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CBDC: A systemic perspective

Peter Bofinger[(a)] and Thomas Haas[(a)]

[(a)]University of Würzburg
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University of Würzburg
Department of Economics
Chair for Monetary Policy and
International Economics
Sanderring 2, D-97070 Würzburg

Corresponding Author

Peter Bofinger

University of Würzburg, Department of Economics

Sanderring 2, 97070 Würzburg, Germany

Email: peter.bofinger@uni-wuerzburg.de

CBDC: A systemic perspective

Peter Bofinger[1] and Thomas Haas
University of Würzburg
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+++++ Preliminary Version+++++

Abstract

In this study, we provide a systemic perspective on central bank digital currencies (CBDC). We separate existing proposals for CBDCs into the perspective of new payment objects, made available by central banks to a broader public, and new payment systems, operated by central banks. From a systemic perspective, CBDC proposals need to be examined to see how they would fit into the existing ecosystem of national, supra-regional, and international payment systems. To analyze the main implications of introducing CBDCs, we provide a price-theoretical banking model, which allows private non-banks to switch between holding bank deposits and CBDCs. In addition to the CBDC payment objects, we also present the option of a store-of-value CBDC. While most CBDC proposals incorporate new payment objects with new or existing payment systems, we discuss whether central banks could establish new payment systems without offering a new payment object.

Keywords: central bank digital currency, central banks, payment systems

JEL codes: E42, E52, E58, G21

[1] Corresponding author: Peter Bofinger, Email: Peter.Bofinger@uni-wuerzburg.de

„Um aus dieser Auffassung vollen theoretischen Gewinn zu ziehen und um sie als Werkzeug währungstheoretischer und währungspolitischer Problemlösung zu verstehen, muß man sich darüber klar sein, daß, wie schon angedeutet, alle die Konten und alle die Umschreibungen in dem sozialen Hauptbuch den Sinn der wirklichen Vorgänge auch in jenen Fällen wiedergeben, wo sich das Leben anderer Methoden bedient als der bankmäßigen Umschreibung mit darauffolgender Skontration, so daß wir in dieser tatsächlich den Grundfall aller Arten von Zahlung vor uns haben und alle andern Arten von Zahlung nur technische Sonderformen jener einen sind, die uns in der Praxis als bankmäßige Gut- und Lastschrift begegnet. Die Schwierigkeit, die diese im Grunde ganz einfache Sache unserm Verständnis bietet, kommt lediglich von unserer Gewohnheit, umgekehrt die Zahlung durch Überhändigung von „Geldstücken" als den Grundfall zu betrachten und alle andern Methoden daraus abzuleiten oder darauf aufzubauen. Wir werden in diesem Kapitel sehen. daß das heißt, die Dinge auf den Kopf zu stellen.“[2]

Joseph A. Schumpeter: Das Wesen des Geldes, p.206.

1. Introduction: Payment objects versus payment systems

The growing public interest in crypto-currencies, the Libra initiative of Facebook, but also the declining role of cash in payment transactions have led to an intensive discussion on Central Bank Digital Currency (CBDC). The surveys by Barontini and Holden (2019) and Boar et al. (2020) show that while almost all central banks are interested in CBDCs, most see themselves in a ’research’-state and less in an ’implementation’-state.

The objectives pursued by CBDCs are often not clearly defined.[3] Bindseil (2020, p. 2) summarizes the current debate as follows:

> *“Core advantages seen by most economists and central bankers include making available efficient, secure and modern central bank money to everyone, and strengthening the resilience, availability and contestability of retail payments.”*

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[2] “In order to derive full theoretical benefit from this view, and to understand it as a tool of monetary theory and monetary policy problem-solving, it must be clear that, as already indicated, all the accounts and all the transfers in the social ledger reflect the meaning of the actual events in those cases, where life makes use of other methods than the banking transfer with subsequent netting, so that in this case we have the basic case of all types of payment in front of us, and all other types of payment are only technical special forms of the one which we encounter in practice as bank credit and debit. The difficulty which this basically quite simple matter presents to our understanding is merely due to our habit of seeing payment by handing over "coins" as the basic case and deriving all other methods from it or building on it. We will see in this chapter that this means turning things upside down.”

[3] Gnan and Masciandaro (2018, p.10) describe it as: “*the case for CBDC is as yet unclear*”.

Accordingly, one can approach the discussion on CBDCs in two separate but interrelated ways. The topic of CBDC can be discussed from the perspective of

- new **payment objects** made available by central banks to a broader public, which implies that central banks compete with commercial banks,
- new **payment systems** operated by central banks, which implies that central banks compete with providers of payment systems.

As these two strands can be combined, the following institutional arrangements are possible (Table 1):

Table 1: Options for digital central bank projects

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="2">New central bank payment objects</td></tr>
<tr><td>No</td><td>Yes</td></tr>
<tr><td rowspan="2">New payment systems operated by central banks</td><td>No</td><td>Status quo</td><td>CBDC: Bindseil (2020)</td></tr>
<tr><td>Yes</td><td>Central bank digital payment systems (CBDPS)</td><td>CBDC: E-krona, Kumhof and Noone (2018)</td></tr>
</table>

Some CBDC proposals, e.g. the proposal by Bindseil (2020) envisage the creation of new payment objects that would be used in the existing payment systems. Under such an arrangement, central banks would assume the functions of a commercial bank and compete with existing commercial banks. The CBDC proposal by Kumhof and Noone (2018) and the e- Krona project (Sveriges Riksbank 2018) envisage the creation of new payment systems within which the new CBDC payment objects can be used. So far, the idea that central banks concentrate on the creation of new payment systems without creating new payment objects (Central bank digital payment systems) has not attracted much attention.

In this study, we will argue that the **payment systems** perspective has so far received too little attention in the discussion on CBDCs. From a systemic perspective, CBDC proposals need to be examined to see how they would fit into the existing ecosystem of national, supra-regional, and international payment systems. If these aspects are explicitly considered, it becomes clear that the Kumhof/Noone proposal, as well as the e-Krona project, have little chance of success. The Kumhof/Noone proposal would create a payment system that is completely isolated from the existing systems and the e-Krona proposal would create a purely national payment system that would have to compete with international systems such as PayPal.

In contrast, a CBDC as a new payment object without its own payment system has similar characteristics as commercial bank deposits. Thus, these solutions face the problem that central banks would become competitors of commercial banks without any **market failure** that would justify such state intervention.

So far, illustrative models that help to understand the implications of introducing CBDCs are still lacking in the discussion about CBDCs. We introduce a simple price-theoretical banking model to provide an analysis of the potential effects that payment object CBDCs might have. As our analysis shows, these effects could be very far-reaching and profound, which complements and amplifies the above assessment that central banks would become competitors of commercial banks without any market failure.

Thus, convincing CBDC proposals are still deficient. The systemic view could even suggest refraining from creating new payment objects and to concentrate entirely on **creating new payment systems**. With the dominance of only a few private payment system providers, a market failure could be identified in this field. However, creating national systems is not the solution. Rather, central banks would have to find answers to digital platforms like PayPal or Libra, at least at the European level, but ideally at the global level.

From a systemic perspective, it is an open question whether private individuals should be given the opportunity to have **direct access to central bank money** apart from cash. An alternative to cash would be CBDCs, which are used exclusively as a store-of-value. Thus, transactions could only be made from one's own bank account to one's own CBDC account. Such store-of-value CBDCs would be a substitute for cash in its function as an absolutely safe asset. As such an asset cannot be provided by private institutions, a provision by the central bank could be justified. The competition with commercial banks is limited as store-of-value CBDCs could not be used for payments.

In Chapter 2 we provide a brief overview on the existing payments ecosystem. In Chapter 3 we discuss CBDC proposals that aim at new financial assets that are used within existing payment systems. In addition to the CBDC payment objects that have been discussed so far, we present the additional option of a store-of-value CBDC. In Chapter 4 we discuss the risks that are associated with CBDCs as new financial assets and without new payment systems. To analyze the effects of CBDCs on the banking system, we introduce a simple banking model that allows for non-banks to hold CBDCs. In Chapter 5 we introduce institutional arrangements that could mitigate the discussed risks. Chapter 6 discusses CDBC proposals where CBDCs as new payment objects are used in new payment systems that are operated by central banks. These systems can be interconnected with the existing payment system or they can exist in isolation. In Chapter 7 we discuss whether central banks could establish new payment systems without offering a new payment object. Chapter 8 concludes this paper.

2. The existing ecosystem of payment systems

The contribution and the effects of new payment objects and systems can only be assessed in connection with the existing ecosystem of payment systems. Ugolini (2017, p.22) describes this ecosystem as follows:

> "*different payment systems actually coexist (often concerned with transfers of different nature, like credit card networks, derivatives clearinghouses, or foreign exchange markets), but it is the interaction among all of them that constitutes the economy's payment system proper.*"

For an understanding of payment systems, it is important to describe their main features. In a simplified way, one can identify the following constituent elements:

- A **network infrastructure** for the transfer of funds from a payer to a payee. This can be a one-way or two-way transfer
- **Payment instruments** which connect payers and payees, and which trigger the flow of funds
- **Funds** that are in the possession of the payer and which guarantee the finality of payments when they are received by the payee
- A **single currency or multiple currencies** in which the funds are denominated that can be used within the system

The simplest payment system is the **cash payment system**. It has a decentralized network as funds are exchanged on a peer-to-peer basis. This informal network is supported by the legal tender status of banknotes. In this system, the payment instrument (i.e. banknotes or coins) is identical to the funds that are exchanged. The cash payment system is typically a one- currency system as banknotes can only be used within their own currency area. The role of the US-dollar as a parallel currency in countries with weak domestic currency is an exception.

