UNIVERSITY OF TWENTE.

Financial Engineering & Management

Quantifying the impact of the introduction of a CBDC by the ECB on the Dutch banking sector

W.H. Vincent

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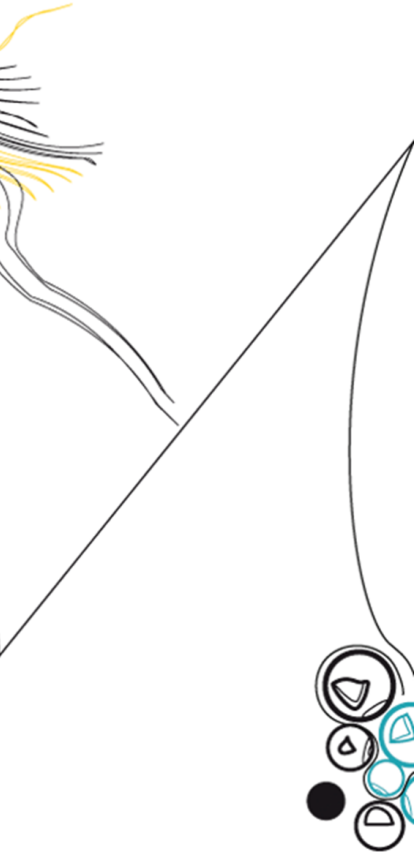

Supervisors University:
prof. dr. L. Spierdijk
prof. dr. A. Bruggink

Faculty BMS
University of Twente
The Netherlands

Supervisors Rabobank:
L. Zijp
S. Begeer

Rabobank
Utrecht
The Netherlands

Management Summary

Introduction

The European Central Bank (ECB) is considering introducing a digital euro, a type of Central Bank Digital Currency (CBDC). This research explores the financial effects of the introduction of a digital euro on Dutch banks, focusing on the impact on financial intermediation and briefly addressing development costs and payment service disruptions. The goal of this research is to provide guidelines to Dutch banks on how certain design choices of the digital euro will influence them financially.

Approach

This research begins with a literature review to assess existing knowledge in the field. It then delves deeper into banking business models and the current financial intermediation function of banks. A core aspect is developing a model to evaluate the impact on financial intermediation for Dutch banks, particularly considering the introduction of the digital euro in 2022. Four scenarios, escalating in severity regarding the introduction of the digital euro, are analyzed using scenario analysis. These scenarios indicate an impact on the bank based on certain adoption parameters of the digital euro. To perform these analyses, the model and the scenarios developed are based on a mix of explicit and implicit assumptions. The probabilities of the scenarios are assessed in collaboration with the Dutch National Bank (DNB). Sensitivity analyses are conducted to gauge the effects of interest rates and holding limits. Additionally, there is a brief delve into the impact on payment services and development costs of the digital euro, and this is compared with the impact on financial intermediation.

Findings

The research on the financial impact of the digital euro on Dutch banks reveals that financial disintermediation poses a manageable risk under the proposed holding limits. The study assesses various scenarios for the digital euro introduction using certain assumptions that might be debatable. Therefore, its results should be viewed as rough estimates of potential impacts rather than precise figures. These results indicate that the most probable scenario could result in a loss of 1.61% of total profits in 2022 at maximum digital euro adoption. The analysis also identifies a potential holding limit of €11,701 before liquidity ratios hit legal minimums. Significantly, the study finds that the impact on earnings is highly sensitive to interest rate fluctuations. It also compares the impact on financial intermediation to the impact on payment services and development costs, suggesting that the digital euro's role as a payment medium and associated remuneration policies will be key factors in its overall impact on the banking sector. These findings are useful in guiding Dutch banks on the effects of digital euro designs and facilitating informed discussions on the digital euro's compensation models.

Keywords: CBDC, Digital Euro, Financial Disintermediation, Scenario Analysis, European Central Bank, Banking, Liquidity

Preface

Dear reader,

This thesis marks the end of my journey in Industrial Engineering and Management, specializing in Financial Engineering and Management, at the University of Twente. The project was conducted under the dual guidance of Rabobank and the University of Twente.

I am deeply thankful to my academic supervisors, Laura Spierdijk and Bert Bruggink at the University of Twente, for their invaluable feedback and insights throughout my master's thesis. Their guidance was instrumental in shaping this research.

My appreciation also extends to Rabobank for offering me the opportunity to conduct my thesis with them. I was warmly welcomed by the team at Rabobank, which made me feel immediately like a part of the team. The knowledge and insights shared by my supervisors and colleagues there were pivotal in grounding my research in practical expertise. Special thanks to my Rabobank supervisors, Lieke Zijp and Simon Begeer, for their constructive feedback and thoughtful comments.

I cannot overlook the support and encouragement I received from my family and friends during this period. Their unique perspectives and ideas were a great source of inspiration and have enriched my research.

I hope you enjoy reading this thesis!

Sincerely,

Willem Vincent

Utrecht, February 5, 2024.

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Glossary

DE	Digital Euro
ECB	European Central Bank
CBDC	Central Bank Digital Currency
DLT	Distributed Ledger Technology
EC	European Commission
EBA	European Banking Authority
BIS	Bank of International Settlements
IMF	International Monetary Fund
PSP	Payment Service Provider
EPI	European Payment Initiative
POS	Point of Sales
SEPA	Single Euro payments Area
HQLA	High Quality Liquid Assets
LCR	Liquidity coverage ratio
NSFR	Net Stable Funding ratio
ASF	Available Stable Funding
RSF	Required Stable Funding
DNB	De Nederlandse Bank

Chapter 1

Introduction

Contents

This chapter introduces the research. This chapter starts by stating the significance of the research in Section 1.1. Furthermore, a description of the company is given (Section 1.2), as well as the problem context (Section 1.3). Furthermore, the problems that need to be researched are identified and explained in Section 1.4, resulting in the choice of one core problem. After that, the goal of the research is determined in Section 1.5. Moreover, the research design and the corresponding research questions are presented in Section 1.6. The chapter is concluded by presenting the scope of this research in Section 1.7.

1.1 Significance

The ECB is contemplating the launch of a DE (digital euro), a form of central bank digital currency (CBDC), that could significantly alter the financial ecosystem in Europe. While this development may bring benefits such as lowering transaction fees and promoting broader access to financial services, it also presents a range of challenges and uncertainties for existing banks. To navigate these complexities, the European Banking Authority (EBA) recommended that traditional banking institutions take the initiative to study how the DE could affect their operations. The EBA further advises that these banks should prepare a strategic plan for adapting to and integrating the DE, once the decision for its implementation is confirmed (EBA, 2023). This thesis investigates the impact the introduction of the DE will have on the Dutch banking sector on behalf of Rabobank.

1.2 About Rabobank

The Rabobank Group (from now on referred to as Rabobank) was established at the end of the 19th century as a cooperative agricultural credit union. Currently, Rabobank is one of the biggest cooperatives in the Netherlands and is also listed in the top 60 biggest banks in the world (by assets under management)(Global, 2023). The Rabobank has almost 2 million members. They are active in 37 countries, serving approximately 9 million customers with over $600 billion in assets (Rabobank, b). The Rabobank has originally a strong focus on the food and agriculture sectors, for which they provide a broad assortment of financial services. However, since the 1950s, the Rabobank also started welcoming non-agricultural entrepreneurs. Slowly the bank evolved into a bank for everyone offering services like loans, mortgages, payment services and insurance (Rabobank, a).

This research is conducted for the Center of Expertise of the CFO Department and the Working Group for the DE of Rabobank. The Center of Expertise is responsible for optimizing processes within the CFO department of Rabobank as well as for the testing and evaluation of new business cases. The goal of the working group for the DE is to follow the current situation and publications done by the ECB.

1.3 Problem Context

In order to understand the context of the problem it is first important to understand what a CBDC is. Furthermore, it is important to understand what the current developments are concerning the introduction of a CBDC by the ECB and what the effects of this introduction might be on regular banks

1.3.1 What is a CBDC?

In order to understand what a CBDC is, it is first useful to know what money actually is. According to Milnes (1919), money has four functions. It should be a medium of exchange, an overall standard, a measure of value and a store of wealth (Milnes, 1919). Furthermore, money can be split up into two types: retail money and wholesale money:

Wholesale money serves as a medium for settling transactions between financial institutions and central banks. In the European Union, the go-to standard for this is TARGET2, which provides those with TARGET2 accounts the ability to execute real-time gross settlements.

Retail money is the type of currency utilized by individuals, businesses, and organizations for purchasing goods and services. It primarily exists in two forms: physical cash, which includes notes and coins, and digital money, often managed by commercial banks. These two forms can be easily converted back and forth through the services offered by retail banks (Graham, 1940).

A more recent classification of money was given by Bech and Garret in 2017 by the money flower (Figure 1.1). They mention the following four characteristics of money (Bech and Garratt, 2017):

1. **Peer-to-Peer:** This refers to the system where users can directly transact money with each other without the need for a middleman. While the money is sent straight to the other party involved, an optional fee may be paid to validators who help in securing or facilitating the transaction.
2. **Digital:** In this context, the term indicates that money exists solely in a digital format. This could be in a centralized database like a traditional retail bank account or a decentralized database such as a distributed ledger (DLT). When a transaction occurs, the digital record of the account is updated to show the new balance.

3. **Central Bank Issued:** This term indicates the origin of the money. For instance, physical cash is minted and distributed by a nation's central bank. In contrast, digital funds in a retail bank account are credited by the retail bank itself, even though they are generally backed by central bank-issued money.
4. **Wide Accessibility:** This denotes how easily money can be acquired, traded, and stored. The ease of accessibility may vary depending on regional or economic factors. For example, having a bank account may be a luxury in some developing countries, while it is generally a standard practice in most developed nations.

CBDCs are built upon these characteristics of money. CBDCs are also often talked about in two forms: wholesale and retail. According to Fabio Panetta (2023), a (new) wholesale CBDC makes no sense as the current TARGET system of wholesale settlements already resembles a CBDC structure, and it is therefore not disruptive to introduce a wholesale CBDC (Panetta, 2022). This means that the focus of this thesis will entirely be on a retail CBDC. Furthermore, when a CBDC is mentioned further on in this thesis, there is referred to a retail CBDC.

A retail CBDC refers to a currency that possesses all of the characteristics mentioned by Garret and Bech. Currently, there is no such currency available, and therefore it will be a currency with a unique set of features added to the current payment landscape. In Figure 1.1 it can be seen how all forms of currency relate to these different characteristics. It can be seen that bank deposits are digital and widely accessible but are not central bank-issued and peer-to-peer (due to the need for an intermediary like a bank).

To conclude with a definition that fits these characteristics, according to McKinsey (2023) a CBDC is "a digital form of a government-issued currency that isn't pegged to a physical commodity. They are issued by central banks, whose role is to support financial services for a nation's government and its commercial banking system, set monetary policy, and issue currency."

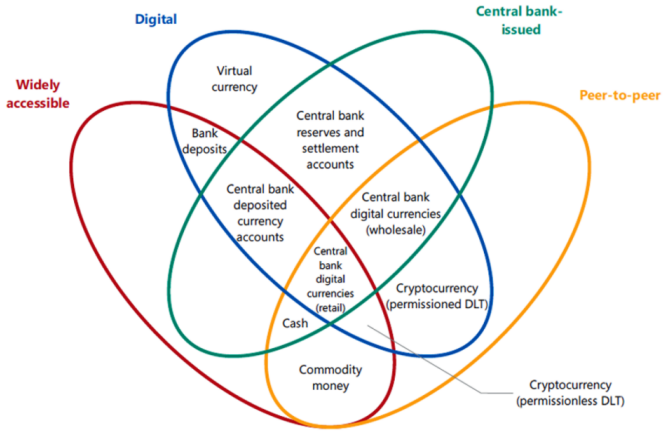

Figure 1.1: Money Flower (Bech and Garret, 2017)

1.3.2 A CBDC by the ECB - The Digital Euro

CBDCs are not a recent innovation, they have historical roots that go back nearly 30 years. In 1993, Finland's central bank introduced the Avant smart card, which functioned as an electronic version of cash. Despite being phased out in the early 2000s, this initiative can be credited as the world's inaugural CBDC (IMF, 2022). However, not since recently has CBDC's regained the interest of central banks around the world. This was mainly due to the rise of cryptocurrencies and the launch of coins by big tech companies like Libra by Facebook, for example. This led central banks all over the world to feel threatened by digital money over which they have no

control (BNR, 2023). Furthermore, the following trends helped fuel the interest in CBDCs (McKinsey, 2023):

- **Declining Use of Cash:** For example, in Europe, the utilization of cash has seen a one-third reduction from 2014 to 2021. In countries like Norway, a mere 3% of transactions are conducted in cash. This changing landscape has prompted central banks to reevaluate their role within the monetary system.
- **Increasing Adoption of Private Digital Assets:** According to the ECB, about 10% of households in six major EU countries have digital assets. This growing consumer interest poses a potential challenge to traditional fiat currencies as the standard measure of value.
- **Diminishing Perception of Central Banks as Innovators:** Central banks are increasingly being seen as less innovative in the payments sector. However, CBDCs present them with an opportunity to regain a pioneering role by leading public discussions on the future utility of cash and digital payments.
- **Expansion of Global Payment Systems:** As payment systems become more globalized, many central banks are looking for ways to exert more local control. They view CBDCs as a potential stabilizing force that could anchor local digital payment infrastructures.

This led central banks all over the world to start investigating the launch of a CBDC. At present, 87 countries, representing more than 90 per cent of global GDP, are exploring CBDCs (McKinsey, 2023). This also led to the start of research into the use of a CBDC for the European population by the ECB.

In July 2021, it was decided by the ECB to start with an investigation phase, which should last 24 months from the start of Q4 2021 until the end of Q3 2023. This investigation phase aims to "address key issues regarding design and distribution". The current proposed timeline by the ECB can be seen in Figure 1.2 (ECB, 2023b).

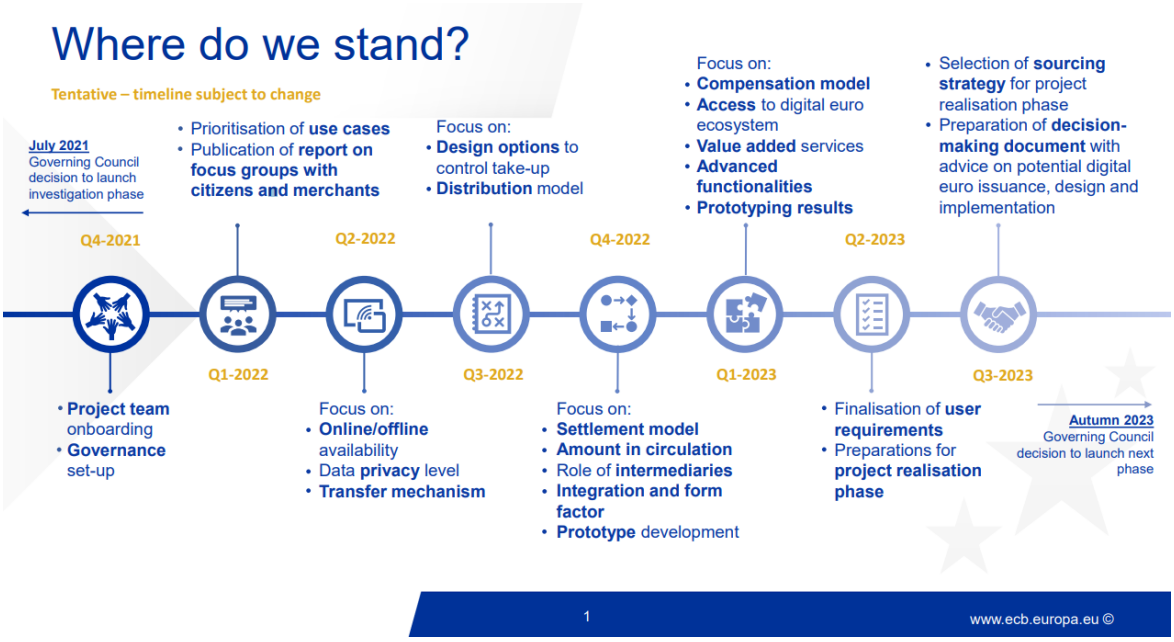

Figure 1.2: Timeline DE (ECB,2021).

A DE must be able to meet the needs of Europeans while at the same time helping to prevent illicit activities and avoiding any undesirable impact on financial stability and monetary policy (ECB, 2021). On June 28th 2023, the European Commission (EC) launched a proposal for a

regulation for the European Parliament on the establishment of the DE, out of which the first highly likely design features of the DE became clear. However, it should be stated that as of the writing of this thesis, a lot is still unknown about the exact design of the DE (European Commission, 2023). However, something that the ECB repeatedly made clear is that a DE will:

- be cash-like and complement cash, but not replace it;
- be linked to the euro;
- be available for all citizens and firms within the Euro area.

Next to these features, in October 2020, the ECB (ECB) outlined several objectives that a DE should meet to serve the needs of the public and the economy effectively. These goals can be seen in Figure 1.3. Furthermore, the ECB announced they will work with five external companies to develop a potential user interface: Amazon, Nexi, Worldline, CaixaBank, and the European Payments Initiative (EPI). This suggests that the ECB is opting for a hybrid system, where commercial banks will fulfil a significant role within the CBDC ecosystem (KPMG, 2023). Furthermore, the ECB stated that intermediaries would take over all end-user-facing activities, such as end-user onboarding or DE account management. There will be no direct interaction between the ECB and end-users of the DE (EBA, 2023).

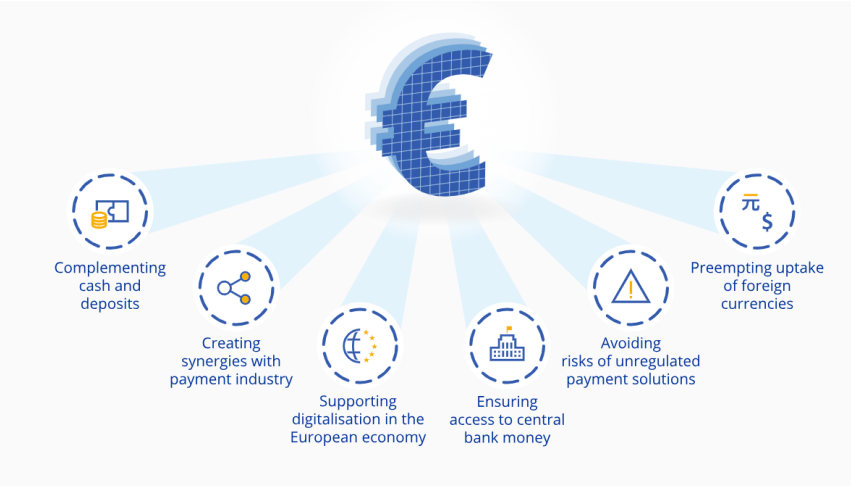

Figure 1.3: Goals DE (ECB,2020).

1.3.3 Impact Introduction Digital Euro on Regular Banks

As mentioned in Section 1.3.2, under the current projected rules, it is most likely that banks will fulfil a significant role within the CBDC ecosystem. This can have a serious impact on the current business operations of regular banks. A few potential impacts were identified:

- **Loss of deposits to DE accounts:** A DE account can be a substitute for (digital) bank deposits. This could lead to a loss in funding for banks, and this can seriously impact their liquidity ratios, lending capacity, and interest margins. Especially in times when banks are perceived as risky and are in financial trouble, people can instantly choose to convert their digital bank money to DEs, which are risk-free because they are covered directly by the ECB. This phenomenon, called digital bank runs, is something the ECB is trying to prevent. To do this, they proposed a holding limit of most likely €3,000 on each DE account (European Commission, 2023). It is important to note that this holding limit contrasts with the concept that money should be a store of wealth, as mentioned by Milnes Section 1.3.1.

- **Costs to launch DE infrastructure:** If banks want to launch DE accounts for their customers, this requires new infrastructure. For example, new IT systems should be added to ensure instant settling of DE transactions. Furthermore, it is, for example, needed to expand operational processes, like the FEC/KYC operations, of a bank to the new DE accounts (KPMG, 2023). It should be stated that these costs are, as of writing, hard to estimate because the exact design of the DE by the ECB is still unknown.
- **Threath to current payment services business model:** Currently, banks are offering payment solutions that make sure that money transfers smoothly from one bank account to another. This is a service that endures a large overhead because the costs to set up such a system are really large (due to, e.g., KYC and AML). However, the extra costs per transaction are often not that large. The initiation of transactions through the infrastructure of the DE, the quantity of which remains undetermined, could profoundly impact the prevailing business model of payment services. This is attributable to the potential reduction in payments stemming from existing overhead, presenting a substantial shift in operational dynamics. It should be noted that there might also be possibilities, as the ECB suspects that they can introduce an infrastructure with lower costs than that of current payment services and they will allow payment providers (like banks) to earn a reasonable profit (European Commission, 2023). On the flip side of this, it is important to note that fintech companies might be able to offer DE accounts as well, worsening the competitive advantage of regular banks.

The consequences mentioned above are useful for understanding the problem at hand.

1.4 Problem Statement

As mentioned in Section 1.3 the implementation of a DE can have a significant influence on the revenue streams and costs of Dutch banks and change these revenue streams and costs. Due to confidentiality and the publication of this thesis, it was not possible to determine the impact of the introduction of the DE on Rabobank specifically. Therefore, this thesis determines the impact of the introduction of the DE on the Dutch banking sector as a whole. The following problem is determined for the Rabobank and the Dutch banking sector. Banks do not know how their revenues and costs will be impacted by the introduction of the DE. This problem can be split into three sub-problems, as discussed in Section 1.3.3, cost due to losing deposits, implementation costs, and how the financials of the current payment services business model will change. Because the financial impact on banks is still unclear, a fact-based discussion on the fairness of the compensation model for the DE is impossible.

Overall, this leads to the following core problem for this research:

The financial implications of introducing a digital euro remain uncertain for Dutch banks.

1.5 Research Goal

The purpose of this research is to be able to estimate the financial impact the introduction of the DE might have on Dutch banks. Due to the current uncertainty about the design of the DE, it is highly unlikely that a clear and definite impact of the introduction of the DE can be determined. However, the goal is that by formulating different scenarios and defining the likely impact of these scenarios, a clear guideline will be provided to Dutch banks on how certain design choices will influence Dutch banks. Furthermore, an estimate should be derived for the impact on the Dutch banking sector. This will help Dutch banks conduct a fact-based discussion on the fairness of the compensation model for the DE based on the estimated financial impact based on suggested policies by the ECB.

1.6 Research Design and Research Questions

In order to achieve the research goal, we have formulated research questions to structure the research. The main research question of this research is formulated as:

What would be the potential financial impact of the introduction of the digital euro by the ECB on the Dutch banking sector?

Chapter 2: Literature Review
In order to understand the knowledge already available, it is important to conduct a literature study. Theory provides clarification of relevant terms, methodologies, and theories.

- Research question 1: *What are the latest developments for the potential design of the digital euro as published by the ECB?*
- Research question 2: *What are ways to estimate the impact of the introduction of a CBDC on banks according to literature?*

Chapter 3: Bank Business Models and Financial Intermediation
In order to be able to assess the impact of the introduction of the DE on Dutch banks, it is also important to know what the current situation looks like.

- Research question 3: *How does the current business model look for Dutch banks and what are important factors to take into account concerning the introduction of the digital euro?*
- Research question 4: *How do Dutch banks make a profit from financial intermediation and what are important factors to take into account concerning the introduction of the digital euro?*

Chapter 4: Model of the Impact on Financial Intermediation
In this phase, a model will be designed in order to assess the impact on financial intermediation due to the introduction of the digital euro. Furthermore, different scenarios will be evaluated with the help of this model.

- Research question 5: *How can a model be built in which different scenarios can be run to test the impact of the introduction of the digital euro on financial intermediation performed by Dutch banks?*

Chapter 5: Scenarios and Results
In this phase, the impact of the different scenarios on Dutch banks will be determined.

- Research question 6: *Which scenarios are important to consider in order to determine the impact on financial intermediation for the introduction of the digital euro?*
- Research question 7: *What is the impact of the developed scenarios on the Dutch banking sector?*

Chapter 6: Payment Services and Development Cost
In this phase, it is elaborated on how the payment services of banks might be influenced by the introduction of the DE and what the development cost for the digital euro might be for Dutch bans.

- Research question 8: *What are the payment services that banks offer?*
- Research question 9: *What is the impact of the introduction of the digital euro on these payment services?*
- Research question 10: *What can be said about the development cost of the digital euro?*

Chapter 7 and 8: Conclusion and Discussion
In the conclusion, the main research question will be answered. This will be done with the help of all the sub-research questions mentioned above. After this, the discussion will reflect critically on this conclusion.

To summarize the research design, the flow diagram in Figure 1.4 shows an overview of the methodology that is used to answer the main research question. This flow diagram serves as the basis on which information was gathered in order to answer the main research question.

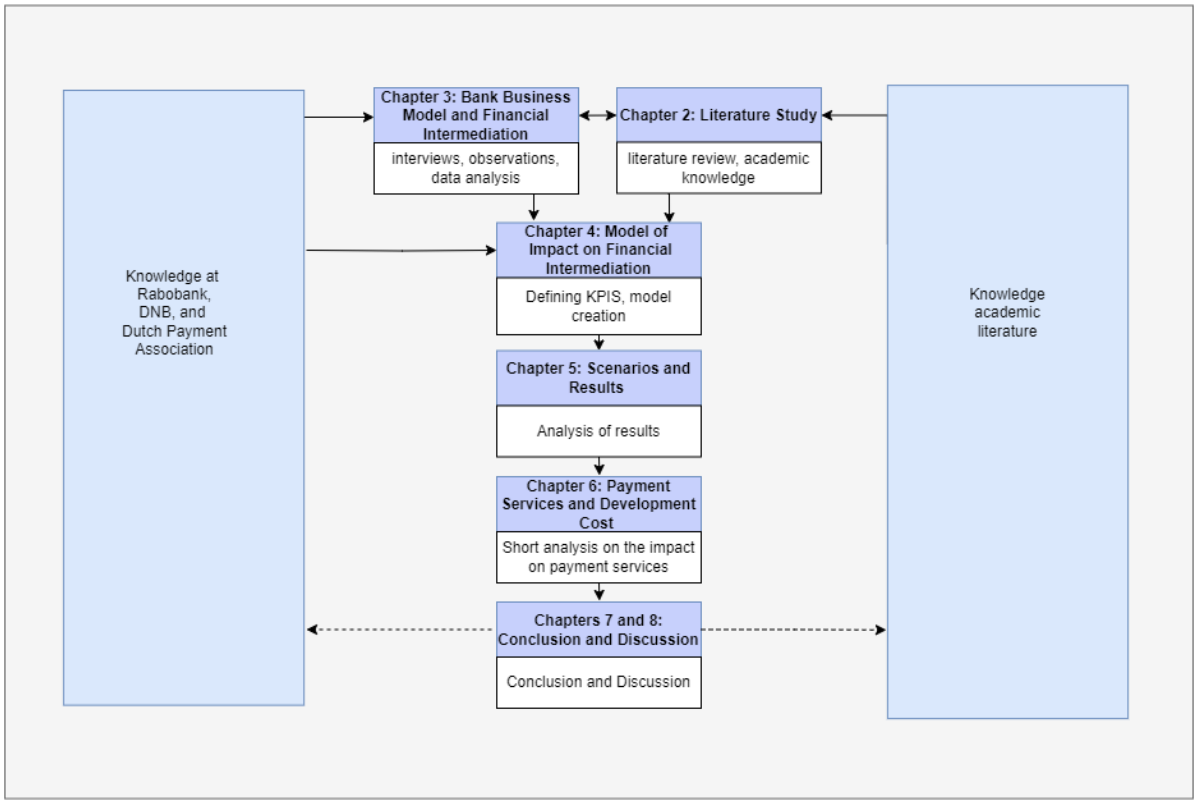

Figure 1.4: Flow diagram of the research structure.

1.7 Research scope

To ensure that the research can be completed within the allotted 26-week timeframe, it's crucial to clearly delineate its scope and limitations. The research is designed to be both academically rigorous and complex while remaining achievable within the specified period.

As stated in Section 1.3.1 this research focuses on the implications of the introduction of a retail CBDC, the wholesale version is outside the scope of this research. Furthermore, from the initial research, it was concluded that modelling the adoption of the DE will fall outside of the scope of this research as well. This is due to the high complexity of the needed modelling technique, Agent-Based Modelling (ABM) as well as due to the results converting to 0 or 100 percent due to the network effect (Martens, 2021). Therefore, this research will focus on scenario analysis, in which the results will be evaluated for different adoption scenarios as well as for different design features of the DE. The goal is to eventually be able to give a financial indication of the consequences of different scenarios resulting from the introduction of the DE by the ECB. Due to confidentiality, the research will focus on the Dutch banking sector and not on Rabobank. This means that for this research, only publicly available data is used.

The initial focus of our study was on examining the effects on financial intermediation, the influence on bank payment services, and the costs associated with developing a DE infrastructure for banks. However, as the research progressed, it became apparent that estimating the development costs for the DE was not feasible at this stage. Additionally, due to the scarcity of data, creating a model for payment services proved too challenging. To address these issues, the study first developed a model to assess the impact on financial intermediation, exploring various scenarios. Subsequently, an additional chapter was included to provide some context on the effects on payment services and the development costs. In Figure 1.5 a graphical overview of the scope of this research can be seen.

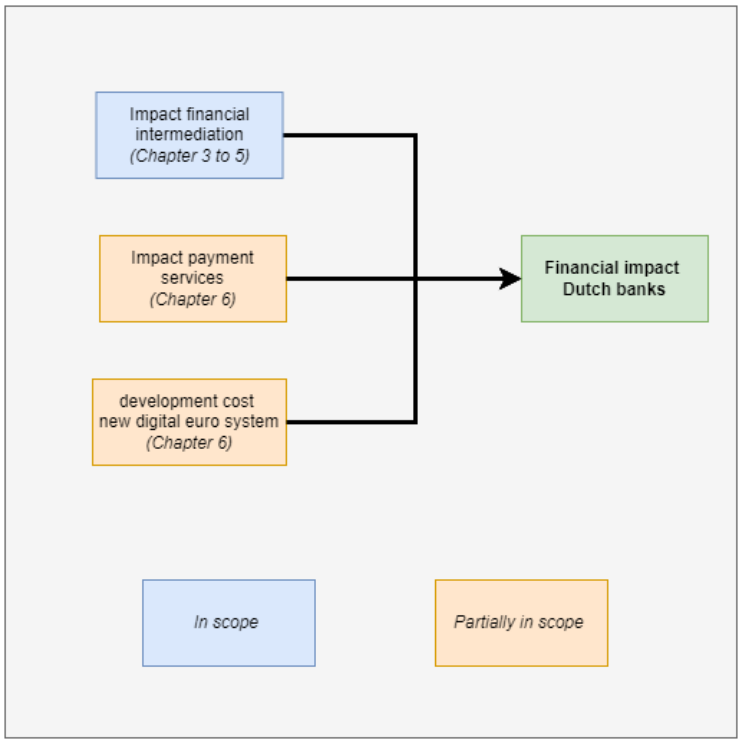

Figure 1.5: Scope research.

