and Thomas (2023) discuss how CBCD demand may result in a change in central banks' liquidity management system, from a floor system with ample reserves to a corridor system with scarce reserves. The reason is that CBCD demand draws reserves out of the banking system. Floor and corridor systems are discussed in more detail in a separate appendix.

gains from CBDC, whether reserves are supplied ex ante or ex post. Thus, there seems to be some potential costs of supplying the reserves ex ante, but no obvious advantages.

Box D. The academic CBDC literature, including the equivalence/neutrality result

Central to the international literature and in this paper is how CBDC may produce negative effects on the financial system if CBDC is well-suited as a store of value. More specifically, both in the academic literature and the more practical-oriented central bank literature, great emphasis is placed on what is referred to as "disintermediation through deposit substitution": When bank deposits are transferred to CBDC, banks lose deposit funding, which can adversely affect banks' funding costs and lending. The literature focuses extensively on how CBDC can be designed to prevent, or at least significantly mitigate, the macroeconomic/financial consequences (cf. Sections 3 and 4). However, empirical evidence is non-existent in this field since developed economies have not yet introduced a CBDC. It is therefore difficult to predict demand for and consequences of introducing CBDC. Some studies therefore rely on model analyses in an attempt to shed light on this. Widely used are so-called dynamic stochastic equilibrium models (DSGE models). Such models model the behaviour of different agents (the general public, banks, central banks) and, given a number of assumptions, the models can create scenarios for, for example, demand for CBDC, banks' funding costs and provision of credit, and how much of banks' deposit funding must be replaced by central bank funding. Furthermore, different types of bank models are used to illustrate the relationship between CBDC and a possible run on banks (often with reference to and expansion of models ala Diamond and Dybvig, 1983). A detailed discussion of this literature falls outside the scope of this paper. We refer to some studies that provide a good overview of this academic literature, cf. Auer et. al. (2021), Auer et. al. (2022), Ahnert et. al. (2022), Keister and Sanches (2021) and Infante et. al. (2022).

An advantage of the model-based studies is that they often provide a clear relationship between assumptions for the analysis and the results. Such studies can provide useful insight, but in many cases the results appear to be based on fairly strict assumptions that will not necessarily hold in practice. The results and consequences of CBDC depend on the assumptions and model layout. Thus, such studies do not always provide useful guidance for the practical work with CBDCs. We believe Bindseil (2020) takes an appropriate approach to this, when he criticises Kumhoff and Noone (2018) and writes: ... *The solutions they propose through their four principles may partially contradict the initial intuition of Central Bank Market Operations practitioners ...*

We believe that Bindseil's comment can be made more general and be directed towards a larger portion of the literature. When Auer et. al. (2021) criticise recommendations to design CBDC based on financial stability considerations, they write, ... *While intuitive, the argument that a CBDC increases financial fragility is actually difficult to justify when considering it in a general equilibrium model, with all facets of CBDC. Therefore, design recommendations based on financial stability arguments should be taken with a grain of salt* ... (Our underlining). But since most of the general equilibrium models also make a number of simplifying assumptions, which may be more or less realistic, this formulation may as well be turned around, as a reminder that many of the model analyses in the CBDC literature must also be taken with a grain of salt. A study from Fed, Infante et. al. (2022), that summarises the literature, concludes as follows: ... *If a CBDC were contemplated, adding some combination of ceilings on CBDC holdings, limits on the amount users can transact, or tiered remuneration might be helpful to combat any financial instability issues. All that said, the plethora of models in the literature and the myriad of conclusions that fall out of those models argue for humility. There are enough*

uncertainties and contingencies that it seems likely that there will always be an element of a leap of faith in any decision to move forward ... (Our underlining).

Here we wish to focus on one key assumption found in a number of studies, which drives the so-called "equivalence result", also referred to as the "neutrality result". This exists in different varieties, but they all have in common that if the equivalence result holds, several of the macroeconomic/financial challenges associated with CBDC will vanish or decrease. "Disintermediation" is no longer a problem. In particular, banks' funding costs and provision of credit remain unaffected when the public transfers bank deposits to CBDC. Brunnermeier and Niepelt (2019), Niepelt (2020a), Niepelt (2020b) and Niepelt (2022) provide a theoretical basis for the equivalence result. It is discussed at a more general level in Ahnert et. al. (2022) and ECB (2022a) (as in many other studies). The most important precondition for the equivalence result is that banks' loss of deposit funding as a result of demand for CBDC is automatically and to an unlimited extent replaced by central bank funding. Furthermore, central bank funding must be non-collateralised, i.e. it must have the same property as deposit funding. If banks must provide collateral for loans from the central bank, costs arise that erode banks' interest margins and that must be passed on to banks' borrowers. This may in turn influence banks' lending behaviour so that the equivalence result does not necessarily hold. If the central bank has to accept collateral with a higher credit risk, this could affect the risk on the central bank's balance sheet. The theoretical literature mentioned above highlights the importance of this assumption and that it may be unrealistic since central banks require eligible collateral for loans to banks. The authors point out that the assumption can be a starting point for understanding why the equivalence result does not necessarily hold: *... Its purpose is to provide a benchmark, not the most realistic description, in order to identify key conditions for equivalence and thus, potential sources of non-equivalence ...* (Niepelt 2020b).

A number of studies show that banks' deposit funding can be replaced by central bank funding, which reduces negative effects of CBDC on banks' funding costs and provision of credit. It is indicated that the central bank may have facilities for this and almost act as "lender of first resort". Banks are then ensured continuous funding on the same terms, so that banks' funding costs and credit management behaviour are not particularly affected. However, some studies clearly demonstrate that this may increase the risk on the central bank's balance sheet if the central bank must accept higher-risk collateral. For example, as stated by Burlon et al (2022):

... Much of this literature focuses on the trade-off between the potential benefits of CBDC as a safe and innovative means of payment and the risk of bank disintermediation through deposit substitution ... ... under certain conditions, there are no allocative and macroeconomic consequences of CBDC-induced bank disintermediation as society is implicitly indifferent between obtaining lending through bank deposit funding and via central bank financing. A key common feature of these models is that they abstract from modelling the central bank's collateral requirement, a financial friction that has been shown to play a key role in the potential (non-neutral) effects the introduction of a CBDC may trigger on the banking sector and the real economy ... ... Our paper contributes to the strand of the literature that highlights the importance of this transmission channel by showing that if these requirements are binding and the cost of central bank funding relative to that of deposits differs, issuing CBDC has a non-neutral effect on bank lending and the real economy ...

A study from the European Central Bank (Meller and Soons, 2023) also emphasizes that the equivalence result is not realistic: *... Serving as a benchmark, Brunnermeier and Niepelt (2019) present an "equivalence" result: under certain conditions, banks would, in theory, be*

unaffected by a deposit outflow to CBDCs if the central bank were to redirect liquidity back into the banking system under favourable conditions. Our model could replicate the equivalence result by assuming an environment in which central bank funding is the cheapest adjustment option and does not require collateral. However, we focus on the realistic situation when the equivalence result does not hold due to liquidity regulation, collateral requirements and in the absence of unconventional monetary policy instruments …

Niepelt (2022) challenges his own equivalence result and points out that the result, rather than being based on unrealistic assumptions, is based on inconsistent central bank policy regarding collateral requirements:

… We show that, when the public and the private sector provide liquidity equally efficiently, portfolio shifts out of deposits into CBDC do not undermine bank lending nor affect the allocation as long as the central bank passes its new funding back to banks at an equivalent rate … … Given that central banks typically only provide secured funding one might conclude that an unsecured loan—and thus, equivalence—is "unrealistic." But the situation is more complex. Unsecured loans under the equivalent policy with CBDC are the mirror image of unsecured implicit lender-of-last-resort guarantees that provide the liquidity backing for deposits in the two-tier system. If those implicit guarantees were secured, then the equivalent loans would be secured as well. Rather than prescribing an unrealistic policy the equivalence result points to a potential inconsistency of central bank policies …

However, in our view these two situations are not comparable, as in reality and opposed to what Niepelt seems to assume, lender-of-last-resort loans to banks are normally not unsecured. If a financial crisis occurs, the central bank will consider measures on a discretionary basis, including collateral for loans and risks to the central bank's (and taxpayers') balance sheet. For example, The Central Bank Act in Norway requires that loans to banks must always be secured by adequate collateral, including loans where the central bank acts as lender of last resort in times of turbulence. Second, banks are regulated and subject to liquidity and capital requirements, which reduces the likelihood that the central bank will have to act as lender of last resort and provide banks with loans in times of financial stress. On the other hand, unsecured loans that need to be granted to banks as a result of CBDC demand to ensure equivalence would almost be an "on-demand" facility: it is envisaged that the central bank will automatically and without limit replace banks' deposit funding with central bank funding on an ongoing basis. Hence, the consequence of unsecured on-demand loans from the central bank caused by CBDC demand is in reality not the same as the consequence of loans extended by the central bank as lender of last resort.

We are therefore not convinced by this line of argument. In our view, some of the CBDC literature underestimates the consequences of the assumption that the central bank can just replace banks' customer funding with central bank funding, almost as a standing facility, to avoid disruptions to the banking system. The result of such a practice could be a much larger footprint of the central bank in the financial system than at present. The central bank's role would change from being a liquidity backstop for banks, to become a (potentially major) funding source for banks. Commercial banks would still create money through lending, but the central bank would become an additional intermediary between private creditors and debtors, and thus get a much more central role in the credit market than now. Furthermore, unsecured central bank lending to banks "on demand" would imply a direct link from the credit decisions of commercial banks to the risk on the central bank's balance sheet. This would be a profound change of the financial system compared to the present setup.

4. Possible designs of CBDC to avoid macroeconomic/financial costs

The literature discusses several possible designs of a CBDC aiming at preventing excessive demand for CBDC and the widespread use of CBDC as a store of value:[30]

(i) An upper limit – a "cap" – for how much CBDC each individual can hold, possibly with a "waterfall mechanism" determining the outcome of the excess amount
(ii) A multi-interest system, i.e., CBDC deposits above a certain size bear interest at a lower rate
(iii) The central bank issues CBDC only in exchange for government securities
(iv) Token-based CBDC stored only on a physical device (CBDC can be lost)

The first two proposals in particular have been extensively analysed in the literature. An upper limit on CBDC holding is technically possible with both the account-based system and the register-based token system. In both systems, one can enter parameters so that the transactions do not go through if the limit is exceeded. For tax reasons, a system that calculates interest income on CBDC requires that interest income can be identified to named persons or companies. This is technically simple in an account-based system, where the account holder is identifiable. We assume that this is also possible in a register-based token system by registering interest income from register-based token CBDCs on the identifiable owner. The third option, that the central bank issues CBDC only in exchange for government securities may, admittedly, reduce demand for a CBDC and prevent the above-mentioned disturbance to the banking sector. But it introduces other problems and seems poorly applicable, especially in Norway. These proposals are discussed in further detail below.

4.1 An upper limit – a cap – on CBDC

An upper limit means that the public may hold CBDC in an account in the central bank, but only up to a certain amount. Any attempt to receive a payment that will bring the deposit above the limit will be rejected by the settlement system. This will be highly effective in preventing CBDC-demand to become too high, because it is simply not possible to hold more than implied by the sum of the individual caps. But this design of CBDC involves various costs:

- An efficient payment system requires that the public is confident that transactions will be carried out seamlessly and preferably on an unlimited, or at least large, scale. With a limit on CBDC, some transactions may be declined. The efficiency of the payment system may be impaired and the system may also come to a halt. This, in turn, can quickly have major economic consequences.
- Diverse groups may express different needs in favour of maintaining CBDC. Households can manage with considerably lower amounts than businesses. A grocery chain must obviously be able to accept more CBDC than individuals. This can be solved by different groups being assigned different amount limits, but it complicates the payment system.[31]

[30] In principle, demand for CBDC may be high even if CBDC is not primarily used as a store of value. Demand for CBDC may also be high if CBDC gains a large market share as a means of payment. The decisive factor is how important demand for CBDC becomes relative to bank deposits, irrespective of what CBDC is used for. However, demand for CBDC will probably be considerably higher if CBDC is attractive as a store of value.

[31] In its consultation paper, the Bank of England (2023) recommends an amount limit of between £10,000 and £20,000 but does not rule out that the amount could also be lower. They relate this amount to, among other things, the size of wages and the need to receive wages and other public benefits in the form of CBDC. They recognize that different groups may have different needs to maintain CBDC, so that amount limits may have to vary between different groups. The ECB has not yet taken final decisions on the introduction and design of CBDC, but argues that CBDC should be "retail", and in the first instance may only be held by households.

- One cannot exclude the possibility of shadow prices – or multiple prices – on CBDC, if market participants attempt to circumvent the restrictions on how much CBDC that can be held.
- An upper limit on CBDC can be challenging if CBDC is to be legal tender (so that debt can always be settled in CBDC unless otherwise agreed). This needs to be further clarified (see Syrstad (2023).
- The literature proposes a "waterfall mechanism", which means that if the threshold amount is reached, the excess amount must be converted into bank deposits and transferred to an ordinary bank account. As an example, assume that person A is to transfer NOK 100 in the form of CBDC to person B and that person B only has room for NOK 50 in his CBDC account. The excess NOK 50 must then be transferred to person B's ordinary bank account. On the recipient bank's balance sheet, customer deposits increase by NOK 50 (liability), which is compensated by increased holdings of central bank reserves (assets). On the central bank's balance sheet, NOK 50 in the form of CBDC is converted into reserves: CBDC is destroyed and becomes reserves. With such a waterfall mechanism the transaction will not stop, but it may be confusing for the payee. This also raises some questions related to interoperability between CBDC and traditional banking money and the extent to which banks should be able to hold CBDC on their own balance sheets, see *Box E. Interoperability between the banking system and CBDC*. Niepelt (2023) provides examples that illustrate the complexity in a waterfall mechanism … *While technically probably feasible, this arrangement appears quite complex and fragile …*
- Challenges of a more political nature may also arise. The country's population is offered to hold CBDC, money issued by the state, but only to a limited extent. Today, demand for cash is admittedly low, but the public can hold as much cash as they desire. It may be difficult for the central bank, and the central authorities in general, to communicate this design of CBDC to the public.