The most widely used payment system is the **bank-based payment system**. In the euro area, the infrastructure for this system is provided by SEPA and the TARGET network which is operated by the European Central Bank. In the United States, two networks coexist: Fedwire is operated by the Federal Reserve Banks and CHIPS is operated by the banking system. It characterizes this payment system that it can be used with a variety of payment instruments. In addition to traditional instruments like bank transfers and checks, payments can be triggered by bank debit cards and mobile payments. The funds that are exchanged are bank deposits *and* central bank reserves. The bank deposits of the payer decline and the deposits of the payee increase. If the payer and the payee have different banks, the exchange of deposits is paralleled by an exchange of central bank reserves between the bank of the payer and the bank of the payee. In the euro area, this exchange is provided by the TARGET system. TARGET and Fedwire are one-currency systems.

Credit card payment systems play an important role in national and international payments. These systems (VISA, Mastercard, American Express) are typically one-way systems from the purchaser of a product to the seller and have their own infrastructures for data transmission, authorization, clearing, and settlement. They offer debit and credit cards as well as mobile payments as payment instruments. The funds that are used for settlement are bank-deposits. In the case of credit cards, an immediate settlement is not required. When prepaid cards (electronic money) are used, credit card payment systems can also be used without a bank account. In contrast to bank-based payment systems and the cash-payment system, credit card systems are multi-currency systems.

A more recent development is the **PayPal payment system**. It has evolved as a payment system for eBay but is now a completely independent international payment system. Compared to bank accounts, it has the advantage that accounts can be opened without information on the identity of the owner. Only an email address is required. Compared to credit card payments, PayPal is a two-way system and the payee does not require specific interfaces and a contractual relationship with the credit card company. PayPal payment instruments are internet transfers and mobile payment solutions. In addition, PayPal uses credit card systems and bank-based systems for payments. PayPal settlements can be made with deposits held with PayPal, but also with bank deposits. Thus, PayPal can be considered a hybrid, PayPal also allows for multi-currency payments and to hold deposits in different currencies.

Table 2: The payment ecosystem

Payment system	Market infrastructure	Payment instrument	Object for settlement	Unit of account
Cash payment system	Peer-to-peer Legal tender	Banknotes Coins	Banknotes Coins	National Currency Euro
Commercial bank payment systems	Euro area: SEPA/TARGET/ SWIFT US: CHIPS/Fedwire	Bank transfer Debit cards Cheques Mobile Payment	Bank deposits (between payer and payee) **and** Central bank reserves (between bank of payer and bank of payee)	Euro: SEPA Dollar: CHIPS/ Fedwire Multi-Currency system: SWIFT
Credit card payment systems (VISA/Mastercard/ American Express)	Systems have their own procedures for data transmission/ authorization/clear ing/settlement	Credit cards Debit cards Mobile Payment Anonymous: Travel cash card (Switzerland)	Bank deposits (between payer and payee)	Multi-Currency schemes
PayPal	PayPal	PayPal-Transfer Mobile payments	PayPal accounts Bank accounts	Multi-Currency

The current spectrum of payment systems ranges from a purely public payment system (cash payment system) to a purely private payment system (PayPal). The bank-based system is a hybrid, as it uses private bank deposits and central bank reserves as funds and the interbank payment network is provided by the central bank. In credit card systems the role of the state is reduced as the infrastructure is private and only for the monthly settlement of balances, bank deposits are required.

Thus, if cash is no longer used for payments, this does not imply that the central bank has no more influence on the payment systems. This will only happen with a declining role of the bank-based system which relies on central bank reserves and the RTGS provided by the central bank. In other words, the real threat to the role of central banks in payment systems are private payment systems like PayPal and possibly Libra. They could lead to closed payment systems that no longer rely on traditional bank deposits.

The presentation of the existing payment ecosystem shows that payment systems do not need their own currency and that the same payment instruments, i.e. mobilpay solutions can be used in different payment systems. This contradicts the views of Brunnermeier et al (2019) who argue that *"a digital currency is inseparable from the characteristics of the platform on which it is exchanged"*. As credit card systems and PayPal show, payment platforms are typically **multicurrency platforms** which in fact is their special advantage.

In line with our presentation, the usage of the word "**payment instrument**" by Brunnermeier et al. (2019, p. 5) is also problematic:

> "*We say a collection of payment instruments form an independent currency if the following two conditions hold:*
>
> *(i) The payment instruments are denominated in the same unit of account.*
> *(ii) Each payment instrument within the currency is convertible into any other*."

We differentiate between payment instruments (e.g. credit cards) and payment objects. Therefore, payment instruments are not connected to a specific currency. They also are not necessarily connected to a specific payment system. Mobilpay solutions for example can be used for the commercial bank system, the credit card system, and PayPal. The distinction between payment instrument, payment object, and unit of account has also been acknowledged by the Libra association, which announced in their second white paper, that in addition to issuing one global payment object they would issue Libras denominated in individual currencies, e.g. a euro-Libra, dollar-Libra or Yen-Libra (Libra 2020). However, the single-currency Libras and multi-currency Libras are both compatible with the same (Libra-) payment system. The payment instruments (e.g. Libra wallets) are again independent of the unit of account of the payment objects.

3. CBDC taxonomy

CBDC can be designed as the provision of new financial assets by the central bank that can be used within the existing payment systems. By providing access for the public to new forms of central bank money, the central bank becomes a competitor to private and public suppliers of similar financial assets.

The range of assets that central banks can supply to the broader public can be described by three dimensions:

- **Token-based** CBDCs, which are exchanged on a peer-to-peer basis and **account-based** CBDCs which are based on accounts held with the central bank.
- Among the account-based CBDCs, one can further differentiate between CBDCs that can be used **universally** (i.e. for payments and as a store-of-value) and CBDCs that can only be used as a **store-of-value**.
- Finally, one can differentiate between **retail CBDCs** which are accessible to everyone and **wholesale CBDCs** which can be used only by a limited group of users.

Table 3 provides an overview of the possible options.

Table 3: Classification of CBDC objects

<table>
<tr><th colspan="2"></th><th>Retail: CBDCs for anyone</th><th>Wholesale: CBDCs restricted to companies and providers of payment platforms</th></tr>
<tr><td colspan="2">Token-based CBDCs: for peer-to-peer payments</td><td>Prepaid cash cards (‘e-money’)</td><td>--</td></tr>
<tr><td rowspan="2">Account-based CBDCs</td><td>Means of payment and store-of-value</td><td>All-purpose CBDCs</td><td>All-purpose CBDCs</td></tr>
<tr><td>Store-of-value only</td><td>Store-of-value CBDCs (‘safe assets’)</td><td>Synthetic CBDCs (‘safe assets’)</td></tr>
</table>

An additional feature of CBDC objects is convertibility, i.e. whether CBDCs are always and fully convertible and redeemable in bank deposits and central bank reserves.

4. CBDC as new payment objects

4.1. Token-based CBDCs

Token-based CBDCs can be regarded as a substitute for cash. They would resemble the prepaid cards (e-money) that are provided by banks and credit card companies. The main advantage of such cards is their anonymity as they do not require a bank account. In this regard they are a perfect substitute for cash. While this feature is appreciated by many users, the fight against money-laundering sets rather strict limitations for such payment objects.

With the 5th Anti-Money Laundering Directive, the conditions under which electronic money products can be issued anonymously are extremely strict:

- The **maximum top-up amount** for e-money that can be issued anonymously was reduced from 250 euros to 150 euros. In addition, the maximum cash redemption amount was capped at only 50 euros. German legislators have set the limit to 100 euros and 20 euros, respectively.
- **Online payments** conducted via anonymous electronic money products will not be allowed to exceed 50 euros.
- Acquirers may only process payments using anonymous **prepaid cards from a third country** if these cards were issued in the third country with similar restrictions.

Therefore, the scope for token CBDCs seems extremely limited. Fernández (2018, p. 50) describes it as follows:

> *“It is very difficult that the same central banks that require commercial banks to implement costly mechanisms to prevent money laundering and the financing of terrorism (the AML/CFT regulation) are issuing at the same time the means to carry such activities. One may argue that this is already the case with cash. But anonymity is intrinsic to cash, whereas in the case of CBDCs it would be a deliberate decision.”*

Accordingly, in its e-krona project, the Sveriges Riksbank (2018) explicitly states that its token-based CBDC should be traceable.[4] The only exception for non-traceable transactions are cash/ prepaid cards, "*used as cash and handed over from one user* to *another*." (Sveriges Riksbank 2018, p. 16)

However, with such restrictions it is not very likely that there will be a very large demand for token-based CBDCs. Cash or prepaid cards are much more complicated for their holders to handle than normal credit cards. If central banks decide to issue such cards, the effect on the entire payment system is likely to be extremely limited.

4.2. Account-based payment CBDCs

Account-based CBDCs which are not accompanied by a new central bank payment system can be regarded as a **fully-fledged bank account with the central bank** accessible for everyone (retail CBDCs). By opening such accounts central banks would de facto open a new division that operates in the same way as a commercial bank. Bindseil (2020, p. 26) describes this as follows:

> "*The attractiveness of CBDC for payment purposes does not only depend on the amount of CBDC that would be remunerated at a fairly attractive level, but also on other features of the use of CBDC as means of payment. It will matter in particular whether account services of CBDC include the services that deposit accounts with commercial banks typically offer, like remote internet access, mobile phones and cards, periodic payments to other accounts, debit orders, user-defined maximums for different types of transfers.*"

The private banking sector would rightly complain about such competition with a public entity. The public provision of core banking services could only be justified if one can identify an **obvious market failure**. From the perspective of payment systems and services in advanced economies, the current payment ecosystem does not suffer from obvious failures in terms of safety and efficiency of payments[5] which would warrant a massive public interference.[6] One might argue that access to central bank money is a public good but we will show that this is also possible with a more limited variant of CBDCs which are not used for payments.