Chapter 2

Literature Review

Contents

This chapter focuses on reviewing the existing literature to understand what knowledge is already available in the literature. The goal of this chapter is to answer the following sub-research questions:

- *What are the latest developments for the potential design of the digital euro as published by the ECB?*
- *What are ways to estimate the impact of the introduction of a CBDC on banks according to the literature?*

In order to do this Section 2.1 will elaborate on the methodology used in this literature review. In Section 2.2 the results of the literature review and the answers to the sub-research questions will be discussed. This chapter will be concluded with a discussion and conclusion about the results of the literature review in Section 2.3.

2.1 Methodology

In this literature review, the selection of papers will be based on the framework provided by Fuertmueller et al. in 2013. This section will elaborate on the data sources used, the search query used, the selection criteria for the papers, the extraction and synthesis processes, and ultimately the papers that were obtained (Furtmueller et al, 2013). Additionally, the PRISMA flow diagram is used to represent the selection process (Page et al., 2021).

Data Sources
For this systematic literature review, Scopus, EBSCO, and Google are used as data sources. Google is added due to the sheer volume of working papers published by the European Commission (EC), Bank of International Settlements (BIS), ECB, European Banking Authority (EBA), and the International Monetary Fund (IMF) easily accessible via Google. These databases were chosen for their extensive coverage of academic works from numerous disciplines

and their standing as a reliable resource for academic study.

Search Query
The following keywords were selected for our literature review: CBDC OR DE OR Central bank digital currency, Financial Impact OR Impact, Banks OR Financial institutions, Banking OR Rabobank OR ING OR ABN AMRO, Modelling OR Model OR Simulation, Payment.

Selection Criteria
The Selection criteria for this literature review are based on the following factors: general information like the title, authors, year of publication, and relevance of the papers to our research question. The DE is a relatively new concept for which new publications appear very quickly. Furthermore, the design of the DE becomes more clear with the day. Therefore, extra attention is given towards the publication dates. For this literature review, there is focused on publications after 2021, as this is the year the ECB started with their research phase and a lot of new publications have come out since then.

Selection Process
The integrity, transparency and dependability of this study are enhanced through adherence to the PRISMA guidelines, as referenced in. A comprehensive explanation of the PRISMA selection methodology can be found in Appendix A, which includes the steps taken within the PRISMA Flow Diagram and the flow diagram itself. Furthermore, an overview of the articles analyzed can be found in Appendix A. It should be noted that the study is restricted to articles written in English. Furthermore, various case studies and systematic review articles were omitted because they were deemed irrelevant to the focus of this research.

Literature Review Bias
In this systematic literature review, the scope of databases was limited to Scopus and EBSCO, which involves the risk that relevant sources are left out of this review. According to the PRISMA 2020 guidelines, two primary types of bias risk are considered. The first relates to the potential for bias within the individual who conducts the literature review. The second concerns the risk of bias in the synthesized conclusions due to the absence of certain studies or specific study outcomes (Page et al., 2021).

2.2 Results

The literature on CBDCs is rapidly growing. In 2022 and 2023 alone, there were 231 Scopus publications that mentioned the word CBDC, compared to 29 between 2018 and 2019. In this section, the results of the literature review will be evaluated. First, the latest developments concerning the design and rule set surrounding the DE will be discussed. Next, the literature on the impact of a CBDC on financial impact will be discussed. Lastly, the literature on the impact on individual banks will be discussed. In total, in this literature review, 12 articles were analyzed as well as the documents published by the ECB and the EC.

2.2.1 Current Design Features Digital Euro

In order to be able to assess the impact of the introduction of the DE, it is important to know in what form the DE will be introduced. In this section, the current state of the proposals in the literature will be evaluated. On 23 June 2023, the EC published a regulatory framework facilitating the possible introduction of a DE (European Commission, 2023). From

this framework, the most likely potential design features of the DE can be extracted. This section will be based on this report. Something that becomes immediately clear from the proposal is that the EC is planning to oblige certain parties to accept payments in the DE and others to distribute the DE to foster adoption. This is in line with the goal of the ECB to use the DE mainly as a means of payment and not as a means of value (Panetta, 2022).

Technical Features
According to the proposal, the DE should be designed in a way that facilitates its use by the general public, including financially excluded persons or persons at risk of financial inclusion, persons with disabilities, functional limitations, or limited digital skills, and older persons. DE users will not be required to have a non-DE payment account. Some functionalities of the DE require, nevertheless, a non-DE payment account. Examples of these functionalities proposed by the EC are waterfall and reverse waterfall functionalities. This is a functionality in which the DE account is coupled to a non-DE account, and transactions can go automatically via the DE payment ecosystem while the money goes automatically into the non-DE account. Something important to note is that when using waterfall functionalities, there should be the possibility of sending more money than the holding limit allows. This way, the payment ecosystem of the DE can also be used for large payments. Currently, no transaction limits are foreseen to prevent this from happening. However, transaction limits are a topic of discussion.

Another technical feature of the DE will be that payments should be possible both online and offline. Offline payments should be similar in nature to cash. In order to do this, payment service providers (PSPs) should therefore not process personal data related to offline DE payment transactions but only personal data related to depositing or withdrawing DEs from DE payment accounts to load them onto local storage devices, or the other way around. Furthermore, the final settlement should occur at the moment of updating the records of relevant DE holdings in the local storage devices.

Furthermore, the DE should not be programmable money. According to the Fed, programmable money is money that can be coded to perform a specific set of functions or rules (Lee, 2021). The EC wants the DE to be totally fungible, such that it can be used for any type of payment transaction.

Accepting Payments with the DE
The DE will be granted a legal tender status, meaning that some merchants will be obliged to accept payments within the DE. However, micro-enterprises that do not accept electronic means of payment, non-profit legal entities, and individuals who do not act in the course of a commercial activity will be exempt from this obligation.

Distribution of the DE
The DE can be distributed by all PSPs, but only credit institutions that manage payment accounts are obligated to do so. Not only people but also legal entities should, upon request by their clients, be able to open DE accounts. However, according to the current proposed regulation, it looks like only people are allowed to store a balance on a DE account; legal entities should connect their DE account to a normal payment account so that the funds can be immediately transferred to that account. Something important to note is that it should be possible for users to have one or several DE accounts held at the same time at different PSPs. Additionally, it should be made possible for DE account holders to switch their DE accounts between providers at any moment in time. Furthermore, the proposal notes that member states should designate specific public entities that would also provide basic DE services. This is done so that people who do not have a payment account at a credit institution can still open a DE account. This is mainly useful for countries with low digital adoption or low trust in financial institutions, which is not the case in the Netherlands. For people outside the European Union,

PSPs may only distribute the DE to natural and legal persons residing or established in a member state whose currency is not the euro if the ECB and the national central bank of that member state have signed an arrangement to that effect.

Payment Fees for Financial Institutions
According to the EC, the ECB should regularly monitor the fees and charges associated with payments with the DE. The EC proposes a maximum fee or charge that should allow for free competition between intermediaries below that level. On the one hand, they mention that fees or charges should not exceed the relevant costs incurred by PSPs to provide DE payment services; however, intermediaries may include a reasonable margin of profit. The relevant costs on which the maximum fees will be based are based on the costs incurred by a representative group of the most efficient PSPs in a given year. On the other hand, fees or charges should not be higher than those requested for comparable private digital means of payment, like international card schemes for example.

Interest Rates
According to the proposed framework, the DE shall not bear interest. This is done to primarily use the DE as a means of payment while limiting its use as a store of value (Panetta, 2022).

Holding Limits
Another measure in place to prevent the DE from being a store of value is a holding limit. The EC proposes holding limits to minimize the effect of financial disintermediation on financial institutions. The exact height of the holding limits should be determined by the ECB, according to the EC. Sources within the ECB mention that a holding limit of €3000 per individual is enough to contain the impact on the bank's balance sheet and keep the financial system stable, even in pessimistic times (Meller and Soons, 2023). This means that while a user can have multiple DE accounts, they can most likely have a maximum stored value of €3000 divided over these accounts. Currently, there is also a strong debate about holding limits for businesses. In October 2023, the EC published a report in which it seems unlikely that businesses will be able to hold a balance on their DE account (European Commission, 2023). This means that funds received on a DE account by businesses should be wired directly to a bank account.

Privacy and Anti-Money Laundering:
Payments should be able to be authorized by users with the help of European Digital Identity Wallets. A European Digital Identity Wallet is a digital tool that allows individuals to store and manage their personal data and identity information in a secure and user-friendly way. To protect the privacy of the users of the DE, the ECB, the national central bank, and the PSPs will not get access to personal transaction data. For offline proximity payments, payment providers will only get access to funding and defunding data, similar to depositing and withdrawing cash. In order to prevent money laundering, PSPs should transmit this funding and defunding data, upon request, to financial intelligence units and other competent authorities. Online payments with the DE will be treated as normal online payments, and current AML requirements are in place for these payments (European Commission, 2023).

2.2.2 Impact of CBDC on Financial Stability:

In order to understand the impact that the introduction of a CBDC might have on financial stability, it is, according to Kaczmarek (2021), useful to understand how the monetary system is currently looking. The current monetary system is depicted in Figure 2.1. It can be seen that, on the one hand, central banks issue cash in the form of banknotes, and on the other hand, commercial banks issue digital forms of payment in exchange for deposits.

Adalid et al. (2022) argue that the DE will replace banknotes on the one hand and bank deposits on the other hand. When banknotes are replaced, not much will happen for financial stability.

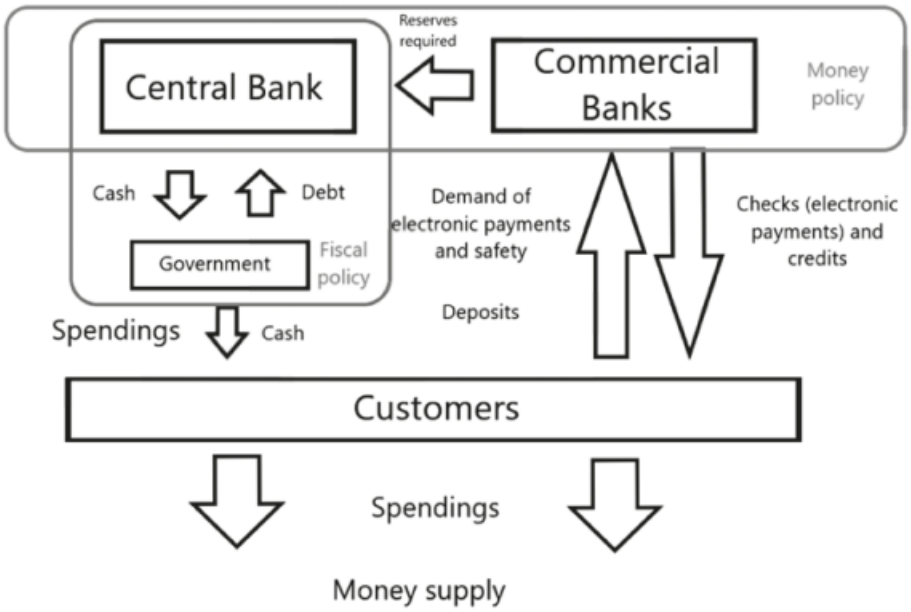

Figure 2.1: Current monetary system (Kaczmarek, 2021).

However, when deposits are flowing towards CBDCs (especially in times of panic), this can lead to funding shortages for banks. Adalid et al. (2022) mention different scenarios to counter these deposit outflows and the effects of these outflows on the balance sheet of the Eurosystem. An example of one of these scenarios is a reduction of a bank's assets by selling them to the ECB, such that the deposit outflow is matched. This example can be seen in Figure 2.2. It is important to note that this means that the Central Bank will take on the role of a regular banker, which might not be realistic. However, the scenarios mentioned by Adalid et al. are mainly useful to understand what happens with the balance sheets of the Eurosystem when deposits flow to the central bank (Adalid et al., 2022).

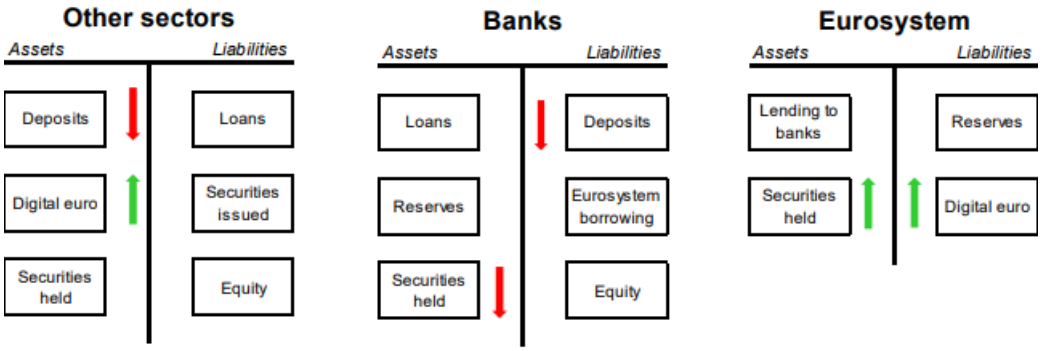

Figure 2.2: Balance sheet Eurosystem if banks sell their own assets (Adalid et al. 2022).

An important point noted by Brunnermeier and Niepelt (2019) in their paper called "On the Equivalence of Private and Public Money" is that financial stability does not necessarily have to change by deposits outflowing to CBDCs. They make the point that if the central banks loan these deposits back to the bank for the same interest rate as banks pay on deposits, bank funding will not be challenged. However, Brunnermeier and Niepelt argue that this result relies on the assumption that central banks should change from their current practice of only providing collateralized funding for banks (Brunnermeier and Niepelt, 2019).

Castrén et al. (2022) argue that the introduction of a CBDC can encompass large funding gaps, with negative consequences for commercial banks when replaced with short-maturity funding from the central bank or the wholesale market. They even state that this funding stress can propagate to non-financial sectors (Castren et al., 2020). Meller and Soons (2023) propose a constraint optimization model to study the impact of a CBDC on banks' funding structures and the demand for central bank reserves given liquidity risk considerations. The result of their study on data from 2021 is that with a holding limit of €3000 per person, no additional central bank funding would be needed (Meller and Soons, 2023). An important limitation of this research is that in 2021, banks held a lot of excessive reserves. With the monetary tightening that is ongoing as of the writing of this thesis, it is unrealistic to assume that this will also necessarily be the case when the DE is introduced.

This view is opposed by Warren (2023), as he argues for a CBDC without a holding limit. He mentions the following points: The first is that a holding limit would not limit the threat of a bank run, as people can already move money around with one click of a button. This means that banks should adjust to the risk of digital bank runs anyway, despite the introduction of the DE. Secondly, imposing holding limits will make the privacy characteristic of the DE difficult to obtain due to the fact that records of the balance of each account have to be registered together with the name of the owner of the account. Lastly, by introducing the DE, competition may arise for the deposits of consumers. This could lead to banks incentivizing consumers to maintain their deposits by raising interest rates, for example. This could lead to more bank revenue ending in the hands of consumers (M. Warren, 2023).

2.2.3 Impact of CBDC on Banks

As of the writing of this thesis, there are only a few papers that try to quantify the impact of the introduction of a CBDC on banks in such a way that the financial impact for an individual or a group of banks is determined. Furthermore, the papers in the literature focus only on the funding side of the impact. Castrén et al. (2022) use a network approach to consider how sector-level balance sheets might change under different CBDC scenarios (Castren et al., 2020). This determines the impact of the loss in deposits. While this applies to the sector as a whole, it is not applicable to individual banks. BIS published a paper in 2021 in which they presented a simplified financial model to explore how banks might maintain their liquidity levels when facing withdrawals of deposits. The model suggests that banks could offset deposit losses by securing High-Quality Liquid Assets (HQLAs) through long-term funding from institutional sources (BIS, 2021). However, when depositors change their deposits into DEs, this is mostly during times of distress. It is questionable if this form of funding is available during times of distress due to the fact that liquidity often dries up during these times (Muñoz and Soons, 2023). A study published by Garlova et al. examines how the liquidity ratios of major Canadian banks would be affected if stable retail funding were replaced by less stable funding sources with higher run-off rates. The study, however, also does not factor in the limitation that the banking system has a finite amount of reserves available (Gorelova et al., 2022). The study by Meller and Soons does include collateral and reserve constraints at individual and banking system levels, making it possible to consider how individual banks would select their preferred funding. This paper also emphasizes the different results of running the model at different times. This is the result of the different liquidity and reserve amounts in the market (Meller and Soons, 2023). Another interesting article that tries to determine the impact of the introduction of a CBDC, authored by Marco Gross and Elisa Letizia (2023), introduces a multi-faceted model designed to study the possible effects of introducing a Central Bank Digital Currency (CBDC) on banking institutions and the broader private sector economy. The model integrates insights from choice theory, game theory, the field of industrial organization, reinforcement learning, and the principle of stock-flow consistency. These simulations also explore how different factors, such as fluctuating interest

rates or shifts in consumer preferences, could influence the outcomes. The model can also be used to determine the profit decrease of a banking system as a whole by the introduction of a CBDC (Gross and Letizia, 2023). The last article also evaluates the impact of shifts towards the DE. They do this by adapting the theoretical framework of Dutkowsky and Van Hoose (2018b, 2020) to the Euro Area. The study investigates the conditions under which a DE could be introduced on a large scale without leading to bank disintermediation or a credit crunch (Fegatelli, 2022).

2.3 Conclusion and Discussion

The goal of this chapter was to answer the following sub-research questions:

- *What are the latest developments for the potential design of the digital euro as published by the ECB?*
- *What are ways to estimate the impact of the introduction of a CBDC on banks according to the literature?*

To answer the first research question, in this literature review, the latest developments concerning the DE were evaluated by analyzing the latest publications done by the ECB and the EC. Furthermore, to answer the second research question, 12 articles concerning the impact of the introduction of a CBDC on financial institutions were analyzed

In this literature study, it was found that from the latest proposal published by the EC, a lot of uncertainty arises. For example, the minimum fee for the transfer of payments should not be higher than the current lowest price of a comparable service. In the Netherlands, processing payments is currently unprofitable (McKinsey, 2022). Furthermore, how much of the cost of the introduction of a DE will end up at the banks? Can current AML and KYC employees also work on transactions with the DE? Something noticeable is that almost all the literature found related to determining the impact of deposit shifts towards DE accounts, and almost zero literature examined the impact of the introduction of the DE on the payment business models of banks. Meaning that none of the above-mentioned questions were answered within the literature. This might partially be explained by the different payment infrastructures in different countries. The Netherlands is one of the only countries in Europe where payments are not profitable (McKinsey, 2022). Introducing a new payment network as proposed by the EC (Section 2.2.1) can have severe influences on this profitability.

There are different opinions on the impact on financial intermediation due to the outflow of deposits to DEs present in the literature. It becomes clear that it can have a severe effect on banks' profitability if a lot of euros are converted to DEs. However, liquidity can be brought back into the system by the central bank (Adalid et al., 2022). It should also be noted that a lot of the studies found in the literature were based on data from a time when interest rates were negative. During this time, there were a lot of excessive reserves being stalled at the central bank, and there was a lot of liquidity in the market. This means that the introduction of the DE did not often lead to a severe decrease in lending, and banks were able to catch the deposit outflows with the help of their excessive reserves. Furthermore, if extra funding was needed, this was easily obtainable in the market due to the large amount of liquidity available. Currently, we are heading towards an environment where interest rates are a lot higher and the spread between the interest rates offered on savings and the interest offered by the central bank widens. This means that it can be expected that it will be "more expensive" to lose deposits to the DE, and this will hurt banks more. However, because there will most likely be a holding limit of €3000 per person (Section 2.2.1) the effect of the deposit outflows will probably be minimized (Meller and Soons, 2023). Furthermore, the result of the deposit outflow could be countered by the

central bank if they replaced the lost deposits by funding the banks themselves (Adalid et al., 2022). However, this relies on heavy assumptions, and there have been no signs of this in the proposal published by the EC in June 2023. In the literature, it is argued that not implementing a holding limit will be profitable for society as it enlarges the choice of storage of wealth and will not increase the threat of digital bank runs, as this threat is already apparent. This is an interesting point; however, as mentioned, it currently looks like the holding limit will be introduced.

Most of the literature is about how the banking sector as a whole would react to a DE and how the liquidity of the market would be impacted. There are only a few publications that translate the impact on financial intermediation due to the introduction of the DE to a profit change for modelled banks, and in these publications, multiple assumptions are made. In conclusion, while existing literature offers valuable insights into the potential impact of a Central Bank Digital Currency CBDC on banks, particularly in terms of disintermediation due to deposit shifts, it largely overlooks the implications for banks' payment business models. Furthermore, few publications translate the impact on financial intermediation into a profit impact for banks. In the literature, there are currently no specific publications available for the introduction of a DE in the Netherlands, such that the literature does not account for the varying conditions and regulatory landscapes specific to the Netherlands. Furthermore, all publications look at the deposit outflow in a worst-case scenario, not looking at different scenarios regarding the adoption of the DE, thereby leaving significant gaps in our understanding of the full range of consequences that the introduction of the DE might entail on the banking sector in the Netherlands.

Overall, it can be concluded that in this chapter, the sub-research questions are answered while, of course, keeping in mind that it is always possible that some relevant publications might be missed due to the chosen methodology of this literature research.

Chapter 3

Bank Business Models and Financial Intermediation

Contents

The goal of this chapter is to answer the following sub-research questions:

- *How does the current business model look for Dutch banks and what are important factors to take into account concerning the introduction of the digital euro?*
- *How do banks make a profit from financial intermediation and what are important factors to take into account concerning the introduction of the digital euro?*

To do this, in this chapter, the current banking sector will be analyzed, and important factors concerning the introduction of the DE will be analyzed. In Section 3.1, the general business model of banks will be evaluated. This thesis focuses, as mentioned in our scope (Section 1.7), mostly on the impact of the DE on financial intermediation. Therefore, in Section 3.2, there will be a zoom-in on financial intermediation and what aspects are important in light of the introduction of the DE. Lastly, this chapter will be concluded with a discussion and conclusion in Section 3.3.

3.1 Business Model of Banks

The banking sector is poised for a substantial transformation with the impending introduction of the DE. To understand how this might impact banks, it is essential to first explore the fundamental nature of banks and their revenue streams. This analysis delves into the ways banks operate and make money, and how these might be influenced by the DE. According to the DNB (2017), banks are institutions that take deposits from the "public" and use these deposits to provide loans to generate capital. Within this definition, the term public refers to a group of people being outside of a restricted circle (DNB, 2017).

Revenue Streams of Banks
A bank earns revenue through various means. Primarily, they earn interest income by offering

lower interest rates to depositors compared to the higher rates they charge borrowers. This is often possible due to the fact the banks attract deposits with a short duration, and loan it out against a higher interest rate for a long duration. This also means that a bank should be able to pay back these short deposits once demanded by the depositors. Once a bank's interest expenses are deducted, the resulting net interest income represents the income from this operation. This phenomenon is often called financial intermediation. According to the theory of financial intermediation, the role of a bank is to reduce transaction costs and informational asymmetries between savers and borrowers. Banks possess an informational advantage, allowing them to screen and monitor investors on behalf of savers. This function justifies the transaction costs they charge. Additionally, these intermediaries help bridge the maturity mismatch between savers and investors and facilitate payments by providing payment settlement and clearing systems. They also engage in qualitative asset transformation activities (Scholtens and van Wensveen, 2003). In current economic systems, more factors play a role, as during the last decade's information parity increased and transaction costs decreased, but the role of intermediaries did not decrease (Allen and Santomero, 1997). An example of this might be that to pay digitally or with a card, depositors often also need a bank account further ensuring the role of banks in the financial system.

Adding to this, the Monti-Klein model provides a deeper insight into how banks manage these operations under competitive market conditions. In this model, banks are viewed as making two simultaneous decisions: setting the interest rate for deposits and determining the interest rate for loans. These decisions are interdependent and form the crux of the bank's profitability strategy. In an oligopolistic banking market, which is a scenario also seen in the Netherlands, banks have some pricing power which they use to maximize profits by managing the spread between the interest rates on deposits and loans depending on the supply curve for deposits and the demand curve for loans (Klein, 1971).

Building on this comprehensive view of banking operations, the model developed by Lindley and Sealey offers another layer of understanding, particularly in how banks navigate the complex landscape of financial service production. This model, known for its emphasis on the production aspects of banking, complements the insights provided by the Monti-Klein model. In the Lindley and Sealey framework, banks are conceptualized not merely as intermediaries but as active producers of financial services. This model pivots around the idea that banks, in essence, manufacture financial products such as loans, requiring a careful orchestration of various inputs like capital, labour, technology, and information. The operational efficiency in managing these inputs is a critical focus, given its direct impact on a bank's competitiveness and profitability (Sealey and Lindley, 1977). Banks can also have additional revenue streams next to providing intermediation; banks also generate revenue by charging fees for services like keeping your account open, payment services, and managing investments. For example, when payments are made (to a business), for each transaction, some money goes to the bank. Furthermore, banks generate revenue by offering capital market services to connect corporations needing funds with investors seeking returns on their capital. They provide sales and trading, underwriting, and M&A advisory services. Banks facilitate trades through in-house brokerages and help companies raise debt or equity (Loo, 2022). Each bank can make its own mix of revenue streams and can excel in different segments.

The introduction of the DE is set to bring about significant changes in the banking sector, presenting both challenges and opportunities for financial institutions. This new development could notably impact depositor behaviours, potentially altering the dynamics of how banks attract deposits and distribute loans. As a result, banks may need to revisit and adjust their interest rate setting and risk management strategies to adapt to the new landscape shaped by the DE. Additionally, the competitive environment in the banking sector is likely to undergo shifts, compelling banks to modify their business models and service offerings to stay competitive

in the era of digital currency. A direct consequence of the introduction of the DE could be the phenomenon of disintermediation. This term refers to the potential loss of deposits to the DE system, as banks may no longer be able to fulfil their intermediation function on the funds that move out of their traditional system (Adalid et al., 2022). Disintermediation can significantly impact a bank's revenue resulting from the intermediation of deposits and payment services. Another consequence could be the loss of transactions towards the DE system which might impact the revenue resulting from transaction fees. These are the main revenue streams that are expected to be influenced by the introduction of the DE.

In light of these potential impacts, this thesis will focus specifically on analyzing how the introduction of the DE might affect these critical revenue streams of banks. It will focus for the largest part on the implications of the DE on the intermediation of deposits. In Chapter 6 the the provision of payment services, will also be briefly analyzed. Other revenue streams of banks, although important, will remain outside the scope of this thesis to maintain a targeted and in-depth analysis of the most affected areas.

Ownership Structure of Banks

In the previous section, the general revenue streams which can be present in banks are noted. However, there is still a broad amount of differentiation between banks. Banks can also be distinguished by their ownership structure. Banks can be owned by different entities which also severely influences the goals of these banks. For example, shareholder-owned banks might have more pressure to maximize profits due to the fact that individual shareholders are often money-driven. State-owned banks will be more likely to take into account the interest of the state. While co-operative banks or credit unions will look after the interests of their members. Furthermore, there exist purpose-driven banks. These banks are those whose members, up and down the hierarchy, have a strong sense of why their company exists, and whose actions are guided by those beliefs. They have the incentive to earn an economic return that is compatible with achieving the purpose of the corporation, i.e. creating value for its stakeholders (Boerman, 2022). Purpose-driven banks might have unique ownership structures like for example, Triodos through foundations to protect their initial purpose of sustainable banking (Grattan, 2023). The ownership structure of a bank is important to consider when looking at how banks might react to the introduction of the DE. Each type of bank may respond differently based on its underlying goals and motivations. Shareholder-owned banks might focus on how the DE can enhance profitability, while state-owned banks might assess its impact on national financial policies. Co-operative banks and credit unions would consider the benefits to their members, and purpose-driven banks would evaluate the alignment with their core values and mission.

Funding of banks

Something else to consider when looking at banks is that banks can be distinguished by the way they are funded. BIS makes a distinction between two types of bank funding (BIS, 2017):

- **Retail funding:**
  Retail funding is funding that consists for the majority of customer deposits, including savings accounts, checking accounts, and term deposits. This form of funding is generally perceived as stable, particularly in stable economic and political climates, and is often less susceptible to market volatility.
- **Wholesale funding:**
  Wholesale funding is procured from the interbank market, encompassing various instruments like interbank loans, certificates of deposit, and commercial paper. Institutions and other entities are the primary players in this domain opposed to individual consumers.

Understanding these funding mechanisms is crucial, especially when considering the implications of the introduction of the DE. Banks have various characteristics based on their funding structures and operations, and the impact of the DE can vary significantly across these different attributes. The DE, primarily aimed at private clients, is likely to have a more pronounced impact on the retail funding aspect of banks. As the DE becomes a new means of transactions and savings for individual consumers, it could shift the dynamics of how retail customers interact with banks. This shift could lead to changes in the volume and stability of retail deposits, which have traditionally been a cornerstone of bank funding. In the case of wholesale funding, the impact might be less direct or immediate. Since the DE is expected to be more aligned with retail banking activities, its introduction may not significantly disrupt the interbank markets or the instruments used for wholesale funding. However, it's important to consider the broader effects on the financial system and how they might indirectly influence wholesale funding strategies and costs.

To conclude, banks can have a whole variety of the characteristics mentioned above. The goal of this thesis is to determine the impact of the introduction of the DE on the Dutch banking sector, but it is important to note that the impact can be different depending on the different characteristics of the banks mentioned above.

