STAFF MEMO

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The demand for safe liquid assets and the implications of issuing a Central Bank Digital Currency for bank funding instruments

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The pros and cons of issuing a Central Bank Digital Currency (CBDC) is currently debated by Norges Bank and other central banks. A CBDC would grant access to the central bank balance sheet to a broader set of economic agents, including for example companies or individuals. How such access would be designed or administered are topics of the discussion. One dimension to consider is the potential impact on the stability of the financial system through the effect of CBDC issuance on bank funding markets. This article provides an overview on research related to the demand for financial institutions' funding instruments and derives implications for the issuance of a CBDC. A key message is that CBDC has the potential to substantially crowd out bank funding instruments due to its superior safety features.

Central bank digital currencies, safe assets, bank funding markets, financial stability, money demand.

1. Introduction

The issuance of Central Bank Digital Currency (CBDC) can conceptually be perceived as the offer of a new asset to the general public. As such, it can potentially change the asset holdings of households, Non-Financial Companies (NFCs), and financial companies. Depending on the degree of substitutability with other assets such as cash or bank deposits, it can have additional repercussions on the financial sector or the central bank that act as counterparties to these holdings.

Since there are no real world examples of CBDC at hand, it is hard to assess how the introduction of CBDC would affect the demand for other risk-free or relatively safe assets, such as bank deposits and other assets that are important funding sources for Norwegian financial institutions. Inferences have to be drawn from comparisons of other liquid assets with low credit risk. Comparable examples of these safe liquid assets are government bonds, secured or unsecured bank deposits, and money-

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market funds. The following should give a comprehensive overview of existing studies from which such inferences can be made.

This review aims to extract information on the demand for safe and liquid assets and its determinants, which can be used to build reasonable scenarios for the introduction of a CBDC. In what follows, the first section introduces a schematic of safe liquid assets that classifies financial instruments according to their degree of liquidity risk and credit risk, and describes recent insights into the demand for safe assets. Section 3 examines the demand for wholesale funding instruments of financial institutions. Section 4 reviews literature on the demand for money and deposits from a macroeconomic, household-oriented, and bank-oriented perspective. The section ends by showing findings on deposit demand in turbulent times. Section 5 briefly reviews the substitutability between wholesale and retail funding sources for financial institutions. Section 6 concludes.

2. Classification of safe liquid assets

A Central Bank Digital Currency (CBDC) is a new financial asset that with a few experimental exceptions (see for example the case of Ecuador or Uruguay) has not been issued. The exact features of this potential new asset are therefore not yet defined. As a new form of money, however, two features are crucial: CBDC should neither have liquidity risk nor credit risk. As such, it competes for demand with other safe and liquid assets. Golec and Perotti (2017) provide an overview of how assets with almost no liquidity risk and almost no credit risk can be classified. Figure 1 below provides a further simplification of their framework. This review follows the classification. CBDC can be regarded as a very safe and very liquid asset, similar to cash in this setup. If central banks were to issue a new asset in form of a CBDC, the supply of other safe assets and therewith the funding possibilities of governments and financial institutions would be affected. The following gives an overview about what we know about the elasticities of substitution between these instruments.

The supply of safe liquid assets mainly comes from three sources: central banks (cash), governments (treasuries and government-backed securities), and financial institutions (deposits, wholesale funding instruments). [2] For governments and financial institutions the main motivation for issuing these assets is to fund their activities. The demand for safe liquid assets comes from households, financial institutions, non-

[2] In principle, highly rated corporate debt from non-financial companies could also fall within the category given a sufficiently deep secondary market. The following analysis, however, as well as monetary aggregates (M1-M3) do not consider corporate debt.

financial corporations, governmental bodies, and central banks. They can have diverse interests in holding safe liquid assets, which will be discussed where it becomes relevant (store of value, medium of exchange, unit of account).