The difficulty to identify an obvious market failure also applies to **wholesale universal CBDCs**. Large firms and investors have even more options for conducting their national and international payments in an efficient way.

A fundamental problem of universal CBDCs would be the **enormous administrative challenge** for central banks. In their present institutional setup, central banks would be unable to open and to operate millions of private bank accounts.

[4] Both types of e-krona assume that there is an underlying register so that it is possible to record transactions and safeguard who is the rightful owner of the digital krona. This means that digital transactions with e-krona will be traceable.

[5] BIS-Surveys conducted amongst central banks shows that payments safety and payments efficiency are the main motives considered by central banks for issuing CBDCs (Barontini and Holden 2019; Boar et al. 2020).

[6] This point is also made by Panetta (2018, p. 25): "*From this vantage point the advantages of a CBDC are at best unclear: its potential benefits in terms of improving the ease of transactions are probably insufficient to justify the involvement of central banks in an activity that is well served by private suppliers.*"

Thus, if account-based CBDCs are not accompanied by a new payment system operated by central banks their scope is very limited. They would be only another payment object that is used within the bank-based system or the systems operated by private providers. In other words, if central banks want to have an influence on payment systems, it is not enough that they start to operate as an additional commercial bank.

4.3. Account-based store-of-value CBDCs

While the case for universal CBDCs is not obvious, the access of the citizens to central bank money could be met with a restricted version of CBDC. CBDCs could be designed as an account with the central bank that cannot be used for payments but only as a store-of-value. Thus, the owner of a CBDC account can only make payments from his or her own bank account to the CBDC account and vice versa.

This version of CBDC would offer the **absolute safety of banknotes** in a digital version. This safety is especially relevant in the situation of a banking crisis. Until now, banknotes provide a safe store-of-value until the crisis is over. With a declining use of cash, it is highly likely the infrastructure of cash payment systems (ATMs, cashiers in banks, cash supply by central banks) will be drastically reduced. Consequently, in the situation of a bank-run, the technical facilities for a broadly-based exchange of bank deposits into cash will be insufficient to accommodate a fully-fledged bank run. As a result, the central bank could no longer be able to act as lender-of-last-resort.

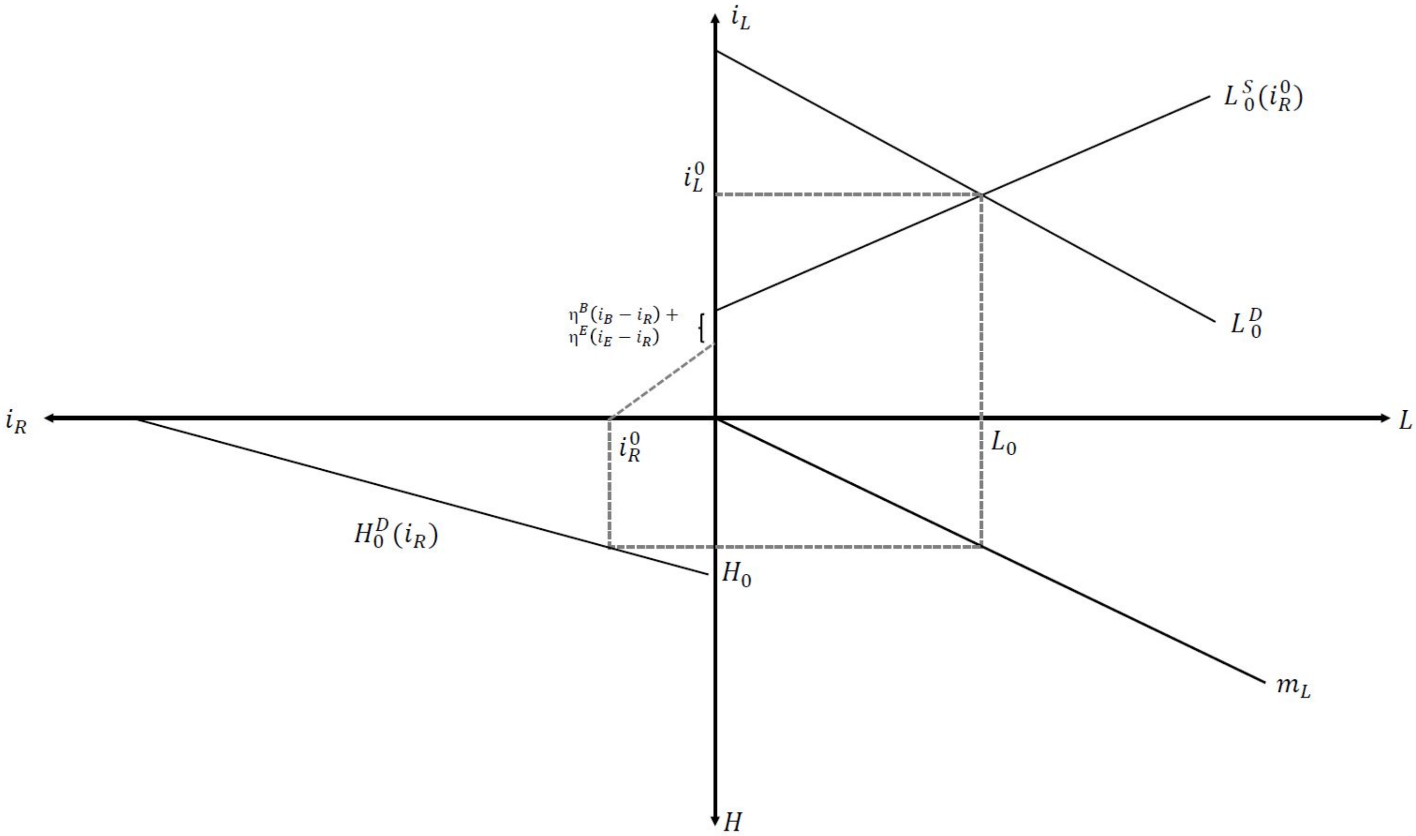
A store-of-value CBDCs could be limited to **wholesale CBDCs**. One could argue that bank deposits up to 100.000 Euro are already absolutely safe as they are protected by the national deposit insurance schemes. Therefore store-of-value CBDCs could be limited to deposits of more than 100.000 euro. They would provide an attractive investment for larger investors and firms that are not fully protected in the case of a bank restructuring which according to the BRRD requires a bail-in of major depositors. As safe assets for larger investors, store-of-value CBDCs become substitutes for other safe assets such as government bonds. The remuneration rate for these wholesale CBDCs would have to be zero or negative. In any case, it should be below the deposit rate for bank deposits to avoid a privileging of larger investors over average households. It could e.g. be the minimum between a fixed rate of zero, the deposit facility rate, and the yield on outstanding government bonds.

Wholesale store-of-value CBDCs could be restricted to providers of payment services as collateral for their depositors ('stablecoins'). The designers of Libra plan to use bank deposits and government bonds as collateral. But, as indicated, the stability of bank deposits in a crisis is limited. As for government bonds, massive sales by Libra would likely result in price losses. These problems could be avoided if suppliers of stable coins could use CBDCs as collateral. Adrian and Manicini-Griffoli (2019) speak of **synthetic CBDCs** (sCBDCs). This model is already being practiced in China, where Alipay is obliged to keep its accounts with the central bank. Similar synthetic CBDC solutions could be provided by private banks as a service for their customers. Banks could e.g. offer to back all deposits voluntarily with 90 or even 100 percent central bank reserves. Some private banks already back their customer deposits with at least 50 percent reserves. Synthetic store-of-value CBDCs could even be introduced without the central bank. If a bank decides to back all deposits 100% with central bank reserves, the depositors hold indirectly CBDCs. As described above, payment provider, that do not rely on bank deposits, could become a threat to the central bank's control over payment systems. Requiring payment providers to back their deposits 100% with central bank reserves could be an important tool for the central bank to retain control over these payment systems.

5. Risks of CBDCs as new payment objects

In the discussion of CBDCs as new payment objects, two main risks are discussed: a general disintermediation of the commercial banking system, accompanied by higher refinancing costs for banks and a potential emergence of full-reserve systems or narrow banks, and digital bank-runs. However, so far illustrative models to systemically analyze the effects and implications of introducing CBDCs are lacking. Thus, we introduce a simple banking model to analyze the effects of CBDCs on the banking sector. The derivation of the model and all equations are provided in the appendix of this paper. Figure 1 shows a graphical depiction of the baseline model with the credit market in the first quadrant, determining the equilibrium quantity of loans L_0 at the intercept of bank's loan supply L_0^S and non-bank's loan demand L_0^D.and the corresponding bank loan interest rate i_L^0. The credit multiplier relation m_L shows the required amount of high-powered money H_0 to refinance the provided loans. Banks obtain high-powered money through refinancing loans from the central bank at the refinancing rate i_R^0 that is set by the central bank. The credit multiplier depends inter alia on the minimum reserve requirements for banks, the amount of cash holdings of non-banks as well as the ratios of bank's issuance of bonds and equity in relation to provided loans.