Dutch Banking Sector

The goal of this thesis is to quantify the impact of the introduction of the DE on the Dutch banking sector. Therefore, this section will elaborate on Dutch banks and the Dutch banking sector. In the Netherlands, multiple banks are registered, which have a total amount of assets on their balance sheet of 2.6 trillion DNB (2023). The Dutch banking sector is characterised by a few large players and a number of smaller banks. Due to the nature of the DE, it is expected to impact retail deposits. Therefore, this thesis will focus on banks with significant retail banking market share in the Netherlands. This section will elaborate on the four largest retail banks of the Netherlands, as they have a market share in household deposits under the management of more than ninety percent in the Netherlands DNB (2023). The four largest retail banks in the Netherlands are:

- **Rabobank:** Rabobank is a large cooperative bank with 9 million business and private customers. It's one of the world's leading financial services providers in the food and agribusiness sectors. Rabobank had 396 billion euro in customer deposits under management in 2022 (Rabobank, 2022a).
- **ING:** ING is a leading European bank. ING has more than 60,000 employees and serves around 37 million customers, corporate clients, and financial institutions in over 40 countries. ING had 641 billion euros in customer deposits under management in 2022 (ING Group, 2023)
- **ABN AMRO:** ABN AMRO has a significant presence in both the retail and commercial banking sectors. ABN AMRO has approximately 7 million customers and 20,000 employees. In 2022, ABN AMRO had 255 billion in customer deposits under management (AMRO, 2022).
- **De Volksbank:** De Volksbank is the parent company of SNS, ASN Bank, RegioBank, and BLG Wonen. As a bank with more than 3 million customers, it has a high focus on retail banking. In 2022, De Volksbank had 44 billion euros in customer deposits under management (Volksbank, 2023).

Specific metrics of these individual banks which will be used for further analysis can be found in Appendix C.

3.2 Financial Intermediation

As mentioned before, an important revenue stream for banks is financial intermediation (Scholtens and van Wensveen, 2003). As found in the literature review (Section 2.2), the introduction of the DE might have an impact on this revenue stream. In this section, different concepts of financial intermediation will be explored, along with an examination of how these concepts may be impacted by the introduction of the DE.

As mentioned in Section 3.1, financial intermediation is the concept of banks earning money by offering lower interest rates to depositors compared to the higher rates they charge borrowers. This is often possible due to the fact that banks attract deposits with a short duration and loan it out against a higher interest rate for a long duration. As with the introduction of the DE, it is expected that banking customers might move some of their deposits towards DE accounts. It is important to consider what types of deposits there are and how they are influenced by the introduction of the DE. Deposits exist out of the payment and saving accounts of people as well as the payment and saving accounts of companies. Dutch banks use these deposits to invest in different types of assets, like loans, for example.

In the literature, a distinction is made between two types of deposits, demand deposits and time deposits. Demand deposits refer to funds held in a commercial bank that can be withdrawn by the depositor at any time without any prior notice. These deposits are typically held in checking accounts, savings accounts, and money market accounts. Demand deposits are often used for day-to-day transactions and are considered highly liquid. Time deposits, on the other hand, are funds held in a commercial bank for a fixed period of time, typically with a predetermined maturity date. These deposits cannot be withdrawn before the maturity date without incurring a penalty. Time deposits are also known as certificates of deposit and are considered less liquid compared to demand deposits. They often offer higher interest rates than demand deposits and are used by individuals and institutions for savings and investment purposes (Timberlake and Fortson, 1967).

Since the DE is designed to be a means of payment and not a store of value, according to Panetta (2022) it is expected that the DE will mostly influence demand deposits. This is due to the fact that if the DE is designed to facilitate everyday digital payments efficiently, it could directly compete with demand deposits as a means for conducting transactions. Individuals might prefer to hold a portion of their demand deposits in DE for transactional purposes. Another reason the DE is not a substitute for time deposits is due to the fact that the DE would, under the current proposed design (Section 2.2.1), offer no interest, making time deposits more attractive for those seeking to earn interest on their savings.

Banks lend out deposits for a longer duration at a higher interest rate than they pay over the generally shorter demand deposits, for instance, to businesses or individuals in the form of mortgages. However, currently, Dutch banks have stalled large amounts of deposits at the ECB. The remuneration on this balance is "the lowest" compared to all other assets with a comparable maturity, as this is considered a risk-free return for banks. The ECB renumerates banks for this balance with the deposit facility rate, which stands, as of writing (9-25-2023), at four percent. This means that banks can earn a risk-free yield of 4 percent at the ECB. This while they pay, as of the writing of this thesis (9-25-2023), one point five percent over the deposits in the savings accounts of their customers. The high balance at the ECB exists mainly due to the fact that there is ample liquidity in the market, as mentioned in Chapter 2. This is the result of the fact that banks have no more favourable loans to commit themselves to because the central bank flooded the market with liquidity during the COVID-19 pandemic (ECB, 2023). This is important to keep in mind when trying to determine the impact of the introduction of the DE on Dutch banks, as this means that banks might not have to sell assets to stay solvent when

deposits flow out of the bank.

If banks need money, banks can also lend money to each other using the euro short-term rate, which is the rate of overnight borrowing between financial institutions. This rate stands currently at 3.905 percent, which is lower than the deposit facility rate, which is noticeable because lending to financial institutions should be deemed riskier than lending from a central bank. This is due to the fact that financial institutions that have no access to the deposit facility rate get charged an "intermediary fee" by banks when they put the money at the central bank for these institutions (van Geffen, 2023).

In order for a bank to stay solvent, the ECB mandates regulatory requirements for banks. These requirements are made up in Basel III and come in the form of ratios with which banks need to comply in order to keep the financial system stable. This means that banks cannot always invest the deposits of their customers as they want (KPMG, 2021). In order to understand how banks might react to the outflow of deposits due to the introduction of the DE it is important to consider which options they have within this regulatory framework. In order to understand this, it is important to understand the liquidity ratios to which banks should suffice. Two important ratios regarding the liquidity of a bank that are important when losing deposits to a DE are discussed below.

3.2.1 Liquidity Coverage Ratio

In order to understand what happens to bank funding and how banks can replace lost deposits due to the introduction of the DE, two requirements regarding liquidity are especially important. The first requirement is that banks should suffice to is the liquidity coverage ratio (LCR). According to BIS (2013) the LCR aims to ensure that a bank has an adequate stock of unencumbered high-quality liquid assets (HQLA) that consists of cash or assets that can be converted into cash at little or no loss of value in private markets to meet its liquidity needs for a 30-calendar-day liquidity stress scenario. Under Basel III the LCR should have a minimum of 100% as of June 2019 (BIS, 2013). In order to determine these cash outflows, weights are given to the liabilities of banks. For example, a minimum of 7.5% of stable deposit outflows should be considered for this stress test scenario (van den End, 2010). HQLA are a class of assets that can be easily and quickly converted into cash with little or no loss of value. HQLA should be unencumbered, meaning they are not pledged as collateral or otherwise restricted, ensuring that they can be sold or used to obtain liquidity whenever needed (BIS, 2013). Different assets should have different weights in the determination of the HQLA, cash and equivalents can be considered 100% while corporate bonds rated AA can only be considered for 80% as HQLA. The liquidity coverage ratio should be greater than 100% and is depicted in Equation 3.1

$$\frac{\text{Stock of HQLA}}{\text{Total net cash outflows over the next 30 calendar days}} \geq 100\% \tag{3.1}$$

More information about how HQLA and the net cash outflows are built up in relation to different balance sheet items can be found in Appendix B.1.

3.2.2 Net Stable Funding Ratio

The second liquidity requirement is the net stable funding ratio (NSFR). According to BIS (2014) the NSFR is the amount of available stable funding (ASF) relative to the amount of required stable funding (RSF). This ratio should be equal to at least 100% on an ongoing basis.
“Available stable funding” is defined as the portion of funding expected to be reliable over the time horizon considered by the NSFR, which extends to one year. The amount of such stable funding required ("Required stable funding") of a specific institution is a function of the liquidity

characteristics and residual maturities of the various assets held by that institution as well as those of its off-balance sheet exposures. For available and the required stable funding BIS defines certain weights for different balance sheet items. For example, stable retail deposits with a maturity greater than one-year count 85% for the available amount of stable funding (van den End, 2010). The formula for the NSFR is depicted in Equation 4.1.

$$\frac{\text{Available amount of stable funding}}{\text{Required amount of stable funding}} \geq 100\% \tag{3.2}$$

More information about how the available and required stable funding is built up in relation to different balance sheet items can be found in Appendix B.2.

3.3 Conclusion and Discussion

The goal of this chapter was to answer the following sub-research questions to better understand the context of the banking sector and how the DE will impact it:

- *How does the current business model look for Dutch banks and what are important factors to take into account concerning the introduction of the digital euro?*
- *How do Dutch banks make a profit from financial intermediation and what are important factors to take into account concerning the introduction of the digital euro?*

To answer the first research question, first, the general business model of banks is discussed. This chapter has explored different models according to the literature, which elaborates on the workings of a bank. Furthermore, it elaborates on how banks generate revenue and how this revenue could be influenced by the DE's introduction. Furthermore, other aspects of banking business models are discussed, like different ownership structures, how a bank is funded and the banking sector in the Netherlands.

To answer the second research question, there is zoomed into financial intermediation and important aspects that should be taken into account concerning the introduction of the DE. The chapter also addresses critical regulatory frameworks like the Liquidity Coverage Ratio and Net Stable Funding Ratio, which play a pivotal role in how banks might respond to the changing landscape of deposits due to potential financial disintermediation.

Overall, it can be concluded that with this exploration, the subresearch questions are answered. This helps to understand the context of the banking system in which the DE will be introduced as well as important aspects to take into account in terms of the broader effects of the DE on the banking system.

Chapter 4

Model of the Impact on Financial Intermediation

Contents

The goal of this chapter is to answer the following sub-research question:

- *How can a model be built in which different scenarios can be run to test the impact of the introduction of the digital euro on financial intermediation performed by Dutch banks?*

To do this, in this section, a model will be designed to assess the financial impact of the introduction of the DE on financial intermediation. This model will be evaluated for different scenarios in Chapter 5. In this chapter, first, the model will be introduced in Section 4.1 after which the foundations and assumptions of the model will be discussed in Section 4.2. In Section 4.3 the fixed and dynamic input parameters will be determined, with the help of which the model is built in Section 4.4. This chapter ends with a conclusion and discussion in Section 4.5.

4.1 Introduction to the Model

In Chapter 3.3 it was determined on what revenue streams and aspects of a bank's business model the DE might have an influence. In this chapter, a model will be represented that allows us to look at the impact on financial intermediation that happens due to the introduction of a DE based on different changeable parameters, which will be altered in Chapter 5. The choice is made to make it a deterministic model, which helps establish clear, direct relationships between various parameters and facilitates the formation of foundational assumptions for scenario analysis in this thesis. Furthermore, this choice is made because uncertainty regarding the introduction does not make it possible to assign probabilistic features to the model since it is not possible to say something regarding the probabilities of events happening. The model is bound by the following three main uncertainties:

- The future of the financial system is unclear. Future interest rates, regulations, transaction costs, market liquidity, and a lot more items are uncertain and impossible to predict.
- The design of the DE and its underlying system are, for the most part, still uncertain. Furthermore, it is still uncertain if the DE will come at all.
- The size and scale of user adoption of the DE are still really uncertain and, for a large part, also dependent on the design of the DE.

Despite being subject to these uncertainties, this model tries to estimate the impact of the introduction of the DE on financial intermediation performed by the four biggest banks in the Netherlands by making as sound as possible assumptions. The goal is to determine the drivers behind the impact of the introduction of the DE. Knowing the drivers behind the impact helps banks understand how certain design choices might influence Dutch banks. The model is designed to assess the annual impact, aligning with the availability of mostly yearly data points. In figure 4.3 a visualization of the model can be seen.

Goal of the model: The model aims to estimate the impact on financial intermediation due to the introduction of the DE on the annual earnings of the Netherlands' four largest banks by assuming certain input parameters for different scenarios. This is done to identify the key drivers of these impacts and understand the financial effects of different design choices of the DE.

4.2 Foundation and Assumptions Model

In this section, the foundations and assumptions of the model will be constructed that will help to estimate the impact on financial intermediation due to the introduction of the DE.

In Adalid et al. (2022) scenarios are discussed on how the balance sheet of the Euro system might change when a DE is introduced. This paper is useful for understanding how the balance sheet of the Eurosystem and banks might change due to the introduction of the DE. This conceptual idea is used in our model. Furthermore, our model is built upon the models of BIS (2021) and Meller and Soons (2023). In the paper of BIS (2021) the loss of funding is captured by lending long-term wholesale funding while keeping the LCR constant. After this, the impact of these operations on the net interest margin is determined. In the model of Meller and Soons (2023) it is modelled how banks might restructure their balance sheet due to deposit outflow based on the liquidity ratios and how much reserve demand the Eurosystem would have faced in total. An important distinction between these previous publications and the model developed in this publication is that the deposit outflow will not be the starting point of the model. The deposit outflow will be determined based on underlying data (like the average spending of individuals in the Netherlands) and assumptions in Chapter 5.

It is important to note that for this model, it was chosen not to conduct a micro-economic analysis like in the study performed by Gross and Letizia (2023). This is due to the fact that it is really difficult to estimate the utility of the DE. In the study of Gross and Letizia (2023) the utility of a CBDC is highly dependent on the interest rate offered on the CBDC, while the interest rate offered on the DE will most likely be zero (European Commission, 2023). Furthermore, the base utility in Gross and Letizia (2023) given to the DE is estimated by the utility of cash for a cash-like CBDC and set to zero for a deposit-like CBDC. This would entail that if the DE were a deposit like CBDC, the utility would be zero, which would make it impossible to do further analysis.

When deposits are lost, this means a decrease in liabilities on a bank's balance sheet. A bank's balance sheet should be realigned so that the asset and liability sides are equal again. Examples of scenarios for a bank's balance sheet are discussed in Adalid et al. (2022) and can be seen

in Figure 2.2. Here it can be seen that when deposits are lost on the liability side, a post on the asset size has to decrease or a post on the liability side has to increase. Choosing how to optimize the balance sheet of a bank is a difficult task in which many strategic considerations have to be taken into account. For this thesis, the goal is not to optimize a bank's balance sheet. Rather, the goal is to estimate the financial impact of the loss of deposits to the DE based on an existing balance sheet and not to optimize a bank's balance sheet. Therefore, certain simplifications are made.

Banks have multiple options to adjust their balance sheets when deposits are retracted. Banks could sell assets or attract new funding. According to the model of Klein (1971) deposits can be attracted when banks increase the interest rates offered to depositors. Funding for central banks can be attained by providing collateral (ECB, 2023a). However, these types of balance sheet adjustments are not directly translatable to a profit impact for banks since, for example, the selling price of assets for a lot of assets is not clear, the demand function of deposits is not known, and the interest rates for which banks can loan against collateral depend on the collateral are not publicly available. To estimate the impact of the introduction of the DE, a lot of assumptions need to be made. In this section, the primary assumptions are presented. It is essential to acknowledge that these are not the only assumptions; others will be discussed later in this thesis, and some are implicit. The main assumptions made are the following:

- It is assumed that banks do not change interest rates to attract additional deposits. This assumption is deemed realistic to a certain extent for the current market environment, where banks are not increasing interest rates while the deposit facility rate is substantially higher than the interest offered on savings. This can have multiple reasons; however, an important factor is that banks currently have enough liquidity to fulfil their demand for loans, and there is a lot of excess liquidity in the market (ECB, 2023). Furthermore, the model tries to estimate the impact on the whole Dutch banking sector, which means that Dutch banks are mostly competing over deposits with each other, meaning that the deposits will stay in the Dutch banking sector. Overall, this means that the assumption is made that the competition of Dutch banks over deposits does not impact our model. Also, it can be expected that Dutch consumers will not transfer their deposits abroad very quickly. The total share of household deposits that are transferred abroad as of October 2023 is only 1.6% of the total deposits, while it should be noted that this percentage is increasing (Rotteveel, 2023). It should be noted that this assumption might be stretched when liquidity becomes more scarce in the market (due to the introduction of the DE) and competition for deposits rises.
- Next to this assumption, to estimate the financial impact of the introduction of the DE, it will be assumed that banks first sell (decrease assets) their High-Quality Liquid Assets (HQLA) for which market quotes are publicly available, as much as strategically chosen funding requirements, the LCR and NSFR, allow (BIS, 2013) (BIS, 2014). If the LCR and NSFR fall below the specified minimum requirements, the banks then resort to attracting long-term unsecured wholesale funding (increase liabilities). The LCR and NSFR are regulatory standards established to ensure that banks maintain robust short-term and long-term liquidity positions (Section 3.2). In normal times, wholesale funding is more expensive than bank deposits (Meller and Soons, 2023) When considering the model of Klein (1971) this leads to a decrease in profits for banks due to lower spreads between loans and funding. This assumption is comparable to the assumption made in the papers of BIS (2021) however, for our analysis, the NSFR is also added as a constraint, and our LCR and NSFR can be set to a predetermined minimum.
- Compared to the paper of Meller and Soons (2023) it is chosen not to incorporate central

bank lending as an option because the amount banks can loan is dependent on the quality of the assets provided as collateral (ECB, 2023a) as well as the fact that currently the main refinancing operation rate is higher than the long-term wholesale funding rate.

- In this thesis, long-term unsecured wholesale funding is chosen because the rates for these types of funding are publicly available, making it possible to translate the increased wholesale funding into a cost increase. Furthermore, due to the fact that long-term wholesale funding (maturity 5 years) is used, the LCR and NSFR increase if this type of funding is acquired (Section B.1 and B.2).
- In our model, we maintain the assumption that costs linked to financial intermediation and the creation of financial products are constant. This approach stands in contrast to the Sealey and Lindley (1977) banking production model, where labour is considered a variable input that adjusts in quantity and cost according to the volume and complexity of banking services. Our model, however, is based on the premise that only High-Quality Liquid Assets (HQLA) are sold, and otherwise, wholesale funding is attracted. These operations typically require minimal operational intermediation, suggesting that the overall operational workload and processes within banks would remain unchanged.
- Due to a lack of data, this thesis does not model how the whole banking sector in Europe will react, due to which complex interdependencies between the availability of interbank funding and the introduction of the DE will be out of scope. With our preliminary findings, this is considered an assumption that will not impact the results much, as it looks like banks with their current balance sheets and under the current circulating holding limit will be able to catch deposit outflows with their cash reserves. This assumption, however, gets more stressed when liquidity becomes scarce in the market, and a higher holding limit could lead to multiple banks ensuring liquidity stress while at the same time drying up the wholesale market (Meller and Soons, 2023). According to Meller and Soons (2023), under a holding limit of €3000 or €4000, deposit outflows would not negatively affect the liquidity of the Eurosystem even under a bank run scenario.
- For this thesis, it is assumed that the DE is a substitute for balances on payment accounts, savings accounts, and cash. These are chosen as they are the most prevalent due to simplicity; other types of accounts are left out of the scope.
- Currently, it looks like there will be a separate online and offline holding limit together constrained by one total holding limit (ECB, 2023a). For this model, only the total holding limit is considered, and the online and offline wallets are considered as one wallet with this holding limit.
- Furthermore, the result of the financial introduction of the DE will be determined on the balance sheets of the four biggest banks in the Netherlands (Rabobank, ING, ABN AMRO, Volksbank). This is deemed a realistic assumption as the total market share of the four big banks in household deposits under management is 92% (DNB, 2023). Furthermore, other banks which have the other 8% are mostly banks like Van Lanschot Kempen which mostly focus on asset management. Furthermore, it is also realistic to assume that most people have at least one account at one of these four banks, representing 100% of the Dutch banking clients. To model the results of the impact of the DE, their balance sheets are aggregated, and they will be treated as one bank. The model will determine the impact of the introduction of the DE on this aggregated balance sheet and their combined NSFR and LCR.
- To maintain simplicity in the analysis, the model assumes that long-term wholesale funding rates, non-interest income, and non-funding-related expenses will remain constant. Additionally, this approach allows for a clearer focus on the direct effects of the changes

under consideration without the added complexity of fluctuating external financial variables.

In Figure 4.1 it can be seen how the balance sheet of a bank looks before and after the deposit loss due to the introduction of the DE. The dotted line in our model can be both the NSFR and the LCR constraint, depending on which is constrained first.

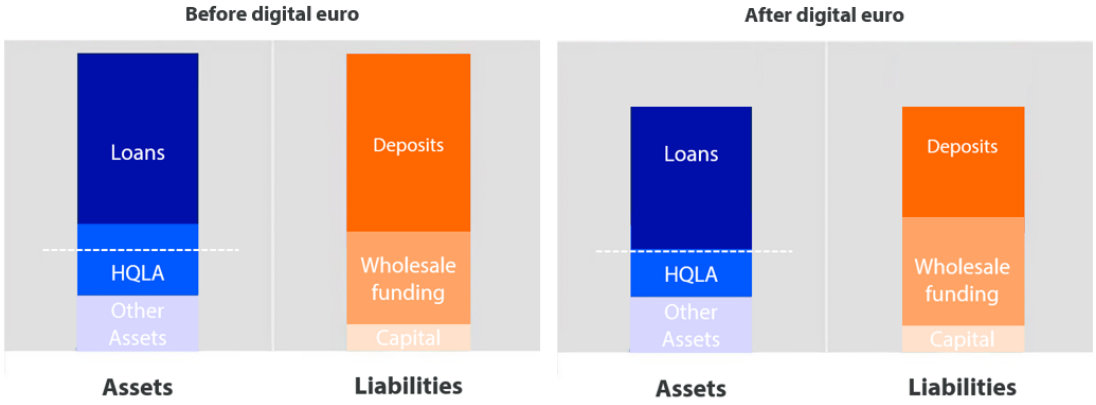

Figure 4.1: Illustration of aggregate banking system balance sheet before and after DE introduction, assuming replacement with long-term wholesale funding (adapted from BIS, 2021).

4.3 Input Parameters

To estimate the impact on the profitability of the Dutch banking sector due to the impact on financial intermediation, a model will be constructed. In this section, the input parameters for the model to determine how much deposits will flow out of the bank are determined. The input parameters are constructed for three subcategories: input parameters of the deposit outflows, input parameters of the bank, and input parameters of the market. The input parameters of the bank and the market will have a fixed value, while the input parameters for the deposit outflows will be altered for different scenarios in Chapter 5. In Figure 4.2 a graphical representation of the model can be seen in which the fixed input parameters are depicted in orange while the dynamic parameters are depicted in purple.

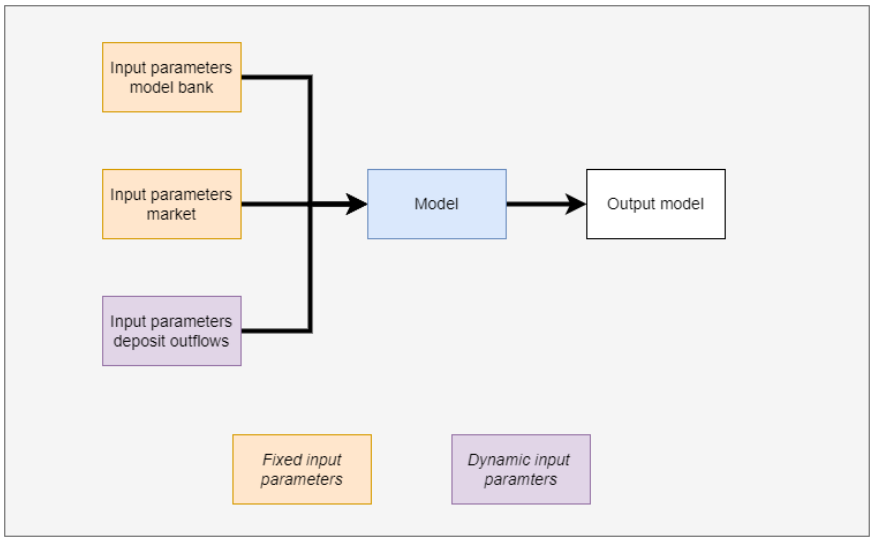

Figure 4.2: fixed and dynamic input parameters model.

Something that is done differently in this thesis compared to the literature provided by, for example, (BIS, 2021) and (Meller and Soons, 2023) is that the amount of outflow of deposits (from different sources) is changed based on different assumptions for different scenarios. Therefore, this thesis is also the first in the literature to make a distinction between types of deposits that might be substituted by the DE. Therefore, multiple new input parameters have to be defined.

4.3.1 Dynamic Input Parameters Deposit Outflows

In this section, the input parameters for the deposit outflows will be determined. Due to the different nature of the proposed rule set as published by the EC (Section 2.2.1) between individuals and businesses, first, a distinction needs to be made between private and business clients. Private clients are individuals who are clients at the bank for their own personal finances. Business clients are businesses that are clients at the bank and who use the bank for financial services for their business.

To determine the impact of the loss of deposits, it should be known to what extent DE accounts are adopted. This can be used to determine how many people and businesses will start using the DE account instead of their normal account. The parameter used to determine the share of the adoption of the DE for private clients will be indicated by α. As private clients with a DE account will most likely be subject to a holding limit, it is important to consider this in the model. The holding limit is useful to indicate how much deposit banks can lose in a worst-case scenario. The holding limit for private clients will be denoted by H_i.

Furthermore, it is important to consider which classical sources of money are being converted to DE. If private clients use the DE as a substitute for cash, it means that there is less room to convert bank deposits to DE (due to the holding limit). Hence, it becomes pivotal to ascertain the average amount of cash that gets converted into DE. The variable that represents the average amount of cash converted to the DE by private clients is denoted by D_c. Furthermore, a distinction is made between deposits converted from savings (D_s) and payment (D_p) accounts for private clients. This distinction is important due to the difference in funding costs for banks between these deposits. Balances converted from payment accounts are generally more expensive to lose than deposits from savings accounts, as there is no interest paid on the balances in payment accounts. Therefore, for the model, it is also important to determine the funding cost of these different types of balances converted to the DE.

According to a publication done by the ECB on October 18, 2023, businesses are not allowed to have a balance on their DE account (ECB, 2023a). Therefore, it is highly unlikely that businesses will be able to hold a balance in their DE account. However, in this model, the possibility is still added to be able to consider what the potential impact would be. This means it is important to consider how many businesses will use a DE account to receive payments. Therefore, an adoption parameter for businesses is defined as β. The holding for businesses will be denoted by H_b. Given that businesses are likely to receive frequent payments into their DE accounts, it's assumed they will only withdraw amounts that exceed their holding limit. This implies that businesses will only move funds beyond this set threshold. Furthermore, it is assumed that the money that is now on the DE account of the business would have otherwise been on their payment account, as businesses would normally receive payments on their payment account. In Table 4.1 the dynamic parameters are summarized, and they are given a value for different scenarios in Chapter 5.

Parameter	Description
α	Share of adoption DE accounts Private clients in %
β	Share of adoption DE accounts Business clients in %
H_i	Holding limit private clients
D_c	Average balance of cash converted to DE account private clients
D_s	Average balance from savings accounts converted to DE account private client
D_p	Average balance from payments account converted to DE account private clients
H_b	Holding limit business clients

Table 4.1: Dynamc input parameters deposit outflows

4.3.2 Fixed Input Parameters Model Bank

To determine the impact on the financial intermediation of the bank, a simplified model of a bank is made, also requiring certain inputs. While the model of Sealey and Lindley (1977) requires, for example, labour and technology as inputs, this model will assume that these inputs will stay the same and that the only input that is changed is the deposits, as mentioned in the section above. To come to the number of deposits a bank will lose, first the total number of clients of the four banks should be used as input for the model; this will be denoted by C. Furthermore, businesses that accept digital payment services are likely to be obliged to accept the DE, as mentioned in 2.2.1. Therefore, it is also important to consider the number of business clients for the four banks, which will be denoted by B.

The cost banks pay on funding from payment accounts will be expressed by F_p, and the cost of funding from savings accounts will be expressed by F_s. To determine the cost of funding for business payment accounts for banks, the variable F_B is introduced.

To determine how banks will replace the funding that is lost, a few more input parameters have to be determined. In Section 3.2.1 and Section 3.2.2, the NSFR and LCR are introduced. When a bank rebalances its balance sheet, these requirements should be taken into account; therefore, in this model, the initial LCR (LCR_i) and the initial NSFR ($NSFR_i$), as well as the minimum LCR (LCR_{min}) and minimum NSFR ($NSFR_{min}$), will be inputs of the model.

A bank has certain reserves on its balance sheet to satisfy these requirements. For example, a bank has HQLAs on its balance to satisfy the minimum liquidity coverage ratio. If a bank loses funding on the liability side of the balance, to restore this balance, a bank could reduce its HQLA assets as much as the LCR allows. In order to consider this option, the amount of $HQLA$ of a bank will be put in the model, as well as the net cash outflow during a 30-day stress period N_{lcr}. The HQLAs that are put in the model are unencumbered HQLAs, which are available for LCR calculations according to ECB regulations. Furthermore, because of the deposit outflow from the introduction of the DE, the net cash outflows get lower. The net cash flows are calculated with the help of a stress factor, which is multiplied by the deposits. In order to take this into account, this stress factor, which according to the BIS should have a value between 5% and 25% (BIS, 2021), should also be put in the model(S_{lcr}). For the NSFR the required stable funding (R_{nsfr}) should be put into the model, and from this and the initial NSFR, the available stable funding can be deducted.

A summary of these input parameters with the fixed values for this model can be found in Table 4.2. In order to come to these values, certain assumptions are made. It is important to note that clients can have multiple payment accounts at different banks; however, clients with a DE account are subject to one holding limit despite their number of DE accounts. This means that for our analysis, the number of clients for each bank can't just be added together and multiplied by the holding limit, as there might be duplicate individuals. Therefore, the assumption is made

that all people in the Netherlands above the age of 15 have a payment and savings account at a Dutch bank. This same assumption is extrapolated to business clients; it is assumed that all businesses in the Netherlands have a bank account at a Dutch bank. It should be noted that this means that this model estimates the impact of the introduction of the DE in the Netherlands and does not take into account the deposit migration out of other European regions.

Furthermore, the funding costs for different types of accounts are determined for the end of December 2022. This is done to make sure that these rates are in compliance with the Pillar 3 reports analyzed for the four big Dutch banks. Out of which the funding positions of the individual banks are taken, which are aggregated to model the Dutch banking sector.

As can be seen in Appendix B.2, BIS makes a distinction between stable and unstable deposits and gives them both a different ASF factor and stress factor to calculate the ASF for the NSFR and the net cash outflows for the LCR. Stable deposits are, according to BIS (2013), deposits that are fully insured by an effective deposit insurance scheme or by a public guarantee that provides equivalent protection. It is assumed that the deposits that will leave the bank in this model, for the most part, fall under the deposit insurance scheme and therefore are stable. This leads to a stress factor of 0.10, which belongs to stable deposits.