4.2 Multi-interest system for CBDC

Demand for CBDC may also be regulated with interest rates on CBDC deposits. In this context, it is the interest rate on CBDC relative to the interest rate on bank deposits that is relevant. In a situation where interest rates in the economy are low, the interest rate on bank deposits may be close to zero. It cannot then be ruled out that the interest rate on CBDC will have to be set below zero in order to limit demand. However, the risk of negative interest rates may make CBDC unattractive as a means of payment in the eyes of the public. In light of this, the literature discusses a two-tier system to limit demand for CBDC. Under such a system, the public receives interest on CBDC at a given rate up to a specific quota. CBDC deposits in excess of the quota bear lower interest. For example, deposits within the quota can bear interest at the policy rate, while deposits above the quota bear interest at a rate less than the policy rate. It is also conceivable that deposits within the quota bear zero interest, while deposits above the quota bear negative interest.[32] This is analogous to how Norges Bank currently manages banks' liquidity (central bank reserves) under the quota system. Compared

Enterprises shall be eligible to receive CBDC, but the amount shall immediately be converted to ordinary bank deposits via a waterfall mechanism. This limits high demand for CBDC and reduces the need for some groups to have higher limits than others (ECB, 2023). In a speech to the European Parliament, Fabio Panetta, member of the ECB Executive Committee, suggests a limit of 3000 to 4000 euros per person (see ECB Would Limit Digital Euro to Maximum 1.5T, Says Fabio Panetta (coindesk.com)

A limit equal to 3000 Euro is suggested by Bindseil and Panetta (2020). Meller and Soons (2023) use a model to simulate effects on banks' and the central bank's balance sheet when the public transfers bank deposits to CBCD. They conclude that an upper limit of 3000 Euro will be sufficient to avoid the financial disturbances.

[32] A standard reference here is Bindseil (2020).

to setting a limit on CBDC, this alternative is probably more practicable and transparent for users, but it raises some issues.

The most important objection to a multi-interest rate system is probably that the instrument is least effective when the need is greatest. In times of financial turbulence and when the public wishes to hold deposits that are completely free of credit risk, demand for CBDC as a store of value may be high. The CBDC interest rate may then have to be used very aggressively, and perhaps be set far below zero in order to curb demand. The literature provides several examples of how increased demand for CBDC may affect banks and the central bank's balance sheets, banks' funding costs and the provision of credit (cf. Section 3). The examples provide good illustrations of how CBDC can influence these parts of the financial system in normal times. However, the calculation examples say little about the effect of CBDC when demand for CBDC becomes very high. And unlike setting a limit on CBDC, a multi-interest rate system works through price incentives. At the prices set, the public can hold as much CBDC as they want. One can, of course, introduce a limit on CBDC in addition to a multi-interest system, but then the design of CBDC starts to become complicated and unclear for users.

Political challenges may also arise with a multi-interest rate system, particularly if the CBDC interest rate turns negative. It can be difficult to communicate to the country's population that the government charges households and firms in this way when they hold money issued by the government. In recent years with low-interest rates, we have seen that banks have been reluctant to set negative interest rates on deposits from the general public. The public is not used to negative interest rates on deposits, and one must expect considerable opposition to negative interest rates on CBDC, perhaps also from the political side. The CBDC interest rate is discussed in further detail in Section 7 under *Monetary policy*.

Monnet (2023), Niepelt (2023) and Monnet and Niepelt (2023) are critical of introducing an upper limit on holding CBDCs and of a multi-rate system aimed at reducing demand for CBDC. Their views appear to be a criticism of two CBDC reports from the European Central Bank (ECBb,c). They argue that in its design of a CBDC, the ECB gives too much weight to banks' interests and gives too little weight to other benefits of a CBDC: *... The ECB has highlighted its commitment to developing a digital euro and has explicitly stated that the digital currency will adhere to three principles: preserve European strategic autonomy, reduce rent extraction by payment service providers, and serve as a robust monetary anchor when cash transactions decline. This column argues that a fourth, implicit objective – to protect banks and their business model – risks undermining the project. This could prove to be a significant missed opportunity given that social benefits of the digital euro substantially exceed its private ones … …The design choices the reports document raise doubts about the ECB's objectives and strategy. As a consequence, the digital euro might well be dead on arrival…* (Monnet and Niepelt 2023).[33]

Monnet and Niepelt point out that if too much weight is given to banks' interests and to preventing the above-mentioned financial/macroeconomic challenges, a CBDC will become so unattractive that demand will be low ("dead on arrival"). Monnet (2023) notes that a CBDC might discipline the banking system and give banks an incentive to be less dependent on deposit funding by lengthening their funding maturities, which will reduce banks' liquidity risk (cf our comment in box B). It is nevertheless our view that even if banks lengthen their

[33] Monnet and Niepelt (2023) is a CEPR/VOX-blog, "Why the digital euro might be dead on arrival", which is based on Niepelt (2023) and Monnet (2023).

funding maturities and thereby reduce their liquidity risk, banks' aggregate deposits would have to be substantial. This is inherent in the financial system: banks create money and credit as a part of maturity transformation, and the general public needs substantial amounts in their deposit accounts (M1). In our opinion, the arguments of Monnet and Niepelt are definitely interesting, but nevertheless, we believe that their arguments do not disarm the financial/macroeconomic challenges that high demand for CBDC may result in.

4.3 The central bank issues CBDC only in exchange for government securities
Kumhof and Noone (2018) and Kumhof et. al. (2023) lay forth principles to prevent runs on banks, ensure that banks do not lose deposit funding that must be replaced by central bank funding, and ensure that banks' ability to provide credit is not reduced. The most important condition is that the central bank shall issue CBDC only in exchange for government securities. This prevents the public from exchanging bank deposits directly to CBDC. This can be formulated in slightly different manners, depending on the types of institutions that hold government securities:

- Suppose banks initially hold government securities. When the public requests CBDC, banks sell government securities to the central bank and receive reserves. On the asset side of banks' balance sheet, government securities are reduced, while reserves increase. On the central bank's balance sheet, government securities increase on the asset side and reserves increase on the liability side. Thereafter, the public's deposits in banks are reduced and reserves are transferred from banks' accounts in the central bank to the general public's CBDC accounts in the central bank. The overall effect is that deposits and government securities are reduced on banks' balance sheets, while government securities and CBDC increase on the central bank's balance sheet. In this way, banks could conceivably sell government securities in exchange for reserves ex post, "on demand" in pace with increased demand for CBDC from the public. Alternatively, banks can sell government securities to the central bank ex ante and build up a buffer of reserves to meet public demand for CBDC.
- A substantial share of outstanding government securities is held by institutional investors who are not banks and do not have an account with the central bank. It is then conceivable that banks first buy government securities from these investors. On the asset side of investors' balance sheet, government securities decline, while deposits in banks increase. On banks' balance sheets, government securities on the asset side increase, while investor deposits increase on the liability side. Again, banks sell government securities to the central bank in exchange for reserves. When the public requests CBDC, the public's deposits in banks are reduced, while reserves become CBDC on the central bank's liability side. For banks, the overall effect is that deposits from the public are replaced by deposits from investors. For investors, the overall effect is that government securities are replaced by bank deposits and for the general public that bank deposits are replaced by CBDC.
- Whether government securities are held by banks or other institutional investors, this mechanism prevents the central bank from having to provide loans to banks, possibly at inferior collateral, when the public requests CBDC (cf. discussion in Section 3).

There are a number of challenges associated with a system where the central bank issues CBDC only in exchange for government securities. A precondition is that the outstanding holdings of government securities must be sufficiently large. This may be the case in some countries, including the United Kingdom and the United States, but definitely not in Norway. Moreover, from a practical point of view, such a system must be facilitated, whereby

government securities are to be sold and purchased between banks, other financial institutions and the central bank, all in order to meet the public's demand for CBDC. In a critique of the proposals of Kumhof and None (2018), Bindseil (2020) argues that it would violate a principle where all forms of money are directly convertible against each other. If the central bank issues CBDC only in exchange for government securities, CBDC and the other important form of central bank money – central bank reserves – are not directly convertible. This is probably the most important objection to the proposal of Kumhof and None (2018) since it may undermine singleness (uniformity of value) between CBDC and other forms of money. This may occur if the outstanding holdings of government securities are not large enough to meet demand for a CBDC. In this context, it is important to remember that government securities serve several purposes, including offering a risk-free alternative for different types of investors. Higher demand for government securities as a result of increased CBDC demand may influence government securities prices, even if only a small share of outstanding holdings is used to meet CBDC demand. Kumhof and None (2018) are aware of these challenges linked to their proposals and therefore allow discretionary central bank lending to banks in exchange for collateral that the central bank deems satisfactory given the situation. All in all, the proposal of Kumhof and None (2018) and Kumhof et al (2023) deserves attention, and variants of this proposal should not be ruled out, not least because alternatives discussed above are also fraught with challenges. In the literature, particularly in the "practical-oriented central bank literature", the first two proposals discussed above take precedence: A limit on individual holdings of CBDC or a multi-interest rate system.

4. 4 Token-based CBDC stored solely on physical devices

Norges Bank is not considering introducing a CBDC that can only be stored on a physical unit. Such a solution means that the money is lost if the unit is lost (analogous to cash: if you lose your wallet, the money is lost). However, we mention it as an alternative here because such a solution would imply that CBDC is unsuitable as a store of value. The risk of losing the token and thus the money is too important. A solution of this sort is likely to reduce the macroeconomic/financial challenges discussed above. However, it should not be ruled out that there may also be high demand for this form of CBDC in times of crisis. At times, there has been an increased demand for cash during times of financial turmoil, and correspondingly, demand for token based CBDC stored on physical devices could also increase. One must then just place the token safely in the safe instead of cash. The macroeconomic challenges are therefore not entirely eliminated.

4. 5 Balancing applicability and macroeconomic/financial challenges

The discussion above illustrates a trade-off:

- The more a CBDC is designed to prevent being used as a store of value, and the more it is designed to avoid the macroeconomic/financial challenges, the more complicated and confusing the design of a CBDC will be for users, and the less user-friendly a CBDC will be, alternatively,
- The more user-friendly the design of a CBDC is, the more CBDC can be used as a store of value, and the greater is the risk is of macroeconomic/financial challenges.

Box E. Interoperability between the banking system and CBDC

Interoperability between CBDC and the banking system means that the public should be able to seamlessly switch from their own CBDC to others' bank deposits and from their own bank deposits to others' CBDC (in addition to switching between their own bank deposits and their own CBDC). The payment system may seem inefficient to the public if bank money and CBDC cannot be used "interchangeably". Interoperability between CBDC and the banking system can

be ensured in two ways depending on whether banks can hold CBCD on their own balance sheets.

First, suppose that banks cannot hold CBDC on their own balance sheets. Further, suppose that person A is to transfer NOK 100 in the form of CBDC to person Bs ordinary bank account On the recipient bank's balance sheet, customer deposits and reserves increase by NOK 100. On the central bank's balance sheet 100 CBDC is converted into reserves: CBDC is destroyed and becomes reserves. Similarly, assume that person A transfers NOK 100 from his ordinary bank account to person B, who is to receive this as CBCD. On the central bank's balance sheet, central bank reserves are reduced, while CBDC increases: Reserves become CBDC (CBDC is created). *In this case, interoperability is ensured in that reserves and CBDC seamlessly and continuously switch places on the central bank's balance sheet.*

It is probably more efficient that banks can hold CBDC on their own balance sheets. The banks then hold retail CBDC in the same way as they hold cash today. Banks buy CBDC from the central bank by drawing on their reserves. The public buys CBDC from banks by drawing on their bank deposits, as they pay for cash today. Conversely, the public can supply CBDC to banks and increase bank deposits, while banks can supply CBDC to the central bank and increase reserves. *In this case, interoperability is ensured by banks holding CBDC on their own balance sheets, serving as a buffer for public demand for CBDC.*

One question that then arises is how much CBDC banks should be able to hold and to what extent a CBDC can be an alternative to reserves as a means of settlement between banks. If CBDC becomes a substitute for reserves in banks' liquidity management, this may have implications for the central bank's liquidity management and the overnight rate. We assume that a potential CBDC will be designed as a means of payment for the general public and not as a means of settlement between banks (cf. introduction). Interbank settlements require access to reserves, not least intraday, and banks are dependent on market operations by the central bank that are "denominated" in reserves.

5. Is CBDC necessary to ensure confidence in our money and singleness between central bank money and privately issued money?

There is now a large body of literature discussing CBDC, both academic literature and more practical-oriented central bank literature.[34] In this section, we will take a closer look at one argument that is often highlighted in the CBDC literature, that if cash disappears, CBDC will be necessary to ensure confidence in our money and singleness (uniformity of value) between different types of money. In our view, this argument is not always well justified. The background is as follows:

The literature emphasizes that cash ensures singleness between different types of money, in particular singleness between central bank money and bank money, and hence singleness between bank deposits in different banks. Cash binds together central bank money and bank money. The public can draw on bank deposits and raise cash at par value. This ensures singleness between bank deposits in diverse banks. We achieve a common unit of account, whether we pay with cash or bank deposits. The literature indicates that with low and falling use of cash, CBDC must take over the role of cash to ensure singleness between central bank money and bank money. The literature also states, in our view a bit vaguely, that CBDC will more broadly ensure that the public maintains confidence in our money. Today's money

[34] As mentioned earlier, we do not provide a literature review in this paper, cf. the references referred to in Box D and other references in this paper.

consists mainly of privately issued bank money. Confidence in bank money means that the general public perceives bank deposits as highly secure, and that the credit risk associated with bank deposits is virtually zero.

