Master Thesis

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Central Bank Digital Currency: Implications of Narrowing the Traditional Banking System

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Abstract: This thesis examines the implications of a Central Bank Digital Currency (CBDC) narrowing the traditional banking system. The traditional banking system gets narrowed when commercial banks main source of funding (retail deposits) move to a CBDC. The implications for the functioning of commercial banks as financial intermediaries is discussed when a significant outflow of retail deposits impairs the ability of commercial banks to issue loans in the first place using their money creation process. The main finding is that commercial banks' ability to issue loans using retail deposits to fund their lending activity does not only gets affected when retail deposits flow to a CBDC. But that the outflow of retail deposits to a CBDC also affects the ability of commercial banks to rely on alternative sources of funding (wholesale funding). This indicates that commercial banks cannot respond effectively to a significant outflow of retail deposits, if a bank run on retail deposits in a crisis scenario were to occur.

Key words: CBDC, Central Bank Digital Currency, commercial banks, central banks, narrow banking, wholesale funding, bank run, retail deposits, traditional banking.

Table of Contents

1. Introduction

Threats of declining cash usage among the public and the rise in popularity of Bitcoin and other cryptocurrencies, has led to central banks asking themselves if they should provide any form of digital currency to the public. The issuance of a digital currency by a central bank will be referred to as a CBDC (Central Bank Digital Currency) throughout this thesis. The issuance of such CBDC does not require the central bank to adopt the same underlying technologies such as the distributed ledger of Bitcoin and other cryptocurrencies. Instead, central banks can allow the public to open deposits accounts at the central bank, which only requires a centralised ledger (Dyson & Hodgson, 2016).

Currently, central banks have only issued two forms of money. Namely, cash and reserve deposits that the central bank itself holds, which are available for commercial banks. The public only has direct access to cash, which they can withdraw from their bank accounts (retail deposits) provided by commercial banks. Since commercial banks use reserve deposits held at the central bank to issue loans, the public has only indirect access to these reserves through loans. With the introduction of a CBDC, the public has an additional form of direct money to hold. This implies that a newly created CBDC competes with cash and retail deposits in the economy. Since the public is free to decide which form of money they want to hold (Grym et al., 2017).

Current literature suggests that competition between retail deposits and a CBDC implicitly narrows the banking system (Raskin & Yermack, 2016). Traditional narrow banking systems mainly exist in the form of a proposal to create such system. These proposals advocate regulation of the traditional banking system, to decrease the risks associated with fractional reserve banking performed by commercial banks. Fractional reserve banking implies that commercial banks are only required to hold a fraction of reserves of their retail deposit liabilities. This makes commercial banks vulnerable to so called "bank runs" (Smets, 2016). In a bank run, the public decides to simultaneously withdraw their retail deposits from commercial banks. Commercial banks experience liquidity problems when a bank run is initiated, since they can only pay out a fraction of their retail deposit liabilities. In a traditional narrow banking system, commercial banks are therefore limited in their fractional reserve banking. For instance, the most extreme case of a traditional narrow banking proposal

argues that commercial banks should be required to hold 100% of their deposits liabilities as reserves (Pennacchi, 2012).

However, such system differs from the "implicitly" creation of a narrow banking system under a CBDC. A narrow banking system under a CBDC implies that retail deposits currently held at commercial banks, move to the deposit accounts at the central bank. Deposit liabilities are now backed by the liquid assets of the central bank. This in turns makes the central bank a narrow bank, which indicates that commercial banks could see an outflow of their main source of funding: retail deposits. Whether such narrow banking system actually develops depends on the outcome of competition between retail deposits and a CBDC. This competition determines whether the public is willing to shift their retail deposits from their bank accounts held at commercial banks, to their CBDC accounts (Broadbent, 2016).

Opening deposits accounts at the central bank is currently considered by several central banks. For example, the Swedish Riksbank has started a project in March 2017, to evaluate the possibilities of issuing a CBDC (E-krona). They consider a CBDC that is cash-like to complement declining cash usage in their economy, which has reduced the public's access to direct central bank money. Currently, central banks face many questions regarding the actual design of the CBDC. Such as who should provide accounts of the CBDC? Should it generate interest? And what are the implications for monetary policy and financial stability? (Skingsley, 2016)

The purpose of this thesis is to increase the understanding of the implications relating to financial stability, if a CBDC were to narrow the traditional banking system. Current literature fails to discuss the implications of a CBDC impairing the ability of commercial banks to issue loans in the first place (Broadbent, 2016). It is therefore believed that commercial banks can continue to issue loans and create an equal amount of retail deposit liabilities, if a bank run on retail deposits is initiated by a CBDC (Dyson & Hodgson, 2016). By examining the implications of impairing the ability of commercial banks to issue loans in the first place, important insights are gained in the implications for commercial banks' lending when a CBDC narrows the traditional banking system. Furthermore, by including these implications into the discussion of a CBDC existing in a crisis scenario. It is argued that the existence of a CBDC can have much greater impact on financial stability than assumed in current literature (Dyson & Hodgson, 2016). To examine these implications, a theoretical

approach is chosen. Since a CBDC has never been implemented before, it is not possible to perform empirical research on the subject.

This thesis provides an in-depth analysis of two core articles. The first article is that by Dyson & Hodgson (2016), who discuss the implications of having retail deposits and a CBDC compete with each other. The second article is that by Kiser (2003), whose model is used to show how an individual commercial bank extends loans when its ability of money creation is impaired by the introduction of a CBDC. The model shows a commercial bank that firstly has to obtain either retail or wholesale deposits to fund their lending activity. The discussion part of this thesis builds further on these two core articles. Following the article by Dyson & Hodgson (2016), a discussion is provided on how competition between retail deposits and a CBDC can result in a significant outflow of the main source of funding (retail deposits) of commercial banks. The implications of impairing the ability of commercial banks to issue loans in the first place is examined by altering the model by Kiser (2003) to include the effects of a significant outflow of retail deposits on the funding decision of an individual commercial bank. The discussion part builds further on this altered model, by discussing the implications of the aggregate response of commercial banks. At last, a crisis scenario is introduced.

The structure of this thesis is as follows. Section 2 provides a literature review on the traditional banking system and CBDCs. Section 3 analyses the implications of competition between retail deposits and a CBDC on the basis of Dyson & Hodgson (2016). Section 4 shows a model of commercial banks substitutability between the two different sources of funding (Kiser, 2003). Section 5 provides a discussion on CBDC and narrow banking, implications for commercial banks on individual and aggregate level, and introduces a crisis scenario. Section 6 concludes.

2. Literature review

Before going deeper into analysing the two core articles in this thesis. I will first establish knowledge about important concepts relating to these papers. Firstly, an explanation of the working of the traditional banking system and narrow banking is given. Since this thesis focuses on analysing the implications of a CBDC on the working of the traditional banking system, general understanding on this subject is required. From here follows a more extensive explanation of a narrow banking system and how such system relates to the traditional banking system.

After establishing knowledge about the working of the traditional banking system, concepts related to a CBDC are introduced. Firstly, the underlying technologies that Bitcoin and other private cryptocurrencies use are explained. Hereafter, CBDCs are introduced and is explained how a CBDC differs from a cryptocurrency such as Bitcoin. Furthermore, the motivations and possible benefits of issuing a CBDC by a central bank are discussed. From here follows a discussion on the initial implications of the introduction of a CBDC. These implications relate to the opening of accounts at the central banks by a CBDC, which is the feature that implicitly narrows the banking system.

2.1 The traditional banking system and narrow banking

2.1.1 Traditional banking

It is important to first make a distinction between two different views of commercial banks regarding their role of financial intermediation. This, because the core articles in this thesis describe two different roles of commercial banks in their role of financial intermediation. The first view is consistent with the paper by Kiser (2003), which describes commercial banks to make and hold loans by firstly obtaining insured retail deposits as funding. The insurance of retail deposits is a promise guaranteed by the government in case the commercial bank were to default. In addition to this type of funding, commercial banks can attract alternative sources of funding (wholesale funding).[1] This wholesale funding market

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[1] Kiser (2003) also mentions that commercial banks can attract non-interbank wholesale deposits. However, these funds do not relate to the traditional banking system but to the shadow banking system.

refs to the interbank market, which is the market where commercial banks can transfer excess liquidity among each other (Allen et al., 2009).

The process of financial intermediation where a commercial bank funds themselves with retail deposits is illustrated in figure 1. The first step (Step A) of the process includes depositors transferring money to the commercial bank. The depositor receives a checking or savings accounts in return, which the depositor can use to withdraw their funds at any time. In the following step (Step B), the commercial bank loans these funds (retail deposits) to a borrower. The underwriting of loans by a commercial bank includes mortgage and non-mortgage loans made to retail and commercial borrowers, who promise to repay their loan (Gorton & Metrick, 2012).
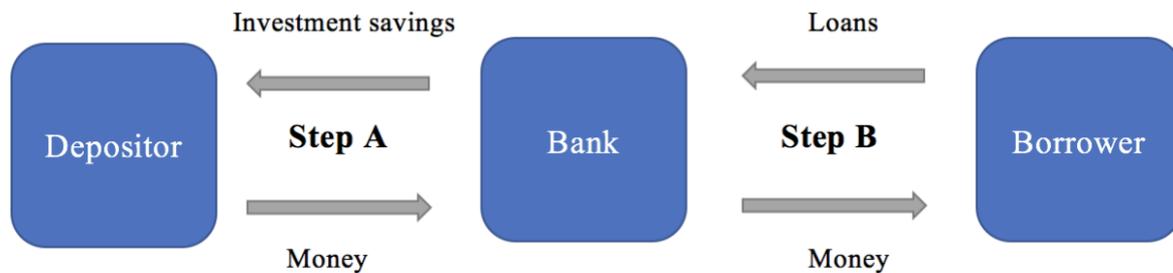
Figure 1: Traditional banking (Gorton & Metrick, 2012, p. 426).

However, in the modern economy commercial banks do not act simply as a financial intermediary by obtaining funds and loan these found out, which is the process shown in figure 1. Rather, commercial banks are capable of extending loans and simultaneously create an equal amount of retail deposit liabilities. This view is consistent with the article of Dyson & Hodgson (2016). This process is referred to as the money creation process by commercial banks in the modern economy (McLeay et al., 2014). By using this process, commercial banks create the majority of money in the modern economy. The amount of loans commercial banks can make using this process depends on several factors. Firstly, the amount of loans commercial banks can extend is limited by its competitive environment. Secondly, commercial banks activities are restrained by regulators who to try to ensure that the financial system operates safely. Thirdly, lenders can repay their debts, thereby "destroying" money created by commercial banks. Fourthly, monetary policy by central banks to ensure that the money creation process is consistent with low and stable inflation, can limit the amount of

money created by commercial banks. This monetary policy is conducted by the setting of short-term interest rates on central bank reserves held by commercial banks. This in turn influences the rate by which commercial banks are willing to lend each other money in the interbank market (McLeay et al., 2014).

Fractional reserve banking

Commercial banks are required to keep a fraction of their retail deposits as reserves to promote bank solvency. By holding only a fraction of the retail deposit liabilities, commercial banks perform fractional reserve banking (Smets, 2016). Fractional reserve banking makes it possible that the holding of liquid assets, including reserves at the central bank, to be much smaller than their retail deposit liabilities (Broadbent, 2016). Commercial banks can replenish these reserves by borrowing from the central bank in case they were to fall short on these reserves (Gorton & Metrick, 2012).

Maturity transformation

The commercial banks performs "maturity transformation" because their retail deposits liabilities are short term based, while the loans extended are long term based. This means that there is a maturity mismatch in the current banking system making it inherently funeral to bank runs (Smets, 2016). This, because the loans commercial banks extend are "illiquid", making them hard to sell in a secondary market. This means that if a significant amount of depositors tried to withdraw their funds, the commercial banks would not have enough liquid resources to meet its demand. For this reason, retail deposit insurance and central bank lender of last resort facilities exist (Broadbent, 2016).

2.1.2 Narrow banking

The maturity mismatch making commercial banks vulnerable to bank runs has led to several "narrow" banking proposals. A narrow bank is defined as follows: "a narrow bank represents a financial institution that issues demandable liabilities and invests in assets that have a negligible amount of nominal interest and credit risk" (Pennacchi, 2012, p. 1). Commercial banks and their role of financial intermediaries in a narrow banking system can differ depending on how restrictive their assets in terms of nominal and credit risk are. Pennacchi (2012) has given an example of narrow banks where their assets portfolios becomes less restrictive, shown in table 1.