Figure 1: baseline model



5.1. CBDCs effects on banks

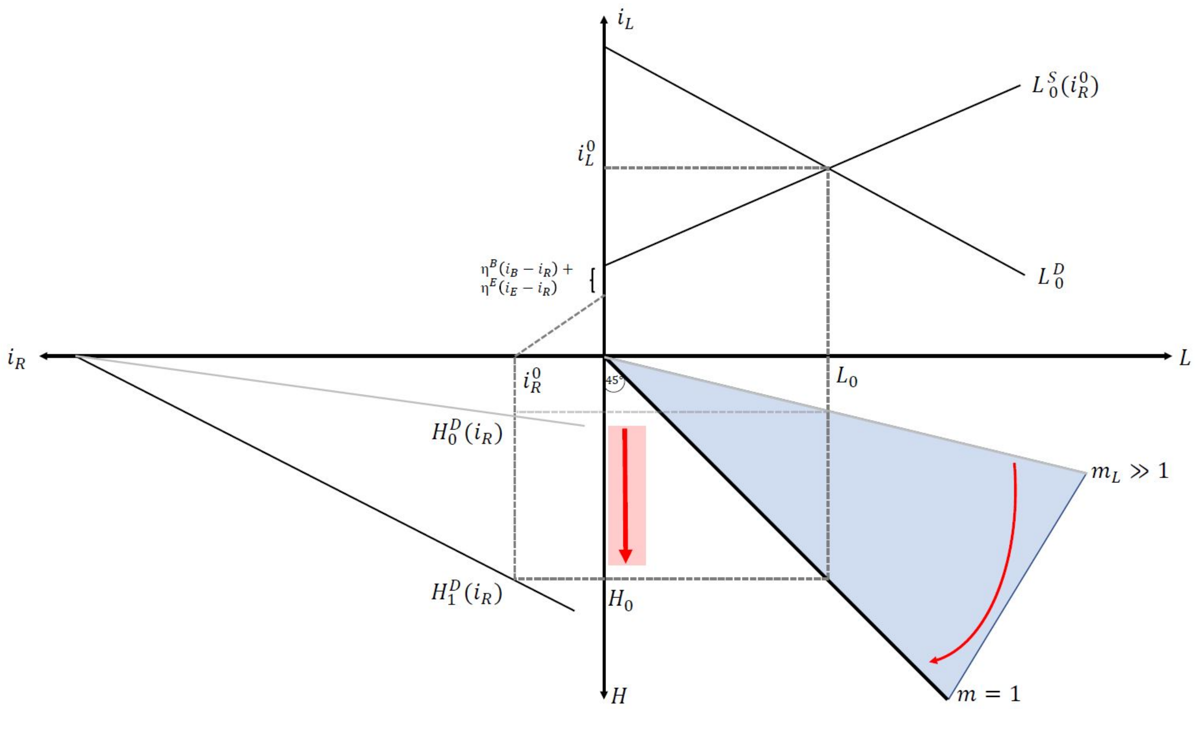
For this part of the analysis, we refer to CBDCs as account-based payment CBDCs as introduced in section 3.2. This concept is most widespread in the discussion on CBDCs.

Hence, private non-banks can shift any amount of deposits from their commercial bank account to their central bank account. We also assume there is no upper limit (general or per capita) for CBDCs.

Account-based payment CBDCs could lead to a massive shift from traditional bank deposits to the central bank. Such disintermediation would shorten the balance sheet of commercial banks, as they would then have less sight deposits of non-banks as well as less reserves at the central bank. For the central bank's balance sheet this implies an exchange of liabilities, as the reserves of commercial banks are exchanged with CBDCs of non-banks. The central bank would have to compensate the banks for this decline in reserves to a large extent by refinancing loans, since reserves represent only a fraction of deposits. An outflow of deposits out of the banking system is currently only possible by withdrawing cash from banks or purchasing bonds or equity issued by banks. From our model perspective, the effect of exchanging deposits with CBDCs would be similar to a cash withdrawal, hence the cash holding coefficient c rises and this results in a **decreasing credit multiplier**.

In the extreme case of a complete withdrawal of bank deposits out of the banking system, the multiplier would approach a value of 1. Due to the decreasing credit multiplier, the demand of commercial banks for high-powered money rises **disproportionately**. Figure 2 shows this case graphically.

Figure 2: demand for financing increases after a shift from bank deposits to CBDCs

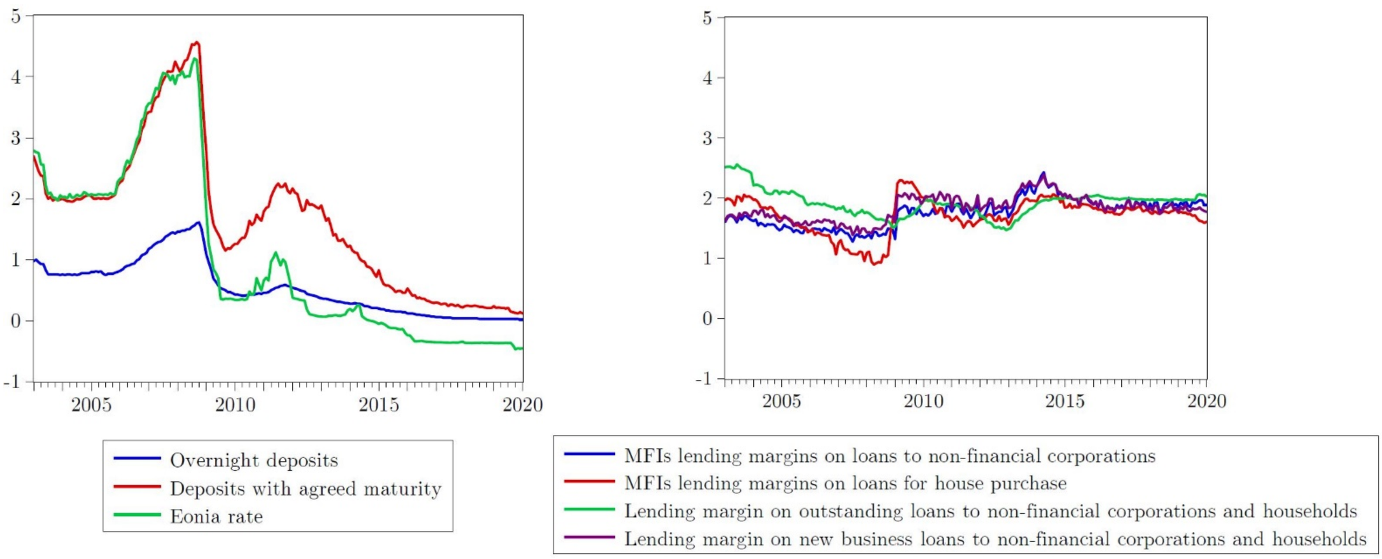


5.2. Disintermediation of banks

5.2.1. Increase in refinancing cost

The shift from bank deposits to CBDCs could lead to an increase in refinancing costs for banks. Sight deposits are usually remunerated at a low rate and are thus a cheap form of financing for banks. The effect on banks funding costs depends in this case mainly on the ratio of the deposit rate and the refinancing rate. The left-hand figure in figure 3 shows the EONIA overnight rate as well as the rates for overnight deposits and deposits with agreed maturity for the euro area.

Figure 3: refinancing rate, deposit rates, and average lending margins for euro area countries.



Source: ECB Statistical Data Warehouse, own calculations

Until the advent of the financial crisis, overnight deposit rates were about a percentage point below the refinancing rate. After a brief widening of the spread, the rates aligned with the refinancing rate even below the deposit rates. Hence, it is not clear whether a shift from bank deposits to CBDCs increases the refinancing costs. Even in an interest rate environment as before the financial crisis, the refinancing costs would not necessarily rise, as the central bank could lower the refinancing rate for banks after introducing CBDCs in order to dampen the negative effects for banks. This could be justified, as the higher costs for banks are due to the decision of the central bank to compete with banks for deposits. It could also be necessary for the central bank to adjust the refinancing costs for banks or provide banks with longer-term refinancing operations at low costs if the higher refinancing costs would affect the provision of loans by banks and thus could have a restrictive impact on the real economy. The right-hand side figure shows the average lending margins for euro area banks for the corresponding period. Although the interest rates fluctuated quite substantially over the last two decades, the margins are quite stable. Hence, banks have been able to pass on interest rate changes well and are likely to pass on potential future increases in refinancing costs as well. Thus, it is not clear whether refinancing costs increase and even if they increase banks might be able to compensate these higher costs. However, it is highly likely that banks have to increase the amount of refinancing due to the introduction of CBDCs. This has several implications that we discuss in the next sections.

5.2.2. Collateral constraint

In case of very extensive disintermediation, the compensation via additional central bank refinancing loans could be limited by the availability of eligible collateral from individual banks or the banking system (e.g. Bindseil 2020; Bank for International Settlements 2018). The central bank could then decide to reduce haircuts for collateral or broaden the list of eligible collateral to the extent that banks are able to continue providing loans. This has wide-ranging implications for monetary policy that we discuss in section 4.2.5. The central bank could also decide to refrain from adjusting its collateral framework. In that case, banks are only able to obtain a limited amount of central bank reserves.