The significance of a CBDC in ensuring confidence in our money and singleness between central bank money and bank money is emphasised in the literature. In a study by the ECB, it is stated that (Ahnert et al, 2022): *... The combination of banking supervision and regulation, deposit insurance, and the central bank as lender of last resort ensure that it [bank deposits] can always be converted, at par, into cash ... ... The ongoing digitalization of the economy poses a formidable challenge to the status quo. As the use of cash is declining, the promise of convertibility at par becomes less and less meaningful* (our underlining)*. To ensure that public money can perform its function as anchor of the monetary system, it must be widely accessible and used. Accordingly, a digital update of cash in the form of CBDC could help ensure that the two-layer system of public and private money can prevail in the future ...*

This is also central to Brunnermeier and Landau (2022, p. 11), a work commissioned by the European Parliament:
... Current monetary systems are held together by the public money issued by the central bank in the form of reserves (for banks) and cash (for the general public). Public money defines the unit of account: it can be supplied elastically and can be made exchangeable against all private forms of money. It serves as a bridge for converting one private money into another. It guarantees a uniform currency anchored on the unit of account. Those functions will remain central in a digital economy but more difficult to fulfil if cash disappears from day-to-day exchanges and the general public ends up living in a totally private monetary environment (our underlining)*. The main rationale for developing a digital euro would be to preserve the role of public money in a digital world. To the extent that money becomes digital, central bank money must be made available in digital form in all parts of the economy and society. All other (private) forms of money must be practically related to it through convertibility and interoperability. This effectively allows all payment instruments to replicate the unit of account properties of public money ...*

The Bank of England (2023, p. 24) seems to hold the same view and more generally highlights the importance of CBDC in ensuring confidence in the financial system:
... Our primary motivations for the digital pound are the availability of central bank money as an anchor for confidence and safety in money, and promoting innovation, choice, and efficiency in payments. We consider there are two primary motivations:

- *To sustain access to UK central bank money – ensuring its role as an anchor for confidence and safety in our monetary system, and to underpin monetary and financial stability and sovereignty;*
- *To promote innovation, choice, and efficiency in domestic payments as our lifestyles and economy become ever more digital ...*

Although the singleness/confidence argument is found in large parts of the CBDC literature, we believe it can be questioned. One could argue that what ensures confidence in our money and singleness between central bank money and bank money is singleness between bank deposits and central bank reserves, and not singleness between bank money and cash. Central bank reserves are the medium of settlement between banks. All bank deposits and central bank reserves are valued equally at par.

Moreover, the banking system is regulated (capital and liquidity requirements), a deposit guarantee scheme exists, and the central bank can act as lender of last resort (liquidity insurance). The latter means that the central bank can provide liquidity support to banks and supply central bank reserves. Taking this into consideration, Norges Bank (2018) concludes that bank money is credit risk-free for all practical purposes and that credit risk associated with bank money is not a reason to introduce a CBDC. One could argue that these are the factors that ensure confidence in bank money and singleness, and not that bank money can be converted into cash.

With a system that ensures a very high degree of confidence in bank money, which is virtually risk-free, and given singleness between bank money and central bank reserves, it would appear that it is central bank reserves, and not cash, that ensure confidence in our money and singleness between central bank money and bank money. In many countries, like the Scandinavian countries, cash makes up an infinitesimal proportion of our money, and it is hard to imagine cash playing the crucial role in ensuring confidence and singleness. And if it is not cash that ensures this in the first place, then it does not seem obvious that CBDC must be introduced in response to falling cash use to ensure confidence and singleness. We would be cautious about drawing conclusions, but we believe much of the literature is too hasty in ascertaining the importance of a CBDC in ensuring confidence in our money and singleness between central bank money and bank money.

To our knowledge, there is not much literature that adequately and convincingly discuss whether CBDC – and singleness between CBDC and privately issued bank money – is *necessary* to ensure confidence in our money or whether singleness between bank deposits and central bank reserves is *sufficient* to ensure this. Brunnermeier and Landau (2022, p. 23) discuss this issue and refer to today's financial system and the role of banks, writing:

… It could be argued that the combination of those three tools − tight bank regulation with regulators that can shut down banks, lender of last resort, and deposit insurance − makes it possible to have a system in which 100% of the money held by the general public is issued by private banks and nevertheless considered as safe. … However, because there is no precedent in modern history without public money, it would be dangerous to base public policy on that assumption … … <u>This is certainly an issue worthy of further research</u> … (our underlining).

Niepelt (2018) argues that today's system means that privately issued bank money (M1, referred to as inside money) represents a secure claim on central bank money (M0, referred to as outside money) and ensures singleness between these two types of money: … *The current monetary system relies on the strong perception in the non-bank sector that inside money constitutes a secure claim on central bank money. The deposit insurance system and more importantly, actual LOLR assistance in crisis times; bank supervision; and various other types of assurances by government foster this perception of a fixed exchange rate between inside money in the regulated banking sector and outside money*[35] *…*

Niepelt (2023) criticises the ECB for not adequately explaining why a CBDC is necessary for ensuring a monetary anchor for the financial system, pointing out the role played by central bank reserves in ensuring this anchor: *… The report [ECB (2022)] motivates the digital euro as an instrument to preserve the role of public money as anchor of the payment system in the digital age. But it is silent on the exact reasons why the trend decline in cash use for payment*

[35] LOLR: Lender of last resort.

purposes endangers the role of public money as anchor of the payment system … … The digitalization of payments does not change the role of central banks as lenders of last resort. Nor does it change interbank payment systems, in which banks settle by transferring central bank money (reserves). It does not, on its own, undermine the option to withdraw cash either, as long as the ECB ensures the availability of banknotes …

Armelius et. al. (2020) argues that confidence in bank money can be ensured either in that the public can hold central bank money or by bank regulation. Arguably, if the public can hold central bank money, then bank money can always be converted into central bank money ensuring singleness between central bank money and bank deposits (and hence singleness between bank deposits from different banks). However, they note that not only cash or CBDC, but also central bank reserves may ensure singleness between central bank money and bank money:

… Cash is often considered fundamental to the uniformity of money. This is because when all commercial bank money is convertible into cash at par value, one commercial bank's money automatically becomes convertible into another commercial bank's money. Convertibility into a CBDC would support uniformity of money in the same way. Thus, if cash disappears, convertibility and the uniformity of money would be maintained by a CBDC. However, cash or a CBDC are not the only mechanisms we can use to transfer money between individuals or to convert money issued by different commercial banks (or other money issuers) between them at par value. All commercial banks (and other money issuers) have access to central bank reserves, and all electronic payments are ultimately settled with central bank reserves. These facts are important parts of the mechanism to ensure the uniformity of money …[36] (our underlining)

As mentioned above, it is not obvious to us whether CBDC is necessary to ensure confidence and singleness, or whether virtually credit risk-free bank deposits and singleness between bank deposits and reserves are sufficient. We support the need for further investigation into this question. Furthermore, there are now new developments internationally with experimentation on tokenisation of assets, and a growing literature about this. The literature discusses whether wholesale-CBDC will be necessary to ensure singleness between tokenised deposits, see *Box F. Possible need for a wholesale CBDC to ensure parity between tokenised bank deposits.*

Box F. Possible need for a wholesale CBDC to ensure parity between tokenised bank deposits

There are now new developments internationally with experimentation on tokenisation of assets,[37] whereby assets are assigned a special digital representation that can be traded on new platforms/trading venues. These may be different types of assets such as securities, real estate and other fixed assets. If a trend towards tokenised assets gains momentum, the money in which trades in such assets are settled should also be tokenised.

The means of settlement between private participants on such platforms is conceived as being tokenised bank deposits, a CBDC or a stablecoin. The platform/trading venue facilitates the

[36] However, Armelius et. al. (2020) also shows that risk premia on bank deposits may cause singleness to fail. They argue that in such cases it may be necessary for the public to have access to central bank money to ensure singleness, which could be an argument to introduce CBDB.

[37] See BIS (2023), OECD (2020a, 2020b), Banque de France (2021, 2023), Panetta (2022) and Maechler and Moser (2023). ECB has announced that the bank will explore new technologies for wholesale central bank money settlement (ECB 2023b).

purchase and sale of tokenised assets and the transfer of, for instance, tokenised bank deposits between customers using so-called smart contracts, i.e. transactions can be programmed and made dependent on predetermined conditions. On such a platform, all assets must "speak the same language", i.e. they must be seamlessly tradeable given the chosen technology and programming structure. Furthermore, possible bridges between the various platforms are envisaged, so that assets can also be transferred across platforms. The process of transferring assets to digital tokens with such properties is called tokenisation, and the assets being traded are referred to as tokenised assets.

The literature contends that this tokenisation will make the payment system more efficient. The literature also highlights the need for wholesale CBDCs as a means of settlement between banks where tokenised assets are traded. Wholesale CBDCs are themselves tokenised central bank money and can be designed for use as a means of settlement between banks on the platforms. With the help of smart contracts, assets are traded, with settlement between seller and buyer and between the banks involved taking place immediately. Studies show that this will entail rapid settlement secured by central bank money and maintain the current "two-tier" structure of settlement, where bank customers transfer tokenised deposits between themselves and where banks use central bank reserves as a means of interbank settlement. On the new platforms, a wholesale CBDC takes over the role of central bank reserves. In the same way as central bank reserves ensure parity between ordinary bank deposits (cf. discussion above), wholesale CBDC may be necessary to ensure parity between tokenised bank deposits. Given the need for tokenised bank deposits and given that a wholesale CBDC is needed to ensure parity between tokenised bank deposits, then this might be an argument for introducing a wholesale CBDC (Carstens 2023, Garrat and Shin 2023). In its annual report for 2023, the BIS summarises this argument as follows:[38]

... The key elements of the blueprint are CBDCs, tokenised deposits and other tokenised claims on financial and real assets ... ... brought together in a new type of financial market infrastructure (FMI) – a "unified ledger" ... ... The full benefits of tokenisation could be harnessed in a unified ledger due to the settlement finality that comes from central bank money residing in the same venue as other claims. Through programmability and the platform's ability to bundle transactions, a unified ledger allows sequences of financial transactions to be automated and seamlessly integrated. This reduces the need for manual interventions and reconciliations that arise from the traditional separation of messaging, clearing and settlement, thereby eliminating delays and uncertainty. The ledger also supports simultaneous and instantaneous settlement, reducing settlement times and credit risks. Settlement in central bank money ensures the singleness of money and payment finality ... (emphasis ours).

However, it should be noted that introducing tokenised assets on a new type of FMI, including tokenised bank deposits and a wholesale CBDC, will be a long process. The BIS cites several challenges, not least technical and legal, but also challenges of a financial nature (Aldasoro et al 2023). The introduction of a wholesale CBDC also raises new issues with regard to the central bank's liquidity management and monetary policy. Under the current system, "normal" central bank reserves are the means of interbank settlement, and the central bank's liquidity management system underpins the overnight rate and the implementation of monetary policy. A wholesale CBDC would result in two different forms of central bank reserves. It must be assessed how these forms should interact and how different designs of a wholesale CBDC settlement system may affect liquidity management, the interbank market, the overnight rate

[38] See BIS (2023)

and thereby the implementation of monetary policy. These are issues that to our knowledge have not been discussed much in the international literature.

6. Implications of CBDC for Norges Bank's liquidity management

The central bank's policy rate decisions must be implemented to ensure that the policy rate passes through to other interest rates in the economy. The central bank achieves this by setting the terms for banks' loans and deposits in the central bank and by controlling the amount of central bank reserves in the banking system. How the central bank manages central bank reserves and formulates the terms and conditions for banks' deposits and lending is referred to as the liquidity management system. The objective of liquidity management is to keep the shortest money market rates, particularly the overnight rate, close to the policy rate. This is how monetary policy in most modern market economies is implemented.

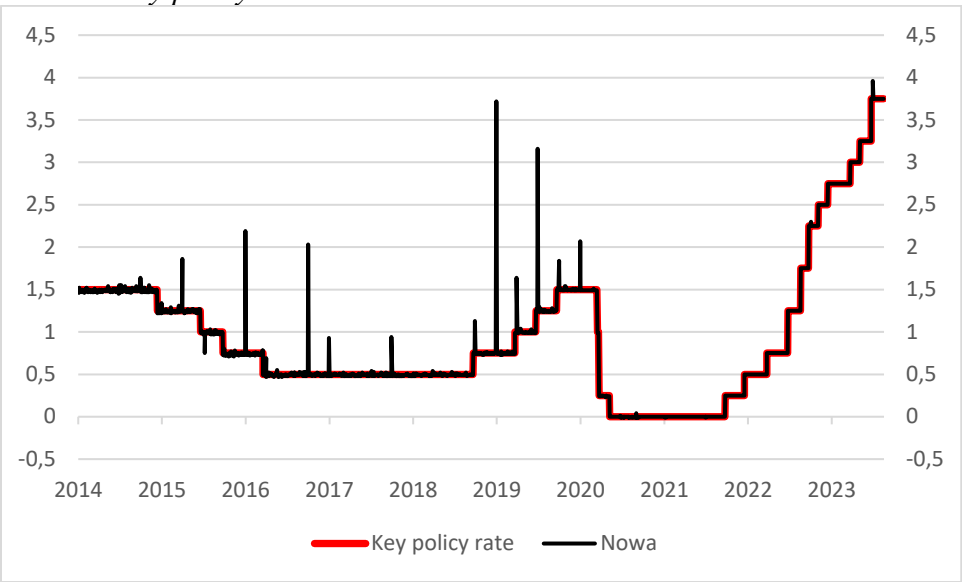
Depending on how CBDC is designed, CBDC may influence Norges Bank's liquidity management. However, given that CBDC is designed in a way that limits the macroeconomic/financial challenges discussed in this paper, we believe that the effects on liquidity management will be manageable.

Norges Bank's liquidity management is based on a quota system with tiered remuneration of reserves. Each bank is a assigned an individual quota that determines remuneration. Reserve holdings within the quota are remunerated at the policy rate, while deposits in excess of the quota are remunerated at a lower rate, the reserve rate (policy rate minus 100 basis points).[39] Norges Bank aims to keep the overall level of reserves around NOK 35 billion within an interval of plus/minus NOK 5 billion. The sum of banks' individual quotas is NOK 45 billion (total quota). If a bank has a negative balance overnight, it must draw a D-loan overnight at an interest rate equal to the policy rate plus 100 basis points (overnight lending rate). The gap between the overnight lending rate and the reserve rate, with the policy rate in the middle, constitutes the interest rate corridor in the quota system.

The quota system provides banks with incentives to keep deposits within the quota. If a bank sees that its deposits is likely to exceed the quota at the end of the day, it has incentives to lend its excess reserves to other banks that have room on their quotas. These banks have incentives to borrow the reserves as long as the rate is somewhat lower than the policy rate. The quota system gives banks incentives to redistribute reserves among themselves overnight in such a way that the overnight rate, Nowa, is quoted slightly below the policy rate, see Chart 4, which shows Nowa and the policy rate. In general, Nowa is close to the policy rate, with the exception of some quarter-ends.[40] The background for the liquidity management system, the change from a floor system to a quota system and Norges Bank's principles for liquidity policy are discussed in more detail in a separate appendix.