The funding costs are taken from the websites of the four big banks, and the most prevalent percentage is chosen for December 2022. Furthermore, liquidity parameters are extracted from the pillar 3 reports of the four big banks. In Appendix C an overview of how these parameters are built up per bank can be found. In Table 4.3 the minimum reserve requirements for this model can be found. For this model, the regulatory reserve requirements are used as determined by BIS (2013).

Parameter	Description	Value	Source
C	Total Private clients Dutch banking sector	14,897,000	All people in the Netherlands older than 15 years (CBS, 2023b)
B	Total Business clients Dutch banking sector	2,241,350	All businesses in the Netherlands (CBS, 2023a)
F_p	Funding cost payment accounts	0 %	Interest rates on payment accounts (ING (2022) (Rabobank (2022b), Volksbank (2023) ABN AMRO (2023))
F_s	Funding cost savings account	0.25 %	Interest rates on savings accounts (ABN AMRO (2023) Rabobank (2022b), ING (2022) Volksbank (2023) ,)
F_b	Funding costs payment accounts businesses'	0 %	Interest rates on payments accounts of businesses' (ABN AMRO (2023) Rabobank (2022b), ING (2022) Volksbank (2023))
$HQLA$	Amount of high quality assets	476,041,000,000	Aggregated HQLA four big banks (Pillar 3 reports ABN AMRO (2023), ING (2022), Volksbank (2023), Rabobank (2022b))
LCR_i	Initial LCR	1.52	Aggregated min LCR four big banks (Pillar 3 reports ABN AMRO (2023), ING (2022), Volksbank (2023), Rabobank (2022b))
$NSFR_i$	Initial NSFR	1.34	Aggregated min NSFR four big banks (Pillar 3 reports ABN AMRO (2023), ING (2022), Volksbank (2023), Rabobank (2022b))
S_{lcr}	Stress factor lost deposits LCR	0.05	Stress factor of stable retail and wholesale deposits (BIS (2013) and Figure B.2)
N_{lcr}	Net cash outflow 30-day stress period LCR	313,705,000,000	Aggregated Net Cash outflows four big banks (Pillar 3 reports ABN AMRO (2023), ING (2022), Volksbank (2023), Rabobank (2022b))
R_{nsfr}	Required stable funding NSFR	1,070,844,000,000	Aggregated RSF four big banks (Pillar 3 reports ABN AMRO (2023), ING (2022), Volksbank (2023), Rabobank (2022b))

Table 4.2: Values input parameters bank model

Parameter	Description	Value	Source
ASF_f	ASF factor	0.95	ASF factor of stable retail and wholesale deposits (BIS (2014) and Figure B.4)
LCR	Minimal LCR	1.00	Regulatory minimum as determined by BIS (2013)
NSFR	Minimal NSFR	1.00	Regulatory minimum as determined by BIS (2014)

Table 4.3: Continued: Values input parameters bank model

4.3.3 Fixed Input Parameters Market

In order to determine the cost of losing HQLAs and attracting long-term wholesale funding, some market variables have to be taken into account. For this model, the interest rate banks receive on their HQLAs at the ECB, which is the deposit facility rate (I_d) should be considered, as well as the interest rate that has to be paid on the long-term wholesale funding (I_w) for which a maturity of five year is chosen due to the fact that this maturity means a zero stress outflow factor in the LCR and no additional funding requirements in the NSFR in the coming years.

In Table 4.4 the input values for the market rate can be seen for December 31, 2022. For the long-term wholesale funding rate, the 5-year Euribor swap rate is chosen, as the Euribor swap rate is a widely recognized and used benchmark in the financial markets, providing a standard reference for various financial instruments. Furthermore, this choice is in accordance with the choice of BIS (2021) when analyzing a similar situation while keeping the LCR constant. For this analysis, the liquidity spread that may be involved when larger transactions are conducted is neglected. Furthermore, the deposit facility rate of the ECB is filled in for the predetermined date. Furthermore, the deposit facility rate is extracted from the website of the ECB (2023c).

Parameter	Description	Value	Source
I_w	Five year wholesale funding rate	2.935%	5 year EURIBOR swap rate 31/12/2022 (Investing.com, 2023)
I_d	Deposit facility rate	2.000%	Deposit rate at 31/12/2022 (ECB, 2023c)

Table 4.4: Values input parameters market

4.4 Model

Now that the parameters have been defined, they will be used to construct a model to estimate the financial impact of the deposit outflow. In Figure 4.3 a summary of all the different input parameters can be seen. In this section, there will be elaborated on how these input variables can be used to come to the output variables which also can be seen in Figure 4.3.

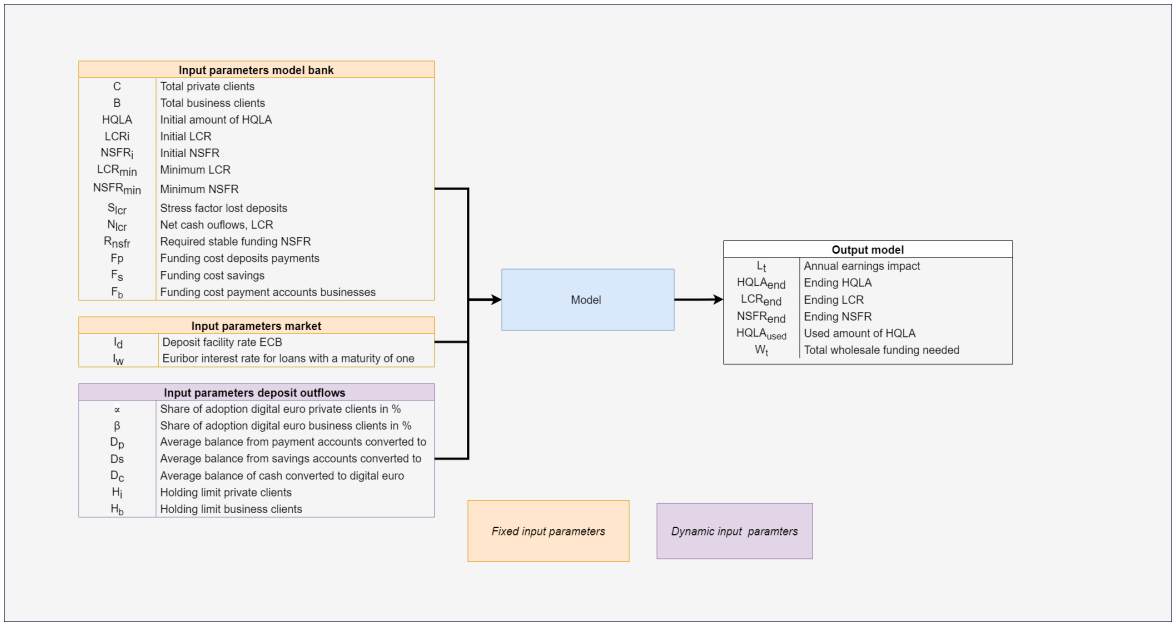

Figure 4.3: Illustration of the models and input parameters.

In the next section, a series of equations are mentioned, each being developed by the author of this thesis. These equations are based on the assumptions and literature studies mentioned in Section 4.2. It is important to note that the equations and formulations presented in this section are the result of the author's independent intellectual effort. The formulas presented in the section below are presented as entities.

To start, the input parameters of the deposit outflows are used in order to find the potential outflow per person. To do this the following equation is constructed which takes the minimum of the converted balances and the holding limit:

$$IP = min(D_p + D_s + D_c, H_i) \tag{4.1}$$

Where:

$$\begin{aligned} IP &= \text{Private client potential flow to DE} \\ D_p &= \text{Average balance from payments account converted to DE account} \\ D_s &= \text{Average balance from savings account converted to DE account} \\ D_c &= \text{Average balance from cash converted to DE account} \\ H_i &= \text{Holding limit private clients} \end{aligned}$$

This equation ensures that the private client outflow doesn't exceed the predefined holding limit. If a client wishes to convert an amount exceeding this limit, the conversion is capped at the holding limit. In the model, it is assumed that the distribution of this limited amount across various sections (like payment, savings, and cash) retains the same proportion as if the entire desired amount were being converted. To make sure this is the case, the following equations are applied:

$$OP = \frac{D_p}{D_p + D_s + D_c} * \text{IP} \tag{4.2}$$

$$OS = \frac{D_s}{D_p + D_s + D_c} * \text{IP} \tag{4.3}$$

$$OC = \frac{D_C}{D_p + D_s + D_c} * \text{IP} \tag{4.4}$$

Where:

OP = Outflow payment account
IP = Private client potential flow to DE
D_p = Average balance from payments account converted to DE account
D_s = Average balance from savings account converted to DE account
D_c = Average balance from cash converted to DE account
OS = Outflow savings account
OC = Cash converted to DE

To determine the overall potential outflow and the specific outflows from each money type, the Private client outflow should be scaled by the total number of bank clients and the rate of adoption. Leading to the following equations:

$$TP_i = (OC + OS + OP) * \alpha * C \tag{4.5}$$

$$OB_p = (OS + OP) * \alpha * C \tag{4.6}$$

Where:

TP_i = Total potential outflow to DE of private clients
OP = Outflow payment account
OS = Outflow savings account
OC = Cash converted to DE
α = Share of adoption DE accounts in
C = Total private clients Rabobank, Volksbank, ING, ABN AMRO
OB_p = Outflow of bank deposits due to private clients

The private client transaction and savings account outflows have been established. Presently, it's highly unlikely that businesses can hold a balance in their DE account. Nonetheless, in our model, the possibility that businesses can hold a balance in their DE account will be considered. Given that businesses are likely to receive frequent payments into their DE accounts, it's assumed they will only withdraw amounts that exceed their holding limit. This implies that businesses will only move funds beyond this set threshold. To model the outflow that can be accounted for by businesses, the following equations are constructed:

$$OB_b = H_b * \beta * B \tag{4.7}$$

$$OB_a = OB_b + OB_p \tag{4.8}$$

Where:

OB_b = Outflow of bank deposits due to businesses
H_b = Holding limit for businesses
β = Adoption rate business
B = total business clients Dutch banking sector
OB_a = Total outflow of bank deposits out of bank
OB_p = Total outflow of bank deposits out of bank due to private clients

Once the total bank outflow has been determined, it should be discovered how a bank could replace these deposits while being subject to the liquidity constraints imposed by the NSFR and LCR. As mentioned in Section 4.3, in this model, it will be assumed that banks first reduce their HQLAs on the asset side of the balance to the extent that their minimum LCR will allow. To determine the HQLAs necessary to meet the minimum LCR, considering the reduction in net cash outflows due to the decrease in deposit funding, the following formula can be used:

$$HQLA_{req} = N_{lcr} - (S_{lcr} * OB_a) * LCR_{min} \tag{4.9}$$

Where:

$HQLA_{req}$ = HQLA required for meeting the minimum LCR
N_{lcr} = Net cash outflow 30 day stress period LCR
S_{lcr} = Stress factor deposits LCR (see Appendix B.1)
OB_a = Total outflow of bank deposits
LCR_{min} = Minimum LCR requirement

From here, it is a straightforward step to determine how many HQLAs can be used to cover the deposit outflows. This is done by subtracting the required HQLA from the available HQLA (Equation 4.10). After this step, we can derive the HQLA used to catch up the deposit outflow, which is the minimum of the HQLA a bank has available, the total outflow out of the bank, and the HQLA available for catching up deposit outflows. This is depicted in Equation 4.11.

$$HQLA_{max} = HQLA - HQLA_{req} \tag{4.10}$$

$$HQLA_{used} = Min(HQLA, HQLA_{max}, OB_a) \tag{4.11}$$

Where:

$HQLA_{used}$ = HQLA used to account for deposit outflows
$HQLA$ = Bank stock of HQLA
$HQLA_{max}$ = HQLA available for catching up deposit outflow
OB_a = Total outflow of bank deposits

After this step, it should be determined if all deposit outflows were accounted for by reducing the number of HQLAs or if additional wholesale funding should be attained. The amount of

wholesale funding will be called wholesale funding LCR, as it could also be possible that later in the model, even more, wholesale funding should be attracted to make sure the NSFR satisfies the predetermined constraints.

$$W_{lcr} = OB_a - HQLA_{used} \tag{4.12}$$

Where:

$$\begin{aligned} W_{lcr} &= \text{Wholesale funding required LCR} \\ OB_a &= \text{Total outflow of bank deposits} \\ HQLA_{used} &= \text{HQLA used to account for deposit outflows} \end{aligned}$$

After determining how much wholesale funding is required for the LCR, the NSFR should also be taken into account. First, due to the outflow of funding, the available stable funding decreases. As mentioned before, not all funding types are weighed equally in the ASF. Therefore, there is an ASF factor to multiply with the different types of funding. Taking this factor into account, the following equation is obtained:

$$ASF_{new} = ASF - ASF_f * OB_a \tag{4.13}$$

Where:

$$\begin{aligned} ASF_{new} &= \text{ASF after deposit outflow} \\ ASF &= \text{ASF before deposit outflow} \\ ASF &= \text{ASF factor} \\ OB_a &= \text{Total outflow of bank deposits} \end{aligned}$$

After having calculated the new ASF it should be checked if the NSFR still satisfies the minimum put in the model. The wholesale funding attained for the LCR is added to the ASF and if this is lower than the stable funding required to meet the minimum, additional wholesale funding is attracted. Because for long-term wholesale funding, no extra RSF is needed (Appendix B.2) this stays constant throughout the model. This is modeled in the following equation:

$$W_{nsfr} = \begin{cases} \text{NSFR}_{\min} * R_{nsfr} - (ASF_{new} + W_{lcr}) & \text{if } \frac{ASF_{new}+W_{LCR}}{R_{nsfr}} < \text{NSFR}_{\min} \\ 0 & \text{otherwise} \end{cases} \tag{4.14}$$

Where:

$$\begin{aligned} W_{nsfr} &= \text{Wholesale funding needed to satisfy the NSFR} \\ NSFR_{min} &= \text{Minimum NSFR} \\ R_{nsfr} &= \text{Required stable funding NSFR} \\ ASF_{new} &= \text{ASF after deposit outflow} \\ W_{lcr} &= \text{Wholesale funding required LCR} \end{aligned}$$

To attain the total amount of wholesale funding needed the amount of wholesale funding needed for the NSFR and LCR should be added. This leads to the following equation:

$$W_t = W_{nsfr} + W_{lcr} \tag{4.15}$$

Where:

$$W_t = \text{Total wholesale funding needed}$$
$$W_{nsfr} = \text{Wholesale funding needed to satisfy the NSFR}$$
$$W_{lcr} = \text{Wholesale funding required LCR}$$

Now that the total wholesale funding needed and the earnings impact of HQLA have been determined, this can be translated to an annual earnings impat. First, the earnings impact due to reductions in HQLA is determined. It is assumed that all HQLAs that are reduced are cash reserves at the central bank which are by far the biggest part of the HQLAs for all four Dutch banks considered (ABN AMRO, 2023)(ING, 2022)(Volksbank, 2023)(Rabobank, 2022b). Therefore, the earnings impact is equal to the deposits times the deposit facility rate (Equation 4.16). Furthermore, the cost of the wholesale funding is also lost as income (Equation 4.17). Something that also should be taken into account is that the cost of funding for the lost deposits is saved (Equation 4.18). The equations can be combined to determine the annual earnings impact for the bank due to the introduction of the DE (Equation 4.19). This leads to the following equations:

$$L_{hqla} = (HQLA_{used} - W_t) * I_d \tag{4.16}$$

$$L_w = W_t * I_w \tag{4.17}$$

$$S_i = OB_b * F_b + OP * F_p + OS * F_s \tag{4.18}$$

$$L_t = L_{hqla} + Lw - S_i \tag{4.19}$$

Where:

$$L_{hqla} = \text{Earnings impact due to loss of HQLA}$$
$$HQLA_{used} = \text{HQLA used to account for deposit outflows}$$
$$I_d = \text{Deposit facility rate}$$
$$L_w = \text{Earnings impact due to wholesale funding}$$
$$W_t = \text{Total wholesale funding needed}$$
$$I_w = \text{Five year wholesale funding rate}$$
$$I_t = \text{Interest rate on wholesale funding}$$
$$S_i = \text{Savings on funding cost}$$
$$OB_b = \text{Outflow of bank deposits due to businesses}$$
$$F_b = \text{Funding cost businesses}$$
$$OP = \text{Outflow payment accounts}$$
$$F_p = \text{Funding cost payment accounts}$$
$$OS = \text{Outflow saving accounts}$$
$$F_s = \text{Funding cost saving accounts}$$
$$L_t = \text{Total annual earnings impact}$$

After having determined the annual earnings impact due to the introduction of the DE L_t for certain input parameters, the output of the model, the ending HQLA, NSFR, LCR the amount of HLQA and wholesale funding used, will also be given by the model, as shown in Figure 4.4.

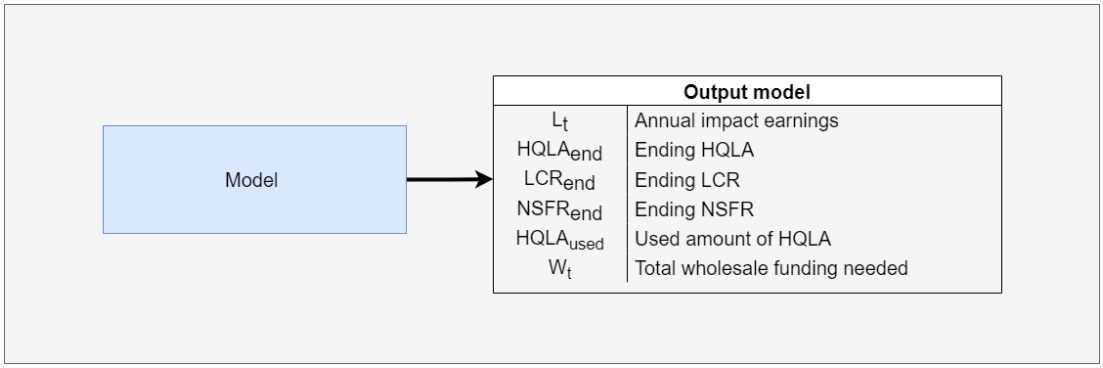

Figure 4.4: Output of the constructed model.

4.5 Conclusion and Discussion

The goal of this chapter was to answer the following sub-research question:

- *How can a model be built in which different scenarios can be run to test the impact of the introduction of the digital euro on financial intermediation performed by Dutch banks?*

To do this, in this chapter, a model is built to determine the impact on financial intermediation of the Dutch banking sector due to the introduction of the DE. Scenario analysis is chosen for this model to effectively estimate the impact of the DE's introduction on financial intermediation. This approach allows for considering various potential outcomes and their implications for the banking sector, given the uncertainties and complexities involved. To do this, certain simplifications are made to estimate this impact. The model's assumptions, including a fixed approach to bank operational inputs and a focus on HQLA management, simplify the complex reality of banking operations. This simplification, while practical for the model's scope, may overlook the nuanced dynamics of real-world banking responses to digital currency adoption. Furthermore, it is important to note that the assumptions underlying this model are bound to the liquidity environment of the banking system. The assumptions for this model are based on the year of writing this thesis. If liquidity in the banking sector is stretched, the question is whether there is wholesale funding available to fill up the gap created by the outflow of deposits.

Different fixed input parameters have been found with their own underlying assumptions, trying to represent the Dutch banking sector as one bank as well as some market parameters. With the help of these parameters, a model is constructed that tries to capture the relationship between different design parameters of the DE, the funding requirements, bank outflow, and the annual earnings impact.

Overall, it can be concluded that the sub-research question in this chapter is answered. The model constructed, while being dependent on assumptions, enables the assessment of the impact of the introduction of the DE based on different scenarios in the next chapter.

Chapter 5

Scenarios and Results

Contents

The goal of this chapter is to answer the following sub-research questions:

- *Which scenarios are important to consider in order to determine the impact on financial intermediation for the introduction of the digital euro?*
- *What is the impact of the developed scenarios on the Dutch banking sector?*
- *What additional insights can be extracted from the developed model?*

To answer these questions, in this section, the impact of introducing the DE on financial intermediation will be determined based on four scenarios. In these four scenarios, the input parameters for potential deposit outflows will be altered. First, the different scenarios will be briefly introduced in Section 5.1 and it will be elaborated on why these scenarios were chosen. After this introduction, the different scenarios are discussed, and the results of these scenarios are presented in Sections 5.2, 5.3, 5.4 and 5.5. Our model will be used to obtain additional insights by exploring the sensitivity of the model to the holding limit and the interest rate

environment in Section 5.6. After which, the results are synthesized in Section 5.7 and the chapter is concluded in Section 5.8 by the conclusion and discussion.

5.1 Introduction Scenarios

In this section, there will be elaborated on the different scenarios that will be constructed regarding the DE and why these scenarios were chosen.

The selection of these four scenarios for the DE is based on a combination of different sources. First, these scenarios are based on interviews conducted by the author with professionals in the banking sector. Furthermore, these scenarios are based on a study performed by Bijlsma et al. (2021). This study investigates the potential adoption and utilization of the DE in the Netherlands. An important conclusion from this research which will be used for this chapter was that 49% of Dutch people are willing to adopt the digital euro. Additionally, the scenarios are informed by current proposed regulations, such as those detailed in (European Commission, 2023), as well as publications by the European Central Bank (ECB), for example, (Meller and Soons, 2023). These scenarios incorporate the author's interpretations of the sources mentioned above. The primary goal of outlining these scenarios is to span the entire spectrum of possible impacts, ranging from minimal to worst-case scenarios based on the proposed holding limit of €3000. Consequently, the scenarios presented are chosen to represent an escalating severity of impact on the Dutch banking sector, each progressively more significant in its potential effects.

The following four scenarios are constructed:

1. **DE as a Buffer**
   In this scenario, people would put a certain amount on their DE account in order to diversify their assets. This means that people would not fund and defund the account often. With the waterfall functionalities as proposed by the European Commission (2023) this means that individuals would still be able to pay with the DE account despite not altering the balance on their account. This scenario has been selected based on insights from a study conducted by Bijlsma et al. (2021), which explores the likelihood of Dutch individuals using their Digital Euro accounts as a financial buffer. According to this research, people in the Netherlands are expected to maintain a specific amount in their digital euro accounts for added financial security.

2. **DE as Means of Payment**
   In this scenario, the DE will be used as a means of payment. However, compared to the first scenario, people would now fund their DE account monthly with the amount they need for their variable expenses. This scenario has been formulated drawing on insights gathered from interviews with banking sector professionals, combined with the author's own analysis and reflection on the subject.

3. **Full Utilization DE Private Individuals**
   In this scenario, the DE will be used by private individuals as much as the holding limit allows. This scenario will be realistic when people lose trust in banks and therefore want to move as much money away as possible from these institutions. This scenario is designed to evaluate the most probable worst-case impact, taking into account the current regulations as proposed by the European Commission (2023), and is further informed by insights from interviews conducted within the banking sector.

4. **Full Utilization DE Private Individuals and Businesses**
   In this scenario, businesses will also be able to hold a balance on their DE account. However, in current publications done by the ECB and the EC, it looks like businesses cannot hold a balance in their DE account. This fourth scenario is still added to consider what would

happen if this were possible. Therefore, this scenario is developed to test the absolute worst-case scenario based on the proposed holding limit.

5.2 Scenario 1: Digital Euro as a Buffer

This is the first of four scenarios, to explore the implications of introducing the DE on financial intermediation. In the first scenario, a scenario will be considered in which people put some money in their DE account as a sort of buffer. People might do this to diversify their assets. A study conducted by Bijlsma et al. (2021), investigating the willingness of Dutch individuals to deposit funds in a CBDC account, provides key insights to inform this analysis. Furthermore, it has to be considered if deposits are transferred from cash, a payment account, or a savings account.

This scenario is based on the following assumptions:

- Adopters will put an amount on their DE account and not necessarily spend this amount.
- This amount is based on a study performed by Bijlsma et al. (2021) where it was studied how many euros Dutch people would put into a DE account. The result of this study is that, on average, Dutch people want to put between €260 and €700 into their DE account. It is assumed that people who adopt the DE will put the average of these values, thus €480, on their account.
- It is assumed that this money is converted from the payment accounts of private clients and that consumers will only convert their savings to the DE under a bank-run scenario. This assumption is in accordance with the statement of Panetta (2022) in which he notes that the DE must be seen as a means of payment and not as a store of value. Therefore, the DE pays no interest, making it no substitute for a savings account. Furthermore, according to Bijlsma et al. (2021), €480 is equivalent to 17.5% of the average balance of Dutch citizens on their payment account.
- In order to pay with the DE, people can use the waterfall functionalities of the DE infrastructure. Meaning that the money is sent directly from a bank account through the DE infrastructure (Section 2.2.1).
- According to the SPACE research performed by the ECB (2022a), Dutch people have an average amount of €46,- in their cash wallet at the start of the day. For this scenario, the assumption of the Joint Research Center of the European Commission's science and knowledge service is used which states that 50% of cash will be converted to the DE. This leads to an amount of €23 being converted to DE. This means that of the €480, an amount of €23 will be converted from cash, and an amount of €457 will be converted from payment accounts.
- For the holding limit for individuals, the holding limit of €3000 mentioned by sources within the ECB (Section 2.2.1) will be used. However, it is important to note that this holding limit is not reached, meaning that it does not make a difference to the results of this scenario.
- For this scenario, it is assumed that businesses cannot hold DE on their accounts; this is highly likely due to the report published by the ECB (2023a). Therefore, the holding limit is zero, and the adoption of the DE by businesses is not relevant.

To summarize, the overall values for this scenario are shown in Table 5.1.

Parameter	Description	Value (euros)	Source
D_p	Average balance from payment accounts converted to DE	457.00	Research into consumer CBDC adoption (Bijlsma et al., 2021)
D_s	Average balance from savings accounts converted to DE	0	
D_c	Average balance of cash converted to DE	23.00	SPACE report (ECB, 2022a) and JRC report(Giudici and Girolamo, 2023)
H_i	Holding limit individuals	3000.00	Meller and Soons (2023)
H_b	Holding limit businesses	0	
β	Share of adoption DE accounts businesses in % businesses	-	

Table 5.1: Input parameters scenario 1.

5.2.1 Results Scenario 1: Digital Euro as a Buffer

In this section, the results of Scenario 1 are discussed, which have been produced based on the input parameters detailed in Table 5.1 and the model outlined in Section 4.4. It should be acknowledged, for the results of this scenario as well as for the results of scenarios that follow, that the model developed in Chapter 4.5, is underpinned by a series of both explicit and implicit assumptions. As such, the results presented in this scenario as well as in other scenarios ought to be interpreted with a degree of caution. They are not to be seen as precise, definitive figures but rather as indicative of the scale or magnitude of the impact. This is important to keep in mind in order to accurately contextualize and assess the outcomes of this analysis.

As mentioned before, Bijlsma et al. (2021) researched in 2021 how many Dutch people were willing to adopt the DE. The result of this study was that 49% of Dutch respondents were willing to adopt the DE. This adoption rate is shown in the tables below, as well as the 10 and 100 percent adoption rates.

The results of this scenario can be seen in Table 5.2. In this results section, the results will be compared to the statistics of the modelled bank, which can be found in Appendix C.

For the 10% adoption point, it can be seen that for this scenario, the bank outflow will be 0.68 billion euros, which is equivalent to 0.05% of total deposits. Furthermore, the annual impact on bank earnings will be -13.61 million euros, which means a reduction of 0.16% of total bank earnings. While the LCR and NSFR do not change significantly and stay (when rounded) at the same level as before the implementation of this scenario.

For the 49% adoption point, it can be seen that for this scenario, the bank outflow will be 3.33 billion euros, which is equivalent to 0.25% of total deposits. Furthermore, the annual impact on bank earnings will be -66.72 million euros, which means a reduction of 0.78% of total bank earnings. The LCR drops one percentage point from 1.52 to 1.51, while the NSFR stays at the same level.

For the 100% adoption point, it can be seen that for this scenario, the bank outflow will be 6.81 billion euros, which is equivalent to 0.51% of total deposits. Furthermore, the annual impact on bank earnings will be -136.16 million euros, which means a reduction of 1.61% of total bank earnings. For the 100% adoption point, the LCR drops two percentage points from 1.52 to 1.50, while the NSFR stays at the same level.

For all adoption points in this scenario, no additional wholesale funding is needed to satisfy the liquidity ratios.

Graphs representing the different variables present in the tables against the adoption rate can be found in Appendix D.1.

Adoption	**Bank outflow (billion euros)**	**Annual impact earnings (million euros)**	**LCR**	**NSFR**	**Wholesale funding needed (billion euros)**
10%	0.68	-13.61	1.52	1.34	0
49% (study performed by Bijlsma et al. (2021))	3.33	-66.72	1.51	1.34	0
100% (full adoption)	6.80	-136.16	1.50	1.34	0

Table 5.2: Results scenario 1: DE as a buffer.

5.3 Scenario 2: Digital Euro as Means of Payment

The second scenario is based upon the vision of the ECB to use the DE not as a store of wealth but as a means of payment (Panetta, 2022). Compared to scenario 1, this scenario assumes that adopters will put the amount needed for their variable expenses on their DE account once a month. This amount is added in addition to the buffer already put on the DE account for diversification in Scenario 1. For the variable expenses, the data for POS and online payments of Betaal Vereniging Nederland is used (Betaal Vereniging Nederland, 2022).

This scenario is based on the following assumptions:

- In addition to the buffer mentioned in scenario 1, adopters will also put money to conduct variable expenses on their DE account.
- It is assumed that adopters fund their DE account from their payment account once a month and that their balance decreases linearly over the month.
- The average variable expenses are calculated by using the POS and online transaction (excluding cash) data of Betaal Vereniging Nederland for the year 2022. It is assumed that adopters put this amount on their DE account.
- It is assumed that adopters shift the average balance to their DE account, which they need to perform their variable expenses based on funding the account monthly and a linear decrease in their balance.
- In total, Dutch people conducted €255.2 billion in POS and online transactions in 2022. Which is, on average, €17,130 per person. Which is divided by 12 (months) and divided by 2 (linear decrease of balance) and therefore leads to an average balance of €713.79 per adopter (Betaal Vereniging Nederland, 2022).
- This amount is added to the €457, meaning that €1170.90 will be converted from payment accounts. Which is 43% of the average balance on payment accounts as researched by Bijlsma et al. (2021) making it reasonable that most Dutch people can convert this balance from their payment account to the DE.
- For cash, the same assumptions are used as in Scenario 1, meaning that an amount of €23 will be converted from cash.
- For the holding limit for individuals, the holding limit of €3000 mentioned by sources within the ECB (Section 2.2.1) will be used. However, it is important to note that in

this scenario, the holding limit is not reached, indicating that this parameter does not significantly impact the outcomes.