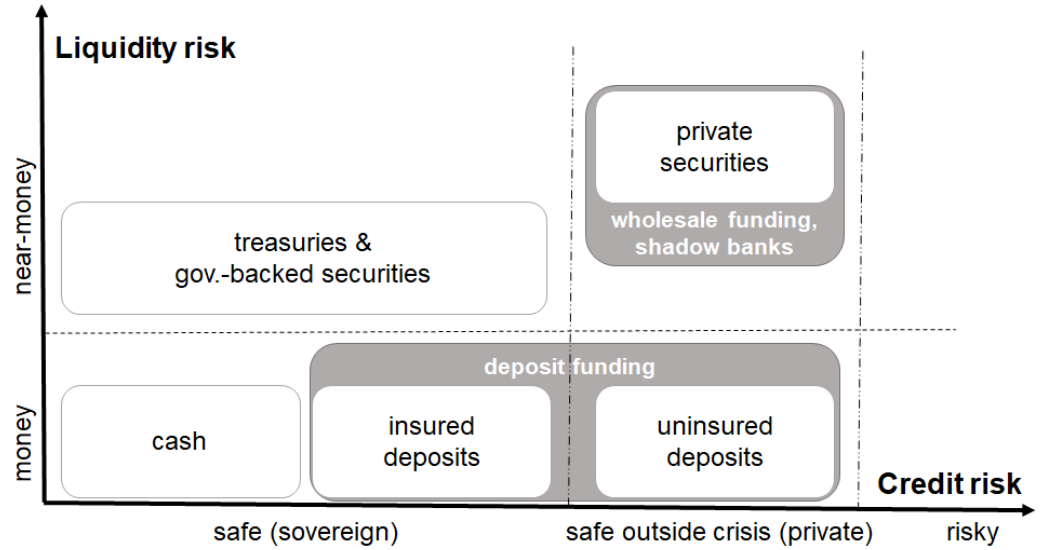
The low credit risk of the securities discussed here not only relies on the safety of the cash flows on which these claims are written but also on the quasi non-existent counterparty credit risk of the issuers. In normal times, issuers are generally believed not to default or at least that default is highly unlikely. In crises, however, the values of underlying claims may deteriorate and issuers, especially financial institutions and occasionally governments, become more likely to fail as recent experience in the Global Financial Crisis or Sovereign Debt Crisis in Europe has shown. As soon as any of these securities are not considered safe anymore, we expect much more dramatic portfolio adjustments than under normal circumstances. Private safe assets are thus susceptible to runs. The following analysis therefore differentiates between elasticities of demand for safe liquid assets in normal times, and elasticities in crisis situations or run behaviour.

2.1. Demand for safe assets

A Gorton et al. (2012) document that the share of safe to risky assets has been surprisingly constant (at around 32%) in the US for at least half a century. Gourinchas and Jeanne (2012) attest a similar relationship for other developed countries (Japan, United Kingdom, Germany, France). Furthermore, Gorton et al. (2012) show that while the share of safe assets was constant, its composition was not. They find a strong negative relation between the share of financial sector's debt and the share of government debt. Within financial sector's debt the share of deposits has declined since 1980 relative to the share of wholesale funding instruments.

The authors suggest to view safe assets as a production factor for total assets, although little is known about this function. There seems to be a stable volume of safe assets relative to risky assets, implying that whenever one issuer offers less, another steps in. The supply of treasuries is mainly driven by budgetary needs (Greenwood et al., 2014; Gorton, 2017). Hence, it is the financial sector that adapts its supply of safe assets whenever needed. Moreover, the financial sector uses marketable safe assets rather than deposits to adapt. In the run-up to the Global Financial Crisis, a fitting substitution pattern was observed between treasury debt supply and shadow banking debt (Sunderam, 2015; Krishnamurthy and Vissing-Jørgensen, 2015).

Figure 1 Classification of safe and liquid assets based on Golec and Perotti (2017)



The money-likeliness of safe assets offers an explanation. With respect to the functions of money, safe assets are not only held for investment purposes but to make transactions (medium of exchange) or as a store of value until transactions are made. This implies the existence of nonpecuniary returns, a convenience yield. How money-like an asset is depends on how liquid it is and whether it is accepted as a means of payment. As Figure 1 points out, deposits are most money-like or the closest to cash because they are often accepted as means of payment. Treasury securities and other liquid wholesale funding instruments of financial institutions are considered near-money since they can easily be converted into cash or deposits.

The demand for safe assets has different motives. The demand for money comes from different agents than the demand for near-money. Money (i.e. cash and deposits as in the monetary aggregate M1, and M2) is primarily held as an asset by households and non-financial corporations supposedly with the purpose of making real transactions. Near-money (i.e. treasuries and private securities) is primarily held as an asset by financial investors, supposedly with the purpose of making financial transactions, and to a lesser extent by households and firms, at least in Europe. Implicitly based on such a distinction, Gorton (2017) draws the conclusion that the "central bank needs to satisfy two clienteles (retail and wholesale) with demands for different kinds of money, each with different implications: one related to inflation (cash) and the other to financial stability (Treasuries)".

Several conclusions can be drawn for the introduction of a central bank digital currency. First, the aggregate demand for safe assets is rather constant. A newly issued safe asset will therefore most likely crowd-out other safe assets, given a certain acceptance. Second, demand for safe assets produced by financial institutions is different for retail and wholesale funding instruments reflecting the differing needs of the respective counterparties. Hence, which kind of safe asset will be most affected by the introduction of a CBDC is based on the features of the CBDC and whether it will be a better substitute for retail or wholesale funding. The following analysis therefore distinguishes these two cases.

3. Demand for wholesale funding instruments

Financial institutions are able to issue safe debt without relying on a government guarantee. They use collateral, securitization, or short maturities to make the cash flows secure. Beside commercial banks, shadow banks issue safe debt. Examples of shadow banks are securitization vehicles, money market funds, markets for repurchase agreements (repos), and mortgage companies. Commercial banks use several wholesale funding instruments. They issue secured and unsecured debt with long-term maturities and they use liquid short-term securities such as brokered deposits. Furthermore, they often own and control shadow banks thereby exposing them to developments in the markets for shadow bank debt.