[39] Somewhat simplified, the size of the quota depends on the size of the bank. For example, the largest banks, which also quote the reference rate Nibor, have a quota of around NOK 5 billion, while the smallest banks have a quota of around NOK 50 million (cf. the references below for details).
[40] For details on Nowa, see Nowa - Norwegian Overnight Weighted Average (norges-bank.no)

Chart 4. Key policy rate and Nowa. Per cent. 2014-2023



Source: Norges Bank

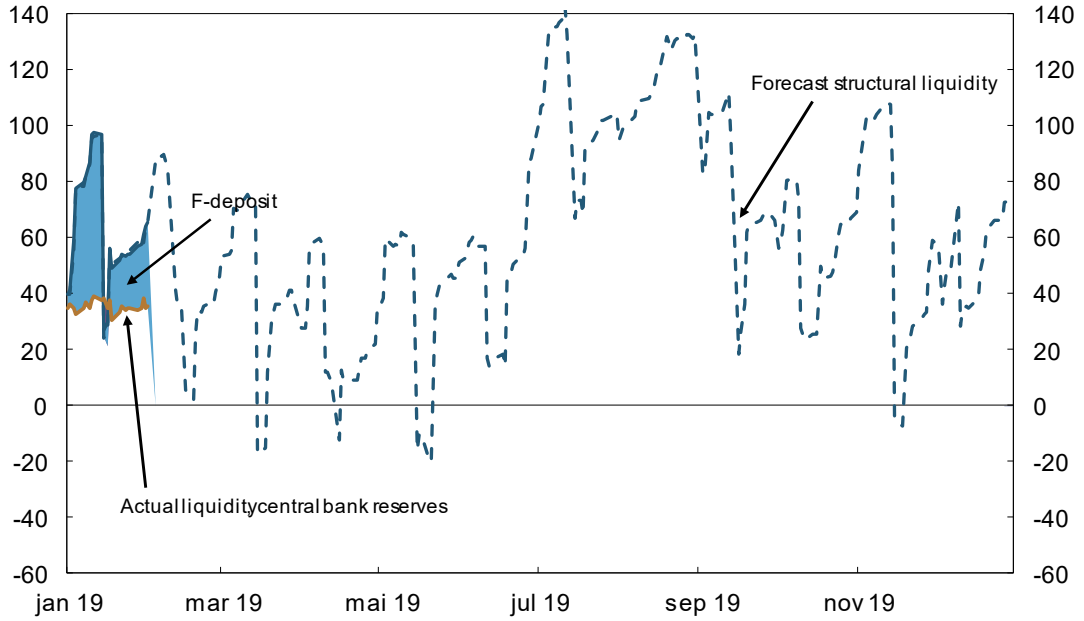
CBDC affects *structural liquidity*, which is the amount of reserves in the banking system prior to Norges Bank's market operations. Structural liquidity may be positive or negative and is determined by autonomous factors, which affect reserves in the banking system but are beyond the control of the central bank. The most important autonomous factor on Norges Bank's balance sheet today is transactions via the government's account (on the liabilities side of the central bank's balance sheet). Payments from the general public (via banks) to the government reduce banks' deposits in the central bank, while government deposits increase. This reduces central bank reserves. When payments are made from the government to the general public (via banks), the government's deposits in the central bank are reduced, while bank deposits increase. This increases central bank reserves.

In order to manage reserves in the banking system, Norges Bank prepares forecasts for structural liquidity. The forecast is an important tool in liquidity management, both for Norges Bank and the banks.[41] Based on the forecast, Norges Bank offers banks F-loans and F-deposits. The allotted amounts in the auctions of F-loans and F-deposits are determined to keep actual liquidity – central bank reserves – around the target of NOK 35 billion. The maturity of market operations is determined on the basis of the forecasts for structural liquidity and normally varies from a few days to up to a couple of weeks. If unforeseen changes occur in autonomous factors, Norges Bank can offer fine-tuning operations at the end of the day. As an example, Chart 5 shows the forecast for structural liquidity through 2019 as well as actual liquidity and outstanding F-deposits in January and February of the same year. In January and February, structural liquidity was positive, and Norges Bank withdrew surplus liquidity using F-deposits to keep the total amount of liquidity around the target of NOK 35 billion.[42]

[41] Forecast for structural liquidity is based, among other things, on general government budgets, last year's payment path via the government's account, maturity and issuance of government securities, planned foreign exchange transactions on behalf of the government as part of the petroleum fund mechanism and direct contact with officers of government institutions for exchange of detailed information.

[42] For more details on the structural liquidity forecast, see
Liquidity in the banking system (norges-bank.no)

Chart 5. Forecasts for structural liquidity through 2019, actual liquidity and outstanding F-deposits in January and February 2019. NOK billion



Source: Norges Bank

With regard to more detailed liquidity management, it is appropriate to use the daily path in Norges Bank's settlement system. This is *highly simplified!!*[43]:

At the beginning of the day:

- Banks have reserves on their account in Norges Bank, normally within the quota.
- Banks can draw on pledged collateral and take up intraday loans.[44]
- Interest payments and redemption of any F-loans/F-deposits are settled.
- Banks settle interbank overnight loans contracted the day before.

Throughout the day:

- Banks transfer reserves among themselves as a result of transactions between banks' customers. This does not change the total amount of reserves in the banking system, only the distribution of reserves between banks.[45]
- Payments to the government reduce banks' deposits (reserves), while reserves increase when payments from the government are made.

[43] The operating pattern of Norges Bank's settlement system is described in detail in a separate circular (see Operating schedule for Norges Bank's settlement system (NBO) from 13 October 2016 (norges-bank.no)

[44] Banks can draw intraday loans against collateral after a new daily separation in NBO at 4:45 p.m. to fund Real-LOM, which serves as collateral for banks' instant payments in the banks' NICS-Real payment system. Other accounts banks have with Norges Bank may be funded only after NBO opens in the morning. This has no bearing on our research question.

[45] Interbank transactions are settled in the banks' payment system NICS, which is located outside Norges Bank, and settled in central bank money (reserves) during central bank opening hours. The details of this system have no bearing on our research question, but for details, see Norges Bank's settlement system – main functions (norges-bank.no)

Towards the end of the day:

- Each bank has a given balance on its account in Norges Bank. Some banks have a positive balance, while others may have a negative balance. Depending on the net effect of autonomous factors, particularly government transactions, Norges Bank may offer banks to participate in an auction in order to adjust overall liquidity in the system. Depending on the level of structural liquidity, this will either be supply of reserves through F-loans or a drain of reserves via (F-deposits). The aim of the operations is to keep reserves around the target of NOK 35 billion.
- Banks borrow or deposit reserves with each other overnight to avoid having to use Norges Bank's standing facilities (overnight D-loans and deposits at the reserve rate).
- Intraday loans are repaid from banks' accounts, and each bank is left with an amount in the account that pays interest overnight, normally within the quota.

This process can also handle CBDC. In isolation, CBDC affects transactions as follows, cf. Section 3:

- When demand for CBDC increases, banks' reserves in the central bank are reduced: The general public converts bank deposits into CBDC, and reserves become CBDC. If banks lack sufficient reserves, banks must draw an intraday loan (against collateral). Borrowed intraday reserves are transferred from banks' accounts to the general public's CBDC accounts at the central bank (both on the liability side of the central bank's balance sheet). Towards the end of the day, banks may then have a negative balance in the central bank that must be covered by an F-loan.
- Reduced demand for CBDC increases banks' reserves at the central bank: The general public converts CBDC into bank deposits and CBDC becomes reserves. If the total amount of reserves towards the end of the day then exceeds the target of NOK 35 billion, Norges Bank offers banks F-deposits.
- A CBDC will be an autonomous factor that affects reserves in the banking system beyond Norges Bank's control, which must be counteracted through auctions of F-loans and F-deposits. This corresponds to how Norges Bank counteracts the general public's demand for cash and transactions through the government's account. However, certain challenges will still remain:

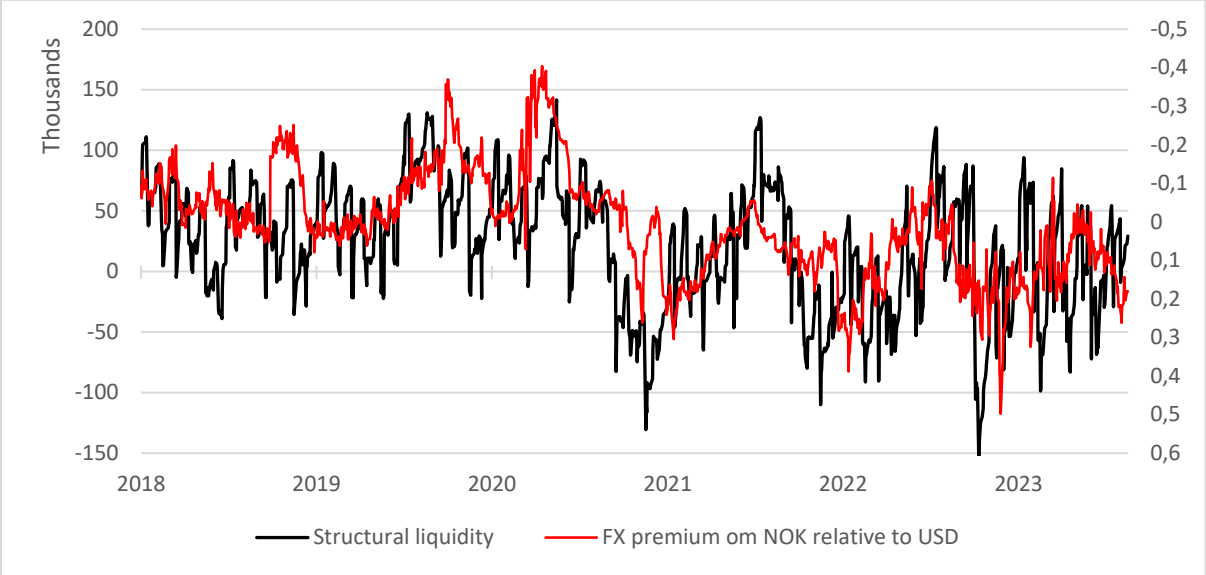
If demand for a CBDC becomes volatile, the forecast for structural liquidity may be more uncertain and subject to more shifts than at present. With CBDC as a new autonomous factor, the central bank's liquidity management may become more demanding. Banks' liquidity may become more uncertain, and Norges Bank may have to offer banks more F-loans and F-deposits and engage in more fine-tuning operations compared with today.

Moreover, it is conceivable that high demand for CBDC in some situations may make it appropriate to use longer-term F-loans in liquidity management. If demand for CBDC has a stable component, it will lead to a persistent negative shift in structural liquidity. Such a negative shift can be counteracted by F-loans with longer maturities than Norges Bank commonly uses today. On top of such longer F-loans, shorter-term F-loans and F-deposits can be used to counteract short-term fluctuations in autonomous factors. The long-term F-loans will then reflect the stable part of demand for CBDC but will not differ in principle from other F-loans. They occur as a result of a negative shift in structural liquidity and can follow ordinary procedure with regard to maturity and price. This does not imply anything new regarding liquidity management. Also today, F-loans and F-deposits with longer maturities may be used to counteract persistent changes in structural liquidity, while F-loans and F-

deposits with shorter maturities are added on top of these. But with CBDC, it is conceivable that the maturity of some F-loans will be longer than today.

More frequent and pronounced shifts in the structural liquidity forecast, and generally more uncertainty concerning structural liquidity, may affect banks' liquidity management and market adaptation. Currently a clear relationship exists between structural liquidity and the NOK scarcity premium relative to USD in the FX-swap market (Chart 6).[46] In periods when the forecast for structural liquidity is low, there tends to be increased demand from banks to buy NOK in the forward market (preferably at one- and three-month maturities). This increases the forward premium as well as the Nibor premium. Indeed, banks are aware of the fact that Norges Bank manages liquidity in the banking system so that banks' total deposits overnight - reserves - always remain near the target of NOK 35 billion. However, in a situation with low structural liquidity, there may be uncertainty as to allotment and price for individual banks. Hence in times of low structural liquidity, banks may seek predictability by acquiring longer-term NOK liquidity in the FX-swap market. High CBDC demand could amplify these effects and may influence banks' adjustments in the FX-swap market and thus premiums in short-term money market rates. High CBDC demand could also affect banks' LCRs *(*see *Box F. How does CBDC affect banks' LCRs?)* However, these factors cannot be precisely estimated.

Chart 6. Structural liquidity (left, NOK billion) and scarcity premium on NOK relative to USD in the FX swap market (right, percentage points). 2018-2023



Source: Norges Bank

As discussed in Box C, banks may be granted loans ex post, after CBDC demand has materialised, or ex ante, before CBDC demand is known. In Norway, it seems particularly problematic to supply reserves ex ante. It is unsuitable for Norges Bank to purchase

[46] The scarcity premium of NOK relative to the USD is based on covered interest rate parity (CIP). According to CIP, the return on investments in two currencies shall be equal when investments with equal risk are FX hedged. Formally, it can be expressed by the equation $i_N=i_\$+(f-e)$, where i_N is three-month Nibor, $i_\$$ is the US Dollar rate on which Nibor quoting is based, and where (f-e) is the FX premium, the difference between the forward exchange rate (f) and the spot exchange rate (e) between NOK and USD (an increase implies a weaker krone). Deviations from CIP may indicate liquidity premiums between NOK and the USD. This is discussed in further detail in Stiansen (2022).

government securities, currency or other securities (e.g. covered bonds) for this purpose. It also seems difficult to offer banks ex ante loans to meet CBDC demand ex post. Banks do not have any incentive to borrow reserves from the central bank before they need the reserves, unless the loans are offered at a particularly attractive rate. But this raises questions about the effect on the overnight rate and the central bank's interest margin on loans to banks. In addition, with a quota system like Norges Bank operates, reserves may have to be withdrawn at shorter maturities, all this just to meet an uncertain demand for CBDC. Indeed, in times of financial turbulence (for example during the coronavirus crisis in 2020), Norges Bank has offered banks long-term loans and at the same time drained reserves with F-deposits with one-day maturity. But in those cases, banks initially needed reserves and had incentives to borrow reserves from the central bank. This type of situation would be incongruous in the context of unknown demand for CBDC.