- For this scenario, it is again assumed that businesses cannot hold DEs on their accounts, as is highly likely due to the report published by the ECB (2023a). Therefore, the holding limit is zero, and the adoption of the DE by businesses is not relevant.

To summarize, the overall values for this scenario are shown in Table 5.3.

Parameter	**Description**	**Value (euros)**	**Source**
D_p	Average balance from payment accounts converted to DE	1,170.79	Research into consumer CBDC adoption (Bijlsma et al., 2021) plus variable expenses (Betaal Vereniging Nederland, 2022)
D_s	Average balance from savings accounts converted to DE	0	
D_c	Average balance of cash converted to DE	23.00	SPACE report (ECB, 2022a) and JRC report(Giudici and Girolamo, 2023)
H_i	Holding limit individuals	3,000.00	Meller and Soons (2023)
H_b	Holding limit businesses	0	
β	Share of adoption DE accounts businesses in % businesses	-	

Table 5.3: Input parameters scenario 2.

5.3.1 Results Scenario 2: Digital Euro as Means of Payment

The results, obtained with the model in Section 4.4 and the input parameters in Table 5.3, of this scenario can be seen in Table 5.4. In this results section, the results will be compared to the statistics of the modelled bank, which can be found in Appendix C.

For the 10% adoption point, it can be seen that for this scenario, the bank outflow will be 1.78 billion euros, which is equivalent to 0.13% of total deposits. Furthermore, the annual impact on bank earnings will be -34.89 million euros, which means a reduction of 0.41% of total bank earnings. The LCR drops one percentage point from 1.52 to 1.51, while the NSFR stays at the same level.

For the 49% adoption point, it can be seen that for this scenario, the bank outflow will be 8.55 billion euros, which is equivalent to 0.64% of total deposits. Furthermore, the annual impact on bank earnings will be -170.94 million euros, which means a reduction of 2.01% of total bank earnings. The LCR drops from 1.52 to 1.49, while the NSFR drops one percentage point to 1.33.

For the 100% adoption point, it can be seen that for this scenario, the bank outflow will be 17.44 billion euros, which is equivalent to 1.30% of total deposits. Furthermore, the annual impact on bank earnings will be -136.16 million euros, which means a reduction of 4.10% of total bank earnings. For the 100% adoption point, the LCR drops from 1.52 to 1.47, while the NSFR drops one percentage point to 1.33.

For all adoption points in this scenario, no additional wholesale funding is needed to satisfy the liquidity ratios.

Graphs representing the different variables present in the tables against the adoption rate can be found in Appendix D.2.

Adoption	**Bank outflow (billion euros)**	**Annual impact earnings (million euros)**	**LCR**	**NSFR**	**Wholesale funding needed (billion euros)**
10%	1.78	-34.89	1.51	1.34	0
49% (study performed by Bijlsma et al. (2021))	8.55	-170.94	1.49	1.33	0
100% (full adoption)	17.44	-348.86	1.47	1.33	0

Table 5.4: Results scenario 2: DE as a means of payment.

5.4 Scenario 3: Full Utilization Digital Euro Private Individuals

The third scenario is a scenario in which people lose trust in the financial system and want to use the DE to the fullest extent. They do this due to the fact that the DE is considered a safer option for money than cash, as it is insured directly by the government (ECB, 2023a). This means that people convert all their balances on a bank account to a DE account, and they do not convert cash due to the fact that cash is also considered a "safe" form of currency.

This scenario is based on the following assumptions:

- In addition to scenario 2, adopters will fill off the amounts already on their DE account with money from their savings account as much as the holding limit allows.
- In this scenario, there is no cash converted to the DE as this form of money is also considered "safe".
- This leads to the fact that €1170.79 will be converted from payment accounts, just like in scenario 2.
- This scenario is considered the worst-case scenario for private individuals. It should be noted that in real life, 20% of households have a bank credit of €2500 or less; however, there is no specific data on this (CBS, 2022). Therefore, for this scenario, it is assumed that every person can convert €3,000 to the DE to model the worst-case scenario.
- Furthermore, the amount converted from the savings accounts will be the holding limit minus the amount converted from the payment accounts. This leads to a value of €1,829.21 for a holding limit of €3,000.
- For the holding limit for individuals, the holding limit of €3,000 as mentioned by sources within the ECB (Section 2.2.1) will be used. For this scenario, the holding limit is an important parameter; in Section 5.6.1 there is elaborated on the role of the holding limit for the results of this scenario.
- For this scenario, it is again assumed that businesses cannot hold DEs on their accounts, as is highly likely due to the report published by the ECB (2023a). Therefore, the holding limit is zero, and the adoption of the DE by businesses is not relevant.

To summarize, the overall values for this scenario are shown in Table 5.5.

Parameter	Description	Value (Euro)	Source
D_p	Average balance from payment accounts converted to DE	1,170.79	Research into consumer CBDC adoption (Bijlsma et al., 2021) plus variable expenses (Betaal Vereniging Nederland, 2022)
D_s	Average balance from savings accounts converted to DE	1,829.21	Holding limit minus D_P
D_c	Average balance of cash converted to DE	0	
H_i	Holding limit individuals	3,000.00	Meller and Soons (2023)
H_b	Holding limit businesses	0	
β	Share of adoption DE accounts businesses in % businesses	-	

Table 5.5: Input parameters scenario 3.

5.4.1 Results Scenario 3: Full Utilization Digital Euro Private Individuals

The results, obtained with the model in Section 4.4 and the input parameters in Table 5.5, of this scenario can be seen in Table 5.6. In this results section, the results will be compared to the statistics of the modelled bank, which can be found in Appendix C.

For the 10% adoption point, it can be seen that for this scenario, the bank outflow will be 4.47 billion euros, which is equivalent to 0.33% of total deposits. Furthermore, the annual impact on bank earnings will be -82.57 million euros, which means a reduction of 0.97% of total bank earnings. The LCR drops one percentage point from 1.52 to 1.51, while the NSFR stays at the same level.

For the 49% adoption point, it can be seen that for this scenario, the bank outflow will be 21.90 billion euros, which is equivalent to 1.64% of total deposits. Furthermore, the annual impact on bank earnings will be -404.59 million euros, which means a reduction of 4.76% of total bank earnings. The LCR drops from 1.52 to 1.46, while the NSFR drops two percentage points to 1.32.

For the 100% adoption point, it can be seen that for this scenario, the bank outflow will be 44.69 billion euros, which is equivalent to 3.34% of total deposits. Furthermore, the annual impact on bank earnings will be -825.69 million euros, which means a reduction of 9.71% of total bank earnings. For the 100% adoption point, the LCR drops from 1.52 to 1.38, while the NSFR drops four percentage points to 1.30.

For all adoption points in this scenario, no additional wholesale funding is needed to satisfy the liquidity ratios.

Graphs representing the different variables present in the tables against the adoption rate can be found in Appendix D.3.

Something that is particularly important to consider for this Scenario is that not all people in the Netherlands have €3,000. According to CBS, 20% of households have bank credit of €2500 or less CBS (2022) on their bank accounts. This means that, in reality, the results for this scenario are less severe than anticipated in this scenario.

Adoption	Bank outflow (billion euros)	Annual impact earnings (million euros)	LCR	NSFR	Wholesale funding needed (billion euros)
10%	4.47	-82.57	1.51	1.34	0
49% (study performed by Bijlsma et al. (2021))	21.90	-404.59	1.46	1.32	0
100% (full adoption)	44.69	-825.69	1.38	1.30	0

Table 5.6: Results scenario 3: DE as a means of payment.

5.5 Scenario 4: Full Utilization Digital Euro Private Individuals and Businesses

This scenario is comparable to scenario three however, in this case, businesses can also hold DE in their account. Currently, it is expected that businesses can not hold a balance on their DE account as noted in the publication done ECB (2023a). However, considering that return pinning might be necessary in stores, and given the ongoing debate about this, this most extreme scenario is still included in our analysis.

This scenario is based on the following assumptions:

- The assumptions for this scenario are the same as for scenario three, however, now business can also hold DE.
- In order to determine the impact of businesses being able to hold DE it is important to consider how many businesses will adopt the DE. According to the regulation framework published by the European Commission (2023) businesses that accept digital payments are also obliged to accept DE payments. According to a study performed by Panteia (2020) in 2020 92% of businesses accepted digital payments in the Netherlands. Therefore, it is assumed that the adoption of the DE for businesses will be 92%.
- As mentioned before in Section 4.3, Due to the fact that businesses are likely to receive frequent payments into their DE accounts, it's assumed they will only withdraw amounts that exceed their holding limit. Furthermore, it is assumed that all this balance is converted from the payment accounts of businesses.
- It is assumed that a holding limit for businesses is the same as the holding limit for individual users.

To summarize, the overall values for this scenario are shown in Table 5.7.

Parameter	Description	Value (euros)	Source
D_p	Average balance from payment accounts converted to DE	1,170.79	Research into consumer CBDC adoption (Bijlsma et al., 2021) plus variable expenses (Betaal Vereniging Nederland, 2022)
D_s	Average balance from savings accounts converted to DE	1,829.21	Holding limit minus D_P
D_c	Average balance of cash converted to DE	0	
H_i	Holding limit individuals	3,000.00	Meller and Soons (2023)
H_b	Holding limit businesses	3,000.00	Meller and Soons (2023)
β	Share of adoption DE accounts businesses in % businesses	91.60%	Panteia (2020)

Table 5.7: Input parameters scenario 4.

5.5.1 Results Scenario 4: Full utilization Digital Euro Private Individuals and Businesses

The results, obtained with the model in Section 4.4 and the input parameters in Table 5.7, of this scenario can be seen in Table 5.8. In this results section, the results will be compared to the statistics of the modelled bank, which can be found in Appendix C.

For the 10% adoption point, it can be seen that for this scenario, the bank outflow will be 10.63 billion euros, which is equivalent to 0.80% of total deposits. Furthermore, the annual impact on bank earnings will be -205.75 million euros, which means a reduction of 2.42% of total bank earnings. The LCR drops one percentage point from 1.52 to 1.34, while the NSFR stays at the same level. The high initial impact is mainly due to the assumption that businesses immediately use the digital euro account up to the holding limit, regardless of the adoption of individual consumers.

For the 49% adoption point, it can be seen that for this scenario, the bank outflow will be 28.06 billion euros, which is equivalent to 2.10% of total deposits. Furthermore, the annual impact on bank earnings will be -527.77 million euros, which means a reduction of 6.21% of total bank earnings. The LCR drops from 1.52 to 1.43, while the NSFR drops four percentage points to 1.30.

For the 100% adoption point, it can be seen that for this scenario, the bank outflow will be 50.85 billion euros, which is equivalent to 3.80% of total deposits. Furthermore, the annual impact on bank earnings will be -948.88 million euros, which means a reduction of 11.16% of total bank earnings. For the 100% adoption point, the LCR drops from 1.52 to 1.37, while the NSFR drops four percentage points to 1.30.

For all adoption points in this scenario, no additional wholesale funding is needed to satisfy the liquidity ratios.

Graphs representing the different variables present in the tables against the adoption rate can be found in Appendix D.4.

For this scenario, just like in scenario three, it should also be taken into consideration that not all people in the Netherlands have €3,000. This means that also for this scenario, in reality, the

results are less severe than anticipated in this scenario.

Adoption	Bank outflow (billion euros)	Annual impact earnings (million euros)	LCR	NSFR	Wholesale funding needed (billion euros)
10%	10.63	-205.75	1.49	1.34	0
49% (study performed by Bijlsma et al. (2021))	28.06	-527.77	1.43	1.32	0
100% (full adoption)	50.85	-948.88	1.37	1.30	0

Table 5.8: Results scenario 4: Full utilization DE private individuals and businesses.

5.6 Additional Insights

In this section, additional insights will be gathered using our model. The sensitivity of scenario three to varying holding limits will be examined, along with an analysis of the maximum holding limit that banks' liquidity ratios can withstand in the worst-case scenario. Subsequently, the impact of differing interest rate environments on the results will also be assessed.

5.6.1 Sensitivity Analysis Holding Limit

This section will determine how the holding limit affects the potential outflow of deposits to DE accounts. As can be seen in Scenario 1 and 2, the holding limit is not reached, therefore a higher holding limit will not influence the results. However, for a "bank-run" scenario like scenario 3, the holding limit is useful to determine the maximal outflow of deposits to DE accounts. As it is currently unlikely that businesses can hold DEs (ECB, 2023a) this section will test the maximum outflow of scenario three for different holding limits. This means that it will be determined how a bank will be impacted for maximum adoption and maximum utilization up to the holding limit for different holding limits. It is assumed, just like in scenario 3, that all the extra money is coming from savings accounts. In table 5.9 the results of the sensitivity analysis can be found.

Holding limit Individuals	Bank outflow (billion euros)	Annual impact earnings (million euros)	LCR	NSFR	Wholesale funding Needed (billion euros)
2000	29.79	-564.99	1.43	1.31	0
3000	44.69	-825.69	1.38	1.30	0
4000	59.59	-1,086.39	1.34	1.29	0
5000	74.49	-1,347.09	1.30	1.27	0
6000	89.34	-1,607.78	1.25	1.26	0
11701	180.37	-3,200.13	1.00	1.19	0
15000	223.45	-4,421.06	1.00	1.19	49.95
20000	297.94	-6,386.16	1.00	1.19	120.71

Table 5.9: Sensitivity analysis holding limit

Table 5.9 shows the results of the sensitivity analysis. An important result is that the Dutch people can put 11,701 euros in their DE account before one of the liquidity ratios of the aggregated bank model is breached. The LCR is constrained first, after which wholesale funding is attracted to make sure the LCR stays above the regulatory minimum.

5.6.2 Sensitivity Analysis Interest Rates

The result of the impact on earnings is dependent on the interest rates, especially on the spread between the cost of funding, the deposit rates, and the wholesale funding rate. In the prior analysis, data from December 2022 was utilized, as it provided a consistent point for extracting uniform data. For this analysis, the data will still be used for December 2022; however, the interest rates are exchanged for the interest rates in December 2023 and the interest rates in December 2021. These two data points were chosen since these times represent different interest rate environments. The interest rates were negative in December 2021 and positive in December 2023. Thereby, it can be seen how the different interest rate environments impact the results. The results of the data points for 2021 and 2023 will be compared with the results of the annual impact on earnings for the year 2022. An overview of the annual impact on earnings for the year 2022 can be seen in Table 5.10.

Scenario	**Annual impact earnings 10% (million euros)**	**Annual impact earnings 49% (million euros)**	**Annual impact earnings 100% (million euros)**
1	-13.61	-66.72	-136.61
2	-34.59	-170.94	-348.86
3	-82.57	-404.59	-825.69
4	-205.75	-527.77	-948.88

Table 5.10: Output Sensitivity Analysis Results December 2022.

December 2021
In this section, the analysis will be done with the same input parameter as in Table 4.2 however, the interest rate parameters are now filled in according to the parameters as described in Table 5.11. This is done to understand the impact of different interest rate environments on the results.

Parameter	**Description**	**Value**	**Source**
F_p	Funding costs payment accounts	0.00%	Interest rates on payments accounts for Volksbank, ING, Rabobank, ABN AMRO at 12/31/2021
F_s	Funding costs savings accounts	0.00%	Interest rates on savings accounts for Volksbank, ING, Rabobank, ABN AMRO at 12/31/2021
F_b	Funding costs payment accounts businesses'	0.00%	Interest rates on payment accounts of businesses accounts for Volksbank, ING, Rabobank, ABN AMRO at 12/31/2021
I_w	Five year wholesale funding rate	0.011%	5 year EURIBOR swap rate 31/12/2021 (Investing.com, 2023)
I_d	Deposit facility rate	-0.50%	Deposit rate at 31/12/2021 ECB (2023c)

Table 5.11: Parameters sensitivity analysis interest rates December 2021.

In Table 5.11 the results of running the scenarios for the interest rate environment in December 2021 can be seen. Due to the negative deposit rates and the zero rates the banks paid to their clients, the modelled bank would actually gain profit due to the deposit outflows. It should be said that this negative rate environment is not representative of history as this was the first time interest rates went negative therefore, it is unknown if this will happen again in the future.

Scenario	**Annual impact earnings 10% (million euros)**	**Annual impact earnings 49% (million euros)**	**Annual impact earnings 100% (million euros)**
1	3.40	16.68	34.04
2	8.72	42.73	87.21
3	22.35	109.49	223.46
4	52.99	139.57	252.77

Table 5.12: Output Sensitivity Analysis Results December 2021.

Table 5.13 displays the differences (delta) in results across various scenarios and adoption rates between 2021 and 2022. These figures can be analyzed to understand the impact of changes in the interest rate environment. For example, in scenario 3, with a 100% adoption rate, the annual impact is €1,049.15 million higher in 2021 compared to 2022. Resulting, as mentioned before, in a positive impact.

Scenario	**Δ 2021 - 2022 annual impact earnings 10% (million euros)**	**Δ 2021 - 2022 annual impact earnings 49% (million euros)**	**Δ 2021 - 2022 annual impact earnings 100% (million euros)**
1	17.01	83.40	170.65
2	43.31	213.67	436.07
3	104.92	514.08	1,049.15
4	258.74	667.34	1201.65

Table 5.13: Delta Results December 2021 and December 2022.

December 2023
In this section, the analysis will be just like in the previous section. However, for this section, the interest rate parameters are now filled for December 2023. According to the parameters as described in Table 5.14. This is done to understand the impact of different interest rate environments on the results.

Parameter	Description	Value	Source
F_p	Funding costs payment accounts	0.00%	Interest rates on payments accounts for Volksbank, ING, Rabobank, ABN AMRO at 12/4/2023
F_s	Funding costs savings accounts	1.50%	Interest rates on savings accounts for Volksbank, ING, Rabobank, ABN AMRO at 12/4/2023
F_b	Funding costs payment accounts businesses'	0.00%	Interest rates on payment accounts of businesses accounts for Volksbank, ING, Rabobank, ABN AMRO at 12/4/2023
I_w	Five year wholesale funding rate	2.75%	5 year EURIBOR swap rate 4/12/2023 (Investing.com, 2023)
I_d	Deposit facility rate	4.00%	Deposit rate at 12/4/2023 ECB (2023c)

Table 5.14: Parameters Sensitivity Analysis Interest Rates December 2023.

As can be seen in Table 5.15 the loss is now even more severe than in December 2022 as the spread between the funding cost and the deposit facility rate widened.

Scenario	Annual impact earnings 10% (million euros)	Annual impact earnings 49% (million euros)	Annual impact earnings 100% (million euros)
1	-27.23	-133.44	-272.32
2	-69.77	-341.85	-697.65
3	-137.89	-675.66	-1,378.89
4	-374.05	-872.99	-1,523.31

Table 5.15: Output Sensitivity analysis interest rates results December 2023.

Table 5.16 displays the differences (delta) in results just like in the previous section, but now for the years 2023 and 2022. These figures can be analyzed to understand the impact of changes in the interest rate environment. It can be seen how much the impact decreased due to the widened spreads. For example, in scenario 3, with a 100% adoption rate, the annual impact is €553.20 million lower in 2022 compared to 2023. Resulting, as mentioned before, in an even more negative impact.

Scenario	Δ 2023 - 2022 annual impact earnings 10% (million euros)	Δ 2023 - 2022 annual impact earnings 49% (million euros)	Δ 2023 - 2022 annual impact earnings 100% (million euros)
1	-13.62	-66.72	-135.71
2	-35.18	-170.91	-348.79
3	-55.32	-271.07	-553.20
4	-168.30	-345.22	-574.43

Table 5.16: Delta Results December 2023 and December 2022.

5.7 Synthesizing Results

In this section, there will be elaborated on the likeliness of each Scenario which is tested in an interview with the De Nederlandse Bank (DNB). Furthermore, the results of the four scenarios will be compared for the 10% adoption point, the 49% adoption point researched by Bijlsma and the worst-case 100% adoption point. Furthermore, there will be a reflection on how the results should be interpreted in light of the assumptions made.

5.7.1 Likelihood Scenarios

Before the results of the impact of the introduction of the DE on financial intermediation are compared, it is also important to consider the likelihood of these scenarios. The constructed scenarios were discussed with the DNB. This was done by informally interviewing the DNB about their expectations regarding the rollout of the DE. During the interview with the DNB, the DNB emphasized the focus of the DE being developed as a means of payment instead of a store of value, as also noted by Panetta (2022). In their opinion, this had the consequence of scenario one being the most likely. Furthermore, it was even noted that it could be likely that people would have zero balance at all in their DE account while they would still use it to conduct payments with the waterfall functionalities. Whether scenario two becomes likely, as per the DNB's assessment, hinges on the eventual design of the DE and the effectiveness of the waterfall functionalities. Furthermore, scenario three would only be realistic during times of financial distress when people would lose trust in banks, shifting their money away from the banks. However, as noted in Adalid et al. (2022) if banks get into real trouble, the ECB has the opportunity to loan the amounts lost to the DE back to the banks. Furthermore, an important point to consider, which is also made by M. Warren (2023) (Section 2.2.2), is that during times of financial distress, people can already easily withdraw their money from banks, especially in the Netherlands due to the digital capabilities of Dutch people. Therefore, it should be questioned if the impact on earnings of scenario three would be the result of the introduction of the DE. Furthermore, the DNB noted again that currently there are no signs that businesses can hold a balance on their DE account, making scenario 4 unlikely (DNB, 2023).

5.7.2 Comparison Scenarios

In Figure 5.1 the percentage of deposit outflows for the different scenarios can be seen. In this figure, the results of the 10% , the 49% as well as the 100% adoption point can be seen.

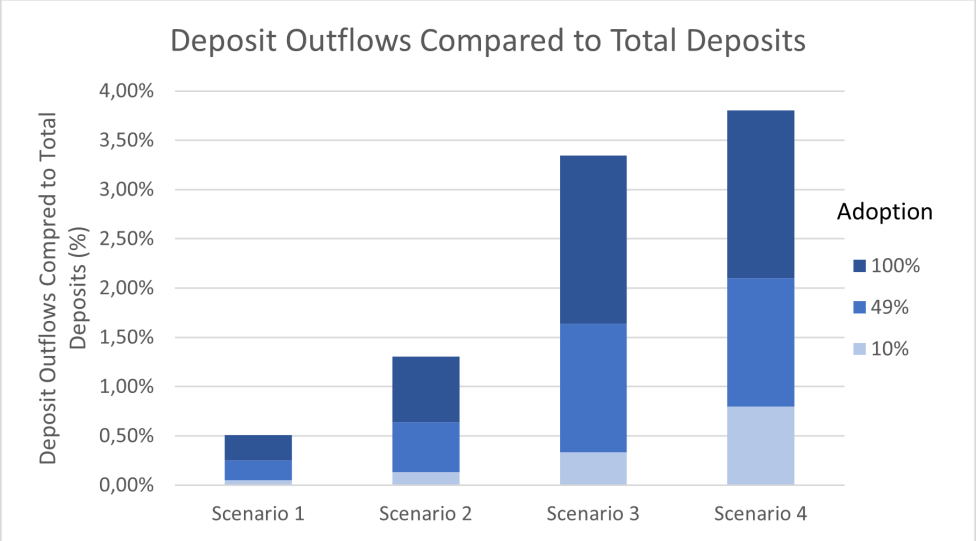

Figure 5.1: Deposit outflows for different scenarios.

In Figure 5.2 the annual earnings reduction for the different scenarios can be seen. It can be seen that for the different scenarios, the annual earnings reduction is relatively higher than the deposit outflows of the banks. This can be declared by the fact that the deposits lost due to the introduction of the DE are quite expensive to lose as banks have to pay no interest on payment accounts, for example.

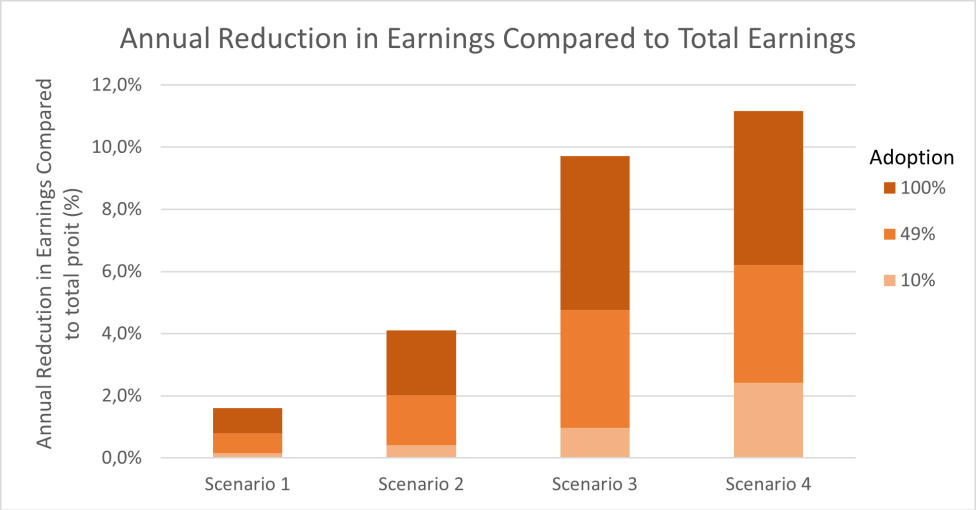

Figure 5.2: Annual earnings reduction for different scenarios

In Figure 5.3, the decline in the LCR for the different scenarios and adoption points can be observed, measured in percentage points. It's important to clarify that this represents a direct reduction in percentage points of the LCR itself, which is a ratio, rather than a decrease relative to the total, as illustrated in the preceding figures.

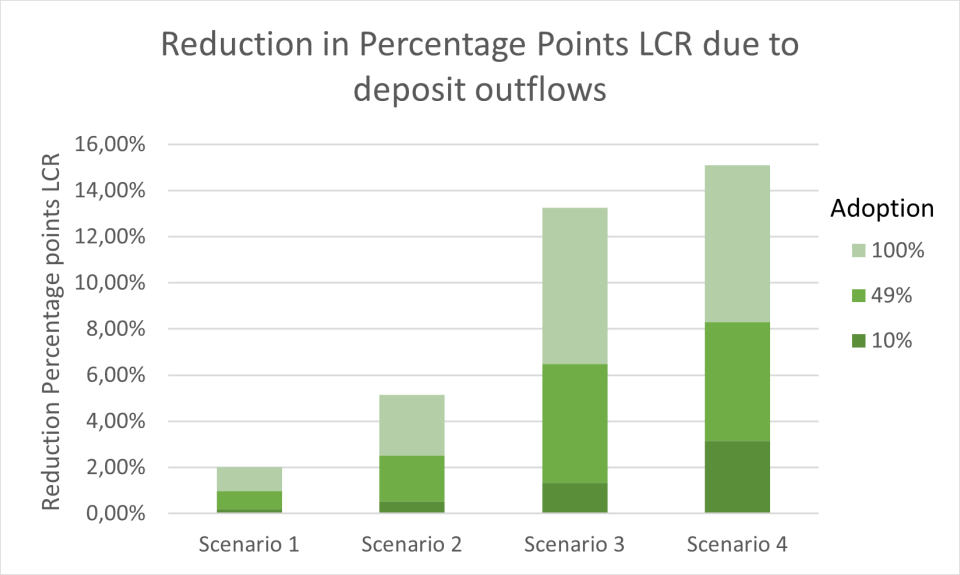

Figure 5.3: Reduction percentage points LCR for different scenarios.

In Figure 5.4, the decline in the NSFR for various scenarios can be observed, measured in percentage points. It can be seen that the NSFR declines less severely than the LCR for all the different scenarios.

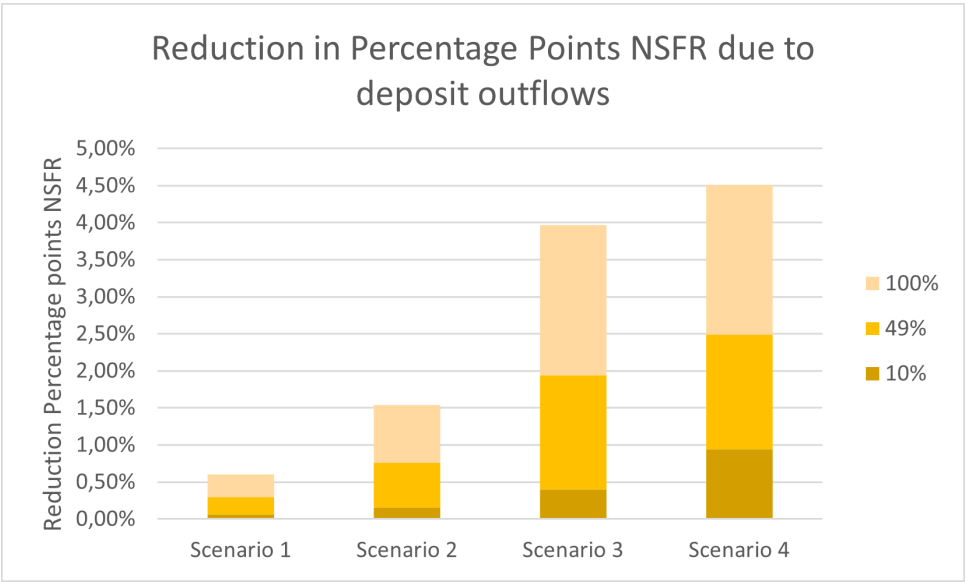

Figure 5.4: Reduction percentage points NSFR for different scenarios.

Overall, the results show that with the current proposed holding limit, banks will not be severely impacted due to the outflow of deposits resulting from the introduction of the digital euro in the Netherlands. The results show that even for the worst scenario at maximum adoption, the annual reduction in earnings for the Dutch banking sector due to financial disintermediation will be equivalent to 11.16% of total profit. Furthermore, the liquidity ratios of the modelled bank are even in the most severe scenario not close to the legally required minimum,.

Something important to consider, as noted before, 20% of households have a balance of €2500 or less on their combined bank accounts, while in our model it is assumed that everyone can convert €3000 to a DE account (CBS, 2022). Meaning that in reality, the results are even less severe. Furthermore, it is noticeable that allowing businesses to hold digital euros in their accounts (Scenario 4) leads to a limited increase in impact compared to Scenario 3.

Considering the circumstances in scenario three, banks can currently handle a holding limit at a maximum adoption of €11,701 before their liquidity ratios are constrained and additional wholesale funding is needed.

As our sensitivity analysis in Section 5.6.1 showed, the annual reduction in earnings due to financial disintermediation is highly dependent on the interest rate environment. With the negative interest rates present in December 2021, the introduction of the DE even leads to an increase in profit for Dutch banks according to our model.