Figure 4: the market for high powered money with collateral constraint

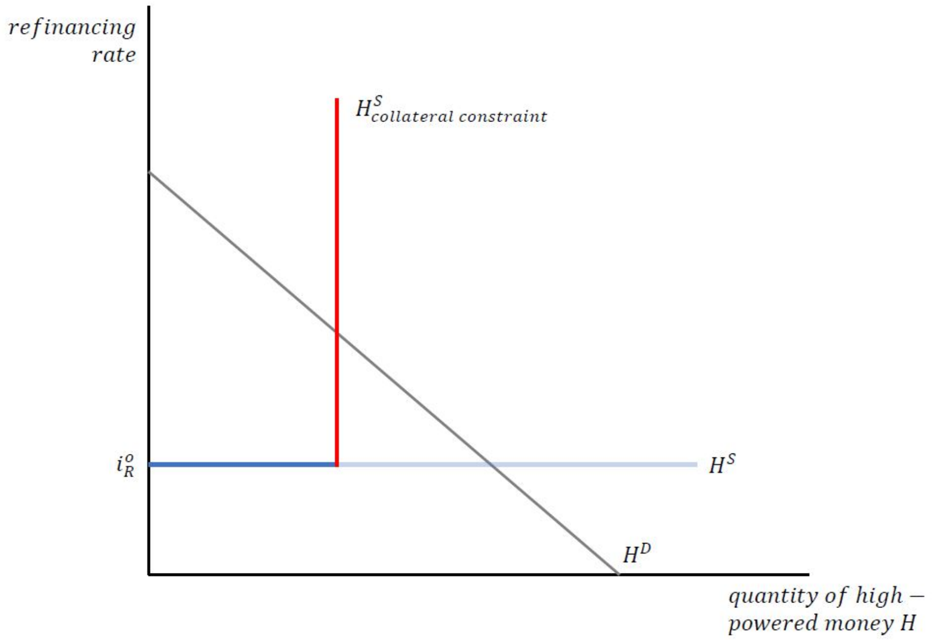
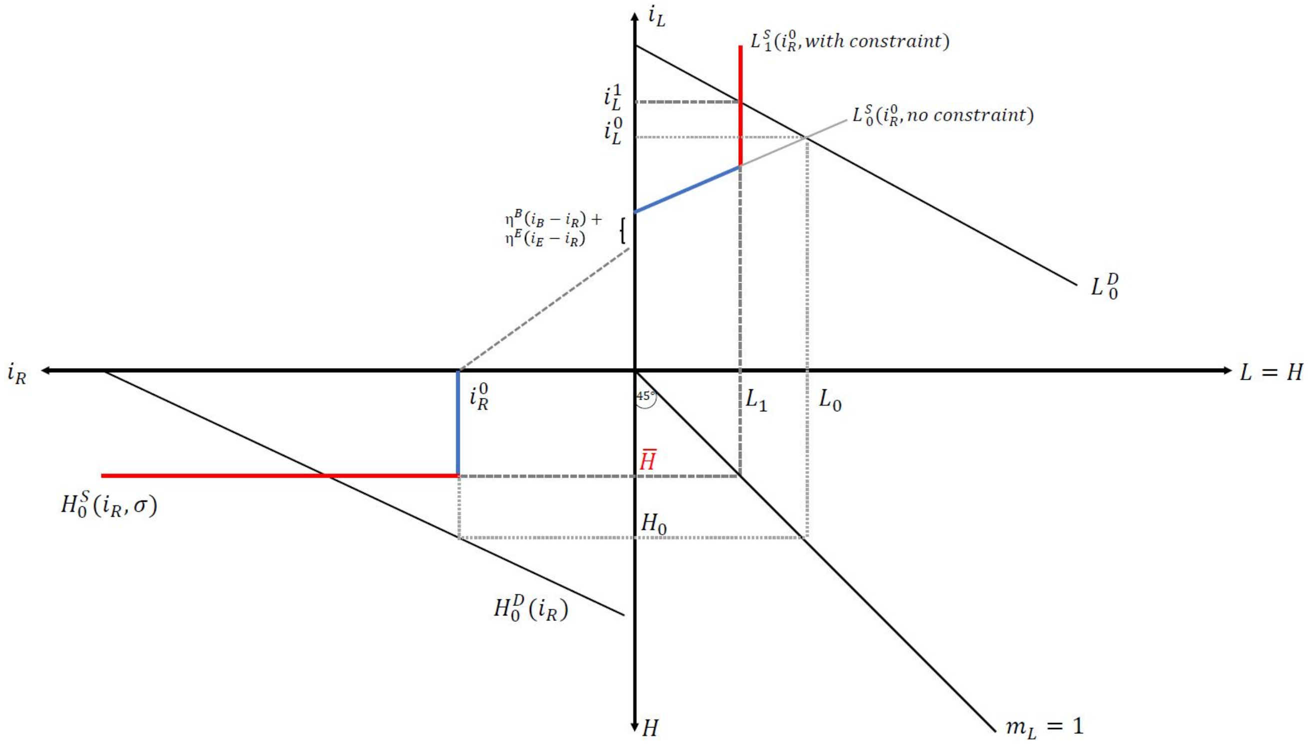


Figure 4 shows the market for high-powered money with a collateral constraint. We first introduce a horizontal supply curve for high-powered money that is only dependent on the refinancing rate set by the central bank. Thus, this supply curve merely illustrates our initial assumption that the central bank sets the interest rate and provides as much high-powered money as banks demand at this rate. A collateral constraint leads to a vertical supply restriction (figure 4). Banks are only able to obtain a limited amount of reserves from the central bank and a **credit crunch** could emerge (figure 5). Thus, the loan supply is restricted, and the real economy could experience a shortage of loans and a surge in loan interest rates. The lower credit multiplier due to the outflow of deposits amplifies this effect as banks need more high-powered money in relation to their provided loans. Monetary policy in the form of interest rate adjustments is ineffective in this situation.

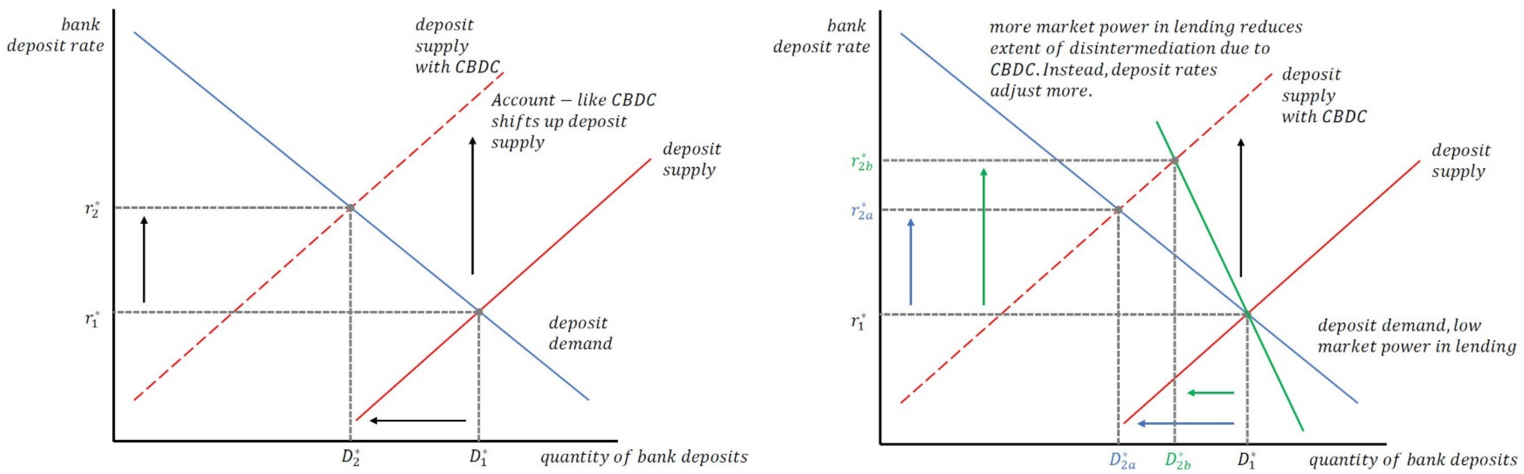
Figure 5: banking model with collateral constraint and credit crunch



5.2.3. Increase in deposit rates

Several scholars argue that banks could raise deposit rates in order to reverse the outflow of deposits (e.g. Committee on Payments and Market Infrastructure 2018, Juks 2018). Mancini-Griffoli et al. (2019) depict this idea graphically in the following way:

Figure 6: An increase in deposit rates



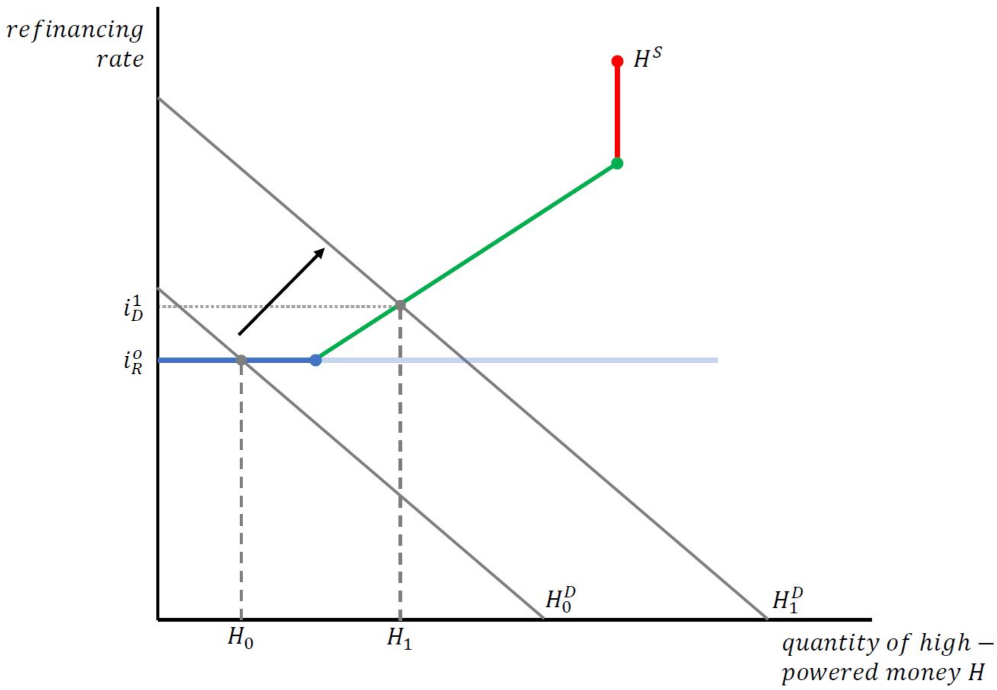
Source: Mancini-Griffoli et al. (2019)

Banks, especially those with higher market power, pass these higher deposit rates on to the lending rates for loans to keep their margins about constant. Hence, Mancini-Griffoli et al.

(2019) assume an increase in the overall interest rate regime of the economy caused by the banking system. This would impair the ability of the central bank to control the interest rate.