100% Reserve Bank (RB)	• Assets are high-powered money in the form of currency or central bank reserves. Liabilities are noninterest-bearing, demandable deposits issued in an amount equal to or less than the reserves
Treasury Money Market Mutual Fund (TMMMF)	• Treasury Money Market Mutual Fund (TMMMF): Assets are Treasury bills or short-term investments collateralized by Treasury bills (i.e., repurchase agreements). Liabilities are demandable equity shares having a proportional claim on the assets.
Prime Money Market Mutual Fund (PMMMF)	• Assets are Treasury bills and short-term Federal agency securities, short-term bank certificates of deposits, bankers' acceptances, highly rated commercial paper, and repurchase agreements backed by low-risk collateral. Liabilities are demandable equity shares having a proportional claim on the assets.
Collateralized Demand Deposit Bank (CDDB)	• Assets include low-credit- and interest-rate-risk money market instruments. Liabilities are demandable deposits that have a secured claim on the money market instruments and are issued in an amount equal to or less than the money market instruments.
Utility Bank (UB)	• Similar to a CDDB but collateral can include retail loans to consumers and small businesses in addition to money market instruments.

Table 1: Examples of narrow banks whereby their asset portfolios become less restrictive (Pennacchi, 2012, p. 2).

Recommendations for a narrow banking system appear mostly after periods of financial distress. Because at these times, the fear of a bank run is at its greatest. Pennacchi (2012) has evaluated these proposals by considering the implications of financial services that traditional banks currently provide, but which under a narrow banking system would be provided by other financial institutions. Pennacchi (2012) argues that it appears to be that the theoretical and empirical evidence relating to proposals of narrow banks, are in favour of such system. A carefully designed narrow banking system could provide similar results as the current banking system involving traditional banks. The greatest benefit of a narrow banking system is that advantages in containing moral hazard and reducing overall risk could be achieved, which leads to less required regulation of the financial system (Pennacchi, 2012).

Synergies created by commercial banks

Commercial banks currently both fulfil a deposit taking function and lending function, which both provide liquidity on demand. Kashyap et al. (2002) argue that combining these two

activities create synergies, since both activities require commercial banks to hold large balances of liquid assets. Kashyap et al. (2002) argue the following: "If deposit withdrawals and commitment takedowns are imperfectly correlated, the two activities can share the costs of the liquid-asset stockpile." (Kashyap et al., 2002, p.33). This indicates that if a narrow banking system were to get implemented, any synergy created would get lost, which can result in large inefficiencies (Kashyap et al., 2002). However, this synergy created could also be a result from the retail deposit insurance guarantees as argued by Pennacchi (2012). Furthermore, the introduction of a narrow banking system requires powerful regulators to transform existing firms. This could create incentives for existing firms to move maturity transformation outside the traditional banking system (Pennacchi, 2012).

Shadow banking system

Moving maturity transformation outside the traditional banking system refers to the shadow banking system. This system will be referred to as the lending activities funded by non-interbank wholesale deposits throughout this thesis. The shadow banking system can be defined as follows: "Shadow banks are interconnected along a vertically integrated, long intermediation chain, which intermediates credit through a wide range of securitization and secured funding techniques such as ABCP, asset-backed securities, collateralized debt obligations, and repo. This intermediation chain binds shadow banks into a network, which is the shadow banking system. The shadow banking system rivals the traditional banking system in the intermediation of credit to households and businesses." (Pozsar et al., 2010, abstract).

In essence, both the traditional banking system and the shadow banking system conduct credit, maturity and liquidity transformation. However, they differ in one aspect: shadow banks lack access to public sources of liquidity. This is different from the traditional banking system, which has access to the Federal Reserve discount window and receives insurance on retail deposits, provided by the government (Pozsar et al., 2010).

2.2 Cryptocurrencies and central bank digital currencies

2.2.1 Introduction to Bitcoin and other private cryptocurrencies

Bitcoin is a form of digital currency that can be transacted via the internet in a decentralised trust less way, that has gained significant attention since its introduction in 2009. Bitcoin can

be considered revolutionary since it is an alternative private currency that is not issued by any central autorhity. Instead of Bitcoin being issued by a central authority, Bitcoin has automated consensus among its network users. This means that users of Bitcoin do not have to rely on one central authority to successfully make a transaction. Bitcoin achieves this consensus among users by making use of a public ledger called the blockchain. This underlying technology does not require users to trust each other (Swan, 2015).

How does this technology work? Figure 2 illustrates the most important distinction between a centralised ledger and a distributed ledger. In a centralised ledger system one central authority is required to certify ownership and to clear transactions (Belinky et al., 2015). This is in contrast to a distributed ledger system which is designed to operate without any central authority. In a distributed ledger system, computers at different locations are connected to each other via the internet, all using the same distributed ledger technology. This distributed network technology includes certain protocols and the supporting infrastructure for the computers to use. This technology allows computers to initiate and validate transactions. The computers in the network are designed to operate without any central authority. This means that the record of all transactions are kept in a distributed database without any central authority. This distributed database works on a consensus based validation procedure and cryptographic signatures. Any transaction that happens between two computers is validated by a part of the network users called a "block". All different blocks that validate transactions are connected to each other, which refers to the blockchain technology (Bech & Garratt, 2017).
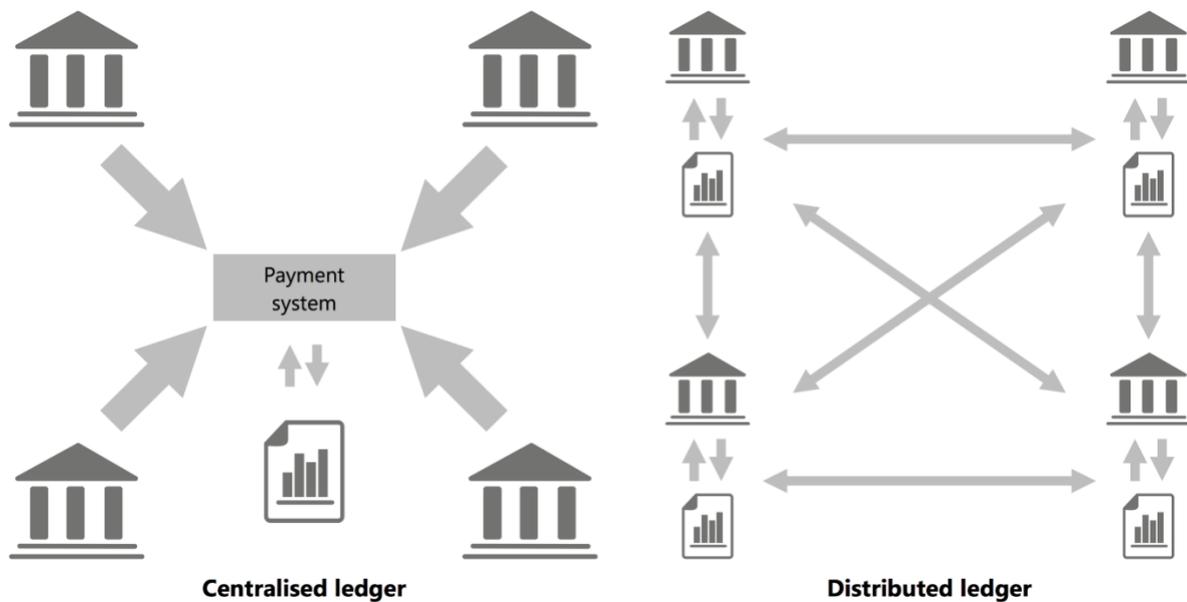
Figure 2: Centralised ledger versus distributed ledger system (Belinky et al., 2015, p. 14).

Since the launch of Bitcoin many other cryptocurrencies have surfaced. These alternative private cryptocurrencies can differ from Bitcoin regarding their optimizations and introduced tweaks to its design (Swan, 2015). However, what Bitcoin and all these other alternative private cryptocurrencies have in common is its blockchain technology. This underlying technology has great potential according to Swan (2015): "Bitcoin and blockchain technology, as a mode of decentralization, could be the next major disruptive technology and worldwide computing paradigm (following the mainframe, PC, Internet, and social networking/mobile phones), with the potential for reconfiguring all human activity as pervasively as did the Web." (Swan, 2015, preface).

2.2.2 Introduction to CBDCs

Central banks have shown interest in monitoring the developments of Bitcoin and other cryptocurrencies. These developments are of interest for central banks because these cryptocurrencies have the potential to get widely adopted for making payments in the economy. The widely adoption of a cryptocurrency for making payments could lead to a reduction in the demand for cash and bank accounts held at commercial banks. This in turn could affect central banks in their seigniorage revenue, monetary policy operations, the safety and efficiency of payment systems, and the policy relating for financial stability (Fung & Halaburda, 2016).

Besides the monitoring of current developments of Bitcoin and other cryptocurrencies, central banks are evaluating which role they should take on regarding these developmens. Central banks are currently considering the possibility of regulating these cryptocurrency. But central banks are also asking themselves if they should start issuing their own digital currency, which could be used by the general public to make payments (Fung & Halaburda, 2016). If a central bank were to introduce a CBDC, the central bank would provide an additional form of money currently issued by central banks. And even more importantly, it will be the first time that a central bank issued any other type of central bank money that is directly used by the public. Currently, the public only has acces to central bank money by obtaining bank notes. Any central bank money issued is based on the monetary policy decisions of a central bank (Grym et al., 2017).

2.2.3 Differences cryptocurrencies and CBDC

Both privately issued digital currencies and a CBDC can be considered a form of digital money. However, a CBDC differs from Bitcoin and other private digital currencies in some important aspects. Firstly, a CBDC adds a central point of control which is in contrast to cryptocurrencies that are specificially designed to lack any central authority, to bypass the control of any central authority. This central point of control added to the CBDD enalbes the central bank to set the supply of CBDC that is issued. This makes it possible to guarantee parity between other forms of money in the economy by the central bank. The setting of supply of CBDC issued is in contrast to most other private digital currencies whose supply is predeterimed (Koning, 2016). Secondly, a CBDC does not require the central bank to adopt the same underlying technologies of a cryptocurrency such as Bitcoin. Instead, the central bank can allow the public to open digital deposit accounts at the central bank, which only requires a centralised ledger. The working of this centralised ledger is shown in figure 2, which can be seen as a network of computers that is controlled by the central bank itself. Why is this relevant? The distributed ledger and blockchain technology of Bitcoin has worked succesfully, but is not without its limiations. The validation process of transactions requires a large amount of computer power. Furthermore, the fact that all transactions are public does not suite many financial applications that may require a certain amount of anonimity (Bech & Garratt, 2017). This has led central banks to focus on researching the possibilities of only adopting certain features of Bitcoin, such as: a degree of anonymity, censorship resistance and reusability of tokens (Koning, 2016).

2.2.4 Motivations and benefits

The exact reasons why a central bank might want to introduce a CBDC, and how to implement a CBDC is still widely discussed by central banks (Fung & Halaburda, 2016). A large amount of motivations to issue a CBDC relate to a CBDC design that allows the public to hold central bank money. Central banks might want to introduce such CBDC to ensure adequate central bank money for the public and to preserve central bank seigniorage.[2] In this case, the central bank introduces a CBDC to complement the declining use of banknotes relative to other payments methods in the economy. The issuance of a CBDC would therefore be a response to the public's need for central bank money (Skingsley, 2016). Other motivations include introducing a CBDC to reduce aggregate risk and improve financial stability by allowing the general public and companies to rely on a CBDC as means of payment and store of value, using essentially risk free money. Another reason why central banks might want to introduce a CBDC is to reduce the lower bound on interest rates, to support unconventional monetary policy, to increase contestability in payments, promote financial inclusion and to inhibit criminal activity (Engert & Fung, 2017).

2.2.5 Implications

Since there is no legislation or international standard on the design of CBDC, there are many potential CBDC designs based on different motivations (Grym et al., 2017). This in turn results in the extent of the implications of a CBDC to depend on its specific design. Most designs of a CBDC are paired with opening accounts (specific feature) at the central bank, which according to Broadbent (2016) makes it important to examine whether the CBDC is designed to compete with either cash or with retail deposits held with commercial banks. Broadbent (2016) argues that if a CBDC is designed to simply replace cash in the economy, that macro-economic effects would most likely not be any significant.

However, retail deposits could shift more significantly to a CBDC if a CBDC is designed to closely represent bank accounts held by commercial banks. In such scenario, the macroeconomic effects could be more significant. This is explained in figure 3, which shows an example of a balance sheet of an individual commercial bank and a central bank in the United Kingdom. The left chart in figure 3 shows an individual commercial bank performing fractional reserve banking. This means that its retail deposit liabilities are currently backed by

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[2] Seigniorage is defined as government's revenue from the creation of money (Klein & Neumann, 1990).

illiquid loans. This maturity transformation makes the commercial bank vulnerable to so called bank runs. Simply because the commercial bank is not capable of repaying all retail deposits liabilities if the public were to demand this. This situation changes if these deposits move from the commercial bank to the central bank (CBDC). Figure 3 shows that the central bank itself holds nothing more than liquid assets. If the retail deposits were to move to the CBDC there would be no fear of a bank run, since all deposits liabilities are backed by the liquid assets of the central bank. If retail deposits indeed were to move to the account of the CBDC, the central bank itself would have a narrow banking structure.