In other words, several factors may make liquidity management more challenging if CBDC is introduced. However, as discussed in Sections 3 and 4, in the interests of the financial system, limitations must nevertheless be placed on holding a CBDC, either through upper limits or through different interest rates. Constraints that sufficiently reduce the macroeconomic/financial challenges will also ease challenges pertaining to liquidity management.

In sum, the assessments concerning liquidity management are as follows:

- CBDC represents an autonomous factor influencing banks' need for reserves. Under the current system for the management of banks' reserves, the quota system, reserves in the banking system are relatively limited. In the event of increased CBDC demand, Norges Bank may have to provide banks with loans (F-loans under the current system). This may lay claim to more of banks' collateral than is currently the case and may have an impact on banks' LCR.
- Volatile demand for CBDC will likely make the structural liquidity forecast more uncertain and subject to unpredictable shifts.
- More fine-tuning market operations may be necessary to maintain reserves in the banking system around the target.
- Liquidity management will probably be more challenging but is nevertheless considered manageable. It is assumed that CBDC will be designed with a view to substantially reducing the macroeconomic/financial challenges discussed in this paper. And the more this is done, the smaller the consequences will be for Norges Bank's liquidity management.

Box G. How does CBDC affect banks' LCR?

Demand for CBDC means that banks lose customer deposits and that they must reduce their reserves in the central bank. If banks initially lack sufficient reserves, they must borrow reserves from the central bank, cf. Section 3. This affects banks' balance sheets and their LCR (Liquidity Coverage Ratio). The LCR requires banks to hold a portfolio of liquid assets of sufficient size to meet obligations arising from a 30-day hypothetical period of stress in funding markets. The portfolio shall contain highly liquid, high-quality assets that can be sold or used as collateral in a period of stress. The LCR has two components: the value of high-quality liquid assets (numerator) and total net payments during the stress period (denominator):

$$LCR = \frac{High\ quality\ liquid\ assets}{Total\ net\ payments\ next\ 30\ days} \geq 100\%$$

The effect of CBDC on banks' LCR is analogous to how transactions over the government's account affect the LCR. Demand for CBDC and payments to the government both represent autonomous factors on the central bank's liability side, affecting banks' liquidity and need for loans from the central bank in the same way.

Below we examine two situations in which banks (i) have sufficient reserves in the central bank to accommodate demand for CBDC and (ii) banks lack sufficient reserves and must borrow them from the central bank.

(i) Banks have sufficient reserves in the central bank to accommodate CBDC demand
In the event of increased CBDC demand, the general public draws on their bank deposits. Reserves must then be transferred from banks' accounts in the central bank to the general public's CBDC accounts in the central bank. On banks' balance sheets, deposits from the public and reserves are reduced equally, for example by 100, cf. Table A showing excerpts from banks' balance sheets.

Table A. Balance sheet of the banking sector (excerpt)

Assets	Liability
Δ Central bank reserves = -100	Δ Deposits from the public = -100 Δ Loans in the central bank

Reduced reserves reduce the numerator in the LCR by the same amount, in this case 100, which in isolation contributes to a lower LCR. At the same time, customer deposits from the general public are reduced. Customer deposits represent outflows in the denominator. But deposits from the public are weighted, depending on which segment of the general public sector holds the deposit. For example, if the deposit has 10 percent weight, the denominator is reduced by 100 x 0.1 =10, which in isolation contributes to increasing the LCR. In sum, in this case:

- The numerator is reduced due to less reserves, Δ*Central bank reserves = -100*
- The denominator is reduced due to lower customer deposits, Δ*Deposits from the public = -10*

The LCR drops because the numerator decreases much more than the denominator. When demand for CBDC increases, forcing banks to reduce central bank reserves, banks' LCRs fall.

(ii) Banks must borrow reserves from the central bank
Suppose banks lack sufficient reserves in the central bank to accommodate public demand for CBDC. Banks must then borrow reserves from the central bank, cf. Table B, in which the public transfers 100 from bank deposits to CBDC and banks borrow 100 from the central bank. On banks' balance sheets, central bank funding replaces deposit funding. Banks' reserves remain unchanged. Banks hold the same amount of reserves at the end of the day as at the beginning of the day because we have assumed that the central bank accommodates demand for CBDC by providing loans to banks.

Table B. Balance sheet of the banking sector (excerpt)

Assets	Liability
Δ Central bank reserves = 0	Δ Deposits from the general public = -100 Δ Loans in the central bank = 100

As regards LCR, the change in the denominator is the same as in the example above. Banks lose customer deposits equivalent to 100, reducing denominator outflows by 10. The effect on the numerator is determined by the types of collateral banks provide for the loan in the central bank:

- If banks pledge securities that are defined as HQLA under the LCR, the numerator is reduced by 100 and the denominator by 10, and the LCR falls "considerably". This produces the same effect as the effect of forfeited reserves.

- Banks can also pledge securities that are liquid but less liquid than HQLA. HQLA reduce the numerator in the one-to-one ratio. Other assets may be liquid but have a lower weight in the LCR. For example, a security with a value equal to 100 and an LCR weight of 50 percent will only be included with 50 in the numerator. If such securities are pledged, the LCR still decreases, but less than if banks pledge the most liquid securities.

In general, banks will want to pledge securities that are, in the following order of priority, (i) illiquid assets under the LCR, (ii) liquid assets weighing less than 100 and (iii) highly liquid assets weighing 100. This is because banks want to pledge securities without reducing the LCR. How banks adjust their balance sheets to provide satisfactory collateral for loans from the central bank and to satisfy the LCR requirement is a broad theme that is not further discussed here. But the isolated effect of CBDC will be a reduced LCR.

CBDC can also indirectly influence banks' LCRs through other channels as a result of banks' adjustments. Above, we assumed that CBDC only led to customer deposits being replaced by central bank financing. As discussed in Section 3, CBDC may also influence banks' financing structure more generally. Banks may want to increase their share of long-term funding to reduce the liquidity risk associated with increased demand for CBDC (but take note that this will only change the composition of whatever funding they have left, not provide new funding for the banking system as a whole, ref discussion in Box B). In general, any bank measures to reduce liquidity risk will also improve the LCR.

7. Potential effects of CBDC on monetary policy

7.1 Background: What will determine demand for CBDC?

As a background for discussing the potential effects of CBDC on monetary policy, it may be useful to discuss which factors that are likely to influence CBDC demand. As discussed in the introduction, the general public currently has access to two means of payment in NOK: bank deposits and cash. Introducing CBDC will add a third alternative.[47] Assuming positive demand, CBDC will have to take market shares from bank deposits and/or cash.[48] Bank deposits currently account for about 98 percent of the money stock and are thus the most relevant alternative to CBDC. Besides, in our discussion, substitution from bank deposits to CBDC is the most interesting case, since it may have significant implications for the financial system, cf. Section 3. Substitution from cash to CBDC will not imply the same risks for the financial system.

[47] New means of payment such as stablecoins or e-money based on NOK may constitute additional alternatives but are not discussed here.

[48] This is because a CBDC should not be created through credit, as is the case for bank deposits. The general public can only obtain a CBDC by equally reducing its holdings of bank deposits or cash.

It is reasonable to assume that the public's demand for CBDC will depend on the features of CBDC *relative to other available means of payment*, primarily bank deposits. The relative features can be divided into three dimensions: safety, liquidity and return. These three dimensions are discussed in further detail below and are assumed to encompass the main features that the general public cares about when choosing between payment assets.

- **Safety**: Obviously, a safe payment asset is preferable to a less safe one. Several factors determine how safe the storage and use of a payment asset is perceived to be:
    - *Credit risk*. By definition, CBDC has zero credit risk, while bank deposits *can* be perceived as having credit risk, at least for amounts exceeding the deposit guarantee. Thus, the relative ratio is determined by the credit risk associated with bank deposits. The deposit guarantee provided by the Norwegian Bank's Guarantee Fund is clearly significant to how the general public perceives the risk degree associated with bank deposits. As long as the guarantee is credible, it implies that the credit risk for bank deposits is zero up to the limit of NOK 2 million per bank. This suggests that relative credit risk is not particularly important for ordinary customers' demand for CBDC. Only those holding large deposits may place emphasis on this.
    - Safety can also be affected by *exchange rate risk* between different means of payment. However, this is irrelevant here as we only compare means of payment in NOK with credible uniformity.
    - If a token solution without a register is chosen for a CBDC, so that a CBDC *can be lost*, this will reduce the safety relative to bank deposits.
    - *Privacy and anonymity* considerations may also be relevant for the perceived safety of a payment asset. If a CBDC is designed to ensure anonymity, some users may see this as an advantage over bank deposits. The same may apply in a (hypothetical) situation where data for payment with deposits are used commercially, for example for targeted marketing, while data for CBDC payments are not.

- **Liquidity**: How liquid a user is when holding a payment asset is determined by whether the asset can be used to settle all kinds of payment transactions, or if limitations exist. Some examples of transactions are settlement between private individuals, purchases at retail outlets, e-commerce and tax payments. Liquidity is also affected by whether the means of payment allows for final settlement around the clock, or whether it is limited to certain periods of time, as well as the costs associated with making the payments. In Norway, bank deposits are now a highly liquid means of payment. Technology such as mobile banking and Vipps implies that bank deposits can be used for virtually all types of transactions.[49] Vipps also allows transactions with final settlement to be carried out at no cost around the clock, at least within the boundary of certain amount limits. The relevant measure of CBDC liquidity thus depends on the convenience of using CBDC relative to bank deposits in various payment situations. That, in turn, depends on the chosen technical solutions for CBDC.

[49] For cash, liquidity is more limited. For example, the public cannot pay taxes, shop online, or pay bills with cash without first converting them into bank deposits.

- **Return** is determined by the interest rate that can be obtained by lending the means of payment, without taking risk. The relevant measure is the relative interest rate on bank deposits and CBDC.

Based on this, we can imagine the following demand function for CBDC relative to bank deposits:

$$E_{CBDC/Deposits} = f((safety\ deposits - safety\ CBDC), (liquidity\ deposits - liquidity\ CBDC), (return\ deposits - return\ CBDC))$$

The way the function is formulated here, CBDC demand will depend negatively on all three arguments.

It is difficult to rank the importance of the three arguments in the demand function. However, we find it reasonable to assume that safety will have a fairly small impact on demand for CBDC relative to bank deposits. This is due to both the deposit guarantee and an assumption that the general public generally does not perceive bank deposits as particularly problematic in terms of privacy and anonymity. The principal issue concerning safety is probably whether a CBDC is designed in such a way that it can be lost.

Relative liquidity between CBDC and bank deposits will probably be more important for demand. A CBDC that can only be used for payment to others who are registered CBDC users will be less liquid than a CBDC with full interoperability against bank deposits. A CBDC that cannot be used for bill payments and online shopping may also see low demand relative to bank deposits. On the other hand, it is conceivable that CBDC will eventually offer functionality that bank deposits lacks, for example by being programmable for use in smart contracts. It is also conceivable that CBDC will provide more efficient cross-border payments than bank deposits. Such functionality will, when taken in isolation, strengthen CBDC in competing with bank deposits as a means of payment.

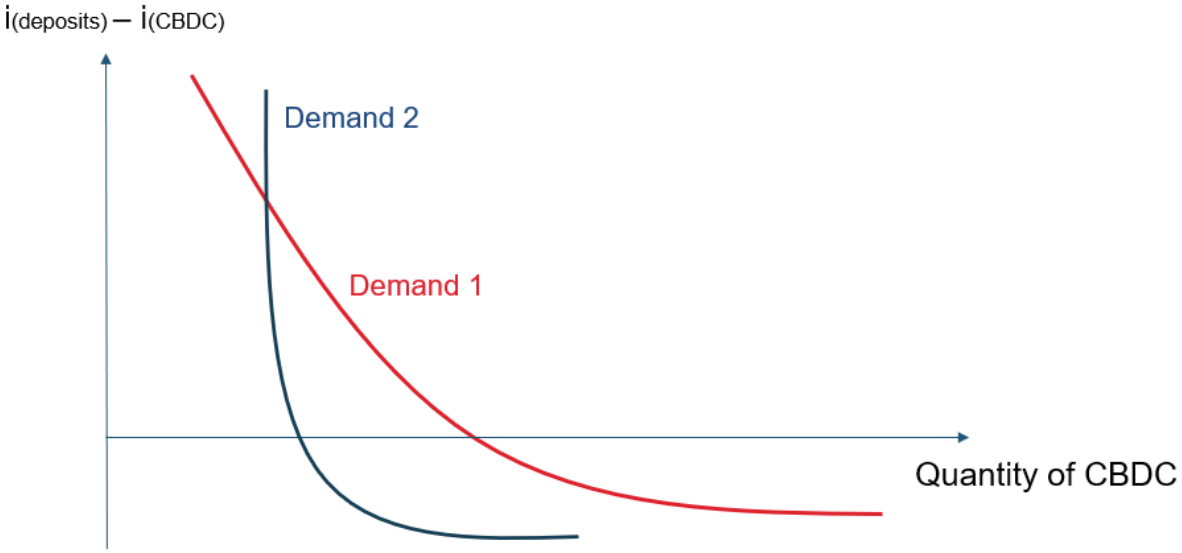
The relative return between bank deposits and CBDC is also likely to affect demand for CBDC, but to what extent is difficult to assess. For the (analogue) central bank money we already have – cash – interest rate sensitivity appears to be minimal. This is illustrated by the continued decline in demand for cash, also during the recent years when interest rates on bank deposits fell towards zero. The explanation is probably that the public perceives bank deposits as sufficiently safe, while the relative liquidity of cash has declined significantly over time. As a result, cash is perceived as a diminishing near substitute for bank deposits.

A payment asset can also be used as a store of value. If CBDC is designed in a way that makes it attractive as a store of value, the relative importance of the arguments in the demand function may be different than argued above. Relative liquidity will probably be less important, while safety and return will mean more. For example, CBDC may be sought after by professional investors who do not benefit as much from a deposit guarantee scheme as private individuals.