Gorton et al. (2012) show that the volume of government debt and privately-produced safe assets in the US are strongly negatively correlated. An explanation is that investors view them as substitutes. Following this substitution hypothesis, Krishnamurthy and Vissing-Jørgensen (2015), Greenwood, Hanson, and Stein (2015), Sunderam (2015), Carlson et al. (2016), and Carlon and Wheelock (2018) show how private safe assets are issued when the convenience yield is high indicating that government-safe assets are in short supply. Table 1 gives an overview of estimates of the elasticity of substitution between government-backed safe debt instruments and privately produced safe debt that appear in these studies. They implicitly assume that the demand for wholesale funding instruments corresponds to a residual demand for safe assets consisting of the part of demand not met by the supply of government securities.

Table 1 Estimates of the crowding-out effect of government safe debt on private safe debt.[3]

Paper	Data	Elasticity of substitution[1]
Krishnamurthy and Vissing-Jørgensen, 2015	1875-2014, q/m/w	-51 to -57 cents (net short-term debt issued by the financial sector per GDP)
Greenwood, Hanson, and Stein, 2015	1952-2009, q/m/w	- 14 to -24 cents (financial commercial paper)
Sunderam, 2015	2001-2007, weekly	-3.5% (asset-backed commercial paper) due to 1% increase in T-bills/GDP
Carlson et al., 2016	1975-2007, monthly	-30 cents (commercial papers) / -47 cents (deposits) / -13 cents (MMFs)
Carlson and Wheelock, 2018	1965-1979, quarterly	-10 cents (Eurodollars issued) / -9 cents (negotiable CDs)

[1] *Numbers show the USD change in private safe asset after 1 USD (or 1%) increase in T-bills to GDP.*

All of the studies look at US treasury supply relative to distinct bank wholesale funding instruments or shadow bank debt securities. Krishnamurthy and Vissing-Jørgensen (2015) group several instruments that were of varying importance over the almost 150 year period they study into short-term debt issued by the financial sector and show that a one dollar increase in treasury debt decreases private-safe debt by up to 57 cents (deflated with nominal GDP). Carlson et al. (2016) study substitution between treasuries and several wholesale funding instruments and find a reduction of private-safe debt between 13 and 47 cents. Overall, all studies confirm the negative relationship but each study uses different time windows and different private-safe assets to evaluate substitution effects. Concentrating on the most comparable numbers, the elasticities of substitution resulting from a one dollar

[3] The comparability of the estimates presented in a highly condensed format in this table and the other tables of the paper is subject to limitations set by each cited studies' specific setting. These limitations include among other factors differences in the sample, time period, control variables, estimation method, and regression specification. Estimates should therefore be read with the necessary caution as rough hints at a quantification of the respective elasticities.

increase in treasuries to GDP range from 9 to 57 cents. However, this substitution does not necessarily imply that total liabilities of financial institutions shrink, as Carlson et al. (2016) show. They argue that while government safe debt crowds out, for example, large time deposits of large U.S. banks, it rather changes the maturity structure and composition of bank liabilities than its total volume.

Sunderam (2015) points out that shadow bank short-term debt in the form of asset-backed commercial papers (ABCPs) was used by investors as a near-money asset before the financial crisis. Sunderam argues that the money attribute of shadow bank debt gave banks the opportunity to fund themselves with these instruments instead of using more expensive deposit funding. He shows that the degree of money-likeness determines the elasticity of substitution and hence the elasticity to money demand. Gorton and Metrick (2009) focus on the downside of shadow bank debt. As with other short-term liabilities of the financial sector, trust in repayment can be lost and a run on shadow bank debt can ensue.

Investors seems to have a clear preference for treasuries and government-backed securities. This crowding-out can happen because government debt has a comparative advantage over privately produced safe debt. It can avoid the negative externality of run risk or risk of fire sales (Greenwood et al., 2015). Hence, although equally liquid, government-backed securities are slightly safer than private-safe assets because they offer a guaranteed store of value in all states, including crisis. Krishnamurthy and Vissing-Jørgensen (2012) make use of this distinctive difference and partition the convenience yield on money-like treasuries into a safety premium and a liquidity premium. They show that US treasuries had on average a convenience yield of 73 basis points (bp) per year from 1926 to 2008, of which at most 46 bp represent a liquidity premium and at least 27 bp a safety premium. Kacperczyk et al. (2018) estimate a safety premium of 8 bp for unsecured certificates of deposits. Gorton and Metrick (2009) illustrate how haircuts that are applied to shadow bank debt reflect the trust and confidence that investors place in these instruments.