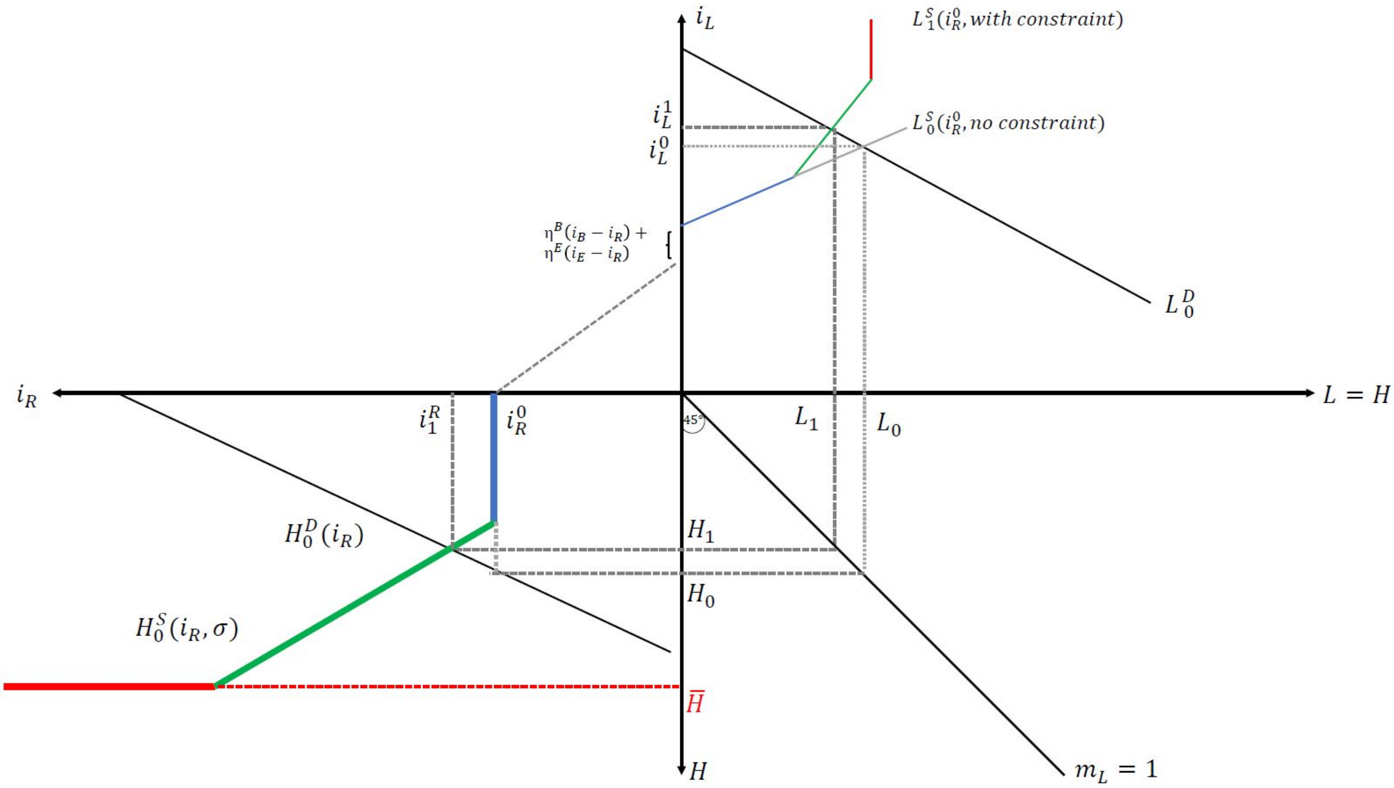
There are two potential reasons why banks would raise their deposit rates to attract an inflow of deposits. First, the spread between the deposit rate and the refinancing rate is large with the deposit rate below the refinancing rate. In this case, it could be favorable for banks to increase the deposit rate instead of using additional refinancing loans from the central bank. The second reason would be that banks are unable to obtain additional central bank loans for example because of a limited amount of eligible collateral. Banks could then try to attract deposits to compensate for that. Figure 7 shows the market for high-powered money for this case.

Figure 7: the market for high-powered money with banks raising deposit rates



In this case, the supply curve for high-powered money has different slopes. It is horizontal at its origin, depicting the case that banks obtain refinancing loans from the central bank with the latter keeping the refinancing rate constant. In case banks cannot obtain refinancing loans from the central bank, e.g. due to a collateral constraint, and to avoid a credit crunch, banks increase the deposit rate to attract an inflow of deposits, which is accompanied by an inflow of central bank reserves. We thus assume that higher deposit rates lead to higher amounts of deposits that flow back to the banking system. Hence, the supply curve is upwards sloping. If at some point no CBDC holder is willing to exchange CBDCs with bank deposits, the supply curve becomes vertical again, illustrating a credit constraint. The higher refinancing costs are paralleled by increasing loan interest rates as banks are likely to pass on these higher deposit rates. Thus, the supply curve for bank loans becomes steeper compared to the initial case. The central bank would effectively lose control over the interest rates in the economy. The interest rate would adjust to the demand and supply of loans and the respective need of banks for financing. Figure 8 shows this case.

Figure 8: banking model with rising financing rates



5.2.4. Emergence of narrow banks and sovereign money systems

Introducing CBDCs could lead to an emergence of narrow banks in case of large shifts of deposits to CBDCs. Thus, the money creation of banks is constrained and hence the provision of loans to non-banks. In case of a collateral constraint and the central bank deciding not to adjust its collateral framework, a sovereign money system effectively emerges. Banks only compete for existing high-powered money by raising their deposit rates. Thus, the central bank loses control over its most important policy tool, the interest rate. Bofinger and Haas (2018) provide an overview of the implications of sovereign money systems.

5.2.5. Monetary policy implications

CBDCs could also affect the monetary policy tools of central banks. Two instruments are widely associated in the literature with CBDCs: negative interest rates and "helicopter money". However, for the central bank to lower the interest rates significantly below zero, banknotes would have to be abolished first, which is mainly a political decision. Apart from the discussion whether "helicopter money" is an efficient monetary policy instrument (e.g. Reichlin, Turner and Woodford 2019), it might not be necessary for the central bank to introduce CBDCs to use "helicopter money" as Engert and Fung (2018) suggest. Especially as a combination of fiscal and monetary policy, "helicopter money" could theoretically be used with the tools already available and without the need for new payment objects (e.g. Galí 2020). Introducing CBDCs is also likely to affect the central bank's balance sheet. Should the central bank decide to adjust its collateral framework to accommodate the higher demand of banks for refinancing loans, the central bank takes on higher credit risk on its own balance sheet. Furthermore, the central bank could become more involved in the process of allocating loans by accepting some loans directly as collateral. In addition, the administrative burden of managing accounts that used to be managed by multiple banks now must be carried out by the central bank alone.

5.3. Bank run risk

The problem of disintermediation would arise in a particular way, if a **crisis of confidence** in the banking system were to occur. With a broad availability of retail CBDCs, the transaction costs of withdrawing large sums of money from the commercial banking system are much lower than the costs of exchanging bank deposits for cash. With such a digital bank run, the refinancing needs of the banks by the central bank would rise sharply. The problem of insufficient collateral would then be particularly acute.

Various proposals for mitigating these risks are discussed. The most far-reaching approach is the Kumhof and Noone model discussed in section 6.2, which, restricts the use of CBDCs in such a way that the then completely isolated CBDC payment system would be completely unattractive.

6. Mitigating the risks of CBDCs as new payment objects

6.1. Upper limits for CBDCs

In order to limit the risks of CBDCs, Panetta (2018) has proposed an **upper limit** for balances on CBDCs. But with universal CBDCs, this is, as Panetta himself notes, not very appropriate from the point of view of the efficiency of the payment system. Specifically, when transferring money to a CBDC account, it could always happen that payments are rejected because the maximum amount has already been reached on the account. While an upper limit for universally applicable CBDCs is problematic, this approach may well be advantageous for pure value-only CBDCs (see Section 5.3)

6.2. A two-tiered remuneration system

Bindseil (2020) has made the proposal to limit the disintermediation potential of CBDCs by a **two-tiered remuneration system**. Tier 1 deposits (CBDC deposits up to 3.000 Euro per capita) should be remunerated at a rate of one percentage point below the deposit facility rate, but with a minimum rate of zero. Tier 2 deposits should be remunerated at a zero rate and at a negative rate if the difference between the deposit facility rate minus one percentage point is negative. Bindseil expects the following effects from his proposal:

- "*It allows assigning the payment function of money to tier-one CBDC, while the store of value function would be assigned to tier two and would essentially be dis-incentivized through an unattractive remuneration rate. Indeed, central bank money should probably not become a large-scale store of value, i.e. a major form of investment of households, as this eventually implies that the central bank would become an investment intermediary of the economy (for which it has no particular qualification).*
- *It ensures that CBDC is attractive to have in principle for all households, as reliance on tier one CBDC never needs to be dis-incentivized by a particularly low remuneration rate.*" Bindseil (2020, p. 23f)

While the Bindseil proposal may prevent a major permanent redeployment of bank deposits held as store-of-value, it is not certain that it could also prevent a **digital bank run**. In principle, this model offers the possibility of lowering the interest rate for the second tier so far into negative territory that such movements could be stopped. However, the interest rate would have to become extremely negative, as it could be attractive to switch to the central bank even if there was a negative interest rate of, say, 10%. Calculated over one month, this would mean a loss of less than one percent, which in the situation of a bank run would be seen as a still attractive insurance premium.

In addition, extremely negative interest rates on CBDCs in banking crisis could have a strong destabilizing effect on the financial system. It would stand in a complete contradiction to the traditional **lender of last resort function** where the central bank tries to stop the panic by an ample supply of safe assets. Prohibitive rates for the access to CBDCs could amplify the panic.