Broadbent (2016) argues that the opening of accounts at the central bank would make the financial system saver. However, focussing on the commercial banking side, the moving of retail deposits to the CBDC could impair the ability of commercial banks to extend loans. Because if these retail deposit were to move to the CBDC, commercial banks lose their main source of funding: retail deposits. Commercial banks therefore may have to rely more on wholesale funding markets to fund their lending activities. According to Broadbent (2016), this might affect the supply of credit by commercial banks.
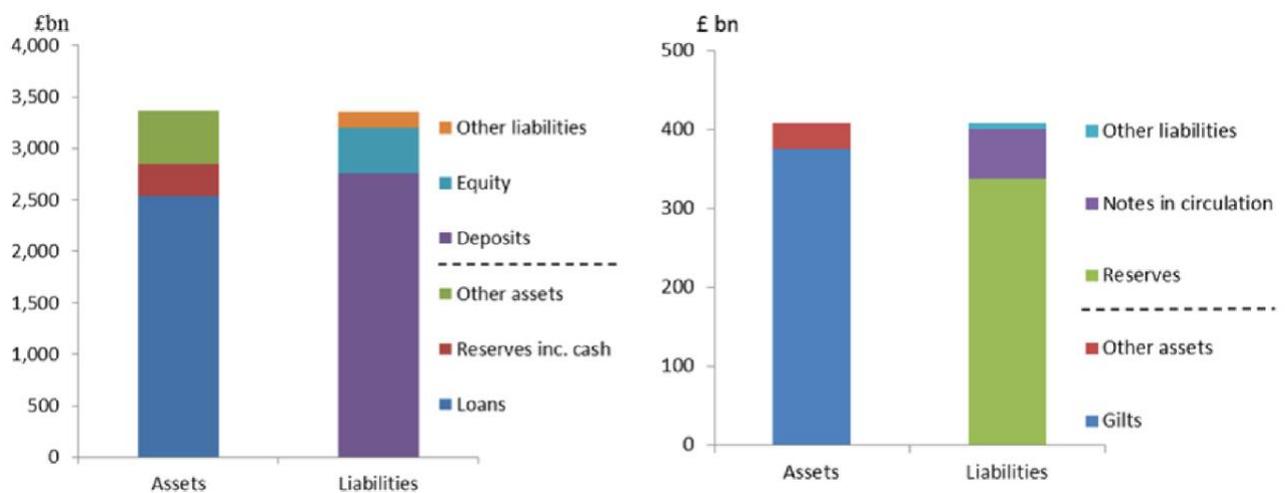

Figure 3: Left chart: balance sheet of commercial bank performing fractional reserve banking (Source: Bank of England). Right graph: balance sheet of central bank holding only liquid assets (Source: Bank of England Annual Report 2015) (Broadbent, 2016, p. 10).

Relating the CBDC to traditional narrow banking proposals

The introduction of a CBDC relates to one narrow banking proposal in particular, and that is the narrow banking proposal by Tobin (Broadbent, 2016). A CBDC that provides the public access to risk free money at the central bank is similar to the so called Deposit Currency Accounts (DCAs), part of the narrow banking proposal by Tobin. Tobin's proposal is now related to the description of narrow banks given in the first part of the literature review, where the assets portfolios of narrow banks become less restrictive.

Tobin is in favour of a narrow banking system that both include a Treasury Money Market Mutual Fund (TMMMF) and a Utility Bank (UB). Tobin argues that the public should be provided deposit currency accounts (DCAs) at the central bank. These accounts are similar to bank accounts, but provide a risk free environment because money stored at these accounts is central bank money. Tobin argues that these accounts should provide a certain interest rate below the Treasure bill rate, which relates the DCAs to the Treasury Money Market Mutual Fund (TMMMF). Furthermore, Tobin proposes that commercial banks can still receive government deposit guarantees, but are prohibited of any risky lending and investment activity. This in turn describes an individual commercial bank as a Utility Bank (UB). The risky lending and investment activities could be provided by investment banks that can obtain funding by uninsured debt and equity. By providing these DCAs, the public has access to a more convenient form of central bank money than cash. Tobin argues that these DCAs may decrease the need for deposit insurance guarantees by governments, which according to Tobin has led to undesirable behaviour of commercial banks. The DCAs as part of Tobin's narrow banking proposal are similar to the accounts of a CBDC currently considered to be issued by central banks. Since both these accounts provide the public a convenient option to hold central bank money (Broadbent, 2016; Pennacchi, 2012).

2.3 Conclusions and final remarks literature review

Currently, the traditional banking system does not represent any type of narrow banking system. The risks associated with the practise of fractional reserve banking are limited by governments providing deposit guarantee schemes and lender of last resort facilities provided by central banks. With the introduction of a CBDC, the topic of narrow banking has gained renewed interest. Since a CBDC that allows the public to open accounts at the central bank implicitly narrows the traditional banking system, if retail deposits were to move to the

accounts of the CBDC. The CBDC accounts are similar to the DCAs mentioned in Tobin's narrow banking proposal. The biggest difference is that the central bank itself is considered a narrow bank when it issues a CBDC. Whether the traditional banking system actually gets narrowed depends heavily on the specific features of the CBDC. To be more specifically, whether the CBDC will closely represent cash or a bank account can determine the extent to which a CBDC implicitly narrows the banking system. There are still many questions unanswered to what extent competition between retail deposits and a CBDC can narrow the traditional banking system.

Furthermore, the impact of such outflow of retail deposits on the traditional banking system is currently unknown. In the modern economy, commercial banks can extent loans by creating an equal amount of retail deposit liabilities (McLeay et al., 2014). Current literature suggests that the ability of commercial banks to make loans in the modern loans can be impaired with the introduction of a CBDC (Broadbent, 2016). However, the implications relating to a significant outflow of retail deposits, thereby impairing the ability of commercial banks to issue loans is unknown. What do can be concluded is that while the ability of commercial banks to perform any money creation in the modern economy may be impaired when retail deposits leave the traditional banking system. The significant outflow of retail deposits does not impair the ability of commercial banks to obtain funding deposits in the first place. Because if all deposits were to leave the traditional banking system, commercial banks can still extend loans by obtaining retail or wholesale deposits, which process is shown in figure 1.

3. Implications of competition between retail deposits and a CBDC, Dyson & Hodgson (2016): "Digital Cash: why central banks should start issuing Electronic Money"

The first core article is that by Dyson & Hodgson (2016). This article examines the economic issues relating to the potential introduction of a CBDC by the Bank of England. This means that the impact of a CBDC is examined for the economy of the United Kingdom. The paper by Dyson & Hodgson (2016) covers the most important aspects regarding the implementation of a CBDC. This article contributes to the discussion who should provide accounts of the CBDC, whether it should generate interest, and what the implications for monetary policy and financial stability are. These are exactly the points central banks are currently investigating, as mentioned in the speech by Skingsley (2016).

The in-depth analysis of this core article focuses on the discussion on competition between retail deposits and a CBDC. This analysis gains insights to what extent competition between these two forms of money can narrow the traditional banking system. Firstly, it is explained what the implications are for commercial banks and central banks when there is a flow of retail deposits to the account of the CBDC. Secondly, the implications of having retail deposits and CBDC compete with each other are examined. The implication of this competition allows it to further examine to what extent it is likely that a shift of retail deposits to a CBDC would occur. This is done by analysing competition of retail deposits and a CBDC as medium of exchange and store of value. Thirdly, implications for narrowing the banking system by changing specific features of the CBDC design, such as paying interest on these accounts are examined. This helps central banks gain an insight to what extent their CBDC design can narrow the traditional banking system.

3.1 What happens if money flows from retail deposits to a CBDC?
This section will first explain how commercial banks handle payments to the account of the CBDC. Hereafter follows a discussion on the implications for commercial banks and central banks.

3.1.1 Settling of payments to a CBDC by commercial banks

Currently, if an individual commercial bank extends a loan the borrower can spend this money freely in the traditional banking system. This leads to flows of money to other commercial banks if the borrower decides to spend his money at another commercial bank. It is likely that the individual commercial bank in turn receives a cash flow from other commercial banks who also extent loans. Since the money of these loans issued does not leave the traditional banking sector, it allows commercial banks to only settle their net differences of cash flows between each other. However, this situation changes if the borrower transfers his funds to their account of the CBDC. In this case, commercial banks can no longer transfer a fraction of cash flow to settle their payments. They must now transfer the full amount of the payment done by the borrower, since the money now leaves the commercial banking sector. Whether commercial banks must pay an amount closer to 100% to settle their payments depends on competition between retail deposits and a CBDC as payment service and store of value. This outflow affects both commercial banks and central banks.

3.1.2 Implications for commercial banks

Demand of credit with CBDC

Dyson & Hodgson (2016) argue that the introduction of a CBDC will have no direct effect on the demand for credit. Simply because the funds that are stored at the account of the CBDC are only stored at the central bank. This means that funds of the accounts of the CBDC cannot be used for any financial intermediation purposes.

Supply of credit with CBDC

Furthermore, Dyson & Hodgson argue that the supply of credit will not be affected if the reserves of commercial banks get drained by the shift of retail deposits to the accounts of the CBDC, because the money creation by commercial banks is not dependent on these reserves. But rather by loss absorbing capital that commercial banks have at their disposal. In addition to this it is argued that any shortage of reserves in the interbank market can be overcome by central banks injecting new reserves into the interbank system to compensate losses.

However, the willingness of commercial banks to issue new loans may be affected with the introduction of a CBDC if the public started to use their CBDC accounts significantly. This indicates that commercial banks are required to pay up to 100% in reserves to settle payments. This may result in an increase in funding costs by commercial banks that have to

borrow back these reserves. Dyson & Hodgson (2016) argue that this "may" have some effect on the willingness of commercial banks to lend money. But that this effect is most likely negligible since other factors such as capital requirements, regulation, and confidence in the future health of the economy, are seen as more important in the determination of amount of bank lending. For this reason, it is seen as a possibility that the supply of credit provided by commercial banks will not get affected by a CBDC. Only if there were to be a significant outflow of retail deposits to a CBDC, the cost of funding could increase since commercial banks will have to depend more on funding from wholesale funding markets.[3]

3.1.3 Implications for central banks

Implications for central banks relate to their role in the interbank market. The interbank market is of focus for central banks, which use this market to implement their monetary policy (Allen et al., 2009). Any shift of retail deposits to the CBDC drains the reserves available in the interbank market. Any outflow of funds from the interbank market will first be compensated by current reserves available in the interbank market which indicates that the amount of funds that can flow to the CBDC before any shortage occurs, equals the reserves available in the interbank market.[4] However, any shortage that does occur in the interbank market must be resolved by interference of the central bank who can inject new reserves into the system. This allows commercial banks to continue to settle their payments among each other. The central bank can use normal market operations to set the interest rate in the interbank market according to its policy target. This in turn indicates that with the introduction of a CBDC, central banks may have to intervene more in the interbank market.

3.2 Assessment of level of competition between retail deposits and a CBDC

3.2.1 How does a CBDC compete with other forms of money?

Currently there are two forms of money circulating in the economy: cash and retail deposits held with commercial banks (electronic money). With the introduction of a CBDC, there is a new form of electronic money in the economy forcing the public to optimize their decision to store their funds in cash, retail deposits or the account of the CBDC.

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[3] For consistency purposes the definition of wholesale funding markets is used. While Dyson & Hodgson (2016) refer to money markets.

[4] The QE program in England of 2009-2912 has put additional reserves in the interbank market system, an amount of 326 billion pounds is registered as of 28th October 2015 (Dyson & Hodgson, 2016).

This brings a unique situation, since both retail deposits held at the commercial bank and a CBDC can be spend electronically. However, the public will not consider retail deposits and a CBDC to be perfect substitutes. This, because the CBDC that is issued by a central bank bears no credit risk, while the other form of electronic money (retail deposits) bears credit risk for the amount above the level that falls under the government deposit guarantee. In the case of the Bank of England, this is £75,000 pounds, in Europe this amount is €100,000. This difference between retail deposits and a CBDC is important for at least two reasons. Firstly, for anyone having retail deposits that do not get covered by government deposit guarantees, the CBDC would provide a risk free environment to store their funds. Secondly, Dyson & Hodgson (2016) argue that there is a fear that governments may find ways to "bail in" depositors in case of a future financial crisis. This would result in governments not honouring their deposit guarantees.