The purpose of this setup is not to quantify the demand function for CBDC, but rather to adopt a framework for discussing the potential effects of CBDC on monetary policy. With four variables, demand cannot be represented graphically, without keeping some of the factors that are assumed to affect demand constant. For given levels of relative security and relative

liquidity, CBDC demand as a function of relative return against bank deposits can be illustrated in a standard chart:

Chart 7. Demand for CBDC as a function of relative return against bank deposits



In the diagram, we have drawn up two alternative demand curves. "Demand 1" illustrates a design in which CBDC offers functionality similar to bank deposits, making them fairly close substitutes. It is then conceivable that CBDC demand is sensitive to relative return. "Demand 2" illustrates a design where CBDC is more similar to physical cash, with areas of uses that overlap less with bank deposits. One could then imagine that demand is less sensitive to relative return.

The above discussion illustrates that CBDC demand will be determined by more than just relative return. In a diagram such as the one above, the location and shape of the demand curve will be determined by CBDC's relative safety and relative liquidity. Those features, in turn, are the result of all the detailed design choices that need to be made for CBDC.

7.2 How can CBDC influence monetary policy space?

In today's financial system, it is the existence of cash that gives rise to a lower bound for nominal interest rates. If the interest rate on deposits is sufficiently low, it may be attractive for depositors to replace their deposits with cash, which has a fixed nominal interest rate of zero. On a sufficiently large scale, such behaviour may trigger a banking crisis.

For households and firms, it is banks' deposit rates, and not the central bank's interest rates, that determine whether cash is an attractive alternative. As discussed above, we have experienced in recent years that demand for cash remains insensitive to changes in deposit rates all the way down to zero. However, the sensitivity may change if nominal deposit rates turn negative.[50]

The risk of increased cash demand in the event of negative deposit rates is probably greatest in sectors that can withdraw and store cash at relatively low cost. There is reason to believe that households fall into this category. For a household, it may be relatively inexpensive to

[50] If "Demand 2" in Chart 7 expresses demand for cash relative to bank deposits, this will be expressed by making the demand curve's elasticity higher (flatter curve) for values on the y-axis below zero.

buy a safe or rent a safety deposit box for storing cash. For larger firms, which tend to hold considerably larger amounts, the costs may prove higher. In countries that had negative policy rates for several years, such as Denmark and Switzerland, there were signs that the banking sector internalised this type of behaviour from its customers: The interest rate on deposits from ordinary households was generally not set below zero, while it was more common for large firms to face negative deposit rates.[51]

As a result of such behaviour on the part of banks, the pass-through from the policy rate to banks' deposit rates diminishes when the policy rate turns negative. Since retail deposits, which are an important component of banks' funding, are not becoming less costly, the pass-through to lending rates will also be smaller. Nevertheless, if the central bank continues to reduce its interest rates considerably below zero, banks will have to pay an increasing amount for their deposits in the central bank without being able to pass on this cost to their deposit customers. The result may be that the pass-through to lending rates comes to a complete halt and goes into reverse, resulting in an increase in lending rates. It is uncertain where this lower bound for the policy rate pass-through lies, and the lower bound will probably vary across countries.

The question then is whether the introduction of CBDC can reduce monetary policy space by increasing the lower bound for the policy rate's pass-through to bank rates. The answer will depend on how CBDC is designed. In the first instance, it is useful to distinguish between two cases, differing with regard to whether a CBDC is interest-bearing or not.

a) Non-interest bearing CBDC

This type of solution could make a CBDC resemble physical cash. Nevertheless, one cannot be certain that demand for CBDC will be the same as demand for cash. This will depend on which features the CBDC offers with regard to safety and liquidity. In an account system or a register-based token system, CBDC cannot be lost in the same way as cash. This initially makes CBDC more suitable as a store of value. Without any other restrictions on ownership, a CBDC may seem to be an attractive alternative as a store of value when interest rates are low, particularly for bigger agents who have less use of the deposit guarantee scheme.

Under the current system with physical cash, the mechanisms discussed above imply that a negative policy rate does not translate into a significantly negative deposit rate for households. But at the same time, other countries' experience indicates some pass-through to corporate deposit rates and a good pass-through to yields on government bonds and other fixed income securities. This may change with CBDC. If large firms and professional investors can avoid negative returns by purchasing a CBDC, the overall transmission of a negative policy rate will be reduced.

Furthermore, one cannot rule out that household demand for non-interest bearing CBDC will be more sensitive to the interest rate on bank deposits than current cash demand is (ie more similar to "Demand 1" in Chart 7 above).[52] The pass-through from the policy rate to household deposit rates may then also weaken, as banks internalise that demand for CBDC reacts more to deposit rates than is the case for cash demand today. In a monetary policy

[51] For the Danish case, see Kuchler et. al. (2020) and Adolfsen and Clasp (2020).
[52] This may occur if a CBDC becomes a substantially more liquid means of payment than cash is now, cf. the discussion on demand above. A CBDC will then become a more equitable alternative to bank deposits, so that relative return may produce a greater impact on relative demand.

expansion, banks can become more hesitant to reducing their deposit rates out of fear of losing deposits, even when the policy rate remains positive. Correspondingly, in a monetary contraction, banks will internalise that an increase in their deposit rates may attract more deposits at the expense of CBDC. It is hard to say how this can affect the pass-through from the policy rate, and if the effect will be symmetrical for policy rate hikes and cuts.

Overall, a CBDC without interest or other mechanisms for limiting demand may change the pass-through from the policy rate to banks' rates and entail a risk of a narrower monetary policy space.

b) Interest-bearing CBDC

At the outset, interest-bearing CBDC solves the problem. The central bank can use the interest rate on CBDC to steer demand, given CBDC's other features relative to bank deposits. As discussed above, features like safety and liquidity determine the location and shape of the demand curve, and thus the level of the interest rate differential necessary to bring CBDC demand within a "desired range". When the policy rate is changed, the CBDC interest rate can be changed to the same extent, so that the interest rate differential (IRD) between bank deposits and CBDC is preserved in the case of full pass-through from the policy rate to banks' interest rates.

However, as discussed above, the demand for CBDC can increase substantially in a financial crisis with loss of confidence in the banking system. In our framework, this will be reflected in a fall in the perceived safety of bank deposits relative to CBDC and result in an outward shift in the demand curve for CBDC in Chart 7. The interest rate may have to be used aggressively to counter such a shift. Whether this is feasible in practice and what the political consequences may be remains an open question.

Using the interest rate to regulate demand is probably somewhat easier under a two-tier interest rate system as discussed in Section 4, see also Bindseil (2020). In order to be resilient to a crisis, the sum of the individual CBDC limits must be calibrated so that capacity exists to replace full use of the limits with central bank lending, without significant problems arising linked to banks' provision of collateral. At the same time, communication efforts are needed to foster legitimacy for the lowest interest rate to be negative, and perhaps considerably negative in a crisis.

Overall, interest on CBDC appears suitable as an instrument for regulating demand (which depends on many elements and is very hard to assess in advance). Since a negative interest rate on CBDC may be required to counteract shifts in demand, a two-tier interest rate system would likely be preferable.

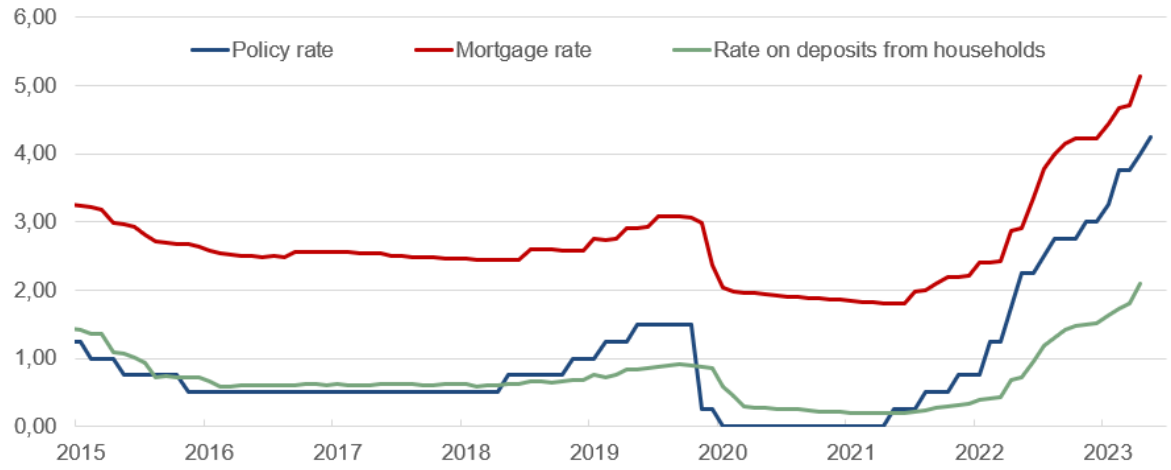
7.3 Interest-bearing CBDC as a monetary policy instrument and the effect on the transmission mechanism

The policy rate under the current system in Norway is the sight deposit rate, which is the interest rate banks receive on their deposits up to the quota in the liquidity management system, cf. discussion in Section 6. Banks that have deposits in excess of their quota towards the end of the day can lend the surplus in the interbank market or bid for F-deposits at an interest rate that normally lies just below the sight deposit rate. Under this system, the sight deposit rate guides the overnight rate in the interbank market. The overnight rate in turn forms

the basis for money market rates with longer maturities and for banks' interest rates to their customers. Under the current system, monetary policy is implemented by ensuring that the shortest money market rates, particularly the overnight rate, are kept close to the policy rate.

Chart 8 below shows the policy rate and banks' average deposit and lending rates to households since 2015. The chart illustrates that banks' interest rates follow the development in the policy rate, but that the pass-through is not always 100 percent. During the monetary tightening that started in the fall of 2021, the policy rate has increased by more than 4 percentage points. The mortgage rate has to a large extent followed suit, while the average household deposit rate has increased considerably less. The deposit rate went from being somewhat higher than the policy rate at the outset to be considerably lower. The same pattern was evident during the previous cycle of monetary tightening, from September 2018 to September 2019.

Chart 8. Policy rate and banks' deposit and lending rates to households. May 2015-Sep.2021. End of month. Per cent



Source: Statistics Norway and Norges Bank

Some contributions to the literature argue that the CBDC interest rate may be a new monetary policy instrument and that CBDC can strengthen the transmission of monetary policy, see for example Meaning et. al (2018). In addition, an extensive academic CBDC literature exists, largely based on DSGE models, that discusses how a CBDC can be used as a monetary policy instrument (see references in Box D). However, conclusions on the benefits and costs of a CBDC as a monetary policy instrument depend on the theoretical model formulation used in the analysis, cf. discussion in Section 1.

In order to illustrate how a CBDC can be used as a new monetary policy instrument and strengthen the transmission mechanism, we consider a setup that deviates from those discussed so far. This setup is characterised by:

1. Account-based CBDC where anyone can open an account in the central bank.
2. No limitations on the amount of CBDC that can be held.
3. The interest rate on CBDC is set at the same level as the policy rate.
4. Monetary policy is implemented with a floor system.[53]

[53] See Box H for a more detailed description of the floor system.

If all market participants can obtain the policy rate on their deposits, this will most likely limit how low banks will set their deposit rates relative to the policy rate. It is conceivable that the policy rate would then become a "hard floor" for banks' deposit rates offered to households and firms. This occurs because banks assume that they may lose a large share of their deposits to CBDC if they set their deposit rates lower than the policy rate. Such behaviour will mean that changes in the policy rate will have a more rapid and pronounced impact on banks' deposit rates than today. A swifter and more pronounced pass-through to deposit rates would also imply a higher and faster pass-through to lending rates. That reflects that the margin between banks' lending and deposit rates is likely to be unaffected by an introduction of CBDC. This margin is determined by other factors, like the degree of competition between banks. It thus seems likely that an introduction of CBDC as described above will lead changes in the policy rate to have a more rapid effect on both deposit and lending rates than is the case today. This will strengthen monetary policy transmission. Nevertheless, the economic significance of this enhanced pass-through is uncertain. At present, the pass-through from the policy rate to banks' interest rates is also relatively high, even though it takes some time before the full effect is achieved.

Under a system such as the one outlined above, banks' interest rates, both for deposits and loans, may on average be higher relative to the policy rate than they are now. These higher spreads can be counteracted by a somewhat lower policy rate over time. However, it may increase the effective lower bound for the policy interest rate, particularly if corporates can hold CBDC, cf. the discussion of the lower bound above. Any effects on the lower bound also depend on whether cash continues to exist and to what extent it will be feasible to set the policy/CBDC rate below zero.[54]

Whether banks will perceive the CBDC interest rate as a binding floor for deposit rates also remains uncertain. As discussed above, it depends on the shape of the demand curve for CBDC. If CBDC becomes an illiquid means of payment compared with bank deposits, customers may choose to keep most of their liquid assets as deposits in commercial banks even if the CBDC interest rate is higher than the rate on bank deposits.[55] In general, there is reason to believe that the CBDC rate will be more binding on banks' deposit rates the closer substitutes CBDC and bank deposits become.

In summary, some benefits may be gained from using the CBDC interest rate as a monetary policy instrument. This comes in the form of faster and perhaps stronger pass-throughs to retail interest rates. On the other hand, this type of solution could cause the beforementioned risks to the financial system to materialise. If the CBDC interest rate is to be used to steer aggregate demand in the economy, it cannot simultaneously be employed to regulate CBDC demand.

Similar considerations are pointed out by Bindseil (2020):

... From the practical perspective of central bank operations, the remuneration rate of CBDC may be perceived less as an independent monetary policy instrument, but more as an instrument similar to the other spreads between ECB policy rates and the remuneration rates of specific deposit accounts. These rates (or spreads relative to the policy rate) may pursue

[54] As discussed above, it can prove politically difficult to set negative interest rates on the public's CBDC deposits.

[55] In Chart 7 above, this can be illustrated by the following: "Demand 2" continues with approximately the same slope also some distance below zero along the y-axis.

specific objectives in terms of incentivizing behaviours of those for which these rates are relevant, including e.g. incentives to rely on the central bank vs. relying on market-based alternatives, with repercussions on the central bank balance sheet and on market functioning. They are not perceived as independent contributors to the monetary policy stance. The (overnight) interest rate on central bank reserves anchors the short end of the risk-free yield curve, and has established itself as the one and only operational target of monetary policy …

… The various central bank operations rates … … are all not perceived as independent monetary policy rates. What matters for monetary policy at the end is the level of short-term market rates, and in particular the overnight interest rate on bank reserves with the central bank, as anchor of all other market interest rates. This principle should not change with the introduction of a CBDC …

Overall, we doubt that a significant net benefit can be achieved from using the interest rate on the CBDC as a monetary policy instrument. The potential gross benefit through more effective transmission from the policy rate to retail interest rates is probably limited and may be outweighed by the potential costs of giving up the interest rate as a tool for regulating CBDC demand.