Assuming that a CBDC would appeal to institutional investors that need to store vast amounts of cash in safe assets, the introduction of CBDC could potentially crowd-out bank wholesale funding. CBDC would enjoy a higher safety premium than bank-issued debt due to the resilience of central banks. Based on the hypothesis of subordinated demand for private-safe assets and a shortage in supply of government-safe assets, CBDC is likely to be preferred over financial sector debt. Nevertheless, certain features of CBDC could mitigate such a crowding-out scenario.

First, CBDC might only be issued against eligible securities which potentially comprise treasuries and financial sector safe debt. Hence, the introduction of CBDC could itself generate higher demand for safe assets. This in turn increases the shortage of government-backed safe assets and extends the residual demand for financial sector's securities. Second, the remuneration of CBDC is crucial in determining the elasticity of substitution. In as much as CBDC yields will be used as a policy instrument and are not market-driven, they will be a less suitable substitute for investors searching for a store of value.

4. Demand for money and deposits

The demand for deposits can be increasingly identified with the demand for money, especially in economies where cash payments are widely replaced by electronic payment mechanisms. Barro and Santomero (1972) define the demand for money as the sum of the demand for currency and the demand for interest-bearing callable deposits (which corresponds to the definition of monetary aggregate M1 or narrow money). Following traditional monetary theories, money demand is determined by real output and the price level based on the idea that money is used to make transactions, and by the nominal interest rate representing the opportunity cost of holding money (instead of another financial asset). Demand for CBDC could be seen as a fraction of the overall money demand. In order to determine this fraction, the central question is how economic agents want to hold money. The interest rate is potentially able to steer this fraction. Therefore, the following presents interest rate sensitivities of money and money-like assets and substitution patterns between them.

4.1. Money demand – macroeconomic perspective

A broad field of studies is dedicated to the measurement of money demand elasticities, which goes beyond the scope of this review to fully reflect. Knell and Stix (2006) provide a meta-analysis of over 900 elasticity estimates from 168 studies between 1972 and 2002. The majority of these studies focus on money demand in OECD countries. They comprise different estimation methods, including the shift to cointegration techniques in the 1980s, which is the dominant method for all papers written after 1990. By summing all estimates, Knell and Stix (2006) document average long-run interest rate elasticities of -0.34 (meta sample from 1995-2002) and -0.25 (1972-1992) and short run elasticities of -0.20 and -0.13, respectively, with sizeable standard deviations.[4] They

[4] Knell and Stix (2006) point out that the elasticity estimate varies depending on whether a short-term rate, a long-term rate or both are employed in the demand estimation. For details see Table 5 in their paper.

further show that the sensitivity of money demand is higher for narrow money than for broad money[5] which might be relevant for CBDC, which would be considered narrow money.

Some estimates for Norwegian money demand are available. For broad money, Eitrheim (1998) estimates the long-run demand from 1969 to 1993 using a multivariate cointegration approach, and checking consistency with an error correction model. He finds that real money demand decreases by 3.73 pp. (2.26 pp. if error correction model, 2.25 with sample extension until 2001) with respect to an increase in the interest rate differential between the 6 year sovereign bond yield and time deposit rate. For narrow money, Bårdsen (1992) derives a demand function with dynamic error correction models for the period from 1968 to 1990. Accordingly, an increase in the interest rate differential between total deposit rate and demand deposit rates by 1 pp. causes a 3.9 pp. decrease of money demand. For cash, Aastveit (2005) measures a 2 pp. decrease in cash demand if time deposit rates increase for a sample from 1980 to 2004.

The variety in estimates emphasises how inferences might depend on the definition of money. Lucas and Nicolini (2015) reconcile some recent competing views that had argued that narrow money demand is almost insensitive to interest rate changes and show that the negative relation still holds when money market deposit accounts, which are a close substitute to interest-bearing deposit accounts, are included in the money aggregate thereby taking the changing nature of money into account. In an accompanying paper, Benati et al. (2020) estimate interest rate elasticities between 0.3 and 0.6 for long samples of 38 economies. In Norway, however, their data show a less stable negative relationship between short-term interest rates and M1 over nominal GPD. With the increasing sophistication of financial markets and financial market participants, the demand for money and deposits has changed. The digitalization of payments made cash holdings almost obsolete (Wang and Wolman, 2016). Further, evidence shows that the substitutability between money and near-money is strong. Nagel (2016) observes that the liquidity premium that is associated with holding money decreases as short-term interest rates – the opportunity costs of holding money – on near-money assets increase. He studies a set of near-money assets and finds them to be almost perfect substitutes to money. Earlier studies using CES utility functions letting agents chose a mix of money and near-money (Chetty, 1969; Poterba and Rotemberg, 1987) as well as newer studies on Divisia money aggregates (Jadidzadeh and Serletis, 2019)

[5] See Stylized Fact 4ii in the paper.

confirm a strong elasticity of substitution between different money-like assets.