The new form of electronic money (CBDC) indicates new competition for retail deposits, which currently only competes with cash in the economy. However, cash can only be physically stored and it requires physical action to move these funds to a bank account. This makes cash far from a perfect substitute to retail deposits held with commercial banks. The similarities of retail deposits held at commercial banks and a CBDC indicates competition as medium of exchange and store of value.

3.2.2 Competition medium of exchange

Competition in payment services

A CBDC competes with commercial banks on payments services they provide. Currently, the Bank of England restricts access to its reserves. This makes it almost impossible for non-bank financial institutions to compete with the traditional commercial banks on payment services. For this reason commercial banks have had an effective monopoly on payments services. The introduction of a CBDC would provide new competition for commercial banks, stimulating commercial banks to improve their payment systems to retain their current customer base.

Dyson & Hodgson (2016) argue that competition in payment services is most likely not fatal for commercial banks for two reasons. Firstly, commercial banks have the possibility to offer interest on the bank accounts they provide. This is possible because commercial banks are allowed to use their retail deposits to fund long term loans. Profit from these financial intermediation activities can be passed on to customers via their bank accounts. This is in contrast the full-reserve structure of a CBDC, which makes it impossible to offer any interest

from activities relating to financial intermediation. Secondly, since money stored at the CBDC cannot be used for any activities relating to financial intermediation. It is likely that fees are charged for using the CBDC accounts as medium of exchange. This would make the CBDC more expensive to use than retail deposit accounts which currently offer "free if in credit". Competition proves to be effective as medium of exchange, to keep retail deposits for this purpose at the commercial bank.

3.2.3 Competition store of value

Considering the fact that retail deposits held with commercial banks and a CBDC differ in their credit risk, it is important to analyse competition as store of value in both normal times and in periods of financial distress.

Implications in normal times

When analysing competition between retail deposits and CBDC in normal times, no significant implications are expected. In normal times, the difference of credit risk between retail deposits and a CBDC plays a less important role. If no credit risk by the public is associated with holding retail deposits at commercial banks, no particular preference to hold a CBDC is expected. However, it still may be the case that there is some preference by the public to use their account of the CBDC. If these retail deposits flow from bank accounts held at the commercial banks to a CBDC, it shrinks the balance sheet of the commercial bank. Because both deposit liabilities and an equal amount of reserves to settle the payments decrease at the same rate.

Focusing on the central banks perspective, no significant changes are expected for central banks and their role in the interbank market, or commercial banks' liquidity management. The interbank market depends on the excess funds of commercial banks. In normal times, any shift of funds from retail deposits to CBDC, will decrease the availability of money in the interbank market. Any non-significant shift of funds to a CBDC will firstly be compensated by the current reserves existing in the interbank system to settle daily payments. In case of the Bank of England, this means that a flow of up £250bn can be used before the central bank must intervene. However, the amount of reserves can differ across countries. If central bank are needed to intervene because the reserves can no longer compensate the amount of retail deposits that move to a CBDC, central banks can inject reserves by "conventional measures" as argued by Dyson & Hodgson (2016).

Implications in periods of financial distress

These dynamics will change if there is a CBDC available to the public in a financial crisis. In a financial crisis the maturity transformation performed by commercial banks may cause a bank run. A traditional bank run occurs if the public chooses to withdraw their funds from commercial banks (Gorton & Metrick, 2012). However, a traditional bank run can be seen as practically problematic for the public to initiate, since it can be seen as an inconvenience to shift funds away from fragile commercial banks. Under a traditional bank run, the public can either choose to shift their funds to other commercials banks that are considered a safer option, or the public can choose to withdraw cash. However. the withdrawal of cash can get limited by withdraw limits set to customers by commercial banks. Furthermore, storing large amounts of cash can be seen as inconvenient and unsafe. For this reason in the financial crisis of 2007, the UK bank Northern Rock saw a bank run where its customers withdrew their funds electronically to another commercial bank.

As mentioned by Dyson & Hodgson (2016), the search for a safe haven for storing funds changes significantly with the introduction of a CBDC. The public can still decide to shift their funds electronically to safer commercial banks. However, there is still the possibility that other commercial banks can fall, resulting in a loss for those who shifted their funds to the other commercial banks. The other "new" option is to shift the funds electronically to the account of the CBDC. As mentioned before, storing funds at a CBDC is completely risk free because deposits are backed by the central bank itself. The CBDC will therefore be seen as a superior option to withdraw funds. Since the CBDC provides the safety associated with storing funds in cash. Furthermore, it brings the convenience of a bank account since it is also connected to the electronic payments system.

For this reason Dyson & Hodgson (2016) argue the following: "runs on commercial banks could be faster and deeper when there is a concern about the health of a bank. It is conceivable that even in a minor panic more people will say "I'll just move my money across to a Digital Cash Account for the next few weeks until this settles down, and then move it back to the bank again if everything turns out to be fine.". In other words, the existence of digital cash may exacerbate bank runs." (Dyson & Hodgson, 2016, p. 27). If such bank run were to occur in a period of financial distress, it can result in a reduction of liquidity ratios of commercial banks, leading to reserves in the interbank market to dry up. In such scenario, the central bank must intervene by issuing additional central bank reserves to the commercial

banks against government bonds. However, there is a possibility that this response is not enough if the commercial banks holdings of reserves and government bonds cannot compensate the loss in retail deposits that move to a CBDC. Two options are left over by which commercial banks can retain sufficient levels of liquidity ratios. Firstly, commercial banks themselves could start selling other assets in order to obtain new reserves. However, commercial banks may not sell their assets successfully if all banks simultaneously try to sell of their assets. Such panic sale may lead to a deterioration of commercial banks equity ratios if the sell price falls below the fair value. Secondly, central banks can intervene by offering to buy a wider range of assets from commercial banks.

However, Dyson & Hodgson (2016) argue the following relating to such significant shift in retail deposits to a CBDC: "But if the flow of funds to DCAs was so significant that we reached this point, it would suggest a deeper insolvency crisis, rather than a short- term liquidity crisis, and it would be much more fundamental problems in the banking system, rather than the existence of digital cash, which was to blame." (Dyson & Hodgson, 2016, p. 27). This indicates that the introduction of a CBDC most likely will not be responsible for such shift, but rather more fundamental problems in the financial system.

3.3 How does the design of the CBDC influence competition?

Implications relating to competition depend on the specific features of a CBDC. The previously mentioned implications discussed by Dyson & Hodgson (2016) mainly focused on implications relating to the risk free aspect of the CBDC. This section covers the implications of certain design features of a CBDC. Firstly, it is described how the implementation of a CBDC can influence competition between retail deposits and a CBDC. Secondly, implications of paying interest by the central bank on the CBDC accounts are discussed.

3.3.1 Implementation of a CBDC

Responsibility for holding CBDC accounts

Central banks must decide how they want to arrange the distribution of the CBDC. Central banks have two options to provide an infrastructure for the CBDC, which differ in responsibility for the administrative burden of organising these accounts. Firstly, the central bank can decide to provide accounts for every citizen themselves. Secondly, central banks can decide to outsource this task by allowing the private sector to perform tasks associated with holding these accounts. Both choices imply that any payment to the account of the

CBDC is fully backed by the central bank. This makes it possible for the public to withdraw their funds at the CBDC fully. Funds of the CBDC are liabilities for central banks and must be balanced by assets. These can consist of noninterest bearing bonds that are solely issued for the backing of CBDC liabilities.

Dyson & Hodgson (2016) argue against the Bank of England providing the accounts for a CBDC itself. Because handling the administrative burden of a CBDC does not suit with the tasks of the central bank. The central bank is responsible for handling regulation and performing monetary policy. This may result in the central bank having no incentive to innovate payment services associated with a CBDC. For this reason it is argued that the better option would be to allow private firms to provide accounts of a CBDC to the public. These private firms would provide everything associated with a CBDC account, such as: account statements; payment cards; balance checks; sort codes; account numbers; internet and/or mobile banking; customer support. Another requirement for these private firms is that they need to make the CBDC compatible with the current payment system. This makes it possible for the public to use their CBDC account for normal payments.

Outsourcing the administrative burden of these accounts brings several benefits for central banks. Firstly, it will minimize the burden of organising the accounts of a CBDC. Secondly, private firms will compete with each other in providing the best experience of a CBDC account. Thirdly, in the case of the Bank of England, the regulatory framework already exists. Fourthly, there would be competition in current payment account services. Dyson & Hodgson (2016) do not explicitly mention that by allowing private firms to compete with each other, more competition in providing payments services for commercial banks is expected. Thereby potentially increasing the use of a CBDC.

3.3.2 Should central banks pay interest on CBDC?

Until now, only a CBDC that is non-interest bearing is considered. Central banks are asking themselves whether they should pay interest on this CBDC. The payment of interest on a CBDC will differentiate it substantially from cash, which the public is currently willing to hold without any payment of interest. Therefore, paying interest on a CBDC will make it look more similar to a bank account. The implications of a CBDC get more complex with the introduction of interest. Currently, only commercial banks receive interest on their reserves in the interbank market. With the introduction of an interest-bearing CBDC, it would mean that the accounts of the CBDC receive a risk free income similar to commercial banks. Dyson &

Hodgson (2016) mention different problems arising with the payment of interest on a CBDC. Considering these problems, they strongly recommend a CBDC design that does not pay any interest.

Implications for commercial banks are that the interest paid on a CBDC, sets a floor on the rate commercial banks must pay to retain their retail deposits. If it is known by the general public that the account of the CBDC pays interest. It would be very easy for holders of both a bank account and a CBDC account, to shift their funds to the account that pays the highest interest. This indicates that an outflow of funds to the CBDC occurs when the interest rate paid on the CBDC is higher than that of the bank account. For this reason, commercial banks are expected to pay an amount of interest equal to that of the CBDC to keep its deposit liabilities, which will effectively stop the outflow of funds, but increases the costs of maintaining funding.

Furthermore, an interest-bearing CBDC impacts government finances. The interest paid on the CBDC must come from central bank revenues, tax revenue or other borrowing. Since the public is currently willing to hold central bank money in the form of cash paying no interest. Dyson & Hodgson (2016) argue that there is no justification for paying interest on the CBDC, considering the expenses it imposes for governments. In addition to this, there is a difference in the amount which the bank rate covers between reserves of commercial banks and the interest rate set on a CBDC. The difference is that the interest paid on reserves of commercial banks only consist of a small part of the balance sheet. Since commercial banks are only required to hold a fraction of their deposits liabilities as reserves on which the interest rate has influence. With the introduction of a CBDC, any amount of retail deposits that shifts to a CBDC would receive interest. The amount of retail deposits that therefore theoretically can receive interest is far greater than the reserves commercial banks are required to keep. This indicates that a larger part of a commercial banks balance sheet will be considered more costly. Dyson & Hodgson (2016) argue that "This turns the Bank Rate into a very different tool, which may have unintended consequences or simply be unmanageable." (Dyson & Hodgson, 2016, p. 31).

3.4 Conclusion

Consistent with the literature review, Dyson & Hodgson (2016) mention that any outflow of funds from the commercial banking sector must be compensated by borrowing back these

reserves which potentially can raise funding costs to the banks to issue any loans. The biggest problem of such shift in funds is that commercial banks can no longer net their payments. The "implicitly" narrowing of the banking system, meaning a significant outflow of retail deposits, is most likely to occur in periods of financial distress. Since the account of the CBDC provides a safe haven for storing funds it increases the likelihood of a bank run to occur. This can lead to central banks having to intervene more in the interbank market to provide liquidity to commercial banks. When time settles, the commercial bank is expected to continue to compete effectively with a CBDC. For these reasons it is believed that only a temporary narrowing of the traditional banking system can be blamed on the existence of a CBDC.

3.5 Limitations & Discussion

Limitations

Without any empirical evidence it is hard to quantify the extent to which certain effects take place. This indicates that the discussion on competition between retail deposits and a CBDC as presented by Dyson & Hodgson (2016) may be helpful in gaining an understanding of possible behaviour of markets when a CBDC is introduced. It is not descriptive on the size of this effect. This makes it the biggest limitation of the research that the significance of the effects such as the amount of funds that will leave the commercial banks cannot be specified. In essence, this would not be problematic if this is taken into account when considering the implications of a CBDC.

Discussion

However, Dyson & Hodgson (2016) misses out on discussing the implications for commercial banks if the amount of funds shifting to a CBDC were to be significant. Dyson & Hodgson (2016) rather argued that a significant outflow of funds to a CBDC will be a consequence of more fundamental problems of the financial system. And that the payments up to 100% in reserves to settle payments to the CBDC may have some effect on the willingness and ability of commercial banks to extent loans using their money creation process.