Appendix: Background for the quota system and principles for liquidity management

In this appendix, a more detailed account is provided of the background for Norges Bank's liquidity management system, the quota system. We place particular emphasis on the transition from the floor systems to the quota system in 2011 and the principles for liquidity management established by the monetary policy and financial stability committee. The reason for this is that some of the macroeconomic/financial challenges associated with CBDC, as discussed in this paper, can be addressed by supplying banks with more reserves or by introducing a floor system. However, this may conflict with the reasoning behind the 2011 revision and with the liquidity management principles.[56]

A.1 Norges Bank's quota system and the transition from a floor system

As discussed in Section 6, in the quota system banks are paid interest on a certain amount of reserves overnight at the policy rate up to a set quota.[57] Deposits in excess of the quota bear interest at a lower rate (the reserve rate), while the interest rate for borrowing reserves overnight (the D-loan rate) is higher than the policy rate. Under the quota system, banks have incentives to redistribute reserves among themselves overnight in order to keep deposits below the quota. The quota system contributes to an efficient overnight market for central bank reserves.

The quota system replaced a floor system in 2011 and can be seen as a trade-off between a corridor system and a floor system. Under a floor system, banks can hold unlimited deposits at the policy rate, while the central bank in a corridor system (without reserve requirements) aims to keep reserves in the banking system at zero, or marginally greater than zero. One advantage of a quota system rather than a corridor system is that moderate changes in reserves do not necessarily feed into money market rates as long as banks' deposits remain within the quotas. If, on the other hand, the supply of reserves exceeds the sum of banks' quotas, the interest rate in the overnight market may rapidly plummet towards the reserve rate. This

[56] Norges Bank's liquidity management system is thoroughly documented in a number of publications and on the Bank's website. Here we refer to Norges Bank (2021b) and
The liquidity management system (norges-bank.no)

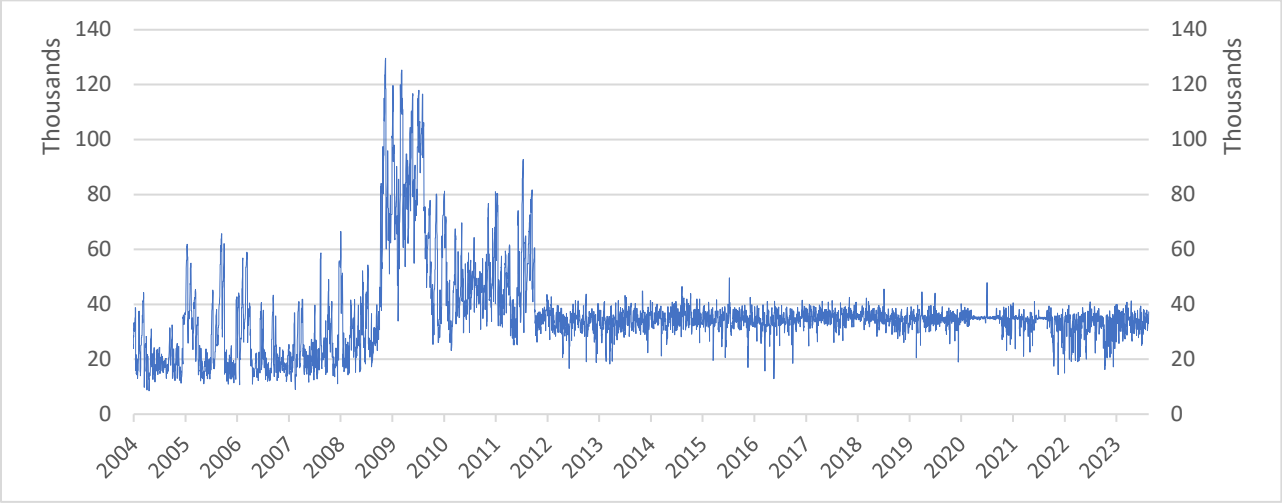
[57] The quotas are calculated twice a year and published in circulars, see
Quotas in the system for the management of bank reserves (norges-bank.no)

occurs because banks will seek to lend reserves to other banks in the overnight interbank market instead of holding reserves in the central bank at the reserve rate. As a consequence, the overnight rate may drop.[58] Under a quota system, it is thus important that the central bank manages reserves so that banks' total deposits in the central bank are kept around the target level and below the sum of banks' quotas. For a more in-depth discussion of corridor and floor systems, see *Box H. Corridor and floor systems in liquidity management,* Bernhardsen and Kloster (2010) and Bernhardsen, Kloster and Syrstad (2016). As regards liquidity management, Borio (2023) argues that countries currently using floor systems should consider re-introducing their initial corridor systems.

In Norway, the above-mentioned reasons make the quota system more suitable than a corridor system, primarily because the government holds an account with Norges Bank. As discussed in Section 6, reserves are affected by transactions over the government's account, which Norges Bank counteracts through market operations aimed at steering central bank reserves towards the target of NOK 35 billion. Nevertheless, on a day-to-day basis some variations will occur in banks' deposits overnight in the central bank, and the quota system "tolerates" changes in banks' deposits (within the quotas) with little effect on the overnight rate.

Two main objectives motivated the transition from a floor system to a quota system: To constrain demand for central bank reserves and to contribute to an efficient distribution of central bank reserves among banks in the overnight market. With the introduction of the quota system in 2011, the amount of central bank reserves was reduced from NOK 50-60 billion to between NOK 30 and 40 billion, the new target for reserves (*Chart A1*). The transition from the floor to the quota system has also increased the redistribution of reserves across banks overnight. In line with stronger incentives to distribute liquidity from banks with surplus liquidity to banks facing liquidity shortages, both volume and number of transactions have increased.[59]

Chart A1: Banks' deposits in Norges Bank overnight (central bank reserves). 2004-2023. NOK billion



[58] Note that central bank reserves can only be transferred between banks' accounts in the central bank, which is a closed system. If some banks lend reserves to other banks to avoid using the central bank's overnight deposit facility, deposits are just transferred to other banks. Total amount of reserves in the banking system remains unchanged. But the desire to hold less reserves in the central bank over-night and to supply more in the inter-bank market produces a price effect: the interest rate in the overnight market falls.

[59] See Akram and Finboy (2021).

A.2 Norges Bank's liquidity policy principles and the role of central bank reserves
In a quota system, as in a corridor system, it is expensive for banks to hold large deposits in the central bank, as deposits above the quota bear interest at a rate lower than the policy rate (deposits above zero in a corridor system). Under the quota system, central bank reserves shall in normal times primarily serve as a means of settlement between banks and not as a store of value. This must be seen in the context of Norges Bank's principles for liquidity policy, where the objectives are: (1) ensure a high degree of pass-through from the policy rate to market rates, (2) facilitate an efficient payment system, (3) offer liquidity insurance and be lender of last resort, and (4) provide a framework for liquidity and credit risk to be borne as far as possible by private agents in the financial system. The first three objectives can be achieved under a system with an ample supply of central bank reserves (such as a floor system). However, if it is emphasised that risk is to be borne by private market participants (point 4), holding central bank reserves as a liquid and value-retaining asset must be more expensive.

The objective that risk should be borne by private market participants reflects a view that central banks should have a low risk tolerance. High risk on the central bank's balance sheet must be borne by the taxpayers/people, and decisions that entail high risk on the central bank's balance sheet should be taken by the people's elected representatives. If banks can borrow large reserves from the central bank at a low price, banks can transform securities pledged as collateral into highly liquid assets (central bank reserves). This may result in considerable risk being transferred from the banking system to the central bank. The central bank's risk will be small if the credit risk on the collateral is low, and the loan value is reduced (haircut). In practice, however, it is difficult for the central bank to eliminate this risk fully. The more reserves the central bank has to offer banks via loans, the more credit risk the central bank may be exposed to.

The principle of risk allocation between private market participants and the central bank must also be viewed in the light of regulatory liquidity and capital requirements that the authorities impose on banks. Much of the motivation behind the authorities' regulation is to ensure that banks arrange their balance sheets so that they can manage risk on a substantial scale without receiving liquidity from the central bank or other public authorities. The transfer of risk to the central bank in particular, or the government in general, should be limited. *The central bank's liquidity policy should support this principle, i.e. contribute to the risk being borne by the private banking system.*

In line with this view, central bank reserves should primarily constitute a means of settlement for banks, ie, a liquidity management instrument that ensures an efficient payment system and guarantees broad transmission of monetary policy. In times of financial turbulence, where the central bank may supply large amount of reserves implying that reserves temporarily can be used as a store of value to a large extent, the supply of reserves should be priced discretionary (depending on the situation) and not be a consequence of the ordinary orientation of liquidity policy. The liquidity management system should therefore be organised so that banks, and more generally Norges Bank's counterparties, lack incentive to use central bank reserves as a store of value to a great extent. In line with this, Norges Bank's counterparties are subject to terms and conditions for account management so that they do not have incentives to hold large deposits in the central bank.

The quota system takes into account the fourth objective of liquidity policy and facilitates liquidity and credit risk being essentially borne by private market participants. The reason is that the quota system entails limited reserves in the banking system and because banks lack incentives to demand reserves involving deposits in the central bank above the quota.

Norges Bank's principles for liquidity management mean that CBDC should be designed primarily as a means of payment and not as a store of value. With a CBDC as a store of value, demand for CBDC may become substantial and the central bank may have to accommodate CBDC demand by providing large loans to banks. Then, risk on the central bank's balance sheet may increase correspondingly. Designing a CBDC primarily as a means of payment and not as a store of value is in line with international recommendations and Norges Bank's assessments relating to the potential introduction of a CBDC, cf. Section 3.

Box H. Corridor and floor systems in liquidity management

Corridor system

In a corridor system, the policy rate is (normally) midway between the interest rate on the central bank's overnight lending rate (upper limit in the corridor) and the interest rate on the central bank's overnight deposit rate (lower limit in the corridor). The central bank aims to maintain reserves at zero. [60] Towards the end of the day, some banks show a positive balance in their central bank account (surplus of reserves), while others show a negative balance (reserve deficit). Banks may show a negative balance towards the end of the day because they borrow reserves from the central bank throughout the day (intraday loans), which are transferred to other banks' accounts at the central bank. Banks with surpluses have incentives to lend reserves to deficit banks (and vice versa), otherwise surplus banks must deposit reserves overnight at the central bank's deposit rate, and deficit banks must borrow reserves overnight at the central bank's lending rate. If banks do not borrow reserves from each other overnight, banks are forced to use the central bank's standing facilities overnight, which proves expensive for banks. The market in which banks borrow and lend reserves overnight is referred to as the overnight market and the interest rate quoted is referred to as the overnight rate. Under a corridor system, banks have incentives to use central bank reserves *solely as a means of payment and not as a store of value*.

Factors that influence central bank reserves, but lie beyond the control of the central bank, are referred to as autonomous factors. The most common autonomous factors are transactions via the government's account (if the government holds an account in the central bank) and notes and coins. Payments to the government (taxes, fees, etc.) are transferred from banks' accounts to the government's account, thereby reducing banks' deposits (reserves). When payments from the government are made, transfers are made from the government's account to the banks' accounts, resulting in an increase in banks' deposits. Moreover, banks pay for notes and coins by drawing on their deposits in the central bank, resulting in a decrease in reserves.

The central bank controls the amount of reserves in the banking system by using market operations. If reserves are supplied to the banking system as a result of autonomous factors, the central bank must offer deposits to banks to keep reserves at zero. If reserves are withdrawn from the banking system, the central bank must offer banks loans (corresponding to F-loans and F-deposits in Norway). [61] Normally, the interest rate on these loans and deposits lies close

[60] In practice, the central bank tends to steer towards a level marginally greater than zero, but this is disregarded here. In a corridor system with reserve requirements, the central bank aims to keep reserves at the level determined by the reserve requirement.

[61] The central bank can supply reserves by purchasing securities or currency and withdrawing reserves from the banking system by selling securities or currency. Internationally, repos are also common in central bank liquidity management.

to the policy rate. Banks have incentives to participate in these market operations because some banks would otherwise be forced to use the central bank's overnight standing facilities.

In a corridor system, it is important that the central bank manages to steer reserves towards the target of zero. The reason for this is that small changes in reserves can influence the overnight rate and hence the implementation of monetary policy. For example, if reserves exceed zero, some banks must deposit these overnight at the central bank's deposit rate. As an alternative, these banks will attempt to lend reserves to other banks, preferably at an interest rate considerably lower than the policy rate, in order to avoid having to use the central bank's overnight deposit facility. This implies that the overnight rate falls, disrupting the implementation of monetary policy.

Floor system

Under a floor system, the policy rate is equal to banks' deposit rate in the central bank. In order to keep the market rate close to the policy rate, the central bank must supply the banking system with reserves that are high enough to push the market rate down towards the central bank's overnight deposit rate. The amount of reserves in the banking system is then considerably greater than zero. A floor system provides the central bank with two independent instruments, the policy rate and the amount of reserves in the banking system. The central bank can supply reserves to the banking system without the overnight rate falling below the policy rate.[62]

The essence of a floor system – unlike a corridor system – is that the alternative cost for banks of holding surplus reserves at the central bank is low. While banks in a corridor system must deposit surplus reserves at a low interest rate in the central bank, all reserves are remunerated at the policy rate in a floor system. Through the central bank's market operations, banks can borrow reserves from the central bank at an interest rate only marginally higher than the policy rate and may at the same time deposit them in the central bank at the policy rate. Apart from the cost of providing collateral for the loans, banks pay a small amount to acquire reserves from the central bank. In other words, central bank reserves are more affordable than in a corridor system. A floor system incentivises banks to use central bank reserves *both as a means of payment and as a store of value.*

[62] If some market participants are active in the money market overnight and do not possess an account with the central bank, the overnight rate may fall below the interest rate on the standing deposit facility. These types of market participants must hold overnight deposits in banks, which have accounts with the central bank.