6.3. Auctioning a limited amount store-of-value CBDCs

A mitigation solution exactly opposite to the Bindseil proposal can be made for CBDCs, which can only be used as a store-of-value. For such CBDCs the risks of excessive disintermediation and a digital bank run could be avoided if the central bank determines the total quantity of CBDCs and provides them by an **auction mechanism**.

Non-banks would bid for a certain amount of store-of-value CDBDs that could be held for a certain period of time (e.g. 3 months or one year). The interest rate on such CDBCs could be indexed as a discount to the current interest rate for the deposit facility. During the holding period, store-of-value CBDCs and bank accounts would be fully convertible up to the maximum amount that an individual investor has received in the auction.

Such a framework could be used by central banks as a CBDC market test without disrupting the financial system.

7. CBDCs in new payment systems operated by central banks

For the e-krona project of the Swedish central bank the provision of a payment system operated by the central bank plays an important role:

- *"In the medium term, Sweden would no longer have a domestic infrastructure for retail payments, given the dominance of global card schemes, pan-European clearing and the ECB's trend towards multi-currency settlement systems."* (Sveriges Riksbank, 2018, p. 19)
- *"If the state, via the central bank, does not have any payment services to offer as an alternative to the strongly concentrated private payment market, it may lead to a decline in competitiveness and a less stable payment system, as well as make it difficult for certain groups to make payments. Ultimately, it may also risk eroding basic trust in the Swedish monetary system."* (Sveriges Riksbank, 2018, p. 12)

- *"a competitively neutral infrastructure which payment service providers can join if they wish to offer services to households and companies. This could increase competition, benefit innovation and possibly slightly reduce the fees charged to the general public."* (Sveriges Riksbank, 2018, p. 3)
- *"Apart from the RIX system for payments between financial institutions, the entire infrastructure for the payment market would be in private ownership."* (Sveriges Riksbank, 2018, p. 9)

Similar concerns were expressed by Christine Lagarde (2019) on the occasion of her first press conference as ECB president:

> *"My personal conviction is that given the developments we are seeing, not so much in the bitcoin segment but in the stablecoins projects, [...] we'd better be ahead of the curve if that happens because there is clearly a demand out there that we have to respond to.*"

As the presentation of the existing payments ecosystem shows, the decline of the cash payment system definitively reduces the role of the central banks in the payment system. It is therefore natural to consider how central banks can continue to be involved in payment operations with innovative solutions. However, it should be borne in mind that central banks play an important role in the payment system via RTGS systems even if cash transactions are no longer carried out.

7.1. The scope for CBDC-based national payment systems (e-krona)

When central banks bring new payment systems onto the market, they must be aware of the fact that they would then be competing with the highly developed credit card systems and the equally highly effective systems of the likes of PayPal. From this systemic perspective, the Swedish central bank's concept of creating a domestic infrastructure for retail payments must be viewed critically. What should be the incentive to use a nationally operating digital payment system for national and international payments if there are already highly effective internationally established platforms for this?

The possibility of maintaining accounts with the central bank would not fundamentally change this competitive disadvantage of a national payment system. If CBDCs can be used in the same way as credit balances at commercial banks, they could also be used as payment objects for credit card systems and the PayPal system. [7]

This highlights the more fundamental problem that it is hardly possible for individual states (and especially smaller states) to maintain national sovereignty in the financial system under the conditions of globally networked financial systems.

7.2. The Kumhof/Noone proposal: a CBDC payment system in isolation

[7] Sveriges Riksbank (2018, p. 13): "*The e-krona could offer a competitively neutral infrastructure which payment service providers can join if they wish to offer services to households and companies.*"

A specific CBDC proposal has been developed by Kumhof and Noone (2018). Their concept is characterized by the following features:

- CBDC pays an adjustable interest rate.
- CBDC and reserves are distinct, and not convertible into each other
- No guaranteed, on-demand convertibility of bank deposits into CBDC at commercial banks (and therefore by implication at the central bank).
- The central bank issues CBDC only against eligible securities (principally government securities).

With this institutional framework, Kumhof and Noone try to design a CBDC system in such a way that the risk of a digital bank run is avoided. In particular, this framework would prevent bank depositors from being able to exchange their credit balances for CBDCs at any time in the same way that they are able to exchange them for cash.

However, the price for this protective measure is extremely high. It implies that the CBDC payment system is not integrated with the settlement system for reserves. In the words of Kumhof and Noone (2018, p. 21):

> "*We take as given that a market for reserves with an RTGS system is present and that it operates separately from the CBDC system.*"

The lack of interoperability is a fundamental difference between the Kumhof and Noone proposal and the e-Krona project, where integration with the RIX settlement system is envisaged.

A stand-alone CBDC system such as Kumhof and Noone have in mind would have the major disadvantage that payments between traditional bank accounts and CBDC accounts would not be possible. A transfer from a traditional account to a CBDC account would require an RTGS system in which the reserves of the payer's bank can be exchanged 1:1 at any time for a CBDC balance of the payee.

Thus, the payment system designed by Kumhof and Noone would be fundamentally different from all existing payment systems. The payment ecosystem existing today is characterized by a high degree of interoperability:

- Cash can be exchanged for commercial bank credit at any time and viceversa.
- Credit card systems are by nature fully integrated with the commercial banking system.
- PayPal offers the possibility of two-way payments between the PayPal account and traditional bank accounts and it is also fully integrated with the credit card system.

The statement by Ugolini (2017, p. 24) confirms the interconnectedness of the existing payment systems:

> "*In practical terms, this means that payment systems (unlike shopping arcades) can hardly work in isolation. New payment systems can emerge and enter the industry only as long as their connection to the "global" payment system (the one that allows the final, legally recognized settlement) is provided*."

All in all, it is not clear why Kumhof and Noone believe that their system would provide "*much greater functionality for retail transactions*" (Kumhof and Noone 2018, p. 4). In other words: Kumhof and Noone's intention to safeguard the CBDC-system against the risk of bank-runs has led them to design an isolated system which would be hardly attractive for retail payments and would probably have little chance to compete with the existing international payment systems

8. The real challenge: How to maintain control over international paymentsystems

From a systemic point of view, it makes little sense for central banks to become active as traditional commercial banks and thus compete with existing commercial banks. First, there is no clear market failure that could justify such state intervention and the implications and risk of such an intervention could be severe as our analysis shows. Second, the central bank would then still operate within the existing payment systems. This would not make any substantial contribution to the objectives of payment security and payment efficiency stated by the central banks in the BIS Survey by Barontini and Holden (2019).

The systemic perspective, therefore, suggests that the focus should not be on new payment objects but rather on new payment systems. A clear market failure can be identified here: very few credit card companies and PayPal have remarkably high market power because these two-sided markets are not sufficiently contestable. Facebook's Libra project shows that further large platforms can be created here that escape state influence.

The CBDC-based payment systems discussed so far, such as the Kumhof and Noone model and the e-Krona, are not an answer to these global challenges due to their limitations (lack of interoperability at Kumhof and Noone and small regional scope at e-Krona).

Therefore, it would be conceivable that central banks at the global level, or at least at the European level, establish a new payment system based on the PayPal model. The newly created central bank group of the Bank of England, the Bank of Japan, the European Central Bank, the Sveriges Riksbank, the Swiss National Bank, and the Bank for International Settlements for CBDCs is a promising step for more research in this field. This would be an ambitious project, but it could be justified from a competitive point of view.

A more modest approach is requiring payment providers like PayPal and Libra that so far operate their payment systems completely independent of the banking system, to back the deposits held with them 100% with central bank reserves. As stated above, this model is already practiced in China. For such a backing, store-of-value CDBDs would be especially qualified. In this context, Adrian and Mancini-Griffoli (2019) speak of synthetic CBDCs. By tying the business volume of payment platforms to central bank reserves, the central bank is able to retain at least some influence over the global payment systems.

9. Summary

So far, the intensive debate on CBDCs has not yet produced promising solutions. In our view this is mainly due to the fact that it lacks a systemic perspective. In the digital era, the developments of the global financial system will not be shaped by a competition of monies (private deposits versus central bank deposits) nor by a competition of currencies (Brunnermeier et al. 2019). It will be determined by a competition of payment platforms that are able to deal with a multitude of currencies and payment objects.

Thus, if central banks want to maintain a dominant or at least an important role in the global financial system it is not enough and perhaps even not necessary to develop new payment objects. It also insufficient to develop national schemes or schemes that are not fully integrated into the existing ecosystem of global payment systems.

While it would be a particularly challenging task for central banks to create a supranational retail payment form, a more modest approach is tying payment platforms to central bank reserves (synthetic CBDCs).

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I. Appendix

i. Theoretical banking model

A broad consensus exists among scholars that the sector most affected by an introduction of CBDCs would be the banking sector. Our theoretical model provides an analytical tool to better understand the implications for private non-banks. The model for the banking market is widely based on the work of Bofinger and Schächter (1995), Bofinger, Maas and Ries (2017) and Bofinger and Haas (2018). Bofinger and Schächter (1995) propose a simple model that features the market for bank loans as well as the market for high-powered money, i.e. central bank reserves. Both markets are linked via a credit multiplier relation as well as an interest rate relation. The market for bank loans features banks as suppliers of loans and non-banks who demand loans. By providing loans, banks create the corresponding deposits and credit the debtors deposit account. The credit market is in equilibrium at the intercept of loan demand and supply. This point determines the optimum quantity of credit at the related interest rate for loans. Bank refinance a fraction of the provided loans with central bank reserves, which the banking sector receives via central bank loans, to comply with regulatory requirements. The fraction of loans that must be refinanced is defined by the multiplier relation. The central bank is assumed to set the short-term interest rate and to endogenously provide high-powered money to banks at this rate.