I argue that payments up to 100% in reserves to settle payments to a CBDC affects the ability of commercial banks to function as money creators. Assume the following situation, a

commercial bank extends a loan of 100$ and creates an equal amount of deposit liabilities. With the introduction of a CBDC, the commercial bank must consider that 100$ of these deposits liabilities can move to the CBDC. If the commercial bank were to know that these deposit liabilities move away from the traditional banking system, it can no longer use their money creation process to create funding. Since the commercial bank now is required to fund these outflow of retail deposits by attracting wholesale funds. This scenario is similar to a scenario where a new commercial bank enters the market. If a commercial bank enters the market, it cannot just create a new loan by creating simultaneously an equal amount of retail deposit liabilities. The commercial bank needs some funding in the first place to be able to extend a loan. Commercial banks can obtain such funding by attracting retail and wholesale deposits (Kiser, 2003).

When the role of commercial banks to function as money creators is impaired by the introduction of a CBDC, their lending decision will depend on its ability to attract funding in the first place. For this reason it is assumed that only models who consider commercial banks as financial intermediaries, who initially obtain deposits to fund lending activities can hold. Dyson & Hodgson (2016) fail to provide a discussion on the implications of a significant outflow of retail deposits to a CBDC impairing the ability of commercial banks to issue loans in the first place. Dyson & Hodgson (2016) fail to relate these implications to a more deeper liquidity crisis, where the likelihood of a significant outflow of retail deposits is at its highest.

4. A model to show effects of sources of funding on bank loan market, Kiser (2003): "Modelling the Whole Firm: The Effect of Multiple Inputs and Financial Intermediation on Bank Deposit Rates"

The second core-article is that by Elizabeth Kiser, who developed a theoretical model which incorporates substitutability between sources of deposits and conditions in the bank loan market, and its effect on the pricing of retail deposits for an individual commercial bank with market power.[5] Substitutability between sources refers to both retail deposits and wholesale deposits that can be obtained by the commercial bank to fund their service of financial intermediation. Furthermore, a commercial bank is assumed to have market power if retail depositors mainly depend on their local depository institutions, and when the local depository institution itself owns a large local market share (Amel & Starr-McCluer, 2002; Kiser, 2003). Kiser (2003) examines whether different types of input can affect the pricing of inputs itself. The theoretical model by Kiser (2003) allows to shift different parameters related to costs of funding which makes it possible to predict the effects of inputs on commercial bank lending. The predictability of the model is also tested empirically by Kiser (2003).

The theoretical model by Kiser (2003) can be seen as an analysis of profit optimization of an individual commercial bank when the commercial bank is forced to obtain funding in the first place to extend loans. Analysing this model increases understanding of how different conditions relating to obtaining funding affects lending. In addition to this, the explanation of the model including the dynamics of the theoretical predictions is required. This, because in the discussion part of this thesis, the model by Kiser (2003) is interpreted to a situation where a CBDC exists. It should be noted that in this thesis it is assumed that commercial banks optimize their lending based on the theoretical model by Kiser (2003).

4.1 Model
The model by Kiser (2003) expands on earlier classical models of the banking firm which describe commercial banks as financial intermediaries.[6] In these classical models,

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[5] The model can be extended to incorporate imperfect competition, providing similar comparative statistics (Freixas & Rochet,1997; Kiser, 2003).

[6] See Santomero (1984) and Freixas & Rochet (1997) for a survey on literature mentioned.

commercial banks serve a financial intermediary function by obtaining deposits to fund their lending activities. These lending activities generate interest which is the main source of income of commercial banks. Commercial banks can obtain retail deposits or wholesale deposits by operating on a larger-scale fund market. These classical models show that commercial banks initially fund lending by obtaining retail deposits. However, as commercial banks obtain retail deposits, they will bid up the price of using these retail deposits, which increases the costs of obtaining these deposits. For this reason, these models assume an upward-sloping supply curve of retail deposits. The main point to be made is that commercial banks will shift to funding other than retail deposits when marginal costs of retail deposits is greater than the marginal costs of obtaining funds from the larger-scale fund market (wholesale funding).

The point at which the marginal costs of these two types of funding intersects depends on the accessibility of larger scale wholesale funding markets. Kiser (2003) examined whether this rate of obtaining and managing wholesale funding differs between commercial banks. It is argued that this rate may differ for commercial banks dependent on its specific characteristics. Kiser (2003) gives the following example: "In particular, well capitalized banks with less risky asset portfolios (or banks that are considered "too big to fail") may pay a lower risk premium for wholesale funds than their riskier counterparts" (Kiser, 2003, p.4). Furthermore, larger commercial banks may face benefits of economies of scope in managing wholesale funding. The model by Kiser (2003) assumes that commercial banks have access to cheap alternative funding to fund their lending activities. This indicates that no bank lending channel exists in the model by Kiser (2003). The bank lending channel is the mechanism by which commercial banks pass on changes in the federal funds rate to their rates charged on their loans. However, commercial banks will not fund their loans with federal funds if they have access to cheaper sources of funding. The federal funds rate is assumed to be part of wholesale funding.

The model by Kiser (2003) is said to be loosely based on the classical models of Klein (1971) and Monti (1972). Kiser (2003) incorporated factors that affect equilibrium values in the model, by shifting retail deposit supply, loan demand and cost, the cost of managing retail deposits, and the cost of attracting and managing wholesale deposits. The main goal of the model by Kiser (2003) is to show the effects of both input mix decision of sources of funding and intermediation on retail rates. The theoretical model has three key assumptions:

1. The first assumptions states that at low levels of total deposits, commercial banks find retail deposits less costly to obtain and manage than wholesale deposits. This refers to banks bidding up the price of retail deposits.

2. The second assumption states that commercial banks hold market power in retail deposits and lending but no market power in wholesale deposits. This assumption considers that commercial banks with large local market shares hold market power in a local area, which is different from wholesale deposits that are assumed to be homogenous and exchangeable over a broad geographic area.

3. The third assumption states that retail deposit supply, wholesale deposit supply, and loan demand functions faced by a commercial bank are entirely distinct.

Going deeper into the setup of the model by Kiser (2003), a commercial bank is assumed to firstly obtain deposits to fund lending activity. The retail and wholesale deposits that can be obtained by a commercial bank are perfect substitutes as input for lending. The model by Kiser (2003) focuses on substitutability between sources on lending, and therefore excludes other income than lending and reserve requirements. The model describes a monopoly bank facing an inverse demand for loans, inverse supply of retail deposits and a perfectly elastic supply of wholesale deposits. Furthermore, the model describes a standard up-ward sloping retail deposit supply function and a standard-downward sloping loan demand function.[7] All functions are expressed in figure 4.

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[7] See Appendix A for further mathematical specifications of the model.
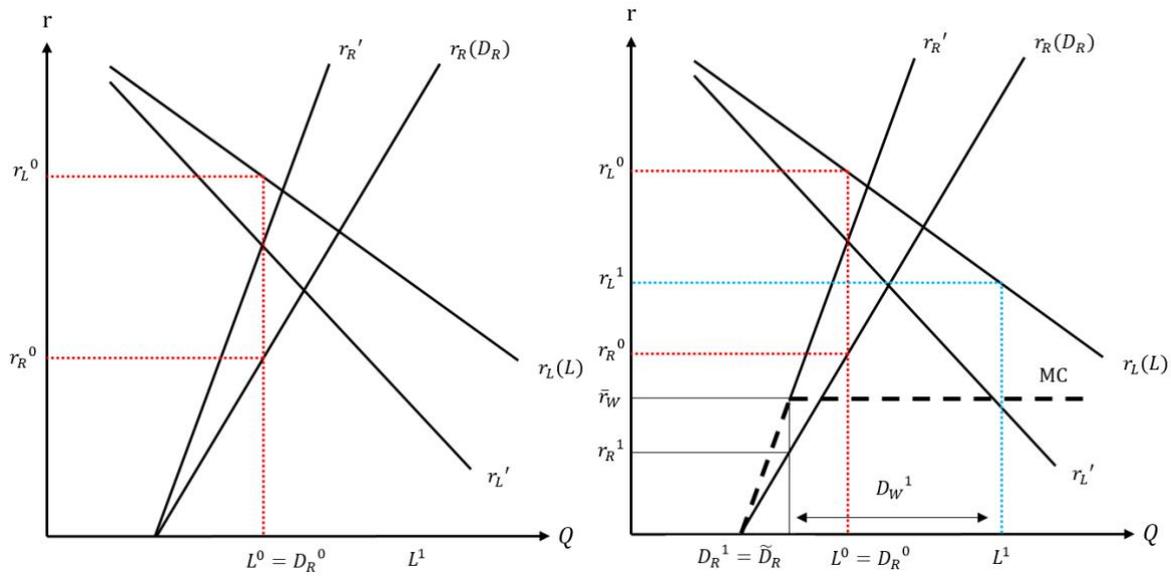
Figure 4: Equilibrium rates and deposits when wholesale funds are unavailable (left) and available (right) (Kiser, 2003, p. 28).

$Q =$	Quantity of loans produced	$D_R{}^0 =$	Total amount of retail deposits available
$r =$	Loan rate	$L^0 =$	Amount loans extended (wholesale funds unavailable)
$r_R' =$	Marginal deposit cost	MC=	Marginal deposit cost curve (wholesale funds available)
$r_L' =$	Marginal loan revenue	$r_L{}^1 =$	Equilibrium loan rate (wholesale funds available)
$r_R(D_R) =$	Inverse supply of retail deposits	$r_R{}^1 =$	Equilibrium retail rate (wholesale funds available)
$r_L(L) =$	Inverse demand for loans	$D_W{}^1 =$	Amount wholesale funds held (wholesale funds available)
$r_L{}^0 =$	Equilibrium loan rate (wholesale funds unavailable)	$\tilde{D}_R =$	Switch point
$r_R{}^0 =$	Equilibrium retail rate (wholesale funds unavailable)	$L^1 =$	Amount loans extended (wholesale funds available)
$D_W{}^1 =$	Amount retail deposits held (wholesale funds available)		

Figure 4 shows the equilibrium rates and deposits when only retail deposit are used as source of funding (left graph) and when both retail and wholesale funding (right graph) are used.

Focusing on the left graph, we see a commercial bank that optimises its profit by setting marginal loan revenue r_L' equal to marginal deposit cost r_R'. In this case, the commercial bank only has access to retail deposits as source of funding. The commercial bank's equilibrium rates are shown in the graph by the red dotted line that intersects with the inverse supply of retail deposits $r_R(D_R)$ and the inverse demand for loans $r_L(L)$. The corresponding retail deposit and loan rates are $r^0{}_R$ and $r^0{}_L$, respectively. In this equilibrium, the amount of loans extended equals L^0, which equals the amount of retail deposits $D_R{}^0$ the commercial bank has available. This indicates that commercial banks that only have access to retail deposits are limited in the amount of loans they can extend.

The profit maximization shown in the right graph differs in one aspect: the right graph shows profit maximization of a commercial bank having access to both retail deposits and wholesale deposits. These wholesale funds are available at rate $\bar{r}_W$. Since the commercial bank now has two sources of funding for extending loans, its marginal cost curve changes from $r_R(D_R)$ to MC. A kink at $D^1{}_R = \tilde{D}_R$ occurs, which relates to the assumption that a commercial banks finds retail deposits less costly to obtain and manage at low levels of total deposits. The kink occurs because a commercial bank will substitute retail deposits for wholesale deposits as marginal costs of retail deposits rise, while marginal costs of wholesale funds stay constant. The bank now sets MC equal to its marginal revenue r_L'. The new equilibrium is shown by the blue dotted line in the right graph. By adding wholesale deposits at rate $\bar{r}_W$ in addition to retail deposits, lending has increased from L^0 to L^1. This increase in lending occurs because retail deposits are substituted for wholesale deposits. A commercial bank that has access to both sources of funding is therefore not limited by the amount of retail deposits available. Consequently, a lesser amount of retail deposits $D^1{}_R$ is held, while total wholesale deposits held equals $D_W{}^1$. Corresponding loan rates and retail deposit rates drop to $r^1{}_L$ and $r^1{}_R$, respectively.

4.2 Theoretical predictions of the model

The model presented in figure 2 can be adjusted to include parameters that can affect the demand and costs of the commercial bank. The predictions by Kiser (2003) are shown in table 2.

Parameter	$L^* \leq \widetilde{D}_R$	$L^* > \widetilde{D}_R$
Wholesale funds rate $\bar{r}_W$	0	+
wholesale operating cost θ_W	0	+
retail deposit operating cost θ_R	-	0
retail deposit supply σ_R	-	0
loan demand σ_L	+	0
loan operating cost θ_L	-	0

Table 2: Theoretical predictions of effects of changes in model parameters on the retail deposit rate (Kiser, 2003).