The potential demand for CBDC might therefore depend on how agents want to hold money and how interest rate differentials change due to the introduction of CBDC. The above shows, the interest rate elasticity of CBDC depends on what is considered as the outside good. Considering a non-money alternative, like government bonds, narrow money, including CBDC, shows on average a higher sensitivity than broad money aggregates which derives from the fact that much reshuffling happens between money assets within broad money aggregates. This implies that interest rate sensitivities towards movements in the rate on very similar money assets, such as checking accounts, might be very high although at the same time rate differentials should be smaller between close substitutes. Nevertheless, since the interest paid on CBDC is a potential policy tool, rate differentials could persist even between very similar instruments. However, the following presents a microeconomic perspective of the agent's choice on money holdings which highlights some non-monetary features of money demand that counterweigh the potential steering power of CBDC interest rates.

4.2. Money demand – household perspective

Money demand (in cash and deposits) mainly stems from households and non-financial corporations. For households, money demand can be thought of as a part of their portfolio choice. The question is which part of their income they allocate toward liquid assets. Perraudin and Sørensen (2000) study the portfolio choice of households between money, bonds, and stocks using US survey data from 1983. They observe a certain natural order of priority of these assets. About 23% of households in their data held only money, half of households owned money and bonds, the remaining share had money, bonds, and stocks, but only a negligible share held money and stocks. This reflects in part that households are risk averse (Arrow, 1971).

Further, stock market participation is strongly dependent on financial wealth and income (Vissing-Jorgensen, 2002), demonstrating that demand for risky assets is a residual that is only positive if more pressing consumption needs have been satisfied. Hochguertel, Alessie, and Van Soest (2002) confirm that wealth (and the marginal tax rate, age, and education) determine the choice between risk-free deposit holdings and risky assets relying on Dutch household data from 1988. Nevertheless, some evidence supports that households substitute money in form of deposits for risky asset holdings. Lin (2020) shows that households' deposit demand declines in stock market booms and is sensitive to stock market returns.

These findings indicate that the yield spread between CBDC remuneration and the return on risky assets might only be a relevant determinant for the demand from the wealthier part of retail consumers. On average CBDC demand from households might be relatively insensitive to returns on less liquid and less safe assets.

4.3. Deposit demand – financial intermediation perspective

The analysis so far focused on the role of deposits as a form of money and the more general question of why economic agents want to hold money (and not another financial asset). Deposit demand is also intensely studied from the perspective of the deposit suppliers, banks. The focus shifts here from the aggregate deposit demand, which depends on the opportunity costs of deposits, i.e. interest rates on other comparable assets, to the residual deposit demand at each bank. The question is not whether to hold deposits but where.

Deposits are an attractive form of funding. They are relatively cheap due to non-monetary compensation that is associated to them. In as much as customers view deposits as money, they carry a convenience yield, i.e. they require a lower yield than other assets of comparable liquidity risk and credit risk. Furthermore, deposit insurance eradicates credit risk premia for a vast share of deposits. Depositors also seem to value further non-pecuniary benefits connected to deposit accounts or encounter switching costs that tie them to a certain bank. As a result, deposits are “sticky”, less interest rate sensitive, and offer banks the opportunity of a comparably stable form of funding although most of them are callable at any time. This stability, however, is based on the assumption that depositors’ liquidity needs do not realize all at once.

Several studies identify bank-specific benefits or switching costs that give banks market power over depositors. Dick (2008) points out service quality and bank location as factors that can lock-in depositors at a specific bank. Deposit markets are thought be regionally limited. Kiser (2002) documents that relocation of households is the most common reason for switching banks. Based on regionally delineated markets, Sharpe (1997) shows that those markets with a higher share of switching depositors have more competitive price levels. Berger and Dick (2007) demonstrate that incumbent banks and banks that enter deposit markets early have larger market shares. Choi and Velasquez (2018) find that banks that offer better service have a higher ratio of deposits to total assets and pay lower interest rates on these deposits, leading to lower funding costs.

Table 2 Deposit demand own-price elasticity estimates.

Paper	***Data***	***Own-Price Elasticity[1]***
Molnar, Nagy, Horvath, 2006	Hungary, 2003-2005	5 – 10.8 demand deposits 8.5 – 19.9 short-term deposits 6.2 - 8.2 long-term deposits
Nakane, Alencar, Kanczuk, 2006	Brazil, 2003-2004	15.5 - 21 time deposits
Adams, Breevort, and Kiser, 2007	U.S., 1990-2001	2.44 rural / 3.69 urban
Dick, 2008 [2002 version]	U.S. 1993-1999	1.77 - 2.99 [10.49 / 0.94 urban]
Ho and Ishii, 2011	U.S., 1994,2000	1.36 / 1.19 rural / 0.86 urban
Molnar, Violi, Zhou, 2013	Italy, 2003-2007	0.9
Kuehn, 2018	U.S., 2010	2.32
Wang and Ching, 2019	U.S., 2000	3.36

[1] Numbers show a % change in market share after 1% increase of own deposit rate.