Bofinger, Maas and Ries (2017) extend the model by adding further refinancing instruments to banks, namely issuance of bonds and holdings of equity to better analyze the maturity structure of bank's liabilities. We use the model of Bofinger, Maas and Ries (2017) as a starting point for our research on the implications of CBDC on the banking sector. Finally, Bofinger and Haas (2018) use the model to show the effects of a sovereign money system on the credit business of banks. We use their model alterations to complement our analysis when discussing the effects of an outflow of deposits on banks. Before that, we introduce the model building blocks.

ii. Credit Market

a. Supply of bank loans

We begin with the credit market and the supply of bank loans. We assume that the loan supply is driven by a profit-maximization of each bank. The following bank balance sheet in table 4 shows the revenues from and costs for bank's credit business.

Table 4: Bank's balance sheet

Assets		Liabilities	
Credit from Banks to Non-banks	$L_{B/NB}$	Deposits	D
		Bonds	B
		Equity	E
Reserves	R	Credit from central bank to banks	$L_{CB/B}$

Banks have credit claims on non-banks and holdings of central bank reserves. These assets are matched by the liability side, which encompasses the refinancing sources for banks.

Considering all revenues and costs, the profit function of a representative bank j is equal to:

$$\pi_B^j = i_L L_{B/NB}^j - i_D D^j - i_R\left(L_{CB/B}^j - R^j\right) - i_B B^j - i_E E^j - O^j - CD^j \tag{1}$$

$$with\ CD^j = \frac{\beta\left(L_{B/NB}^j\right)^2}{y}. \tag{2}$$

The asset side of the balance sheet reveals the revenues. Banks lend out loans to the public and private sector at a price i_L and hold reserves at the central bank remunerated at i_R. Hence, the revenue is given by $i_L L_{B/NB}^j + i_R R^j$. Analogously, the costs are the sum of the refinancing instruments times their respective interest rate, i.e. $i_D D^j + i_R L_{CB/B}^j + i_B B^j + i_E E^j$, with i_D, i_R, $i_B$and i_E being the respective rates for deposits, central bank loans and bond and equity financing. $i_R\left(L_{CB/B}^j - R^j\right)$ shows the net refinancing costs from the central bank, i.e. for simplicity we assume an equality of rates on central bank reserves and central bank loans. O^j denotes operational costs and CD^j the credit risk/default costs. As has been suggested e.g. by Fuhrmann (1986) and Freixas and Rochet (2008), we assume credit risk costs to increase disproportionally with the amount of credit. Furthermore, credit default costs depend positively on the credit default probability β and negatively on national income y. For simplicity, we set the interest rate for deposits i_D equal to the refinancing rate for central bank loans i_R. This can be derived from the fact that each bank j can compensate an outflow of deposits by a corresponding increase in interbank loans and vice versa. The interbank rate is controlled by the short-term rate of the central bank. Due to arbitrage, i_D and i_R move widely in line. Using the balance sheet identity from table 4, we can simplify the profit function:

$$L_{CB/B}^j - R^j = L_{B/NB}^j - D^j - B^j - E^j. \tag{3}$$

To reduce an interest rate risk stemming from short-term liabilities and long-term assets, banks perform a maturity transformation of their balance sheets and issue bonds to non-banks. The fraction of bonds to loans to non-banks is given by η^B. Complying with regulatory requirements, a fixed portion η^E of loans to non-banks is backed by equity. Hence, we get:

$$\eta^B = \frac{B^j}{L_{B/NB}^j} and \tag{4}$$

$$\eta^E = \frac{E^j}{L_{B/NB}^j}. \tag{5}$$

Plugging (2), (3), (4) and (5) into (1) and simplifying the equation, we get:

$$\pi_B^j = [(i_L - i_R) - \eta^B(i_B - i_R) - \eta^E(i_E - i_R)]L_{B/NB}^j - O^j - \frac{\beta\left(L_{B/NB}^j\right)^2}{y}. \tag{6}$$

The first-order condition of the profit function with respect to the credit volume derives the optimum credit supply of one representative bank j:

$$\frac{\partial \pi_B^j}{\partial L_{B/NB}^j} = (i_L - i_R) - \eta^B(i_B - i_R) - \eta^E(i_E - i_R) - \frac{2\beta L_{B/NB}^j}{y} \overset{!}{=} 0 \tag{7}$$

$$L_{B/NB}^{*j} = \frac{(i_L - i_R) - \eta^B(i_B - i_R) - \eta^E(i_E - i_R)}{2\beta} \cdot y. \tag{8}$$

Assuming the economy consists of n identical banks, total optimal credit supply is given by:

$$L_{B/NB}^S = \sum_{j=1}^{n} L_{B/NB}^j = n \cdot L_{B/NB}^j = \frac{[(i_L - i_R) - \eta^B(i_B - i_R) - \eta^E(i_E - i_R)] \cdot y \cdot n}{2\beta} \tag{9}$$

b. Demand for bank loans

The demand for bank loans by non-banks depends mainly on their income and the cost of credit. Similar to banks, larger firms can issue bonds and hence chose between loans from banks and the issuance of bonds. Thus, the credit demand is given by:

$$L_{B/NB}^D = a - bi_L + d(i_B - i_L). \qquad with\ a = \mu + \gamma \cdot y. \tag{10}$$

There is a negative relationship between the demand and the interest rate i_L for bank credit and a positive dependency on income y. Furthermore, γ, b and d are sensitivity parameters. The higher d, the more elastic is the demand of large firms to price differentials of bank loans and rates on bonds.

c. Equilibrium on the credit market

The supply of bank loans (equation (9)) is equal to the demand for bank loans (equation (10)) if the credit market is in equilibrium. Hence, we get the following equilibrium credit volume and interest rate:

$$L_{B/NB}^* = \frac{\left((a + di_B) - (b + d)\left(i_R + \eta^B(i_B - i_R) + \eta^E(i_E - i_R)\right)\right) yn}{yn + 2\beta(b + d)}. \tag{11}$$

$$i_L^* = \frac{2\beta(a + di_B) + \left(i_R + \eta^B(i_B - i_R) + \eta^E(i_E - i_R)\right) yn}{yn + 2\beta(b + d)}. \tag{12}$$

iii. Credit multiplier

After deriving the volume of loans banks provide, we determine the amount of high-powered money banks are required to obtain. We use a multiplier relation between the two variables that defines the fraction of loans, banks have to hold in central bank reserves. Following Bofinger and Schächter (1995) and Bofinger, Maas and Ries (2017), we term this relation the credit multiplier m_L, which is not to be confused with the standard textbook money multiplier. First, conversely to the standard textbook multiplier, banks provide loans to non-banks and obtain the required high-powered money ex-post. Second, the introduction of different refinancing instruments allows for a deviation of money stock M and credit volume $L_{B/NB}$. The credit multiplier is given by:

$$m_L = \frac{L_{B/NB}}{H}. \tag{13}$$

Recalling that money, M, consists of cash, C, and deposits, D, and high-powered money, H, consists of cash, C, and central bank reserves, R, we obtain the following equations:

$$M = C + D \; and \tag{14}$$
$$H = C + R. \tag{15}$$

We assume that the public holds cash as medium of exchange and store-of-value. The amount of cash held is assumed to be proportional to deposits held, hence we define

$$C = c \cdot D, \tag{16}$$

where c is the cash holding coefficient. Banks have a legal obligation to hold a fraction of deposits as reserves, which is the minimum reserve requirement, r, determined by the central bank and defined as:

$$R = r \cdot D. \tag{17}$$

Using the balance sheet identity of table 4 and equation (3) as well as equations (4) and (5), and the identities in equations (14) and (15) we can express the difference between money and credit as:

$$L_{B/NB} = \frac{M}{1 - \eta^B - \eta^E}. \tag{18}$$

Plugging equations (14), (15), (16), (17) and (18) into (13), we get:

$$m_L = \frac{M}{H} \cdot \frac{1}{1 - \eta^B - \eta^E} = \frac{C + D}{C + R} \cdot \frac{1}{1 - \eta^B - \eta^E} = \frac{1 + c}{c + r} \cdot \frac{1}{1 - \eta^B - \eta^E}. \tag{19}$$

The credit multiplier m_L consists of the ratio of money and high-powered money complemented by the term that incorporates the difference between money and loans, i.e. the share of refinancing by banks using bonds and equity. As both terms are larger than one, the credit multiplier is larger than one, too. Only in the special case of a sovereign money system or equivalently a full outflow of deposits, the multiplier could be close to or equal to one.

iv. Market for monetary base

a. Demand for monetary base

Bank's demand for high-powered money depends on the structure of their liabilities and on the amount of loans they granted. It can be determined using the multiplier relation. We assume the central bank sets its refinancing rate, i_R, and provides high-powered money according to the demand of banks. Using the demand equation for bank loans (equation (10)) one can obtain the prohibitive price for bank loans, which has to be adjusted for the spread of bond and equity financing less the refinancing rate to receive the prohibitive price for high-powered money, p. The linear demand function for high-powered money can then be derived using two points on the demand schedule:

$$H^D = \frac{L^*_{B/NB}}{m_L} - \frac{L^*_{B/NB}}{m_L \cdot p} i_R, \quad (20)$$

$$with\ p = \left(\frac{a + di_B}{b + d}\right) - \eta^B(i_B - i_R) - \eta^E(i_E - i_R). \quad (21)$$

b. Supply of monetary base

The supply of high-powered money follows the demand for high-powered money. As stated above, we assume the central bank supplies every quantity of high-powered money that is demanded by banks at its refinancing rate i_R.

v. Baseline model

After we derived the equations of our model, we now proceed to a graphical illustration and discussion of the model. Figure 9 shows the basic model with the credit market in the first quadrant, determining the equilibrium quantity of loans L_0 and the corresponding interest rate i_0. The credit multiplier relation m_L in the second quadrant provides the required amount of high-powered money H_0. The latter can be obtained through refinancing loans from the central bank at the refinancing rate i_0.

Figure 9: baseline model