This table can be read as follows: for each parameter affecting demand and cost, the effect on retail deposit is illustrated in two scenarios: $L^* \leq \widetilde{D}_R$ and $L^* > \widetilde{D}_R$. $L^* \leq \widetilde{D}_R$ represents the proportion of loans extended using retail deposits as source of funding. And $L^* > \widetilde{D}_R$ represent the proportion of loans extended using wholesale deposits. The effects of an increase in a certain parameter can increase the retail deposit rate (+), decrease the retail deposit rate (-), or have no affect (0). For example, for the proportion of loans extended using retail deposits, no effect is expected when there is a change in anything related to wholesale funding. For loans extended using wholesale funding, anything related to retail deposits has no influence on the retail deposit rate.

4.3 Empirical estimations: which conditions affect the funding decision?

While the theoretical model by Kiser (2003) is presented to show how sources of funding affect retail deposit rates. The empirical part of the paper is used to show that commercial banks can differ in rates of wholesale funding they must pay, based its characteristics. How can a commercial bank's characteristics affect its pricing of inputs? Kiser (2003) argues that commercial banks that are well capitalized with less risky asset portfolios may pay a lower risk premium for obtaining wholesale funds, compared to competitors with riskier asset portfolios. Furthermore, it is argued that larger banks may experience benefits from scale in managing wholesale deposits. If these wholesale funds are used as substitutes for retail deposits in the funding of loans, the ability of a commercial bank to buy wholesale funds at a low rate implies that demand for retail deposit should decrease. This, because a commercial bank can obtain cheap wholesale funds to avoid bidding up the price of retail deposits. This is

consistent with the idea shown in the theoretical model that shows that commercial banks will substitute retail deposit for wholesale deposit funding, when costs of wholesale funding is lower compared to costs associated with obtaining retail deposits. As shown in figure 4 (right graph), a commercial bank with access to wholesale funding, results in a decrease of retail deposit rate from r^0_R to r^1_R.

Kiser (2003) performed an OLS and random-effects regression for the empirical estimation. Data for the empirical research is retrieved from the Bank Rate Monitor. Results from the empirical estimation show that the input mix decision of funds used by commercial banks and the conditions in the loan market, affects the pricing of the commercial bank's deposit input. Characteristics of a commercial bank such as: institution size; portfolio risk; local loan risk; local cost; charter type; local market power in retail deposits, support the theoretical predicted effects of the model. This in turn indicates that these factors are predictive in the determination of the pricing of retail deposit rates, and that the substitutability between sources of funding can differ between commercial banks.

4.4 Conclusion

The analysis of the second core-article by Kiser (2003) examined how the use of different types of funding such as retail deposits and wholesale deposits affect the process of financial intermediation performed by a commercial bank. A commercial bank can access wholesale funding market to be less dependent on obtaining local deposits. However, this substitutability depends heavily on the costs associated with obtaining wholesale funding. As retail deposits are only substituted for wholesale deposits if marginal costs of obtaining wholesale deposits are lower. The empirical estimation gained insights in what factors are associated with commercial banks obtaining a lower wholesale funding rate. Commercial banks that operate on a large scale and have relatively non-risky portfolio are associated with obtaining wholesale funds at a lower rate. In turn, this affects the pricing of retail deposits by commercial banks.

4.5 Limitations

Limitations

The model by Kiser (2003) presents a simplified profit optimization of a commercial bank, to examine the effects of substitutability of funding on retail rates. Some assumptions in the

theoretical model are not realistic and deserve some attention. The model by Kiser (2003) excludes any reserve requirements that the commercial bank must hold. By excluding reserve requirements, Kiser (2003) misses to include a discussion on how reserve requirements can affect the substitutability of sources.

Furthermore, it is assumed that retail and wholesale deposits are available to the bank as perfectly substitutable inputs in the production of loans. In reality, a commercial bank will not observe these two types of funding as perfect substitutes. This, because retail deposits are considered to be a more stable source of funding for several reasons. Firstly, retail deposits tend to be covered by deposit insurance by the government, whereas wholesale deposits do not receive such guarantee. In addition to this, these two forms of funding differ in their speed and size of changes in funding costs. Especially wholesale funding may adjust faster to reflect a commercial bank's riskiness (Demirgüç-Kunt & Huizinga, 2010).

Another unrealistic assumption is that it assumed that the federal funds rate is irrelevant to the bank lending decision, thereby stating that no bank lending channel for monetary policy exists. The bank lending channel refers to the mechanism by which commercial banks can pass through changes in the federal funds rate to rates charged on loans. The bank lending channel is based on the premise that banks have no other (major) source of funding other than retail deposits and federal funds. Kiser (2003) argues that when commercial banks have access to other cheaper sources of funding, that the lending decision by commercial banks may not be affected by changes in the federal funds rate. However, it is unrealistic to assume that other types of funding rates are lower than that of the federal funds rate. In Sweden for example, the costs of non-interbank wholesale funding has been historically higher than the interbank rate (Riksbank, 2017).

5. Discussion

This section discusses implications of narrowing the traditional banking system as a result of competition between retail deposits and a CBDC. First a discussion on CBDC and narrow banking is provided, where the importance of examining implications relating to a more permanent shift of retail deposits to the accounts of the CBDC is discussed. This part of the discussion builds further on competition between retail deposits and a CBDC as mentioned by Dyson & Hodgson (2016). The implications of a significant outflow of retail deposits to the CBDC are examined by using the model by Kiser (2003). Firstly, the model by Kiser (2003) is used to show how an individual commercial bank funding decision gets affected when an outflow of retail deposits occurs. Since the model by Kiser (2003) only describes an individual commercial bank, the implications of aggregate response of commercial banks are discussed. At last, the implications of the aggregate response by commercial banks are included in the discussion of a crisis scenario.

5.1 Discussion on CBDC and narrow banking

This part of the discussion examines the importance of considering the implications of a more permanent shift of retail deposits to the accounts of the CBDC. Firstly, it is discussed how a CBDC that is not designed to narrow the banking system, can still narrow the banking system without central banks taking notice of the implications relating to such system. Secondly, it is discussed how central banks may have less control than initially expected over the CBDC design to control competition between retail deposits and a CBDC. Thirdly, a discussion on the implications of a more significant outflow of retail deposits is provided.

5.1.1 Allowing the public to open accounts at the central bank under a CBDC

Before discussing implications of opening accounts at the central bank under a CBDC, a clear distinction must be made between two motivations of central banks to issue a CBDC. Firstly, a CBDC that allows the public to open accounts at the central bank can be used as a tool to implement a narrow banking system. Central banks must consider that creating such system requires heavy regulation of the traditional banking system (Pennacchi, 2012). Secondly, a CBDC that allows the public to open accounts at the central bank may be introduced for reasons non related to the safer making of the traditional banking system. In the literature review it is mentioned that central banks may have many motivations to open accounts at the central bank. To give an example, the Swedish Riksbank is currently investigating whether to issue a CBDC (E-krona) to support the task of promoting a safe and efficient payment

system. In the case of the Swedish Riksbank, the introduction of a CBDC is a response declining cash usage among the public (Riksbank, 2017).

I argue that central banks must consider that independent of its motivations to design a CBDC, that a CBDC that allows the public to open accounts at the central bank can narrow the banking system. The difference between the two stated motivations is that when a CBDC is introduced to implement a narrow banking proposal, commercial banks are most likely not eligible to let their retail deposits compete with a CBDC. A CBDC that is implemented for other reasons than the implementation of a narrow banking system, is most likely in competition with the retail deposits of commercial banks. Implications related to this competition between retail deposits and a CBDC is of high interest, since the implicitly narrowing of the banking system may not initially get paired with the required regulations. In addition to this, central banks may have less control over this competition between retail deposits and a CBDC than initially expected.

5.1.2 Discussion on competition retail deposits and a CBDC

From the literature review we learned that implications of a CBDC depend on the specific design of the CBDC. Especially features of a CBDC that makes the public treat a CBDC more as an alternative to cash or retail deposits is of importance. Because the public must decide whether they want to substitute (if any) their current cash holdings and retail deposits for a CBDC. However, I argue that this rate of substitutability only partly depends on these design features of the CBDC. This, because design features that make a CBDC more similar to cash or retail deposits, lose importance in periods of financial distress. This indicates that central banks may have less control over the rate of substitution than initially expected. Why is this the case? Both a CBDC that is cash like or a CBDC that closely represents a bank account, share two important features which are highly relevant in periods of financial distress. Namely, the combination of zero credit risk and the electronically form of a CBDC. Implications are further discussed by analysing competition between retail deposits and a CBDC in two different economic times, following the first core article by Dyson & Hodgson (2016).

Normal economic times

In normal times, no significant implications are expected of having two competing forms of money. Because any competitive response set by commercial banks will most likely effectively distinct their retail deposits from the CBDC. Commercial banks can compete with a CBDC by offering an incremental spread against the CBDC to compensate any credit risk associated with holding retail deposits. In normal times, this spread will be rather small. In addition to this, commercial banks can provide a wide range of services that will not be offered by the account holders of the CBDC. It is expected that commercial banks will bundle a wide range of services as competitive response (Engert & Fung, 2017). While it is currently hard to specify the effectiveness of responses set out by commercial banks. The main point to be made is that in normal times, a low amount of credit risk is associated with holding retail deposits, allowing commercial banks to compete more effectively with a CBDC. It is therefore assumed that that no significant narrowing of the banking system will occur in normal times.

Crisis

In a crisis scenario, any competitive measure performed by commercial banks is expected to be less effectively. Since in periods of financial distress, the credit risk associated with holding retail deposits at the commercial bank will play an important role. Someone could argue that the competitive responses will still be effectively. And that only a higher spread of interest must be offered by the commercial bank to compensate the credit risk (Engert & Fung, 2017). However, this view misses out on the convenience of the CBDC. As argued by Dyson & Hodgson (2016), it is possible that the public will shift their funds for a small period of time to a CBDC if there is small panic in the creditworthiness of commercial banks. This indicates that independent of the competitive response set by commercial banks, a temporary outflow of funds to the CBDC is expected in a period of financial distress. This implies a temporary narrowing of the banking system. Dyson & Hodgson (2016) argue that this outflow of retail deposits leads to declining liquidity ratios of commercial banks. But that this would not be a problem since any fall in liquidity in the interbank bank market can be compensated by the central bank creating additional reserves. If necessarily, commercial banks can sell of their assets, or the central bank can offer to buy a wide range of assets from commercial banks. Following Dyson & Hodgson (2016), it is assumed that in a crisis scenario the flow of funds to a CBDC will most likely be temporary for this reason.

5.1.3 What happens if the outflow of retail deposits is significant?

Dyson & Hodgson (2016) miss out on discussing implications of a significant outflow of retail deposits to the CBDC by only considering this outflow of retail deposits to be temporary and therefore not significant. Dyson & Hodgson (2016) argue the following related to a significant outflow of funds to the CBDC: "But if the flow of funds to DCAs was so significant that we reached this point, it would suggest a deeper insolvency crisis, rather than a short- term liquidity crisis, and it would be much more fundamental problems in the banking system, rather than the existence of digital cash, which was to blame." (Dyson & Hodgson, 2016, p. 27).

I argue that this view misses out on discussing implications of the possibility that the introduction of a CBDC can implicitly narrow the banking system, which is of interest for at least two reasons. Firstly, the narrowing of the banking system could happen if the preferences of the public to hold or use a CBDC were to change over time. These preferences can be influenced by the design of the CBDC, but are currently hard and almost impossible to quantify. Secondly, especially in a more severe financial crisis, discussing the implications of narrowing the banking system is of high interest. What happens to commercial banks if a more severe crisis occurs, and the public chooses the CBDC as safe haven for storing retail deposits? How can commercial banks continue lending if their retail deposits move to a CBDC? And how does this outflow of funds affect the creditworthiness of commercial banks? These implications of narrowing the banking system are unanswered by Dyson & Hodgson (2016).

5.2 How do commercial banks individually respond to an outflow of funds to the CBDC?

5.2.1 Commercial bank's profit optimization in the first place

The discussion on implications of commercial banks response to a CBDC, considers a situation in which the existence of a CBDC has limited commercial banks in their money creation process, as it is assumed that retail deposits leave the traditional banking system. Therefore, commercial banks will follow the model by Kiser (2003), in which commercial banks firstly have to obtain funding to extent loans. This section examines one parameter that can shift when a CBDC exists. It is examined how an outflow of retail deposits from the traditional banking system affects substitutability between sources of funding. This is done

by altering the supply of retail deposits available in the model. Secondly, the effects of setting a lower bound on retail rates are captured in the model.