Bank market power implies that depositors do not react strongly to interest rate changes. Flannery and James (1984) draw the conclusion that core deposits react "sticky" to market rate changes. They show that deposits have a lower or non-significant impact than comparable short-maturity assets on the interest rate sensitivity of banks' equity market values, implying that their effective maturity is not short-term but rather sticky and hence not the stated maturity. This is a distinctive feature against wholesale funding instruments which pose substantial roll-over risk at maturity. According to Flannery (1982), banks are paying depositors a small premium for being sticky. The inelasticity of deposits insulates banks from funding shocks (Berlin and Mester, 1999). Cornett et al. (2011) show that banks that relied more heavily on deposit funding were able to maintain lending more stable during the global financial crisis.

Table 2 Deposit demand cross-price elasticity and switching cost estimates.

Paper	***Data***	***Cross-Price Elasticity[1]***	***Switching Cost Estimate[2]***
Shy, 2002	Finland, 1997		0% small bank 20% large bank
Ho, 2015	China, 1994-2001		0.8%
Egarius and Weill, 2016	FR, DE, IT 2006-2012		3.9% 5%
Stenbacka and Takalo, 2019	Finland, 2017		2% small bank 15% large bank
Adams et al., 2007	U.S., 1990-2001	- 0.16 rural - 0.0079 urban	
Ho and Ishii, 2011	U.S., 1994,2000,	-0.048 average -0.089 close bank -0.033 distant bank	
Molnar et al., 2013	Italy, 2003-2007	- 0.01	

[1] *Numbers show a % change in market share after 1% increase of competitor's deposit rate.*
[2] *Numbers show the percentage of costs relative to an average account balance.*

Depending on the design and way CBDC would be marketed, CBDC could potentially resemble a current account at a commercial bank. Banks would then face an outflow of deposits if households substitute bank deposits for CBDC. The extent of such substitution would depend, among other factors, on the perceived services- and price-differential between a central bank and commercial bank account. By viewing the central bank as a new competitor in the deposit market, inferences can be drawn from structural models of bank competition in consumer markets. These studies are able to estimate own-price elasticities, cross-price elasticities, and switching costs.

While the own-price elasticities of retail deposit demand can be informative about banks' potential to attract deposits despite competition of CBDC, cross-price elasticities and switching cost estimates give an impression about the likely outflows. Table 2 gives an overview of estimations of own-price elasticities. The numbers illustrate how a bank's market share would increase if the bank offers a 1 pp. increase in its deposit rate to customers and range from 0.9 to 21 pp. Table 3 lists estimates of switching costs for retail deposit accounts as well as cross-price elasticity estimates that show how a bank's market share would decrease if a competitor offers a 1 pp. deposit rate increase. Given the existence of switching costs in some markets, cross-price elasticity estimates are rather low, ranging from 0.79 to 16 bps indicating that deposits might indeed be rather sticky. Amel and Hannan (1999) find that the short-run interest rate elasticities of deposit demand are very small and mid-run (up to 2 years) still low enough to indicate a market power of banks' against competing offers. A randomized control trial, where a new deposit product at randomized rates was offered to Philippine households, analysed by Karlan and Zinman (2018), confirms rather inelastic interest rate sensitivity of retail deposit demand. However, Brunetti et al. (2016) use a biannual household survey in Italy from 2006 to 2012 according to which on average a quarter of households changes banks between two survey rounds. Further, they estimate that a household is on average 3.5 pp. less likely to switch to another bank if the household makes use of one additional service of the bank, such as payments.

Overall, offered interest as well as services are important factors of retail demand, which can determine the potential crowding-out effect of CBDC. Non-pecuniary considerations seem to play an important role in consumers' choice of the supplier of financial services. This suggests a sluggish adoption of a CBDC that is perceived akin to a deposit account. Switching costs might protect banks from outflows but can be eradicated in case CBDC accounts are mandatory or automatically accessible. Another factor could be the perceived safety of deposit holding which will be discussed in the following section.

4.4. Deposit demand in uncertain times

All features of deposit demand described above apply only under one condition, i.e. as long as deposits are perceived as safe. Depositors depend on the promise that they can withdraw their money at any point in time in order to satisfy idiosyncratic liquidity needs. They can only do so, if the bank does not default and has enough liquid assets. Fears about banks' liquidity or solvency can lead to a bank run situation in which every depositor wants to liquidate. In order to avoid bank runs, most countries have a deposit insurance scheme in place that guarantees repayment in

case of bank failure up until a certain amount. Insured deposits are therefore much less information-sensitive than uninsured deposits.