5.7.3 Results in Light of the Assumptions

The results presented in this chapter stem from the model developed in Chapter 4 and the scenarios outlined in this chapter. This model and the scenarios are based on a mix of explicit and implicit assumptions. These assumptions are necessary to derive quantifiable results, especially since many aspects of the DE and its adoption remain uncertain. Although necessary, the validity of certain assumptions in the model might be questionable, suggesting that the results should not be regarded as precise figures. An example of such an assumption is that it is uncertain how banks react to a deposit outflow, as it will depend on their individual strategic considerations. This can lead to them choosing to raise interest rates to attract additional deposits or to sell certain assets, for example. This means that even if scenario one does happen in reality, this will not necessarily lead to the impact as indicated in these results; rather, it is an estimate of how banks would most likely react in such a scenario.

Another reason certain assumptions had to be made is the lack of data available for analysis. An example of such an assumption that is not the most accurate in the model is the use of the Netherlands' population to estimate the Digital Euro's impact, despite ING having a significant retail client base in Germany and Belgium (ING Group, 2023). This aspect is crucial because the introduction of the Digital Euro is expected to affect not only the Netherlands but also Belgium and Germany, thereby influencing the Dutch banking sector. This assumption was necessary due to the lack of detailed data on the average number of bank accounts per individual in these regions, a key factor considering the Digital Euro's holding limit is applied per individual.

Something else that is important to consider when interpreting the result is that the model's relevance is tied to its temporal context. It demonstrates what might have occurred if the DE had been introduced in 2022, using data from that year. With the DE's introduction anticipated no earlier than 2027, market conditions could change, affecting both the input parameters and the outcomes (European Commission, 2023). The deterministic nature of the model, using specific data points, avoids the need to predict future economic variables, which are often unpredictable. This means that the results do not take into account how the context might change leading up to the introduction of the digital euro. But, as mentioned, this is chosen since predicting the future economic variable would not necessarily have led to an increase in the accuracy of the results as most variables are simply not predictable. However, this should be taken into account when interpreting the results.

Therefore, the results should be viewed as indicative rather than definitive figures. For example, our results show that the annual reduction in earnings ranges from a few percentage points to around ten percent (depending on adoption) in the worst-case scenario, which is indicative of the potential impact of the digital euro being introduced in a similar environment as in 2022. The

results indicate that financial disintermediation due to the introduction of the digital euro will not pose an excessive threat to the Dutch banking sector under the current proposed regulations by the ECB and the EC. However, if extrapolated to other environments, the assumptions underlying the model should be tested again. In that case, this model and the developed assumptions provide a guideline for further analysis.

To conclude, a reflection on most of the assumptions can be found in Section 8.1 in which there will be critically reflected on the different assumptions used to come to these results. However, it should be noted that the model also includes some implicit assumptions, which may not be explicitly highlighted.

5.8 Conclusion and Discussion

The goal of this chapter was to answer the following sub-research questions:

- *Which scenarios are important to consider in order to determine the impact on financial intermediation for the introduction of the digital euro?*
- *What is the impact of the developed scenarios on the Dutch banking sector?*
- *What additional insights can be extracted from the developed model?*

To do this, Chapter 5 presents a detailed analysis of the impact of introducing the DE through four distinct scenarios. First, the different scenarios and why they were chosen are discussed. The scenarios range from using the DE as a buffer to its full utilization by private individuals and businesses in order to capture the full range of impact, from low impact to worst-case.

After this, the results of these scenarios are presented, and additional insights that can be extracted from the developed model are discussed. The model developed presents varied outcomes for the annual reduction in earnings due to financial disintermediation across different scenarios. Scenario 1, deemed most probable by the DNB, assumes individuals maintain a €480 buffer in their Digital Euro (DE) accounts, as indicated by research from Bijlsma et al. (2021). Under this scenario, with DE reaching its maximum adoption, the projected annual reduction in earnings is €136.16 million, which constitutes 1.61% of the total profits for 2022. At a more realistic adoption rate of 49%, as researched by Bijlsma et al. (2021), the loss is estimated at €66.72 million, or 0.78% of total profits. Conversely, in Scenario 3, where private clients fully utilize the €3000 holding limit, the loss could surge to €825.69 million, accounting for 9.71% of the total profit for 2022. This scenario also predicts a decrease in the Liquidity Coverage Ratio (LCR) from 1.51 to 1.38 and in the Net Stable Funding Ratio (NSFR) from 1.34 to 1.30. However, it's critical to note that the scenario of universal and maximal adoption of the DE is quite improbable. Even in this extreme case, the liquidity levels of the banks modelled are not dangerously near the regulatory minimum thresholds.

According to our model, if every eligible individual fully utilized the DE, the upper limit for holdings could reach €11,701 before the liquidity ratios of the modelled bank, representative of the four major Dutch banks, fall to the legal minimum, necessitating wholesale funding. This means that all Dutch residents above 15 years old could transfer up to €11,701 from their bank accounts to their DE accounts without causing the liquidity ratios of these aggregated Dutch banks to breach regulatory limits. Our analysis indicates that the DE's holding limit could be safely set at a minimum of €11,701 for this aggregated bank entity without violating liquidity requirements. However, it's important to recognize that the average individual typically does not maintain €11,701 in liquid assets, suggesting that in practice, the DE's holding limit might be set even higher. Moreover, this model is an aggregation of the balance sheets of the Netherlands' four major banks, and thus the exact point at which each individual bank's liquidity ratio would

be compromised may differ.

To assess the sensitivity of the results to the interest rate, a sensitivity analysis was conducted using 2022 data, factoring in the interest rate environments of both 2021 and 2023. Interestingly, in the negative interest rate scenario of 2021, banks effectively gained, rather than lost, from deposit outflows caused by the DE. This counterintuitive result arises from the cost savings in a negative interest rate environment. On the other hand, in 2023, when the gap between the deposit facility rate and savings account rates widened, the introduction of the DE correspondingly led to lower earnings for banks. This variance highlights the strong dependency of our results on the prevailing interest rate conditions, emphasizing that changes in these rates can significantly alter the financial impacts of the DE's introduction.

As noted in Section 5.7.3, while this study's scenarios are grounded in current financial realities, the analysis presented in this chapter is grounded on a combination of explicit and implicit assumptions, essential to navigate the uncertainties surrounding the adoption of the DE and the constraints posed by data availability. The model's findings, pertinent to the economic conditions of 2022, suggest that the introduction of the DE under the current regulations set by the ECB and the EC is unlikely to pose a significant threat to the Dutch banking sector. However, it is crucial to acknowledge the limitations of this model, making the results mentioned above more indicative than definitive. These findings serve as a valuable foundation for future analyses.

Overall, it can be concluded that the analysis in Chapter 5 effectively answers the sub-research questions by evaluating various scenarios of the digital euro's introduction and its impact on financial intermediation for the Dutch banking sector.

Chapter 6

Payment Services and Development Cost

Contents

The goal of this chapter is to answer the following research questions

- *What are the payment services that banks offer?*
- *What is the impact of the introduction of the digital euro on these payment services?*
- *What can be said about the development cost of the digital euro for Dutch banks?*

After having elaborated on how the financial intermediation function of Dutch banks will be impacted, this chapter will answer these research questions to elaborate on what aspects of payment services offered by Dutch banks and the development cost of the DE the introduction of the DE will have an impact. Dutch banks offer multiple payment services. In this chapter, a brief elaboration will be done on how Dutch banks might be impacted by the introduction of the DE for their payment services to give as complete as possible an impact of the introduction of the DE. The introduction of the DE might influence the payment system of a bank in different ways. In Section 6.2, the different payment services of the bank that might be influenced will be discussed. After this, in Section 6.3 a brief estimation of the possible impact on the payment services will be given. Additionally, an explanation will be provided regarding the financial implications of the DE's development cost for intermediaries and banks in Section 6.4. After this, the order of magnitude of the impact on payment services will be compared to the results on financial intermediation in Section 6.5. To conclude, in Section 6.6 a conclusion and discussion are given for this chapter.

6.1 Introduction Payment Services and Development Cost

The goal of this chapter is to estimate the order of magnitude of the impact of the introduction of the DE on payment services and the order of magnitude of the impact of the development cost of the digital euro. As mentioned in our scope (Section 1.7), our research initially aimed to fully explore the effects on the financial intermediation function of banks, the impact on bank payment services, and the costs involved in implementing a DE infrastructure for banks. As the study progressed, it became clear that accurately estimating the development costs for the DE was not feasible, primarily due to the lack of sufficient data and future uncertainties. Similarly, modelling the impact on payment services proved to be a formidable challenge, again due to data limitations. To ensure these critical aspects are still addressed, albeit in a more general sense, Chapter 6 has been introduced. This addition aims to provide insights and approximate assessments of these two areas. The assessments in this chapter will again be based on a set of underlying assumptions, reflecting the challenges and limitations of securing precise data.

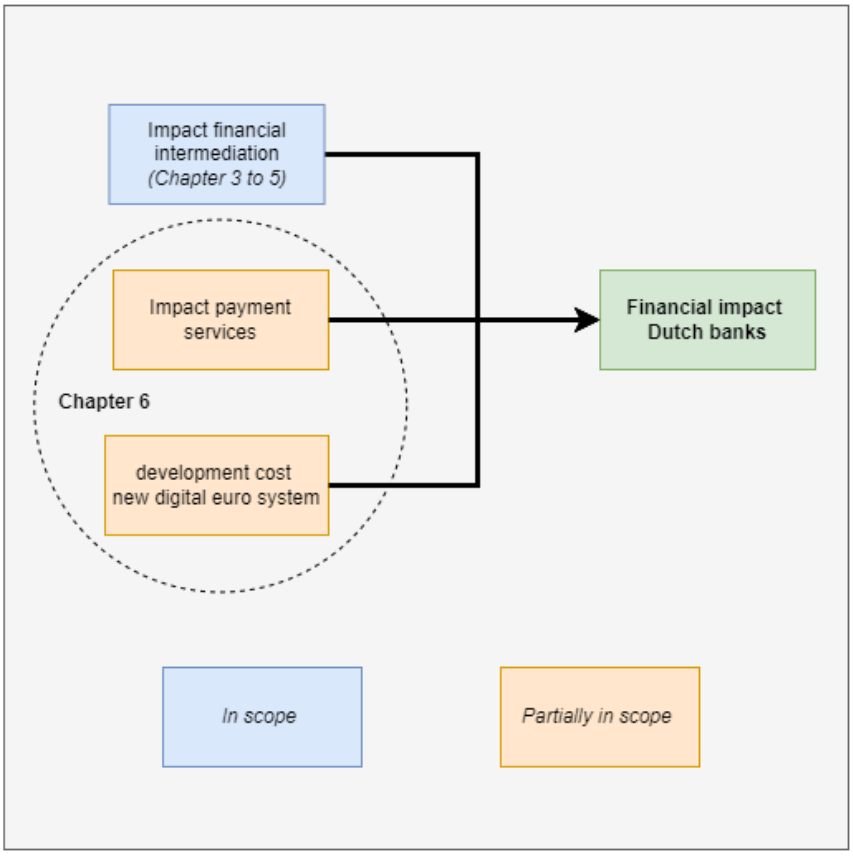

Figure 6.1: Research structure and Chapter 6.

6.2 Payment services

According to McKinsey, in December 2021, there were approximately 24.4 million payment accounts in the Netherlands. Of these, they estimate that about 21.7 million were retail accounts, making up roughly 89% of the total, while around 2.7 million were business accounts, constituting about 11% of the overall figure. This translates to an average of approximately 1.6 payment accounts per individual aged 15 and above in the Netherlands and about 1.3 payment accounts per business. The total outstanding deposits on these payment accounts for the year 2021 were equal to €310,733 million (McKinsey, 2022). With the introduction of the DE, it's conceivable that there could be a significant shift in the payment market, which is currently dominated by

banks providing most of these payment accounts.

In this section, the most relevant payment services will be evaluated, after which the impact of the DE on these services will be discussed. The payment market is a complex market with a lot of different products. First, the taxonomy of the different payment services will be evaluated based on the taxonomy provided by McKinsey in their research on the Dutch payment market. The products can be subdivided into three main categories, namely cash, digital, and card. There will be elaborated on these categories in the sections below.

6.2.1 Cash

Providing cash to their customers is a service that banks have to provide by law. This means that banks have to provide ATMs where customers can deposit and withdraw money. This service costs banks a lot of money to keep in existence. In order to be able to better divide the cost, the three big banks in the Netherlands (Rabobank, ING and ABN) decided to start a joint venture called Geldmaat (Geldmaat, 2022). In 2022, in the Netherlands, Dutch people conducted 1.4 billion cash transactions worth €24.5 billion (Betaal Vereniging Nederland, 2022).

6.2.2 Card

Payments that are conducted with cards make use of card schemes like Visa and Mastercard. For the use of these card schemes often an extra fee is charged. Card payments can be used for three types of transactions: point-of-sale transactions (POS), online transactions, and mobile transactions. POS transactions refer to in-store purchases where customers use cards to settle their bills for specific products or services. Online transactions are transactions where the information on the card is used to make purchases online. Mobile purchases are purchases where the card is loaded onto the NFC chip of a mobile phone, and this is used to make purchases. In Figure 6.2 a graphical depiction of card payments is given. In the top right, it can be seen that the cardholder initiates a payment at a merchant. The dotted lines depict the information and payment flow between parties and the normal lines are the transfer of fees. Important is to note that in the Netherlands the cardholder does not pay the issuer a fee for a transaction, however, issuers charge their customers' payment package cost per year. Furthermore, it should be stated that, in the Netherlands, the interchange fee that the issuing bank gets for their part in enabling a transaction is capped at 0.02 euros per transaction. The key to the four-corner model is that the issuer and the acquirer can be totally different parties that don't know each other. Nevertheless, the card systems of Visa or Mastercard ensure confidence that transactions will be successfully processed. This approach is frequently referred to as the Open Model since it allows various institutions to issue their own cards, adhering to a standardized scheme (Laurer, 2022).

Debit Card:
A debit card is a card that can be used to spend the money present in a banking account. In order to issue debit cards, banks often collaborate with renowned credit card companies, including VISA, Mastercard, and Discover. This partnership enables the use of debit cards at any location that accepts these credit card brands. For physical transactions, a debit card is processed similarly to a credit card, either by swiping, inserting, or using contactless methods at the terminal. Typically, a Personal Identification Number (PIN) is input for security purposes. This number confirms the cardholder's identity. However, some retailers might allow transactions without entering a PIN. When a purchase is made, the bank checks if there are adequate funds for the transaction. Upon confirmation, the transaction gets the green light. If one checks the bank account afterwards, the purchase might be listed as "pending." This indicates that while the bank has reserved the amount, it hasn't yet finalized the payment to the merchant. Once the funds are transferred, the transaction status updates to "approved." Essentially, when using

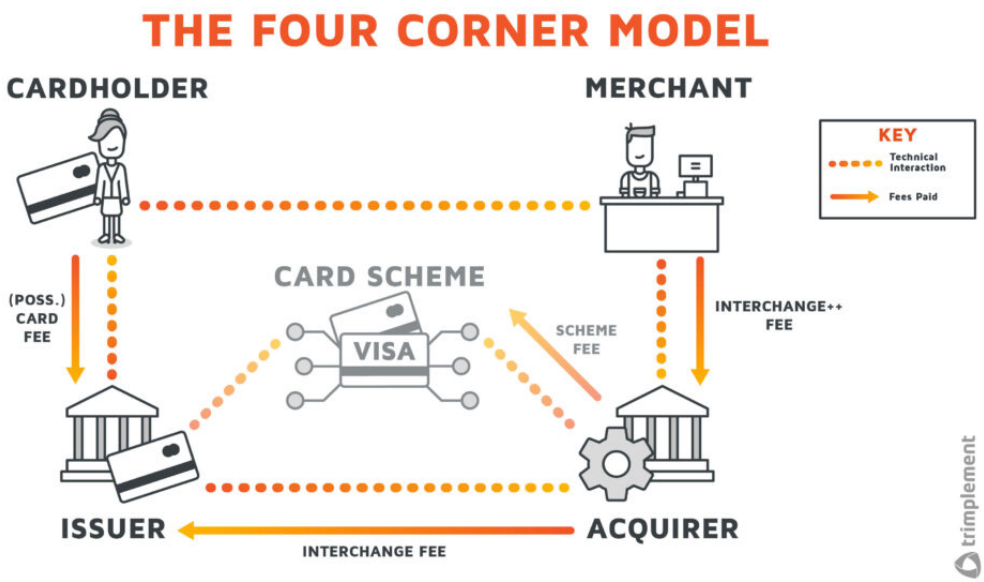

Figure 6.2: Four corner model card payments (Laurer, 2022).

a debit card for purchases or ATM withdrawals, the transaction is possible because the required funds are already present in the associated bank account. Some banks might offer an overdraft facility up to a certain limit if backup funds are available in another account, like a savings account. However, generally speaking, only what's available in the primary linked account can be spent with a debit card (Napoletano and Strohm, 2022). In 2022 in the Netherlands, consumers conducted 5,27 billion cash transactions worth €138 billion (Betaal Vereniging Nederland, 2022).

Credit Card:
A credit card functions as a tool that allows users to borrow money from the card issuer to purchase goods or services. There are two types of credit cards; charge and revolving credit cards. With a charge card, you have to pay off your balance every month or you will be subjected to heavy interest rates with a revolving credit card you can bring some outstanding balance to the next month. The credit card comes with a pre-determined spending cap, known as the credit limit (Frankel, 2023). In 2022, in the Netherlands, consumers conducted 29,9 million POS credit card transactions worth €2,92 billion (Betaal Vereniging Nederland, 2022). It is noteworthy that this is a really small amount compared to debit cards.

6.2.3 Digital

According to Betaal Vereniging Nederland (2023b), digital payments are payment orders that are given and executed remotely. These products are characterized primarily by differences in who initiates the payment (the recipient or the payer), the speed with which the payment is executed, and/or whether there can be a direct confirmation of the receipt of the money to the beneficiary. There are different forms of digital payments for this research the following types are defined:

Bank transfers:
Bank transfers are transfers of money between two bank accounts which are initiated by the payer. These transfers can be split up into three types; SEPA, Instant Payments and NON-SEPA transfers. SEPA stands for Single euro Payments Area, SEPA enables customers of banks to make cashless euro payments via credit transfer and direct debit to anywhere in the European Union. This form of money transfer is also called SEPA CT which stands for SEPA Credit

Transfer. These transfers are often completed within 24 hours, while non-SEPA transfers can take up to 5 days. Almost all digital transactions used the standard SEPA network until 2019, when the ECB launched the Target Instant Payment System (TIPS). This network enabled customers of banks to conduct SEPA instant payments to all other customers of banks connected to TIPS. Fees for an instant payment transaction are fixed at 0.02 cents per transaction for PSPs using the network (ECB, 2022b). In order to use SEPA and TIPS customers should have an IBAN bank account. In 2021 in the Netherlands, Dutch people conducted 1,63 billion domestic SEPACT transactions worth €4.4 trillion (this includes instant payment transactions) (Betaal Vereniging Nederland, 2022).Non-SEPA transfers refer to transfers towards bank accounts outside of the EU. These transfers often go through the SWIFT network, while sometimes other clearing systems are used (ECB, 2023b).

Direct Debit:
Direct debit is similar to a bank transfer, however, now the recipient is the one initiating the payment. Direct debit is often used for recurring payments while bank transfers are often used for one-off payments. Direct debit can be split up into SEPA and NON-SEPA transfers for which SEPA transfers also require an IBAN. This form of money transferring is also called SEPADD which stands for SEPA Direct Debit (Betaal Vereniging Nederland, 2023a). In 2022 in the Netherlands, Dutch people conducted 1,88 billion SEPADD transactions worth €324 billion (Betaal Vereniging Nederland, 2022).

IDEAL:
IDEAL is a Dutch payment method for online payments that makes the use of debit and credit cards abundant. It enables customers of connected banks to transfer funds via their online bank environment directly to other accounts. IDEAL offers multiple services, like a payment QR-code or payment links. IDEAL was owned by multiple Dutch banks until April 2023, when it was announced that iDEAL was bought by the European Payment Initiative (EPI) whose goal is to provide Europe with one standardized payment solution. IDEAL works by creating a SEPA Credit Transfer from within the consumer-trusted online banking portal(ECB, 2023a). In 2022, in the Netherlands, 1,12 billion iDEAL transactions were performed worth €107 billion.

Credit card:
Credit cards can also be used to conduct payments online; this is something for which credit cards are used more often than for POS. According to Betaal Vereniging Nederland (2022) in the Netherlands, consumers made 128 million online credit card transactions worth €10,2 billion.

6.3 Impact Payment Services

The different payment services banks offer have been discussed in the previous section. In this section, the impact of the introduction of the DE on these payment services will be discussed. It will be researched what revenue streams might be impacted by the introduction of the DE. These results will be interpreted to give an order of magnitude to the potential impact of the introduction of the DE on the payment services of Dutch banks.

The revenue streams for payments and deposits can be divided into the following groups (McKinsey, 2022):

Transaction fees: These are fees earned by banks that are directly related to payment transactions. This can be a fixed fee per transaction or a percentage fee on the transaction value, depending on the type of transaction. Interchange fees should be fully taken into account on the issuing side under revenues and are considered negative revenues on the acceptance side. In Section 6.2 the different transaction types have been discussed. It is important to note that each of these different transactions comes with different transaction fees.

Periodic fees: Fees earned by banks on customer subscriptions to specific products (e.g., annual/monthly charges for cards, payment packages, paper bank statements, Point-Of-Sale terminals).

Incidental fees: Fees earned by banks when specific incidents occur (e.g., fee for late payment of credit card balance, for card replacement).

In Figure 6.3 the revenue the Dutch payment market generated spread over these revenue streams can be seen according to research performed by McKinsey (2022). It is important to note that the net interest income depicted in this picture is already discussed in our chapters about financial intermediation. Here it can be seen that one-off fees account for just one percent of the total revenue streams; therefore, it is decided that this revenue stream will be left out of scope for this research.

Figure 6.3: Revenue per type Dutch payment market 2021 (McKinsey, 2022).

The goal of this chapter is to estimate the order of magnitude of the impact of the introduction of the DE on the payment services of the bank. According to the ECB and the DNB, the DE is designed to be a complement to the current payment infrastructure (ECB, 2023a), (DNB, 2023). The DE will be designed in order to complement existing payment accounts, with which users can use waterfall functionalities to conduct payments with the DE account. Furthermore, due to the holding limit in place, users cannot receive large payments on their DE accounts without using the waterfall functionality that requires a bank account, further ensuring the need to keep their payment accounts. Therefore, it can be expected that people will not give up their current payment accounts in the short term. This leads to the fact that the periodic fees for payment accounts will, in the short term, highly likely stay intact for banks. The revenue stream that will highly likely be impacted the most is the fee resulting from transactions. This becomes further prevalent in the proposal of the EC, where it is clearly stated that the remuneration of transactions with the DE will be regulated (European Commission, 2023).

Something that should be noted is that people in the Netherlands currently have more than one bank account. If the digital euro is introduced, people, while not necessarily the case, might choose to replace one of these bank accounts with a digital euro account. This will lead to a reduction in periodic fees for banks. In this thesis, this potential effect is excluded from the scope because of the unpredictability surrounding individual responses to the introduction of the digital euro.

6.3.1 Impact Transaction Fees

As mentioned in Section 6.2, banks offer different payment services that entail different types of transactions. In this Section, these types of transactions will be discussed, combined with the estimated revenue they provide for the banking sector. This estimation is based on data provided by Betaal Vereniging Nederland (2022) and McKinsey (2022).

If users conduct transactions with the DE system, banks will not process transactions with their old systems, but transactions will go via the DE system. Banks are expected to offer DE services, however, they cannot directly give up their old systems that are in place. Furthermore, the cost of payment services is for the most part fixed, which means that the cost does not rise in proportion to the number of transactions while the income from transaction fees does(McKinsey, 2022). This means that the loss of transactions towards the DE can lead to a loss of profit for banks depending on the remuneration on DE transactions proposed by the ECB, of which the specifics are still unclear (ECB, 2023a). For this analysis, the following types of transactions are distinguished: (Betaal Vereniging Nederland, 2022); these transactions are already mentioned in Section 6.2. Cash deposits and withdrawals are analyzed separately due to the different natures of these transactions.

- Debit Card
- IDEAL
- Credit Card
- SEPA DD (inc. TIPS)
- SEPA CT (inc. TIPS)

In order to estimate the revenue streams of these types of transactions, it is important to consider when banks charge clients. For private clients, sending and receiving these transactions is free; however, when merchants receive a payment, they are charged a certain transaction fee. For SEPA DD and SEPA CT transactions, businesses are charged for sending as well as receiving the transaction. Therefore, it is important to make an assumption about the percentage of total transactions that are sent and received by businesses for this type of transaction. Due to the lack of real data, in this thesis, it is assumed that all SEPA DDs are initiated by businesses because normal people will often not initiate a direct debit, while the receiving of SEPA DDs is conducted according to the ratio of businesses to normal people. Thereby, assuming that a business on average receives as many payments as a normal person. This data can be found in Table 4.2. Furthermore, it is assumed that SEPA CT transactions are conducted according to the ratio of businesses to normal people. Furthermore, non-SEPA transactions are left outside of the scope of this estimation as DE transactions do not directly substitute them, this might only happen in a later stadium when multiple digital currencies exist and exchange between different types of digital currencies becomes possible or arrangements between the ECB and national central banks are made (European Commission, 2023). Using the data of the Betaal Vereniging Nederland (2022), out of which the data of payment transactions conducted by Dutch banks in 2022 is extracted, combined with these assumptions and the average transaction price of the four big banks (ABN AMRO Bank N.V. (2022), ING Bank (2022),De Volksbank (2022),Rabobank (2023)), the estimated revenue per transaction is extracted. The results can be seen in Table 6.1.

In the Dutch banking sector, an estimated revenue of €944.73 million from transaction fees was generated in 2022. This was found to be a reasonable approximation when compared to McKinsey's 2021 report, which recorded revenues of €868 million from similar fees. It is important to note, however, that non-SEPA transactions, accounting for €66 million in McKinsey's report, were not included in this analysis. Consequently, the figure reported by McKinsey was lower than that of our analysis. The variance can be attributed to the methodology of our analysis,

which was based on transaction fees from the internet, whereas larger retailers might often benefit from lower, customized rates. Therefore, it is likely that the actual revenue might be slightly lower than what our estimate suggests.

Type of Transactions	**Volume (million trans.)**	**Volume send business clients (million trans.)**	**Volume received business Clients (million trans.)**	**Average Fee Receiving Transaction Business Clients Four Big Dutch Banks (€)**	**Average Fee Sending Transaction Business Clients Four Big Dutch Banks (€)**	**Estimated Revenue (million €)**
Debit Card	4,490	-	4,490	0.063	0	282.9
Credit Card	128	-	128	0.063	0	8.1
IDEAL	1,230	-	1,230	0.250	0	307.5
SEPA DD	1,880	1,880	283	0.135	0.13	282.6
SEPA CT	1,630	245	245	0.135	0.125	63.7
Total						**944.73**

Table 6.1: Estimated revenue per type of transaction.

In Table 6.1 different types of transactions can be seen. As currently expected the DE will be a substitute for all these transactions. People can use it to pay in stores, and online and to transfer money to each other. The expectation is that DE transactions will replace direct debits the least, given that these transactions are initiated by the payee and may involve amounts, such as a salary, that exceed the holding limit (Betaal Vereniging Nederland, 2023a).

Due to the comments made by the ECB and DNB about the DE not being a store of value but being a means of payment, as well as the waterfall design functionalities (Section 2.2.1, Panetta (2022)) it can be expected that the ECB is steering on people conducting as many payments as possible with the DE.

As mentioned before, banks have a lot of fixed costs for their payment factories. The marginal costs per transaction are often really low. This is why revenue loss can almost be seen as profit loss, assuming that the banks have to keep up the same network as for larger volumes. Furthermore, the current EC proposal states that the fees banks can charge for a DE transaction should be lower than (European Commission, 2023):

- The relevant costs incurred by payment services providers, including a reasonable margin of profit.
- Fees or charges requested for comparable means of payment based on the most effective payment providers.

If the remuneration for this is set very low, our estimates indicate that it could result in an additional earnings decrease of hundreds of millions, contingent on both the level of remuneration and the adoption rate of the DE.

In addition to these types of transactions, Dutch banks also handle cash. This is currently a loss-making business for banks; however, they have to keep this business alive due to regulation McKinsey (2021). Revenue generated by cash was 84 million for Dutch banks in 2021 (McKinsey, 2022). As stated by the ECB, the DE should complement cash, not replace it, indicating that this revenue could also decrease while keeping the costs in place (ECB, 2023a), leading to additional losses.

6.3.2 Other Impact Payment Services

Another risk for banks is that, according to the proposal published by the EC, the offering of DE services will not be exclusive to banks. According to European Commission (2023), a wide range of entities, including both public and private institutions, are eligible to offer DE accounts and related services. If large technology companies become more efficient at providing DE services than traditional banks, there's a possibility that DE transactions and their related fees could shift away from the banking sector and towards these tech companies.

However, the DE presents a potential opportunity if the ECB establishes an infrastructure with lower operating costs compared to existing payment services while also permitting fair remuneration. This approach could enable banks to maintain a reasonable profit margin. (European Commission, 2023). If this system can replace the existing payment structure in place at the bank while being more cost-efficient, it might save costs for the banks.

6.4 Development Cost Digital Euro

The development cost of the DE is currently really uncertain. It will depend on how the DE will be designed by the ECB. As mentioned in Section 2.2.1, The current proposal by the EC allows all PSPs to distribute the DE, but obligates only credit institutions to do so. Therefore Dutch banks will be obliged to offer DE services. Furthermore, it is stated that banks should play a role in enabling certain functionalities of the DE.

Currently, the ECB published a document with all the functional and non-functional requirements the DE should meet (ECB, 2023b).

In Figure 6.4 the high-level functional map of the DE can be seen. Processes that have to be completed by intermediaries are according to the publication and the high-level functional map (European Commission (2023), ECB (2023b)):

- Onboarding, lifecycle management and offboarding of users and intermediaries (**user management**).
- Management of liquidity transfers received and sent between TARGET Services and the DE components (**liquidity management)**.
- Processing of DE transactions, including payments between end users, funding/defunding, waterfall (payment + defunding) and reverse waterfall (funding + payment) transactions (**transaction management**).
- Reference data, configuration and identity management, as well as transaction data stored for reporting, operational and legal purposes (**data management**).
- Communication between directly connected actors and the DE service platform, and between the DE service platform and TARGET Services (**interface managemen**t).
- In addition, specific offline functions to support peer-to-peer **offline** functionalities.