5.2.2 Introducing concept of a CBDC: outflow of funds to a CBDC

From Dyson & Hodgson (2016) we learned that competition between retail deposits and a CBDC can result in an outflow of funds from the traditional banking sector. Since the flow of funds to a CBDC indicates that money flows outside the traditional banking system, there is less supply of retail deposits available for a commercial bank to obtain as source of funding. Theoretical predictions of the model by Kiser (2003) show what dynamics come into play if a shock in the supply of retail deposits occurs, which is captured in the model by Kiser (2003), by altering the supply of retail deposits available. This is shown in figure 5 below.
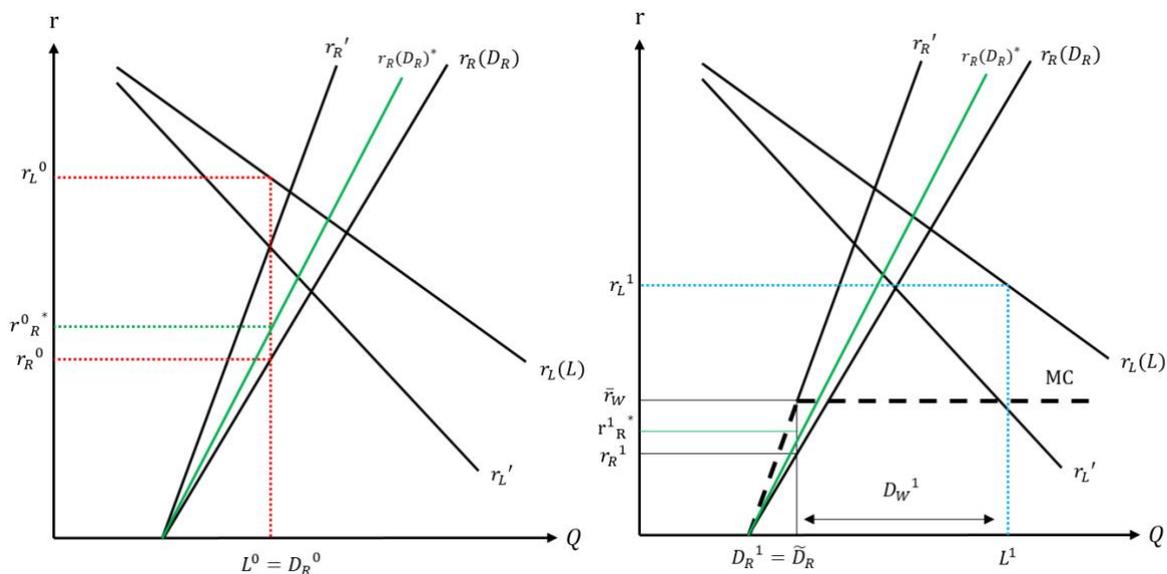

Figure 5: Model by Kiser (2003) altered to include effect decrease supply retail deposits. See next page for a full description of all parameters.

$Q =$	Quantity of loans produced	$D_R{}^0 =$	Total amount of retail deposits available
$r =$	Loan rate	$L^0 =$	Amount loans extended (wholesale funds unavailable)
$r_R' =$	Marginal deposit cost	$MC=$	Marginal deposit cost curve (wholesale funds available)
$r_L' =$	Marginal loan revenue	$r_L{}^1=$	Equilibrium loan rate (wholesale funds available)
$r_R(D_R) =$	Inverse supply of retail deposits	$r_R{}^1=$	Equilibrium retail rate (wholesale funds available)
$r_L(L) =$	Inverse demand for loans	$D_W{}^1=$	Amount wholesale funds held
$r_L{}^0=$	Equilibrium loan rate (wholesale funds unavailable)	$\widetilde{D}_R=$	Amount retail deposits held (wholesale funds available)
$r_R{}^0=$	Equilibrium retail rate (wholesale funds unavailable)	$L^1 =$	Amount loans extended (wholesale funds available)
$r_R(D_R)^*$	Decreased supply retail deposits	$r^1{}_R{}^*$	New equilibrium retail rate (wholesale funds available)
$r^0{}_R{}^*$	New equilibrium retail rate (wholesale funds unavailable)		

Left graph: The decrease in supply of retail deposits is illustrated in the left graph of figure 5, where $r_R(D_R)$ shifts to $r_R(D_R)^*$. A commercial bank reliant on retail deposits as only source of funding cannot access alternative sources of funding to compensate any decrease in the supply of retail deposits available. The shift in $r_R(D_R)$ to $r_R(D_R)^*$ results in new bank equilibrium rates, where the equilibrium retail deposit rate $r^0{}_R$ increases to $r^0{}_R{}^*$, while equilibrium loan rate stays at $r^0{}_L$. The decrease in retail deposit supply due to an outflow of funds available to the CBDC has led to a smaller profit spread.[8] If all retail deposits were to move to the CBDC, there would be no supply of retail deposits in the first place. Indicating that the commercial bank can no longer extent loans.

Right graph: If the bank were to have access to both retail deposits and wholesale deposits as source of funding. A decrease in the total supply of retail deposits from $r_R(D_R)$ to $r_R(D_R)^*$ only affects the proportion of loans that are funded by retail deposits, which amount equals $D^1{}_R = \widetilde{D}_R$. For this proportion of loans, equilibrium retail rates increases from $r^1{}_R$ to $r^1{}_R{}^*$.

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[8] This profit spread refers to the difference between equilibrium retail rate and equilibrium loan rate.

However, the increase in retail deposit rate is limited due to the wholesale deposit rate $\bar{r}_W$. This, because the commercial bank substitutes retail deposits for wholesale funding as marginal costs of retail deposits are higher than marginal costs of wholesale deposits, at $r_R' = \bar{r}_W$. The proportion of loans extended using wholesale deposit therefore does not change. If all retail deposits were to move to the CBDC, the commercial bank can only extent loans by using wholesale funding.

5.2.3 Introducing concept of a CBDC: lower bound on interest rates

The commercial bank may be required to offer an incremental spread of interest to obtain retail deposits from the public if all retail deposits were to leave the traditional banking system. For example, this can happen if the central bank were to pay interest on the account of the CBDC. This indicates that the commercial bank is required to offer a similar interest rate spread to make the public willing to store deposits at the commercial bank. Furthermore, an interest rate spread may be required to compensate credit risk associated with holding funds at the commercial bank (Engert & Fung, 2017). For any interest rate the commercial bank currently offers on bank accounts that is below the interest rate that is required by the public to hold funds at the commercial bank, there is no supply of retail deposits. Why is this the case? Because the public can easily shift their funds electronically to the account that is preferred, it means that a kink at the inverse retail deposit supply would occur below the rate of retail deposits that the commercial bank is required to offer to compete with a CBDC. This assumes that every deposit holder has access to a CBDC, and only focuses on optimizing his or her required interest rate. Thus, the incremental spread required by the public to keep deposits at the commercial bank puts a lower bound on retail deposit rates the commercial bank must offer to its customers, if it were to decide to obtain retail deposits as source of funding. The lower bound can be interpreted in figure 5 as the green dotted line observed at the equilibrium retail rate $r^0_R{}^*$. An increase in the lower bound from $r_R{}^0$ to $r^0_R{}^*$ decreases the profit spread obtained by the commercial bank.

5.3 How does the aggregate response by commercial banks affect their funding?

The analysis of the model by Kiser (2003) shows that an individual commercial bank starts to rely more on wholesale funding to fund their lending activities, as the introduction of a CBDC affects the supply of retail deposits. Since the model by Kiser (2003) shows the profit optimization of an individual commercial bank. It means that the model by Kiser (2003) is

not descriptive of what happens if commercial banks on aggregate respond to a CBDC, and how this aggregate response can affect the availability of wholesale funding itself. I argue that the aggregate response of commercial banks to start relying more on wholesale funding affects the availability of these sources of funding itself. This implies that commercial banks are less able to respond to an outflow of retail deposits by accessing these wholesale funding markets to compete with a CBDC, which makes commercial banks profit maximization to rely more on obtaining retail deposits, which costs increased by the setting of the lower bound on interest rates the commercial has to offer.

5.3.1 What are the implications of aggregate response on funding?

If all banks were to face a significant outflow of funds to the CBDC, all commercial banks lose their reliable source of funding: retail deposits. By examining implications of individual commercial banks response, we learned that a commercial bank will solely rely on wholesale funding (if available) to compensate the decrease in availability of retail deposits. However, I argue that if all commercial banks face the same problem of a significant decrease in retail deposits available, that this could significantly affect the markets of wholesale funding itself. These implications are further discussed below.

Implications interbank market

The interbank market is the market where commercial banks transfer their excess liquidity (Allen et al., 2009). I argue that as commercial banks on aggregate face a significant outflow of retail deposits to the CBDC, it leads the interbank market to dry up, since there is no excess liquidity to trade in the first place. In the beginning stage of an outflow of retail deposits from the traditional banking system, any shortage can be compensated by reserves currently available in the interbank market. Dyson & Hodgson (2016) argue that any shortage in reserves can be addressed by the central bank issuing additional central bank reserves against government bonds held at commercial banks. However, if the outflow of funds to the CBDC is significant, the buying of government bonds will solely be a temporary measure for central banks to provide liquidity, if no reserves flow back to commercial banks. In this scenario, commercial banks can only obtain liquidity by selling other assets to other banks, which is most likely not successful as argued by Dyson & Hodgson (2016). Or, the central bank can offer to buy a wide range of assets from commercial banks. This in turn will also not be sufficient as these assets dry up if all commercial banks funds move to the CBDC.

From here it is assumed that the interbank market will vanish as a significant amount of funds move and stay at the CBDC.

Implications non-interbank market

The significant outflow of funds to the CBDC leaves only the non-interbank market to be left over for commercial banks to fund their lending activities. This in turn puts heavy pressure on the interbank market, possibly increasing the rates of obtaining this type of funding, thereby increasing the marginal costs of obtaining wholesale deposits. From the literature review we learned that this part of wholesale funding relates to the shadow banking activities performed by commercial banks. The maturity transformation currently performed by the traditional banking system, will therefore move outside this system. However, this non-interbank market can solely function as complement to the traditional retail deposits that commercial banks can obtain as funding. Therefore, it is not expected that commercial banks can successfully rely on this type of funding (Noeth & Sengupta, 2011).

5.3.2 Relating the aggregate response of commercial banks to the initial model by Kiser (2003)

Since a significant part of the wholesale market will not be accessible for commercial banks when all retail deposits move to the CBDC, a commercial bank's profit optimizations will depend on obtaining retail deposits. This indicates that the right graph in figure 6, is less applicable for a commercial bank since it can no longer access wholesale deposits to fund lending activity. Instead, the commercial bank must rely on obtaining retail deposits (left graph). However, retail deposits do no longer come from the traditional banking system. The commercial bank now must try to obtain retail deposits back from the accounts of the CBDC. However, this implies that commercial banks can no longer extent loans using retail deposits if the public is not willing to store their deposits at commercial banks. If this indeed were to happen, risky lending activities can no longer be performed as in the traditional banking system we know today. It may be the case that investment banks that obtain funding by uninsured debt and equity will perform the risky lending. Competition between retail deposits and a CBDC now has led to the implementation of a similar narrow banking system as proposed by Tobin where risky lending is no longer performed by commercial banks. However, if the flow of funds to the CBDC were to be significant, the commercial bank

cannot be described as a Utility Bank (UB) as something argued by Tobin. Since the commercial bank no longer has any demandable deposits liabilities at its disposal.
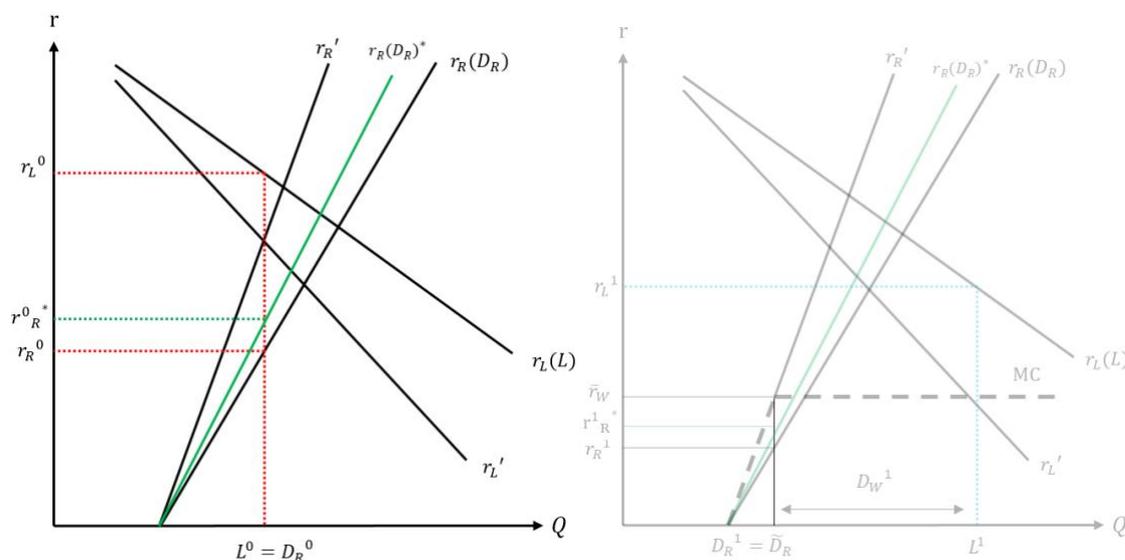

Figure 6: Implications of aggregate response of commercial banks on individual funding decision of a commercial bank, illustrated in the model by Kiser (2003). See figure 5 for a full description of all parameters.