References

Abad, J., G. Nuño and C. Thomas (2023) "CBDC and the operational framework of monetary policy" BIS Working Papers No 1126
CBDC and the operational framework of monetary policy (bis.org)

Adolfsen, J. F. and M. Spange (2020) "Modest pass-through of monetary policy to retail rates but no reversal", Denmarks National Bank Working Paper no. 154
Working paper nr. 154.pdf (nationalbanken.dk)

Ahnert, T., K. Assenmacher, P. Hoffmann, A. Leonello, C. Monnet and D. Porcellacchia (2022) "The economics of central bank digital currency", Working Paper series 2713, ECB
The economics of central bank digital currency (europa.eu)

Ahnert, T., P. Hoffmann, A. Leonello and D. Porcellacchia (2023) "CBDC and financial stability", Working Paper Series 2783, ECB
CBDC and financial stability (europa.eu)

Akram, Q. F. and J. H. Findreng (2021) "Norwegian interbank market's response to changes in liquidity policy", Journal of Banking and Finance Vol. 125, April 2021. See also Norges Bank Working Paper 7/2017
Norwegian interbank market's response to changes in liquidity policy (norges-bank.no)

Aldasoro, I., S. Doerr, L. Gambacorta, R. Garratt og P. K. Wilkens (2023) "The tokenisation continuum" BIS Bulletin No 72.
The tokenisation continuum (bis.org)

Alstadheim, R. and Y. Søvik (2021) "Will banks' lending rates increase with the introduction of a central bank digital currency?", Blog Norges Bank,
Will bank lending rates increase with the introduction of a central bank digital currency? (norges-bank.no)

Andolfatto, D. (2020) "Assessing the impact of central bank digital currency on private banks", The Economic Journal 131, pp 525-540

Armelius, H., C. A. Claussen and S. Hendry (2020) "Is central bank currency fundamental to the monetary system?", Staff Discussion Paper 2020-2, Bank of Canada
Is Central Bank Currency Fundamental to the Monetary System? (bankofcanada.ca)

Auer, R., J. Frost, L. Gambacorta, C. Monet, T. Rice and H. S. Shin (2021) "Central bank digital currencies: motives, economic implications and the research frontier", BIS Working Paper no 976, BIS
Central bank digital currencies: motives, economic implications and the research frontier (bis.org)

Auer, R., H. Banka, N. Y. Boakye-Adjei, A. Faragallah, J. Frost, H. Natarajan and J. Prenio (2022) "Central bank digital currencies: a new tool in the financial inclusion tool kit?", FSI Insights on policy implementation No 41, BIS
FSI Insights No 41 Central bank digital currencies: a new tool in the financial inclusion toolkit? (bis.org)

Bank of England (2023) “The digital pound: a new form of money for households and businesses?” Consultation Paper February 2023.
The digital pound: a new form of money for households and businesses? Consultation Paper (bankofengland.co.uk)

Banque de France (2021) “Wholesale central bank digital currency experiments with Banque de France”
rapport_mnbc_0.pdf (banque-france.fr)

Banque de France (2023) “Wholesale central bank digital currency experiments with Banque de France. New insights and key takeaways”
rapport_mnbc_2023.pdf (banque-france.fr)

Bernhardsen, T. and A. Kloster “Liquidity management system: Floor or corridor?”, Staff-Memo 2/2010, Norges Bank
Liquidity management system: Floor or corridor? Norges Bank Staff Memo 4/2010) (norges-bank.no)

Bernhardsen, T., A. Koster and O. Syrstad (2016) "Alternative monetary policy instruments – the necessary monetary accounting principles", Staff-Memo 12/2016, in Norwegian only, Norges Bank
Staff Memo 12/2016: Alternative virkemidler i pengepolitikken – den nødvendige monetære økosirk (norges-bank.no)

Bindseil, U. (2020) «Tiered CBDC and the financial system», Working Paper Series 2351, ECB
Tiered CBDC and the financial system (europa.eu)

Bindseil, U. and F. Panetta (2020) «Central bank digital currency remuneration in a world with low or negative nominal interest rates», CEPR/VOX
Central bank digital currency remuneration in a world with low or negative nominal interest rates | CEPR

BIS (2023) «Blueprint for the future monetary system: improving the old, enabling the new”, BIS Annual economic report 2023, Chapter 3
III. Blueprint for the future monetary system: improving the old, enabling the new (bis.org)

Bofinger, P. and T. Haas (2021) «Central bank digital currencies risk becoming a gigantic flop», CEPR/VOX, Central bank digital currencies risk becoming a gigantic flop | CEPR

Bofinger, P. and T. Haas (2020) “CBDC: Can central banks succeed in the marketplace for digital monies?”, CEPR Discussion Paper 15489
DP15489.pdf (cepr.org)

Borio, C. (2023) “Getting up from the floor”, Working Paper no 1100, BIS
Getting up from the floor (bis.org)

Brunnermeier, M. K. and D. Niepelt (2019) "On the equivalence of private and public money", Journal of Monetary Economics 106 (2019) 27-41. See also NBER Working Paper 25877
w25877.pdf (nber.org)

Brunnermeier, M and J. P. Landau (2022) "The digital euro: policy implications and perspectives", Report to the European Parliament,
The digital euro: policy implications and perspectives (europa.eu)

Burlon, L., C. Montes-Galdón, M. A. Muñoz and F. Smets (2022) "The optimal quantity of CBDC in a bank-based economy", ECB Working Paper Series 2689, ECB
The optimal quantity of CBDC in a bank-based economy (europa.eu)

Carstens, A. (2023) «Innovation and the future of the monetary system», Keynote speech at the Monetary Authority of Singapore (MAS), Singapore, 22 February 2023.
Innovation and the future of the monetary system (bis.org)

Cæure, B. (2021) "Central bank digital currency: the future starts today, Speech to Eurofi Financial Forum 10. September 2021, BIS
Central bank digital currency: the future starts today (bis.org)

Danmarks Nationalbank (2023) «Høringssvar: EU-kommissionens forslag til forordninger om indførelse av den digitale euro» [Consultation response to the European Commissions legislative proposals on a digital euro, in Danish only]
nationalbankens-hoeringssvar-vedr-forordningen-om-den-digitale-euro (1).pdf

Diamond, D. W. and P. H. Dybvig (1983) 2Bank runs, deposit insurance, and liquidity2, Journal of Political Economy 91 (3)401-419

ECB (2020) "Report on a digital euro", ECB
Report on a digital euro (europa.eu)

ECB (2022a) "Central bank digital currency and bank intermediation", Occasional Paper Series no. 293, ECB
Central bank digital currency and bank intermediation (europa.eu)

ECB (2022b) "The case for a digital euro: key objectives and design considerations",
The case for a digital euro: key objectives and design considerations (europa.eu)

ECB (2022c) «Progress on the investigation phase of a digital euro », First Report
Progress on the investigation phase of a digital euro (europa.eu)

ECB (2022d) «Progress on the investigation phase of a digital euro – second report»,
Progress on the investigation phase of a digital euro - second report (europa.eu)

ECB (2023a) "Progress on the investigation phase of a digital euro – third report"
Progress on the investigation phase of a digital euro - third report (europa.eu)

ECB (2023b) Eurosystem to explore new technologies for wholesale central bank money settlement, Press release 28. April 2023
Eurosystem to explore new technologies for wholesale central bank money settlement (europa.eu)

Fraschini, M., L. Somoza and T. Terracciano (2022) "Central Bank Digital Currency and Quantitative Easing", Swiss Finance Institute Research Paper No. 21-25.
Central Bank Digital Currency and Quantitative Easing (europa.eu)

Garratt, R. og H. S. Shin (2023) «Stablecoins versus tokenised deposits: implications for the singleness of money» BIS Bulletin No 72.
Stablecoins versus tokenised deposits: implications for the singleness of money (bis.org)

Group of central banks (2020) "Central bank digital currencies: foundation principles and core features", Report no. 1, BIS,
Central bank digital currencies: foundational principles and core features (bis.org)

Group of central banks (2021) "Central bank digital currencies: financial stability implications", Report no. 4, BIS
CBDC - User needs and adoption (bis.org)

House of Lords (2021) "Central bank digital currencies: a solution in search of a problem?", Economic Affairs Committee,
Central bank digital currencies: a solution in search of a problem? (parliament.uk)

Infante, S., K. Kim, A. Orlik, A. F. Silva and R. J. Tetlow (2022) "The Macroeconomic Implications of CBDC: A Review of the Literature", Finance and Economics Discussion Series 2022-076. Washington: Board of Governors of the Federal Reserve System, https://doi.org/10.17016/FEDS.2022.076
The Macroeconomic Implications of CBDC: A Review of the Literature (federalreserve.gov)

Keister, T. and D. Sanches (2021) "Should central banks issue digital currency?", Working Papers 21/37 Federal reserve Bank of Philadelphia
Should Central Banks Issue Digital Currency? (philadelphiafed.org)

Kuchler, A., M. Spange and S. Krogstrup (2020) "Negative interest rates: The Danish experience", VOX/CEPR
Negative interest rates: The Danish experience | CEPR

Kumhof, M. and C. Noone (2018) «Central bank digital currencies – design principles and balance sheet implications», Working Paper Bank of England no 725, Bank of England
Bank of England Staff Working Paper No. 725

Kumhof, M., M. Pinchetti, P. Rungcharoenkitkul and A. Sokol (2023) «CBDC policies in open economies», BIS Working Paper no 1086, BIS
CBDC policies in open economies (bis.org)

Maechler, A. M. and T. Moser (2023) Swiss Payments Vision – an ecosystem for future-proof payments, Speech
Swiss Payments Vision - an ecosystem for future-proof payments (snb.ch)

Matthew, M., F. Martinez, M. F. Styczynski and A. Thorp (2022) «Retail CBDC and U.S. Monetary Policy Implementation: A Stylized Balance Sheet Analysis», Finance and Economics Discussion Series 2022-032. Washington: Board of Governors of the Federal Reserve System,
https://doi.org/10.17016/FEDS.2022.032
Retail CBDC and U.S. Monetary Policy Implementation: A Stylized Balance Sheet Analysis (federalreserve.gov)

Meaning, J., B. Dyson, J. Barker and E. Clayton (2018) "Broadening narrow money: monetary policy with a central bank digital currency", Staff Working Paper no. 724, Bank of England
Bank of England Staff Working Paper No. 724

Meller, B. og O. Soons (2023) «Know your (holding) limits: CBDC, financial stability and central bank reliance», Occasional Paper Series 326, ECB
Know your (holding) limits: CBDC, financial stability and central bank reliance (europa.eu)

Monnet, C. (2023) «Digital Euro: An assessment of the first two progress reports», In-Depth-Analysis requested by the ECON committee, European Parliament
Digital Euro: An assessment of the first two ECB progress reports (europa.eu)

Monnet, C. and D. Niepelt (2023) «Why the digital euro might be dead on arrival», CEPR VOX-blog
Why the digital euro might be dead on arrival | CEPR

Niepelt, D. (2020a) "Reserves for All? Central Bank Digital Currency, Deposits, and Their (Non)-Equivalence", International Journal of Central Banking, June 2020, pp 211-238. See also CEPR Discussion Paper 2018/13065
DP13065.pdf (cepr.org)

Niepelt, D. (2020b) «Monetary policy with reserves and CBDC: Optimality, equivalence, and politics», CEPR Discussion Paper 15457
DP15457.pdf (cepr.org)

Niepelt, D. (2022) «Money and Banking with Reserves and CBDC, Discussion Papers 12/22, University of Bern»
unibe2212.pdf (niepelt.ch)

Niepelt, D. (2023) «Digital Euro: An assessment of the first two progress reports», In-Depth-Analysis requested by the ECON committee, European Parliament
Digital Euro: An assessment of the first two progress reports (europa.eu)

Norges Bank (2015) "Financial Stability"
Financial stability 2015 (norges-bank.no)

Norges Bank (2018) "Central bank digital currency", Norges Bank Memo 1/2018, Norges Bank
Norges Bank Memo 1-2018 - Central bank digital currency (norges-bank.no)

Norges Bank (2019) "Central bank digital currency", Norges Bank Memo 2/2019, Norges Bank
Norges Bank Memo 2/2019 - Digital sentralbankpenger (norges-bank.no)

Norges Bank (2021a) "Central bank digital currency – Third report of the working group", norges-bank-memo-1-2021.pdf

Norges Bank (2021b) "Norges Bank's liquidity policy: Principles and challenges", Norges Bank Memo 3/2021
nb-memo-3-2021.pdf (norges-bank.no)

Norges Bank (2023) «Central bank digital currencies - final report from project phase 4. Report from a working group», Norges Bank Paper 2/2023.

OECD (2020a) «The Tokenisation of assets and Potential Implications for Financial Markets», OECD.
The-Tokenisation-of-Assets-and-Potential-Implications-for-Financial-Markets - HIGHLIGHTS (oecd.org)

OECD (2020b) «The Tokenisation of Assets and Potential Implications for Financial Markets», OECD Blockchain Policy Series.
The Tokenisation of Assets and Potential Implications for Financial Markets (oecd.org)

Panetta, F. (2022) Demystifying wholesale central bank digital currency, Speech by F. Panetta, member of the Executive Board of the ECB.
Demystifying wholesale central bank digital currency (europa.eu)

Pfister, C. (2017) "Monetary policy and digital currencies: Much ado about nothing?", Working Paper 2017/642 Banque de France
Template_WP_May2017 (banque-france.fr)

Positive Money (2022) «*CBDB: A Solution in search of a fair hearing*»,
CBDC: A solution in search of a fair hearing? - Positive Money

Rice, T. (2021) «Central bank digital currencies as superheroes?», speech, 26 October 2021 BIS
Central bank digital currencies as superheroes? (bis.org)

Stiansen, K. (2022) "The Norwegian money market", Staff Memo 4/2022, Norges Bank
The Norwegian money market - Staff memo 4/2022 (norges-bank.no)

Syrstad, H. (2023) "Introduction of central bank digital currency – Necessary legislative changes", Staff-Memo 4/2023, Norges Bank
Staff Memo 4-2023: Introduction of central bank digital currency – legislative changes needed (norges-bank.no)

Søvik, Y. (2020) “The rationale for central bank liquidity insurance and liquidity regulation”, Staff-Memo 3/2020, Norges Bank
sm_3_2020_liquidity_insurance.pdf (norges-bank.no)

Waller, C. (2021) “CBDC: A solution in search of a problem?”, Remarks by C. Waller, member of the Board of Governors of the Federal Reserve System, at The American Enterprise Institute,
Christopher J Waller: CBDC - A Solution in Search of a Problem? (bis.org)