Several studies find evidence that deposit withdrawals react to banks' performance. Gorton (1988) studies seven historical banking panics in the US. He shows that withdrawals are triggered by the arrival of negative information about aggregate risk of a recession arguing that in lack of bank-specific information depositors could only extrapolate the overall economic situation to judge the soundness of their investment. Relying on more recent data of US commercial banks from 1994 to 2013, Chen et al. (2019) show that deposit flows are more sensitive to bank-specific information if the information is of better quality. This highlights the role of depositors' information set for their withdrawal behaviour, which consists of hard information as well as beliefs. Saunders and Wilson (1996) catch up on the difference made in theoretical bank run models between informed and contagion (or panic) runs. They identify a period of informed runs during the US Great Depression where failing banks experienced deposit outflows (and surviving banks deposit inflows) and a period of contagion runs where banks experienced outflows independent of their individual health. In the aggregate, informed runs lead to a reallocation whereas contagion runs lead to flight into currency and a contraction of available funds.

Deposit insurance should reduce the link between bank solvency and withdrawal behaviour by making insured depositors less sensitive to negative news. By looking at the Savings & Loans crisis in the U.S. in the 1980ies, Goldberg and Hudgins (1996) point out that uninsured deposits are indeed more information-sensitive as they retract from banks prior to failure. Egan et al. (2017) confirm that uninsured deposits in particular reacted to financial distress of banks during the recent financial crisis. Further, Martinez Peria and Schmukler (2001) document for banking crisis in Argentina, Chile, and Mexico that struggling banks saw withdrawals of insured and uninsured deposits alike and offered higher interest rates on their deposits. However, deposit insurance might not have been credible in these samples as the effectiveness of a deposit insurance depends ultimately on the solvency of the government. Hence, deposit insurance might lose its vigour if a bank run is accompanied with a sovereign debt crisis. For example, Artavanis et al. (2019) estimate that the probability for early withdrawal quadrupled as policy uncertainty led to a sharp increase of Greek sovereign bond CDS prices.

Finally, deposit insurance might attract funds in crisis times. Uninsured deposits might only be turned into insured deposits by slicing them up and distributing them at several banks. By studying deposit flows at one failing US bank in the recent crisis, Martin et al. (2018) document that this

bank is largely able to offset the loss of uninsured deposits through gains in insured deposits as it approaches failure. Iyer et al. (2017) affirm that such reshuffling took place when Denmark reduced the threshold amount of insured deposits. They further point out that especially large and systemically important banks profit from a reshuffling of uninsured into insured deposits as they could attract relatively more flows than their smaller competitors. This might imply that depositors value implicit bailout guarantees, here for too-big-too-fail banks, as well. A Norwegian study by Lie (2011) of deposit movements during the financial crisis found no dramatic movements in deposits, and that depositors mainly reshuffled uninsured deposits to other banks to keep their total deposits insured. Further, Gatev and Strahan (2006) show that banks gained deposit inflows in insured accounts as stress emerged in alternative liquid asset markets, such as the commercial papers market.

Besides government-sponsored deposit insurance, customer relationships can mitigate withdrawal pressures as well. Brown et al. (2020) made a survey among Swiss households which revealed that an exclusive bank-client relationship significantly reduced the probability of withdrawal at two large Swiss banks that experienced substantial outflows during the financial crisis. A similar pattern is found by Iyer and Puri (2012) in an example of a run on a small Indian community bank.

Overall, depositors show similar preference as investors in wholesale instruments for government-safe assets over private-safe assets which gains particular strength in crises. Deposit insurance is credible in most developed economies and helps mitigating outflows by incentivising a reallocation of deposits within the banking system. Demand for CBDC as a safe haven, however, could potentially be very high if uninsured deposits are being withdrawn and can be transferred to CBDC accounts at great convenience. An important feature of CBDC is therefore if and by how much it extends the insured or government-safe amount of deposit holdings. In this respect, CBDC design interacts with the framework of the deposit insurance system.

5. Substitution between bank wholesale funding and deposit funding

Based on the notion that CBDC could potentially crowd-out either banks' wholesale funding opportunities or deposit funding or both, an important question is how banks are able adapt to a change in their funding structure.

The flip side of the stability that retail funding offers is an inflexibility to adapt to sudden funding needs. Because deposit supply is highly price-inelastic, especially in the short-run, banks often reach out to the wholesale funding markets when they wish to expand their balance sheets. Although government-backed supply of safe assets might crowd-out bank wholesale funding opportunities as described above, Carlson and Wheelock (2018) point out that bank balance sheets stay constant. They study a time period from the 1960ies to 1970ies in the US when banks started to use certain forms of wholesale funding: Eurodollar deposits and negotiable certificates of deposits (CDs) indicating that banks substituted deposits for wholesale funding. Using a more recent time period from 2006 to 2009, Cornett et al. (2011) confirm a substitution between wholesale and deposit funding. Banks with more core deposits, especially small banks, rely less on cash holdings and have to increase liquid assets less in times of crisis. Choi and Choi (2020) study how banks adjust their funding structure to exogenous shocks. They show that changes in monetary policy rates cause banks to shift between wholesale and retail funding. A tighter monetary policy induces deposit outflows and banks try to compensate by issuing marketable debt. Xiao (2020) supplements this finding by showing that depositor demographics determine the severity of the deposit outflow, where older clients are generally less likely to withdraw their funds, and that bank size as a proxy for funding frictions determines the ability of banks to replace deposit with wholesale funds.