5.4 Implications of a CBDC existing in a crisis scenario

5.4.1 Can a deeper insolvency crisis be blamed on the existence of a CBDC?

I argue that a deeper insolvency crisis can be provoked by the existence of a CBDC. Because with the existence of a CBDC, bank runs are not only more likely to happen. But the severity of these bank runs could also be greater if we consider commercial banks response into its discussion. A bank run initiated by a CBDC can lead to a deeper insolvency crisis for at least two reasons.

Firstly, bank runs are more likely to happen with the existence of a CBDC, since the public can easily shift their funds to their accounts of the CBDC. Dyson & Hodgson (2016) argue that even in a minor panic, the likelihood of a bank run increases. However, not only a minor panic can initiate a bank run, since bank runs may be initiated sooner if we are at the start of a more severe liquidity crisis.

Secondly, in contrast to Dyson & Hodgson (2016), who argue that a deeper insolvency crisis cannot be blamed on a CBDC. I argue that the bank run initiated by a CBDC can get severe to such extent, that it can lead to a deeper insolvency crisis. Because commercial banks' response to rely more on wholesale funding as they face an initial outflow of retail deposits, increases the credit risks associated with holding retail deposits. Thereby increasing the willingness of the public to store funds safely at the CBDC, increasing the initial problem (outflow of retail deposits) of commercial banks.

Implications of using wholesale funding: increase in credit risk associated with the commercial bank

Following the initial model by Kiser (2003), it shows that commercial banks successfully can rely on wholesale funding to fund their lending activities. The benefits achieved with this use of wholesale funding refers to commercial banks not being restricted by local deposit supply to fund their lending activities, and to refinance any outflow of retail deposits (Calomiris, 1999; Goodfriend & King, 1998). However, this is a rather "bright side" of wholesale funding, which sees the providers of wholesale funds as sophisticated agents who can monitor commercial banks performance effectively. This means that the supplier of wholesale funding can discipline those commercial banks that perform bad, while refinancing those banks who perform good (Calomiris & Kahn, 1991). However, the use of wholesale funding is not without its limitations, since its use will increase the credit risk associated with holding funds at the commercial banks, thereby increasing the willingness of the public to store funds at the CBDC.

Why is more credit risk associated with using wholesale funding?

The use of wholesale funding will be seen as a less stable source of funding. Because the suppliers of wholesale funding may have an incentive to liquidate their funding earlier. Huang & Ratnovski (2011) argue that the suppliers of wholesale funding have lower incentives to conduct the more costly monitoring of the performance of a commercial bank. If the supplier of these wholesale funds receives a costless but noisy public signal that includes information on the performance of a certain commercial bank. For this reason, the supplier of wholesale funds may liquidate funding earlier if such signal is received. Because the initial outflow of retail deposits to a CBDC may signal suppliers of wholesale supplier bad performance, it may increases risks associated with using wholesale funding. The instability

of the use of wholesale funding is also suggested by Broadbent (2016), who argues that especially in a crisis scenario, such reliance is proven to be unstable. This refers to the previous financial crisis where the benefits of wholesale funding were clearly not realized (Acharya et al., 2008; Huang and Ratnovski, 2011). For these reasons, it is believed that the reliance on wholesale funding comes at the cost of enhanced bank fragility. Those commercial banks whose funding structure depends heavily on wholesale funding, are therefore to be seen as risky (Demirgüç-Kunt & Huizinga, 2010).

What dynamics come into play that make a bank run more severe under a CBDC?
How does the severity of a bank run increases considering implications of using wholesale funding? When a bank run initiated by the existence of a CBDC, it firstly leads to an initial outflow of retail deposits. Commercial banks start to rely more on wholesale funding to continue to funds their lending activities, which in turn as previously described is associated with an increase in credit risk. At this point, at least two dynamics of stepping up the wholesale funding can speed up the process by which the public is willing to transfer funds from their bank accounts at the commercial bank, to their account of the CBDC.

Firstly, any increase in credit risk associated with the commercial bank will increase the willingness of the public to "temporary" store funds at the CBDC. These outflows of retail deposits in turn can cause commercial banks to rely more on wholesale funding to compensate this loss in funding. This response is associated with an increase in credit risk. Furthermore, as the required spread of interest to compensate credit risk increases, it is expected that the public will see it as less realistic that the commercial bank can effectively access wholesale markets to fund this incremental spread. Secondly, the increase in credit risk of commercial banks as a result of an outflow of retail deposits may signal suppliers of wholesale funds to liquidate their funding earlier. The initial bank run on retail deposits therefore may increase the likelihood of a run on these wholesale deposits.

The potential of a snowball effect
The implications related to commercial banks response to rely on wholesale funding may reinforce each other. Since the likelihood of an outflow of retail deposits increases as more credit risk is associated with holding funds at the commercial bank, it indicates that the previously stable retail deposits can no longer be used to fund lending activity. However,

since the increase in credit risk can also affect the stability of wholesale funding, this type of funding may therefore also leave the commercial bank. To what extent these two dynamics may reinforce each other is hard to determine. However, since these dynamics can continue to reinforce each other, there may potential be some kind of "snowball effect". This leads me to conclude that the existence of a CBDC do can potentially lead to a deeper insolvency crisis, if these dynamics were to reinforce each other.

5.4.2 Implications of a deeper insolvency crisis

This part of the discussion examines the implications of a CBDC existing in a deeper insolvency crisis. This part of the discussion was left out by Dyson & Hodgson (2016), who argued that such crisis cannot be blamed on the existence of a CBDC. However, in the previous part of the discussion it is argued that the existence of a CBDC do indeed can potentially lead to a deeper insolvency crisis. A deeper insolvency crisis refers to a significant outflow of retail deposits from the traditional banking system.

What happens if a CBDC exists in a more deeper insolvency crisis?

Following the discussion on implications of aggregate response by commercial banks to rely more on wholesale funding, it can be concluded that the model by which commercial banks respond to access wholesale funding markets, becomes less applicable. Simply because the availability of both the interbank and the non-interbank wholesale market, might come to a standstill as in a crisis a significant amount of retail deposits leaves the traditional banking system, which in turn most likely will lead to a contraction in lending. If all retail deposits were to move to the CBDC, it indicates that implicitly a narrow banking system is created. Implicitly refers to the forming of a narrow bank as a consequence of competition between retail deposits and a CBDC. Rather than the implementation of a narrow banking proposal. Following what we learned from the literature review, the forming of a narrow banking system should get paired with heavy regulation, and should be designed carefully. However, since the forming of a narrow banking system can occur due to the existence of a CBDC, it is expected that there is a possibility that these required regulations are not implemented. Such not carefully designed narrow banking system leads to the creation of a system that cannot provide similar results as the traditional banking system as we know today.

The possibility of narrowing the banking system during a financial crisis faces central banks with crucial decisions on regulating the banking system. The following questions should be considered by central banks: must central banks provide credit to commercial banks to allow them to continue their credit intermediation? Or should the central bank itself provide the demanded credit to the public? Furthermore, central bank must consider if their regulatory framework is prepared for the existence of a CBDC operating in a more severe liquidity crisis.

6. Conclusion

Commercial banks can no longer perform their money creation process when a significant outflow of retail deposits forces commercial banks to pay a closer amount to 100% in reserves to settle these payments. For this reason, models that describe commercial banks' ability to extent loans and simultaneously create an equal amount of deposits cannot hold. Only models which take into account that the narrowing of the banking system, can impair commercial banks' ability to issue loans in the first place are applicable. These models describe commercial banks to first obtain either retail deposits or wholesale deposits to fund their lending activities (Kiser, 2003).

In contrast to what is suggested in current literature, the outflow of retail deposits does not only affect the ability of commercial banks to use retail deposits to fund their lending activities. But also the ability of commercial banks to access wholesale markets to fund lending activities. Since all commercial banks must pay an amount closer to 100% in reserves to settle payments to the CBDC when faced with a significant outflow of retail deposits. There is no longer any excess liquidity to be traded among commercial banks in the interbank wholesale funding market. The outflow of money from the traditional banking system leads to the interbank market to disappear.

By considering the implications of impairing the ability of commercial banks to function as money creators in the first place. This leads me to conclude that implications of a CBDC in a crisis scenario may far be greater than suggested in current literature. By considering the implications of commercial banks response to rely more on wholesale funding as they face an outflow of retail deposits, two important insights are gained. Firstly, while commercial banks may initially access wholesale fund markets to either settle payments to the account of the CBDC, or to fund lending activities. Commercial banks cannot regard this as a sustainable option since these markets become less accessible as the amount of retail deposits flowing to the CBDC increases in a crisis scenario. Secondly, the response by commercial banks to initially rely more on wholesale funding can speed up the process by which retail deposits flow to the accounts of the CBDC. This, because wholesale deposits are considered to be a less stable source of funding. This in turn increases the credit risk associated with storing funds at the CBDC which makes the public more likely to store their funds safely at their CBDC accounts. In contrast to what Dyson & Hodgson (2016) argue, it seems that a deeper

liquidity crisis cannot only possibly be blamed on the existence of a CBDC. But the existence of a CBDC may also increase the likelihood of such deeper liquidity crisis to happen.

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Appendix

Appendix A: mathematical specifications of the theoretical model by Kiser (2003)

Linear production function:

$$L(D_R, D_W) \leq D_R + D_W.$$

Standard upward-sloping retail deposit supply function satisfying following conditions:

$$r'_R > 0 \quad \forall D_R > 0,$$

$$r'_R(0) < \infty,$$

$$2r'_R + D_R r''_R \geq 0 \quad \forall D_R > 0.$$

Standard downward-sloping loan demand function satisfying the following conditions:

$$r'_L < 0 \quad \forall L > 0,$$

$$r'_L(0) > -\infty,$$

$$2r'_L + L r''_L \leq 0 \quad \forall L > 0.$$

Retail rate that induces first unit of retail deposits to be supplied:

$$r_R(0) < \bar{r}_W.$$

Level of retail deposits such that marginal cost of retail deposits equals the marginal cost of wholesale deposits:

$$r_R(\tilde{D}_R) + \tilde{D}_R r'_R(\tilde{D}_R) = \bar{r}$$

Cost-minimizations problem:

$$C(r_R, \bar{r}_W, L) = \begin{cases} r_R(L)L & \text{if } L \leq \widetilde{D}_R, \\ r_R(\widetilde{D}_R)\widetilde{D}_R + \bar{r}_W[L - \widetilde{D}] & \text{otherwise}. \end{cases}$$

Profit-maximization problem:

$$\max_L \Pi(L) = \begin{cases} [r_L(L) - r_R(L)]L & \text{if } L \leq \widetilde{D}_R, \\ r_L(L)L - r_R(\widetilde{D}_R)\widetilde{D}_R - \bar{r}_W[L - \widetilde{D}_R] & \text{otherwise}. \end{cases}$$

Unique maximum because cost of deposits is continuous and weakly increasing and marginal loan revenue is continuous and strictly decreasing:

$$L^* = arg \max_L \Pi(L).$$

L^* satisfies the following first-order condition:

$$r_L(L) + Lr'_L(L) = min\{r_R(L) +: r'_R(L), \bar{r}_W\}.$$

Demand for retail deposits :

$$D^*_R \begin{cases} L^* & \text{if } L^* \leq \widetilde{D}_R, \\ \widetilde{D}_R & \text{otherwise}. \end{cases}$$

Demand for wholesale deposits:

$$D^*_W \begin{cases} 0 & \text{if } L^* \leq \widetilde{D}_R, \\ L^* - \widetilde{D}_R & \text{otherwise}. \end{cases}$$