As can be seen in this list, these are often functions that banks already perform for their normal payment factories. It is difficult to see how much the current systems have to change to make sure banks can fulfil these requirements. This is mostly due to the fact that these functionalities are quite vaguely described, and it is not yet clear what these functionalities mean within a DE context. Furthermore, for the offline functionalities, there is currently no comparable infrastructure that exists in Europe from which the development cost can easily be derived.

Some other difficulties that should be taken into account when developing the DE compared to handling current transactions are:

- When are the transactions owned by whom? In the context of the DE, it is still uncertain who bears the legal responsibility for the transaction.
- According to the functional requirements, intermediaries (so Dutch banks) need to onboard new users. How will data privacy and anti-money laundering be combined, and who bears responsibility for these processes? For example, if a user already has a DE account with another bank, he/she should not be able to open a new DE account (Clifford Chance, 2023).
- The development costs of the offline functionalities are currently really uncertain.
- It is uncertain what extra costs need to be made to handle transactions with the DE infrastructure compared to the current infrastructure.

This means that it is still really difficult to estimate the development cost of the DE. Something that might be expected for this development cost is that third parties will develop the DE infrastructure and sell it to intermediaries. This can be expected because it is not entirely logical that all banks will develop the infrastructure separately from each other. The crux will be how difficult it will be to insert this DE infrastructure into the existing payment infrastructure of the banks.

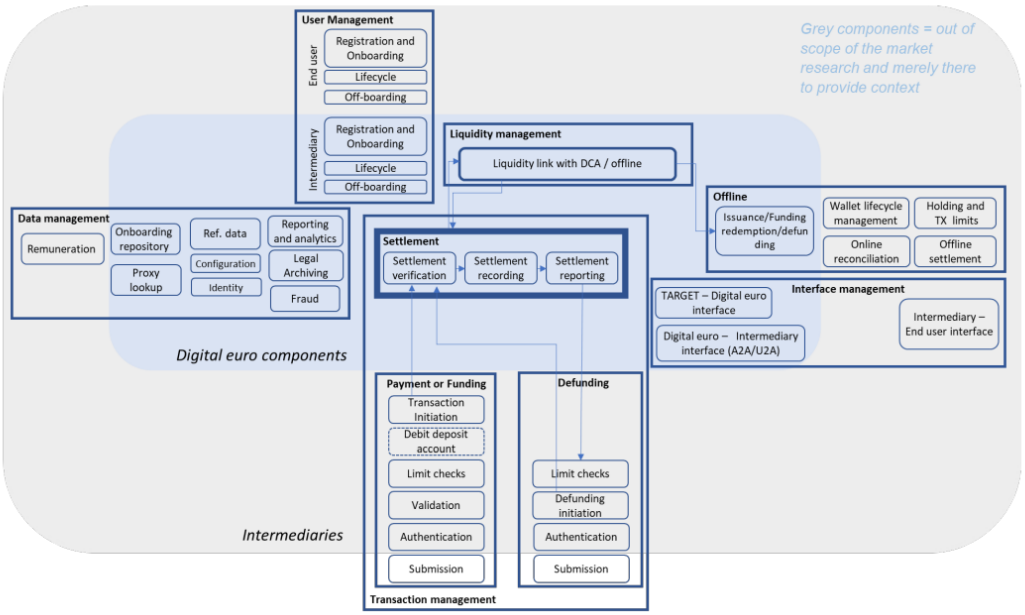

Figure 6.4: Functional requirements of the DE as published by the ECB (2023).

6.5 Comparison with Impact on Financial Intermediation

In this section, the earnings reduction for different scenarios found in Chapter 5 is compared to the order of magnitude of the impact on payment services. According to Panetta (2022) and the DNB (2023), the DE will be designed as a means of payment and not as a store of value. This makes it realistic, according to the DNB, that people will have a low or zero balance on their DE account and use it mostly as a means of payment, with the help of waterfall functionalities (Section 2.2.1). As mentioned before, this leads to the conclusion that, in normal times, Scenario 1 is the most likely scenario according to the DNB. For this scenario, the annual earnings reduction at 100% adoption was 136.16 million euros. If we look at Table 6.1, it can be seen that when there is insufficient remuneration for DE transactions, this amount can also be lost in the payment market. Furthermore, there is the threat that big tech or other companies might take market share in the payment market, further increasing the losses for the payment business of banks. Additionally, the development cost of the DE is still really uncertain, leading to possible significant losses.

If a stress scenario is considered in which at 100% adoption everyone makes use of the full holding limit (scenario 3), the reduction in annual earnings for the banking sector will be 825.69 million, meaning that the annual reduction in earnings is as high as the whole revenue for transactions for the Dutch banking sector. This means that this impact will be greater than the possible impact on payment services. From this, it can be derived that under normal conditions it cannot be concluded that financial disintermediation has the biggest financial impact due to the introduction of the DE, while, of course, still dependent on yet-to-be-designed features of the DE and the liquidity conditions of the market at that moment. However, when maximum deposits flow out, financial disintermediation has highly likely the largest financial impact.

Figure 6.5 illustrates the reduction in earnings upon full adoption across different scenarios, compared with the potential revenue at risk extracted Table 6.1. It's important to distinguish that 'earnings reduction' signifies a definite loss of profit, whereas 'revenue at risk' represents potential, not guaranteed, loss. The latter's impact on profit depends largely on the DE's remuneration. While a direct comparison isn't feasible, this visualization serves to estimate the possible scale of impact on payment services under various scenarios

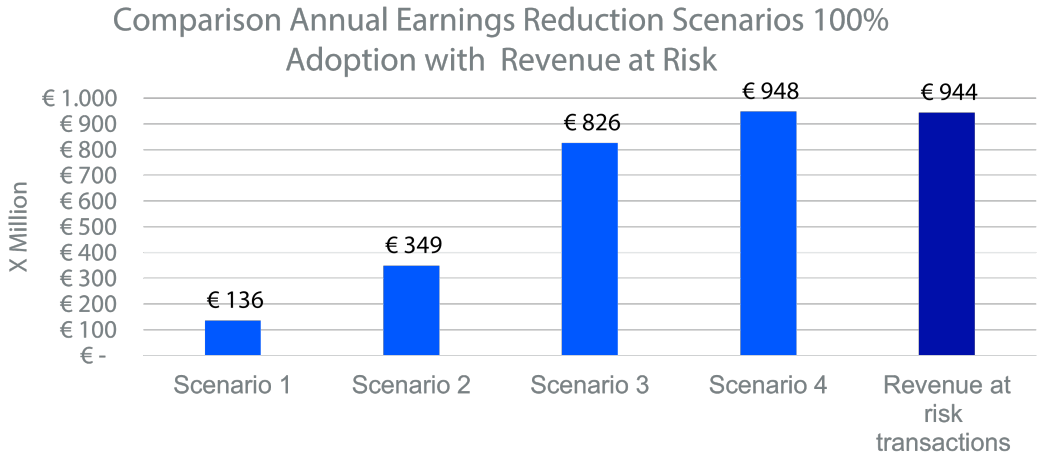

Figure 6.5: Comparison earnings reduction for the different scenarios at 100% adoption with revenue at risk transactions.

6.6 Conclusion and Discussion

The goal of this chapter was to answer the following sub-research questions:

- *What are the payment services that banks offer?*
- *What is the impact of the introduction of the digital euro on these payment services?*
- *What can be said about the development cost of the digital euro for Dutch banks?*

To do this, this chapter has elaborated on the different payment services banks offer. After this, this chapter explored the potential impacts on the payment services of banks, focusing on transaction fees, and development costs associated with integrating the DE into existing banking infrastructures. To answer the third research question, there is elaborated on the development cost of the digital euro. The chapter ends with a comparison to financial intermediation to place the results of this chapter in the context of the results of the previous chapter.

The analysis in this chapter shows that transaction fees, a significant revenue stream for banks, are likely to be the most impacted. The DE's design is intended to complement, rather than replace, current payment infrastructures, suggesting that periodic fees for payment accounts may remain largely unaffected in the short term. However, a reduction in transaction fees is anticipated, heavily contingent upon the European Commission's proposal to regulate the remuneration of transactions with the DE. This could lead to a significant decrease in banks' profits from transaction fees. While in this thesis it is left out of scope that revenue from periodic fees for bank accounts decreases due to the introduction of the digital euro, it is important to note that the introduction of the digital euro may lead individuals in the Netherlands, who typically hold multiple bank accounts, to replace one of these with a digital euro account. This thesis excludes this potential effect from its scope due to the inherent uncertainty in predicting how individuals will react to the digital euro's introduction.

When the findings of this chapter are compared with those of chapter five, it is deduced that a low remuneration for DE transactions might result in an impact on payment services that is comparable to, or even exceeds, the impact of financial disintermediation in scenario 1 (136.16 million euro per year at 100% adoption). This is particularly relevant considering the European Central Bank's focus on promoting the DE primarily as a means of payment rather than a store of value. Panetta (2022).

The development cost of the DE is yet another critical area of concern. The integration of the DE's functionalities—spanning user management, liquidity management, transaction processing, data management, and offline capabilities—into banks' existing systems is a challenging endeavour. The ambiguity in the functional requirements and the novelty of offline functionalities add layers of complexity and uncertainty to the cost estimation process.

It can be said that the financial impact of the introduction of the DE still depends on how it will actually be designed. This chapter tried to look at the order of magnitude of the impact on payment services and compare it to the impact due to financial intermediation, with the conclusion that under normal conditions, it is difficult to definitively assert that financial disintermediation poses the greatest financial risk arising from the DE. This assessment, however, is contingent upon various factors yet to be finalized, including the DE's specific features and the prevailing market liquidity conditions.

Overall, it can be concluded that the analysis in this chapter effectively answers the sub-research questions by providing an understanding of the DE's potential effects on banking payment services and highlighting the significant role of transaction fee reduction and development costs, while comparing these impacts to the impact on financial intermediation.

Chapter 7

Conclusion

The main goal of this research is to answer the main research question:

What would be the potential financial impact of the introduction of the digital euro by the ECB on the Dutch banking sector?

In this research, the banking sector was analyzed in the context of the emerging DE, with a special focus on financial intermediation. This was done with the help of the sub-research questions formulated in Chapter 1.6 which are answered in the conclusions of each individual chapter. It has explored how banks generate revenue and how these streams could be influenced by the DE's introduction. Furthermore, a model is built to determine the impact on the financial intermediation function of the Dutch banking sector due to the introduction of the DE, assuming that the DE would be introduced in 2022. With the help of four scenarios, the possible impact on financial intermediation was tested. The likelihood of these scenarios was discussed with the DNB. Furthermore, sensitivity analyses were performed to test the sensitivity of the results to the interest rate and the holding limit. Chapter six was added to provide context on the impact of the introduction of the DE on the existing payment services of banks and the development cost of the DE for banks. These results were compared to the results of the scenario analysis to determine the order of magnitude of the possible impact on payment services and the development cost.

To perform these analyses, the model and the scenarios developed are based on a mix of explicit and implicit assumptions. These assumptions are necessary to derive quantifiable results, especially since many aspects of the DE and its adoption remain uncertain and some data is unavailable. Although necessary and chosen as realistically as possible, the validity of certain assumptions in the model might be questionable, suggesting that the results should not be regarded as precise figures but rather as an order of magnitude of the potential impact due to the introduction of the DE.

Based on these assumptions, the following conclusions were reached:

- **Under the current proposed holding limit, financial disintermediation due to the introduction of the DE poses a manageable risk to the Dutch banking sector.** The developed model shows different results for different scenarios for the annual earnings impact due to financial disintermediation. The most likely scenario (Scenario 1), according to the DNB, is that people put a buffer of €480 on their DE account as a buffer (research by Bijlsma et al. (2021)). This scenario leads to an annual earnings reduction of €136.16 million, or 1.61% of total profits in 2022, on maximum adoption of the DE. While on the expected adoption point researched by Bijlsma et al. (2021) of 49%, the annual earnings reduction is €66.72 million, or 0.78% of total profits. The scenario in which private clients use the holding limit of €3000 to the fullest extent (scenario 3) results in

a loss of 825.69 million, equal to 9.71% of total profit for the year 2022 at maximum adoption. This is while the LCR drops from 1.51 to 1.38 and the NSFR from 1.34 to 1.30. It is important to recognize that the scenario where all individuals adopt and fully utilize the DE is not highly realistic. Even in this unlikely scenario, the modelled banks' liquidity levels would not approach dangerously close to the regulatory minimum.

- **If the DE is used by every Dutch person to the fullest extent, the holding limit could be €11,701 before the liquidity ratios of the modelled bank hit the legal minimum and wholesale funding is needed.** According to the developed model, all Dutch people over 15 could convert €11,701 of liquidity to their DE accounts from their bank accounts before the liquidity ratios of the modelled Dutch banks reach the legal minimum. This analysis suggests that the holding limit for the DE could be set at €11,701 before our modelled bank, which aggregates the balance sheets of the four major Dutch banks, breaches the liquidity requirement. However, it's crucial to consider that not many individuals typically hold €11,701 in liquid assets, implying that the practical holding limit could be even higher. Additionally, it's important to note that the modelled bank in this analysis represents an aggregate of the balance sheets of the four major banks in the Netherlands. Consequently, the specific point at which each individual bank's liquidity ratio would be breached may vary.
- **Results for the annual impact on earnings due to the impact on financial intermediation are highly dependent on interest rates.** The annual impact on earnings varies greatly with changes in interest rates. In this research, a sensitivity analysis was performed for data from 2022 with the interest rate environment of 2021 and 2023. In 2021's negative interest rate environment, banks experienced an earnings gain, essentially profiting from deposit losses due to the introduction of the DE. However, as the spread between the deposit facility rate and savings accounts increased in 2023, the reduction in earnings attributed to the DE's introduction also rose. Hence, it's clear that these results are closely tied to the prevailing interest rate conditions.
- **It is not a given that financial disintermediation will be a bigger threat than development cost and the impact on payment income due to the introduction of the DE for the Dutch banking sector.** Chapter 6 of our research delves into evaluating the potential magnitude of the DE's impact on development costs and payment income for Dutch banks in comparison to the consequences of financial disintermediation. The findings suggest that it is not necessarily given that financial disintermediation is the most substantial challenge facing the Dutch banking sector. This perspective is particularly relevant considering the ECB's current direction with the DE. The ECB is focusing on positioning the DE primarily as a means of payment rather than a store of value, as detailed by Panetta (2022). Therefore, it enables customers to use the payment infrastructure of the DE without having to put a balance on their DE account. However, the actual impact of the DE on banks hinges on several critical factors. Firstly, the impact is closely tied to the remuneration policies for DE transactions. The fee structure associated with these transactions will significantly influence the revenue streams of banks from payment services. Secondly, the specific design features of the DE will play a vital role. Moreover, the introduction of the DE is set to intensify competition in the payment sector. This new landscape will test the ability of big tech firms and other competitors to capture market share from Dutch banks. The extent to which these entities succeed in leveraging the increased competition that the DE should bring will be a decisive factor in determining its overall impact on the banking sector.

Overall, it can be concluded that these findings help in answering the main research question.

While the results depend on strong assumptions, they can be used to derive an order of magnitude of the impact due to the introduction of the DE. Therefore, our research fits the research goal of this thesis, which states that this research should provide a guideline for Dutch banks on how certain design choices will impact Dutch banks. Our model can be rerun for different potential designs of the DE to see how the financial intermediation function of Dutch banks will be impacted. This can enable a fact-based discussion on the fairness of the compensation model for the DE based on the estimated financial impact based on suggested policies by the ECB.

Chapter 8

Discussion and Further Research

This research is the first to research the possible financial impact of the implementation of the DE on the Dutch banking sector. Furthermore, this was done while only using publicly available data. This led to the fact that a lot of implicit and explicit assumptions were needed to construct the model. Therefore, in Section 8.1, there will be critically reflected on the most essential assumptions and findings and they will be compared with existing literature. In Section 8.2, it will be elaborated on how further research can enhance this research, after which this thesis is concluded with its contribution to research in Section 8.3.

8.1 Discussion

As discussed in the findings of Chapter 5 and Section 5.7.3, it's important to emphasize that the results of this study are not to be interpreted as precise, absolute figures. This research presents a series of estimates and projections concerning the financial impact of the DE on Dutch banks, for which a lot of implicit and explicit assumptions had to be made. It is important for readers to interpret these results with a degree of caution. The figures provided are not definitive amounts but rather approximations intended to illustrate the order of magnitude of different potential scenarios. The nature of the modelling, grounded in assumptions and hypothetical scenarios, inherently carries limitations in precision. An elaboration of how the results should be interpreted in light of these assumptions can be found in Section 5.7.3. In this research, the impact of the introduction of the DE in the year 2022 is analyzed. It should be noted that these results depend on a lot of underlying assumptions, which cannot all be directly extrapolated to the future. In the sections below, there will be critically reflected on different aspects and assumptions of this research.

8.1.1 Impact on Financial Intermediation

In this section, there will be reflected on the most important assumptions and findings compared with the literature for the model of the impact on financial intermediation.

- In the literature as well as in this model, it is argued that during times of financial distress, the DE will be a bigger threat to the current banking system than during normal times. As noted by M. Warren (2023) one could argue that the threat of digital bank runs is already apparent even without the introduction of the DE. In this sense, the DE might even be an opportunity to increase financial stability. When, during times of financial distress, people take money out of the Dutch banking sector and move it to big tech companies or crypto, for example, money leaves the banking system and goes to private parties. When the money flows to the central bank, the money stays in the banking sector and might, in

cases of real distress at banks, even be lent back to the banks by the central bank in order to save them. It's important to note, though, that this potential benefit is predicated on a significant assumption regarding the central bank's role and actions in a crisis. However, it can be stated that funds transferred to unregulated entities are definitively removed from the banking sector's reach. This perspective reframes the DE as a tool that might enhance, rather than diminish, overall financial stability during periods of distress.

- In this thesis, it is assumed that in response to deposit outflows, banks first lower their HQLA reserves, and otherwise they attract wholesale funding. In reality, banks have more options to react to a deposit outflow based on strategic considerations, each having its own financial impact. For example, banks could sell other assets or increase deposit rates to attract additional funding, as stated in the model by Klein (1971). This is done by matching the supply curve for deposits with the demand curve for loans. In the current liquidity environment, this original model cannot be applied to see how much banks will raise their interest rates due to deposit outflows since there is ample liquidity in the market to fulfil all demand for loans and banks deal with an excessive amount of liquidity ECB (2023). Therefore, in this liquidity environment, the simplification of reducing HQLAs and otherwise resulting in wholesale funding is considered realistic. However, the results of this study indicate that the liquidity environment of 2022 should not be directly extrapolated to the introduction of a DE in times with a more stretched liquidity environment.
- As mentioned, the figure for impact on earnings is based on the figures for 2022. The results are highly dependent on the interest rate environment, particularly on the spread between interest on deposits and the deposit facility rate. For our model, the spread between the deposit facility rate is highly positive. For a long time, this was not the case, and the deposit facility rate was below the rate paid on deposits (FD, 2023). This is because banks were competing for deposits to fulfil their demand for loans, which is currently not the case. As of the writing of this thesis, the spread between the deposits and the deposit facility rate had even widened.
- Similar to the effects on earnings and liquidity, other variables, such as the population of the Netherlands, have been incorporated into our model based on one point in time, namely the year 2022. This deterministic approach allows for the examination of scenarios based on specific assumptions without the need to account for the probabilistic variation of each parameter, which is particularly challenging given the uncertainties and lack of data in forecasting future financial systems and technologies like the DE. Furthermore, it helps interpret the results in light of the assumptions, which may become complex when additional assumptions for forecasting have to be made while not enhancing the accuracy of the model. The downside of this approach is that it is imperative to update these parameters when re-evaluating the model for the year in which the digital euro will be introduced.
- The model developed in this research operates under the assumption that the adoption of the Digital Euro (DE) happens instantaneously at a single point in time. This assumption is primarily driven by two factors: the research objective and the need for simplicity. The primary goal of this research is to evaluate the impact of a specific level of DE adoption rather than to examine the process of adoption itself. By assuming immediate adoption, the static model simplifies the analysis, enabling a more focused examination of the direct effects of the DE's introduction. However, this approach does have a notable limitation. In the real world, the adoption of new financial instruments like the DE typically occurs gradually over time. This gradual adoption can lead to a dynamic and evolving impact on Dutch banks, which the model does not account for.
- The model developed in this thesis also hinges on the assumption that wholesale funding

is available. During stressed liquidity environments, this is not always the case, and if wholesale funding is not available and liquidity ratios go to the minimum, other measures might have to be taken to keep the bank solvent. In Meller and Soons (2023) it is stated that liquidity in the European banking system will not become under pressure with a holding limit of €3000; this result is therefore used in this research. When the holding limit is really large, this might put additional pressure on the wholesale market. In this model, it is chosen not to take into account central bank lending, as currently, the Main Refinancing Operation rate is above the long-term wholesale funding rate. When liquidity in the wholesale market gets stressed, this type of financing should again be taken into account due to the fact that the wholesale funding rate might again increase above the Main Refinancing Operation rate.

- Compared to the production model of banking by Sealey and Lindley (1977), the model developed in this thesis assumes that the input of labour and technology stays constant to generate a certain financial output. This has to do with the previous point that the banking system is flooded with liquidity, due to which the introduction of the DE does not necessarily lead to the sale of assets for which these inputs are required. The model is based on the premise that only HQLAs are sold, and otherwise, wholesale funding is attracted. These operations typically require minimal operational intermediation, suggesting that the overall operational workload and processes within banks would remain unchanged. It should be noted that this assumption should be altered when looking at the sale of assets, which requires more operational input to adjust the balance sheet for deposit outflows.
- In this model, there is opted against a microeconomic analysis similar to that in the study by Gross and Letizia (2023) due to the complexities in estimating the DE's utility as mentioned in 4.2. Reflecting on this methodological choice, it becomes evident that while the approach for this thesis enabled us to navigate the complexities of quantifying the DE's utility, it also posed certain limitations. For instance, if the utility of the DE were known, a microeconomic analysis could have offered deeper insights into individual and market behaviours.
- The eventual impact of the introduction of the DE is highly dependent on the adoption of the DE. In this thesis, the choice was made not to research the adoption of a DE due to the difficulties of determining its utility while certain design features are not yet known (Martens, 2021). In the model developed in this thesis, adoption is used as a variable parameter over which different impacts can be determined. The research of Bijlsma et al. (2021) in which it was concluded that 49% of the Dutch population was willing to adopt a DE account that does not offer interest is a guideline to think of real adoption in the Netherlands. This research can be used to interpret the results of this research. Scenario 1 of this research is based on the research of Bijlsma et al. (2021).
- The model assumes that in the worst-case scenarios (3 and 4), everyone is able to transfer the amount the holding limit allows from a bank account to a DE account. This assumption is stretched, as according to CBS (2022), 20% of households have a bank balance of €2500 or less. This means that in order to assess the real impact of these scenarios, data on the distribution of the balances on bank accounts should be available. In this case, the results of this worst-case scenario for scenarios 3 and 4 are higher than in reality. However, one could argue that they are useful to indicate the absolute worst-case results.
- Together with the DNB, there is reflected on the likelihood of the different scenarios (Section 5.7.1). It should be noted that the DNB is playing an active role in promoting the DE. This, while not necessarily the case, could lead to a certain bias in their opinion.
- The model developed in this thesis aggregates the balance sheet of the four biggest banks

in the Netherlands and treats it like one modelled bank. It should be noted that the introduction of the DE will impact individual banks differently. In Appendix C, the data of the individual banks can be seen. Here, it can be seen that the ING has an LCR of 1.34 while the Rabobank has an LCR of 1.73, indicating that the ING will have more liquidity problems due to the introduction of the DE than the Rabobank. However, it is important to consider that the variation in the number of private individuals who hold accounts at different banks could also influence the extent of the impact. For instance, if Rabobank has a larger base of individual clients, this could amplify the impact. These individual differences between banks should be taken into account when interpreting the results.

- The study highlights that deposit outflows from banks can adversely affect their liquidity ratios. Lower liquidity ratios for individual banks may lead to downgraded credit ratings from rating agencies. Consequently, a lower credit rating could increase the cost of borrowing for these banks, as it reflects a higher perceived risk to lenders Fitch (2024).
- In this thesis, the developed model estimates the impact of introducing the DE in the Netherlands on Dutch banks, focusing specifically on banking clients in the Netherlands. It is important to recognize that the DE is a European initiative, and banks such as ING have retail clients across various regions in Europe. Consequently, to accurately assess the impact of the DE on an individual bank like ING, it is crucial to consider the potential migration of deposits from clients in other European countries. This broader perspective is essential to understanding the full scope of the DE's influence on banking institutions operating in multiple European regions.

8.1.2 Development Cost and Impact Payment Income

In this section, there will be reflected on Chapter 6.

- Despite a thorough literature review and research, no significant studies or publications were found that directly address the impact of digital currencies, like the DE, on payment services within banks. This observation underscores the novelty and the emerging nature of the topic. Highlighting this gap emphasizes the need for future research in this area and positions this thesis within the context of a developing field.
- In Chapter 6 it is assumed that periodic revenue out of payment accounts will not be challenged in the short run. This assumption hinges on the fact that intermediaries like banks will be used to offer DE accounts, which they can take on in their normal payment offerings, for which they receive a periodic reward. In the long term, people could choose to take on a bank account less quickly, resulting in the fact that this revenue post for Dutch banks might also decrease.
- In Chapter 6, the financial impact is not researched in depth. However, it can be concluded that the financial impact due to development costs and payment income is dependent on a lot of yet-to-be-determined factors. This, combined with the fact that the ECB is actively promoting the DE as a means of payment, means that it cannot be concluded that financial disintermediation is the biggest threat to Dutch banks. This highly depends on how the remuneration per transaction will look and how the current payment systems in place at banks can integrate with the DE infrastructure.
- One can argue what the point is in developing a DE system that is solely meant as a means of payment. Especially in the context of the Netherlands, as the Netherlands has one of the most digitized payment ecosystems in the entire world McKinsey (2022). Therefore, the added utility of a DE might be limited in the Netherlands. Furthermore, the European Payment Initiative is currently developing a system with the goal of developing a universal European payment system. These two initiatives might overlap with each other.

8.2 Further Research

In this section, suggestions for further research will be given.

- **Different liquidity environment:** Further research could be done to investigate the impact of the DE in varied liquidity environments, moving beyond the 2022 context to understand future implications. Furthermore, the model developed in this thesis could be combined with the existing study of Meller and Soons (2023) to look at how liquidity availability in Europe interconnects with the profit impact for bank(s). To do this, the data underlying the research of Meller and Soons (2023) of all European banks is needed. Furthermore, for different liquidity environments, new options might have to be added to this model, like the possibility of using central bank lending or the option of selling assets.
- **Deep dive into DEs utility:** Currently, it isn't easy to estimate the utility that should be given to the DE and if there is utility at all. Further research could be done to correctly define the utility for Dutch people for the DE to be able to conduct micro-economic analysis. Future research could build upon the study of Gross and Letizia (2023). If this can be obtained, it will also become possible to model the adoption of the digital euro more realistically.
- **Development cost:** For further research on development costs, a comprehensive analysis could be conducted focusing on the expenses associated with integrating the DE into existing banking infrastructures. This study would detail the technological, compliance, and operational costs, differentiating between initial setup and ongoing maintenance expenses. To do this, more specifics about the design features of the DE must be known. Furthermore, there should be looked at the existing payment infrastructure at the researched bank and how this could be integrated with the DE infrastructure to create synergies without compromising the system's self-containment.
- **Impact of remuneration DE:** Further research on payment income in the context of the DE should focus on the implications of transaction remuneration policies. It is crucial to analyze how the fee structures for DE transactions might affect banks' revenue streams. This study should also examine the competitive dynamics in the payment sector, assessing how increased competition, especially from big tech firms, could influence Dutch banks' market share and profitability in payment services. Understanding these dynamics is key to determining the overall impact of the DE on the banking sector's revenue models. This can be done in the future when more is known about the specifics of the DE.
- **Individual banks:** Further research could explore how the DE's introduction impacts individual Dutch banks differently, taking into account their unique balance sheets. A focus on specific metrics, like the LCR and NSFR of each bank, would offer insights into varying levels of susceptibility to liquidity challenges. Analyzing these differences would provide a more granular understanding of the DE's impact on individual banks.
- **Real account balances:** Further research could focus on analyzing the distribution of bank account balances among Dutch households to assess the real impact of worst-case scenarios in the DE's introduction. This study should consider the variability in household bank balances, as indicated by CBS data, to provide a more accurate prediction of the DE's adoption and its implications for the banking sector. This approach would offer a realistic view of potential scenarios, complementing the existing worst-case analyses.
- **More extensive sensitivity analyses:** Further research could explore the sensitivity of the results to the assumptions made, for which no sensitivity analysis is performed in this study. This approach would provide a deeper understanding of how changes in these assumptions might impact the overall conclusions. This is particularly important given the

numerous assumptions that had to be made for this research. This approach will enhance the ability to generalize the findings to various contexts.

8.3 Contribution of this Research

This research marks a significant contribution to the field of banking and digital currencies, being the first to estimate the impact of the DE while focusing on the Dutch banking sector. It stands out by offering a comprehensive view of the DE's introduction, combining both impacts on financial intermediation, development costs, and impact on payment revenues.

The model developed in this thesis to estimate the impact on financial intermediation is built upon the principles of the studies published by BIS (2021) and Meller and Soons (2023). However, the author of this thesis built upon these studies and made significant additions and improvements to make sure the model constructed fits the research goal of this thesis.

Importantly, this study is the first in the literature to make a distinction between types of deposits that might be substituted by the DE, providing a more nuanced understanding of its implications.

Building on the foundation established by Meller and Soons (2023), this study expands the scope of the investigation beyond merely analyzing the impact on liquidity ratios to a hypothetical worst-case deposit outflow scenario. It further explores the implications of such outflows, translating these liquidity impacts into an earnings impact.

Additionally, compared to BIS (2021) an important addition is that this study does not use the average net interest income of a group of banks to determine the impact on the earnings of a bank but considers the funding cost of different types of funding lost to the digital euro, leading to a more accurate annual earnings impact.

Overall, this study pioneers the use of scenario analysis based on data reflective of Dutch society, offering insights grounded in real-world context. This research stands out as the first to integrate various adoption levels with different utilization scenarios, moving beyond the focus of the worst-case scenario commonly seen in other published studies.