These findings indicate that banks are able to substitute funding sources. Due to the higher flexibility financial institutions often use wholesale funding markets to adjust to sudden fluctuations. Nevertheless, literature on funding constraints mostly document a negative credit supply effect indicating that banks shrink their balance sheets in response to funding shocks. If CBDC would have a strong crowding-out effect, the financial sector's ability to raise funds in wholesale markets will be crucial.

6. Conclusions

This review gives an overview of several strands of literature that jointly can give an impression of how the introduction of a Central Bank Digital Currency might impact demand for retail and wholesale funding instruments of financial institutions. It illustrates that CBDC has the potential to crowd-out funding sources of the private financial sector. Thus the introduction of CBDC can have repercussions on financial stability through its effect on funding markets. However, the exact characteristics of CBDC are yet to be defined and part of this policy debate is how and to what extend CBDC is likely to differ from other safe

liquid assets. Any inferences drawn therefore highly depend on the design of CBDC and the economy it is designed for.

An important limitation of this study is that its findings concentrate on the demand for U.S. safe assets since most analyses from which inferences are drawn rely on U.S. data. Several factors should therefore be kept in mind when applying the conclusions that are presented here. For example, demand for safe assets in U.S. dollars might be particularly strong due to the important role of USD in international financial markets. In order to assess how the introduction of a CBDC might impact the banking sector of a particular country, the funding structure of domestic banks as well as the asset portfolio structure of banks' creditors must be considered.

Furthermore, this study did not comment on particularities of demand for safe liquid assets from non-financial corporations nor the footprint of recent trends in digital banking that might affect deposit demand of certain age or income cohorts of retail investors. Taking these caveats into consideration, some tentative assessments can be made.

The current economic environment has a high demand for safe liquid assets as part of the growing amount of total assets. While the share of safe to total assets appears rather stable, its composition is not. A CBDC would have to find its place in this composition as agents substitute other safe assets for CBDC.

The portion of safe assets issued by financial firms has increased since the 1980s reflecting a growing demand for money-like assets from institutional investors in quest of a safe store of value. Institutional investors are counterparties to most of banks' wholesale funding instruments. Retail funding instruments are predominantly held by households and non-financial corporations in need of the payment services that these products provide. These groups of investors have different motives for holding safe liquid assets and arguably behave differently. Therefore, we would expect demand for a CBDC to show different sensitivities when it is designed to appeal to retail investors/customers than when it is used by institutional investors.

Conceptually, we can distinguish three factors that determine demand for CBDC: the interest rate relative to alternative assets, the liquidity services, and the safety premium.

- Money demand depends negatively on the yield spread between money and alternative investment opportunities. Similarly demand for privately issued near-money assets decreases as yields on

alternative assets rise. Wholesale investors display a high demand for safe assets. An important factor could be how and if international and institutional investors can make use of CBDC liquidity services. An easily accessible CBDC is likely to attract their attention. Nevertheless, these investors are interest rate sensitive given their motive to find safe store of value and the abundance of alternative investment opportunities. Retail investors on the other hand display low interest rate sensitivity, especially in the short run.

- Retail investors value non-pecuniary benefits and liquidity services that tie them to their supplier of safe assets. This could indicate low demand from retail investors due to a sluggish adoption of CBDC when they face relevant switching costs relative to the average account balance. However, once they have implemented CBDC as part of their asset holdings, demand might show stable patterns.

- Since CBDC is issued by a central bank, it is likely to have a higher safety premium than financial institutions' debt. CBDC is able to offer a safe store of value even in times of uncertainty or crisis. For this reason, wholesale as well as retail investors have a strong preference for government-issued safe assets over privately issued safe assets. Institutional investors show excess demand for government-back safe assets, like treasuries. Furthermore, where deposit insurance is in place, bank debtors flock into insured deposits at signs of turbulences. This indicates a strong potential for CBDC to crowd-out financial sector debt instruments. These reallocation incentives will intensify in times of market stress or uncertainty. Hence, whatever demand CBDC can attract in normal times, it may increase immensely if a crisis is lingering.

Overall, this review illustrates there could be a high elasticity of substitution between CBDC and other safe liquid assets that are used by financial institutions as sources for funding their activities. Assuming CBDC were generally accessible and offered similar liquidity services as do financial sector debt instruments, the strong preference for government-backed safe assets indicates a high potential for crowding-out. CBDC can be designed in ways that mitigate a crowding out effect by limiting the access to CBDC, reducing the services connected to CBDC use, or requiring safe collateral for the use of CBDC.

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