This research paves the way for future studies and provides valuable guidance for policymakers and financial institutions navigating the evolving landscape of digital currencies.

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Appendix A

Literature Review

A.1 PRISMA Flow Diagram:

In this section, the various steps within the PRISMA flow diagram are handled:

1. Preparation. Downloading the PRISMA diagram from the internet.
2. Database Search: Conducting individual searches in various databases (with the search query of Search Query) using relevant search terms and finding the total number of studies.
3. Remove All Duplicates: Use citation software to remove duplicate articles from the search results. This is done manually in this paper, as can be seen in Double Papers (X.A.3).
4. Records Screened or Title/Abstract Screening: Determining the number of articles to be screened by subtracting the number of removed duplicates from the total number of records.
5. Records Excluded or Title/Abstract Screening: Screening both the title and abstract of the remaining articles and exclude those that are not relevant (for the chosen research).
6. Reports Sought for Retrieval: Calculate the number of articles for full-text screening by subtracting the number of excluded records from the total number screened at the title/abstract level.
7. Reports Not Retrieved: List the number of articles for which you were unable to acquire the complete text.
8. Reports Assessed for Eligibility - Full Text Screening: Read the full text of the relevant reports to see if they qualify for the systematic review.
9. Reports Excluded: After full-text screening, write down the total number of excluded articles and provide reasons for their exclusion.
10. Included Studies: Subtract the number of excluded records from the total number of articles assessed for eligibility.

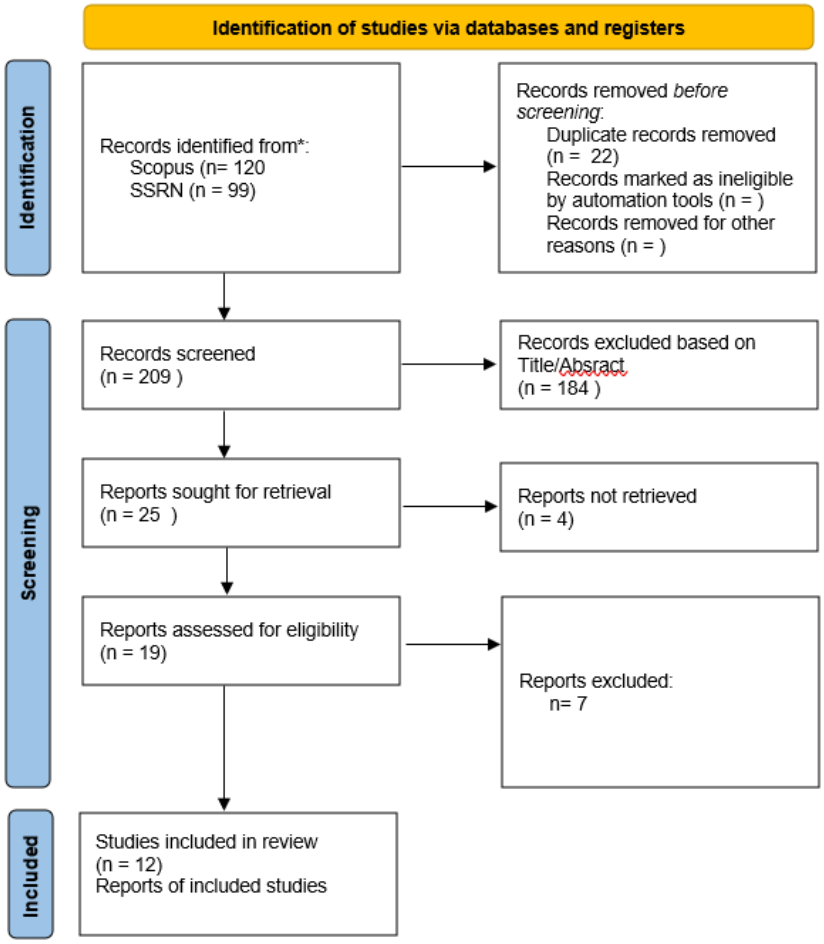

Figure A.1: Prisma Flow Diagram (Page et al, 2021).

A.1.1 Selected articles:

	Title	Author	Subjects	year
1.)	A central bank digital currency in a heterogeneous monetary union: Managing the effects on the bank lending channel	Paolo Fegatelli	Applying DVH theoretical framework to asses banks impact (has formula for bank profit)	2022
2.)	Central bank digital currency, loan supply, and bank failure risk: a microeconomic approach	Jooyong Jun and Eunjung Yeo	Micro-economic model to asses impacts on banks	2021
3.)	Central Bank Digital Currency: Scenarios of Implementation and Potential Consequences for Monetary System	Patryk Kaczmarek	Potential impact banking sector based on scenarios. (Qualitative)	2021
4.)	Let the Digital Euro Circulate: Introducing a Retail C.B.D.C. in the Eurozone With Unlimited Holdings by Users	Mark Warren	Why a holding limit is not necessary (Qualitative)	2022
5.)	Central bank digital currency and bank intermediation	Adalid et al.	Impact euro area banks' balance sheets and activity (Qualitative)	2022
6.)	On the equivalence of private and public money	Brunnermeier and Niepelt	When does a swap between private and public money leave the equilibrium allocation and price system unchanged?	2019
7.)	Adoption and Implications of CBDC: An Agent-Based Modelling Approach	Martens	Agent based modelling	2021
8.)	DNB holding limits	Meller and Soons	Model to asses impact for different holding limits	2022
9.)	Digital currencies in financial networks	Castrén et al.	Financial accounts network to determine effect of introducing CBDC	2022
10.)	Central bank digital currencies: financial stability implications	BIS	Holding liquidity constant by acquiring HQLAS	2021
11.)	Resilience of bank liquidity ratios in the presence of a central bank digital currency	Gorelova et al.	Financial impact of adoption CBDC when funding can be replaced by funding with a higher run-off rate	2022
12.)	To Demand or Not to Demand: On Quantifying the Future Appetite for CBDC	Gross and Letizia	e upper bound estimates of actual CBDC take-up, under different assumptions of CBDC renumeration	2023

Figure A.2: Selected articles for the literature review.

Appendix B

NSFR and LCR

In this appendix, it can be seen how balance sheet items contribute to the NSFR and the LCR for a bank.

B.1 LCR

To determine how balance sheet items should count to the HQLA and net cash outflows two tables were retrieved from BIS (2013) which is the latest update on the LCR. In B.1 it can be seen how different balance sheet items count towards HQLA. To determine the net cash outflow during a 30-day stress period Figure B.2 and B.3 have to be considered.

Item	Factor
Stock of HQLA	
A. Level 1 assets:	
• Coins and bank notes • Qualifying marketable securities from sovereigns, central banks, PSEs, and multilateral development banks • Qualifying central bank reserves • Domestic sovereign or central bank debt for non-0% risk-weighted sovereigns	100%
B. Level 2 assets (maximum of 40% of HQLA):	
Level 2A assets	
• Sovereign, central bank, multilateral development banks, and PSE assets qualifying for 20% risk weighting • Qualifying corporate debt securities rated AA- or higher • Qualifying covered bonds rated AA- or higher	85%
Level 2B assets (maximum of 15% of HQLA)	
• Qualifying RMBS • Qualifying corporate debt securities rated between A+ and BBB- • Qualifying common equity shares	75% 50% 50%
Total value of stock of HQLA	

Figure B.1: HQLA (BIS, 2013).

Cash Outflows	
A. Retail deposits:	
Demand deposits and term deposits (less than 30 days maturity) • Stable deposits (deposit insurance scheme meets additional criteria) • Stable deposits • Less stable retail deposits	 3% 5% 10%
Term deposits with residual maturity greater than 30 days	0%
B. Unsecured wholesale funding:	
Demand and term deposits (less than 30 days maturity) provided by small business customers: • Stable deposits • Less stable deposits	 5% 10%
Operational deposits generated by clearing, custody and cash management activities • Portion covered by deposit insurance	25% 5%
Cooperative banks in an institutional network (qualifying deposits with the centralised institution)	25%
Non-financial corporates, sovereigns, central banks, multilateral development banks, and PSEs • If the entire amount fully covered by deposit insurance scheme	40% 20%
Other legal entity customers	100%
C. Secured funding:	
• Secured funding transactions with a central bank counterparty or backed by Level 1 assets with any counterparty. • Secured funding transactions backed by Level 2A assets, with any counterparty • Secured funding transactions backed by non-Level 1 or non-Level 2A assets, with domestic sovereigns, multilateral development banks, or domestic PSEs as a counterparty • Backed by RMBS eligible for inclusion in Level 2B • Backed by other Level 2B assets • All other secured funding transactions	0% 15% 25% 25% 50% 100%
D. Additional requirements:	
Liquidity needs (eg collateral calls) related to financing transactions, derivatives and other contracts	3 notch downgrade
Market valuation changes on derivatives transactions (largest absolute net 30-day collateral flows realised during the preceding 24 months)	Look back approach
Valuation changes on non-Level 1 posted collateral securing derivatives	20%
Excess collateral held by a bank related to derivative transactions that could contractually be called at any time by its counterparty	100%
Liquidity needs related to collateral contractually due from the reporting bank on derivatives transactions	100%

Figure B.2: Net cash outflows 30-day stress period (BIS, 2013).

Increased liquidity needs related to derivative transactions that allow collateral substitution to non-HQLA assets	100%
ABCP, SIVs, conduits, SPVs, etc:	
• Liabilities from maturing ABCP, SIVs, SPVs, etc (applied to maturing amounts and returnable assets)	100%
• Asset Backed Securities (including covered bonds) applied to maturing amounts.	100%
Currently undrawn committed credit and liquidity facilities provided to:	
• retail and small business clients	5%
• non-financial corporates, sovereigns and central banks, multilateral development banks, and PSEs	10% for credit 30% for liquidity
• banks subject to prudential supervision	40%
• other financial institutions (include securities firms, insurance companies)	40% for credit 100% for liquidity
• other legal entity customers, credit and liquidity facilities	100%
Other contingent funding liabilities (such as guarantees, letters of credit, revocable credit and liquidity facilities, etc)	National discretion
• Trade finance	0-5%
• Customer short positions covered by other customers' collateral	50%
Any additional contractual outflows	100%
Net derivative cash outflows	100%
Any other contractual cash outflows	100%
Total cash outflows	

Figure B.3: continued: Net cash outflows 30-day stress period (BIS, 2013).

B.2 NSFR

To determine how balance sheet items should count to the RSF and the ASF two tables were retrieved from BIS (2014) which is the latest update on the NSFR. In figure B.4 it can be seen how difference balance sheet items count towards the available stable funding, which is used as input for the NSFR. To determine the NSFR it should also be known how the required stable funding should be built up, this can be seen in B.5.

Summary of liability categories and associated ASF factors — Table 1

ASF factor	Components of ASF category
100%	• Total regulatory capital (excluding Tier 2 instruments with residual maturity of less than one year) • Other capital instruments and liabilities with effective residual maturity of one year or more
95%	• Stable non-maturity (demand) deposits and term deposits with residual maturity of less than one year provided by retail and small business customers
90%	• Less stable non-maturity deposits and term deposits with residual maturity of less than one year provided by retail and small business customers
50%	• Funding with residual maturity of less than one year provided by non-financial corporate customers • Operational deposits • Funding with residual maturity of less than one year from sovereigns, PSEs, and multilateral and national development banks • Other funding with residual maturity between six months and less than one year not included in the above categories, including funding provided by central banks and financial institutions
0%	• All other liabilities and equity not included in the above categories, including liabilities without a stated maturity (with a specific treatment for deferred tax liabilities and minority interests) • NSFR derivative liabilities net of NSFR derivative assets if NSFR derivative liabilities are greater than NSFR derivative assets • "Trade date" payables arising from purchases of financial instruments, foreign currencies and commodities

Figure B.4: Available stable funding (BIS, 2014).

Summary of asset categories and associated RSF factors — Table 2

RSF factor	Components of RSF category
0%	• Coins and banknotes • All central bank reserves • All claims on central banks with residual maturities of less than six months • "Trade date" receivables arising from sales of financial instruments, foreign currencies and commodities.
5%	• Unencumbered Level 1 assets, excluding coins, banknotes and central bank reserves
10%	• Unencumbered loans to financial institutions with residual maturities of less than six months, where the loan is secured against Level 1 assets as defined in LCR paragraph 50, and where the bank has the ability to freely rehypothecate the received collateral for the life of the loan
15%	• All other unencumbered loans to financial institutions with residual maturities of less than six months not included in the above categories • Unencumbered Level 2A assets
50%	• Unencumbered Level 2B assets • HQLA encumbered for a period of six months or more and less than one year • Loans to financial institutions and central banks with residual maturities between six months and less than one year • Deposits held at other financial institutions for operational purposes • All other assets not included in the above categories with residual maturity of less than one year, including loans to non-financial corporate clients, loans to retail and small business customers, and loans to sovereigns and PSEs
65%	• Unencumbered residential mortgages with a residual maturity of one year or more and with a risk weight of less than or equal to 35% under the Standardised Approach • Other unencumbered loans not included in the above categories, excluding loans to financial institutions, with a residual maturity of one year or more and with a risk weight of less than or equal to 35% under the standardised approach
85%	• Cash, securities or other assets posted as initial margin for derivative contracts and cash or other assets provided to contribute to the default fund of a CCP • Other unencumbered performing loans with risk weights greater than 35% under the standardised approach and residual maturities of one year or more, excluding loans to financial institutions • Unencumbered securities that are not in default and do not qualify as HQLA with a remaining maturity of one year or more and exchange-traded equities • Physical traded commodities, including gold
100%	• All assets that are encumbered for a period of one year or more • NSFR derivative assets net of NSFR derivative liabilities if NSFR derivative assets are greater than NSFR derivative liabilities • 20% of derivative liabilities as calculated according to paragraph 19 • All other assets not included in the above categories, including non-performing loans, loans to financial institutions with a residual maturity of one year or more, non-exchange-traded equities, fixed assets, items deducted from regulatory capital, retained interest, insurance assets, subsidiary interests and defaulted securities

Figure B.5: required stable funding (BIS, 2014).

Appendix C

Model Bank

In Table C the data of individual banks and the total data for the modelled bank can be found. This data is extracted from the year and pillar 3 reports of these banks (AMRO (2022), ING Group (2023), Rabobank (2022a), Volksbank (2023)).

Bank	**Deposits (million)**	**Profit (million)**	**HQLA (million)**	**net cash outflows (million)**	**LCR**	**RSF (million)**	**ASF (million)**	**NSFR**
Rabobank	396,500	2,786	173,182	99,919	173%	334,668	437,252	131%
Volksbank	44,501	174	13,140	3,309	397%	37,140	64,637	174%
ING	640,770	3,674	186,700	139,103	134%	509,506	672,569	132%
ABN AMRO	255,000	1,867	103,019	71,374	144%	189,530	252,330	133%
Total	1.336.771	8.501	476.041	313,705	152%	1,070,844	1,426,788	134%

Table C.1: variables of the individual banks and the total for the modeled bank

Appendix D

Graphs Results Financial Intermediation

In this section, the results for the different scenarios are presented. The results for the different output parameters of the model are presented against the adoption of the digital euro in these graphs. The dotted line in these figures represents the adoption point of 49% as researched by Bijlsma et al. (2021) with the corresponding output parameter.

D.1 Scenario 1

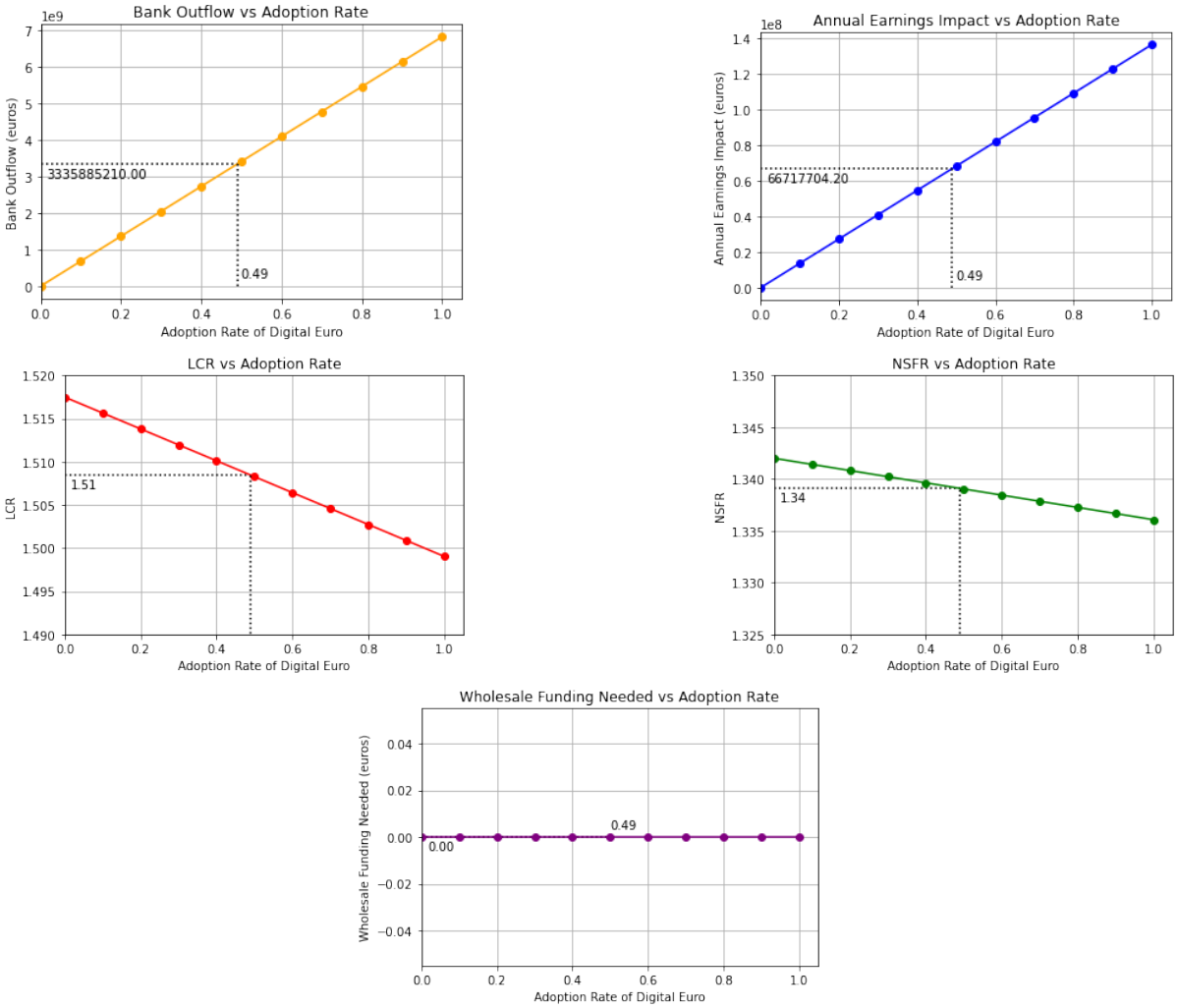

Figure D.1: Graphs of results scenario 1.

D.2 Scenario 2

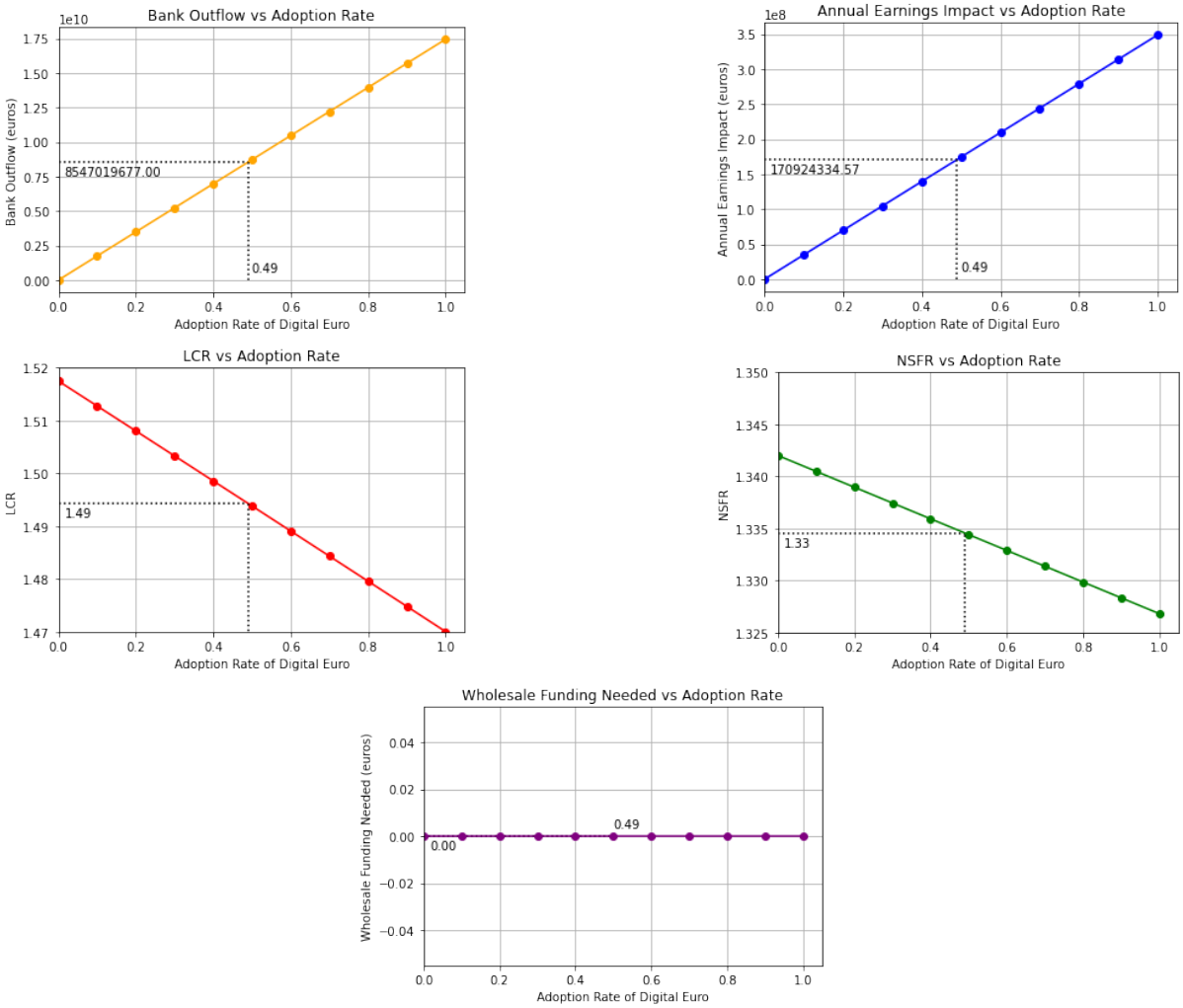

Figure D.2: Graphs of results scenario 2.

D.3 Scenario 3

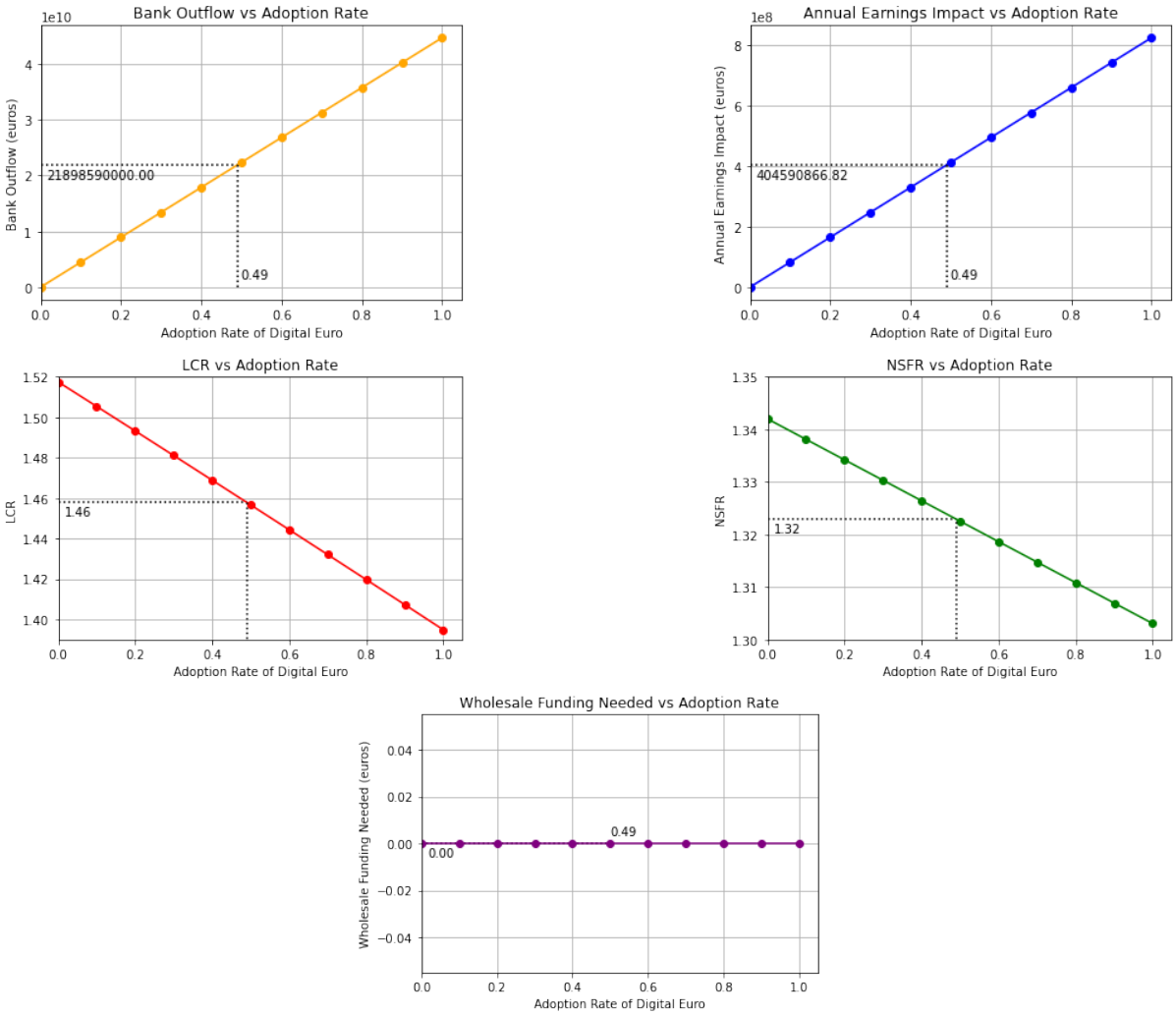

Figure D.3: Graphs of results scenario 3.

D.4 Scenario 4

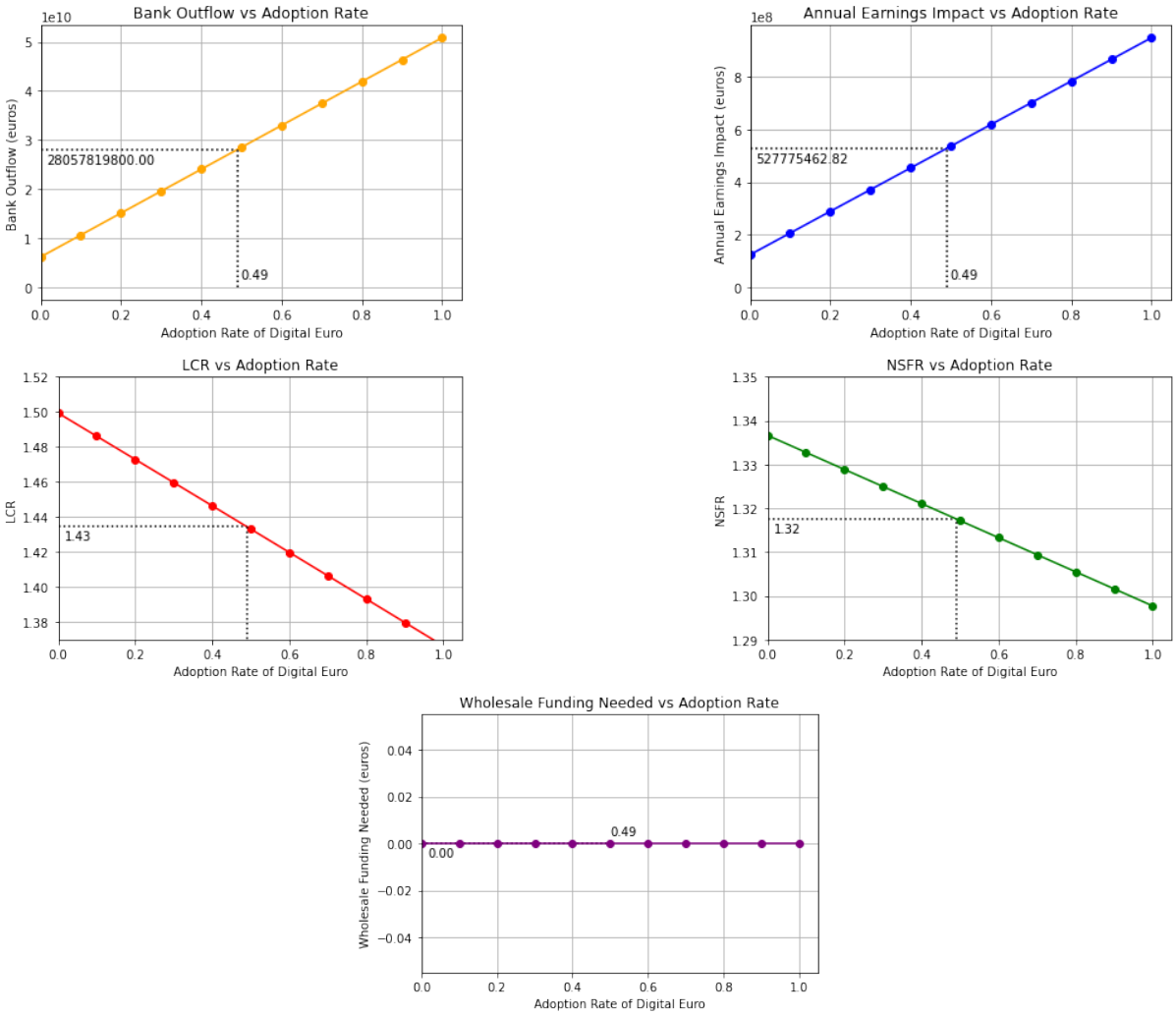

Figure D.4: Graphs of results scenario 3.