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THE IMPACT OF THE INTRODUCTION OF THE DIGITAL EURO ON FINANCIAL STABILITY: AN OUTLOOK ON BANKS REACTION TO DEPOSITS OUTFLOW

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Abstract

The Digital Euro is a digital currency, to be issued by the ECB and made available to residents of the Euro Area. This thesis examines the potential systemic impact of CBDC on financial stability, with a focus on banks' balance sheets. The study investigates the implications of liquidity risk, addressing gaps in the existing literature and providing a comprehensive analysis of key balance sheet components. By exploring a scenario with no holding limits, the research offers insights into strategic and regulatory challenges associated with CBDC integration, intending to ensure stability and resilience in the financial system.

Keywords

Digital Euro; Financial stability; Deposits outflow; Funding sources; Liquidity risks; NPL ratio; Bank risk

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1. Introduction

1.1. What is the Digital Euro? - Overview

The global financial scene is in constant transformation with the swift advancement of digital technologies and the digitisation of payments, as exemplified by the widespread adoption of digital wallets. With the intention to maintain monetary and financial stability and ensure the smooth functioning of the payments system, central banks are increasingly considering the inception of a Central Bank Digital Currency (CBDC). In fact, a report by the Bank for International Settlements, shared how eighty-four of eighty-six central banks[1] in 2023 were investigating CBDCs (Iorio, Kosse, and Mattei 2024). The introduction of a Euro Area (EA) CBDC - the Digital Euro - could represent a significant advance in currency digitisation, but it could also have considerable downturns for financial stability, the role of the monetary authority and the efficiency of the payment framework.

Building on existing initiatives, the Digital Euro aims to address gaps left by current systems. For instance, the European Payments Initiative (EPI) was created to build a European-wide digital payment framework, aiming to provide a viable alternative to the current reliance on non-European card schemes (Mai 2023). In parallel, instant payment infrastructures like the TARGET Instant Payment Settlement (TIPS) and RT1 systems have been developed to support faster, cross-border payments across the euro area (Passacantando 2022). While these initiatives represent progress, they have not yet achieved full coverage or adoption, leaving Europe's payment structure fragmented.

[1] The sample was composed of eighty-six respondents (central banks), which accounts for ninety-four percent of global economic production, and eighty-one percent of the global population. In addition, thirty-three percent of central banks of the sample correspond to advanced economies and sixty-seven percent represent emerging markets and developing economies (Iorio, Kosse, and Mattei 2024).

The Digital Euro's proposal consists of a liability for the ECB, captured in digital form, that complements cash and bank deposits. It is designed as a retail[2], non-interest bearing, Central Bank Digital Currency (CBDC), in accordance with the current proposal for regulation of the Digital Euro (European Commission 2023).

In contrast to cryptocurrencies, a Digital Euro would be backed by the same institution that backs cash – the ECB. Furthermore, it would always be worth its face value, just as cash is. It will be free of charge for natural persons for any digital payment (European Commission 2023, 42, 43, 47, 48). From the perspective of legal persons, the CBDC will be able to be accepted as means of exchange. Indeed, the proposal for a regulation alludes to the attribution of the legal tender status to the Digital Euro, leaving merchants with no option other than mandatory acceptance[3] (European Commission 2023, 5, 12).

1.2. Thesis Statement and Objectives

This thesis examines the possible systemic effects of implementing a CBDC to the financial stability of the EA, with a specific emphasis on how it may affect bank's balance sheets. Its objectives include examining the effect on capital adequacy, credit risk, as well as liquidity risk, so to fill the gaps in literature, and deliver a holistic perspective of the principal components of bank balance sheets. The scope of research is geographically confined to the Euro Area, and it is premised on the assumption that there are no holding limits for retail users

[2] While a retail CBDC is designed for the public to hold digital central bank money, a wholesale CBDC is intended for authorized financial institutions to use (similar to digital reserves of the central bank). The Digital Euro's proposal to be only a retail CBDC stems from the already well-regulated framework for digital wholesale payments (with TARGET2), CB-money securities settlement (with TARGET2 SECURITIES), as well as for instant payments (with TIPS).

[3] Although merchants will be obliged to accept the CBDC as a means of payment, the application of a zero-holding limit to this group is on the table. In this scenario, the amounts received in Digital Euro would be reversed into physical Euro via a "waterfall" mechanism (European Central Bank 2024a, 7).

of the Digital Euro, considering the present situation where the European competent authorities are still debating the specific limits to be implemented.

This research is timely, considering the ECB's continuing progress on the development of the Digital Euro, with a decision on its launch anticipated by October 2025 (European Central Bank 2024a). Overall, the thesis aims to contribute valuable insights into the strategic planning and regulatory frameworks necessary for the seamless integration of the Digital Euro in the financial system.

2. The Case for the Digital Euro

2.1. Motivation and Institutional Support

The potential introduction of a retail digital euro has collected strong encouragement from key European institutions, including the ECB, Member States, and the European Parliament (European Commission 2023). During the Euro Summit in March 2021, Member Countries urged for more robust payment systems as well as a more creative and effective digital financial sector, promoting preliminary research into the potential launch of a digital euro (European Council 2021). This came after the Council and European Commission jointly issued a statement in 2019, emphasizing the potential risks of "stablecoin" initiatives reaching a global scale (European Council 2019), and incentivizing the ECB, in addition to further central banks and national authorities to access the pros and cons of central bank digital currencies and to foster discussions with European payment actors on how the private sector can help fulfil the demand for fast, easy and affordable cross-border payments. In 2022, the Council Recommendation on the Economic Policy of the Euro Area highlighted the potential of a digital

euro to support public digital money, promote innovation, and enhance the euro's international position and the open strategic autonomy of the Union (European Council 2022).

Today, 13 out of 20 EA countries rely primarily on international card schemes for digital payments (European Central Bank 2024a). This reliance not only raises concerns about resilience but also limits the ability of the European Union to maintain control over its financial systems, especially in a politically fragmented global economy. A digital euro could supply a safe, effective, and widely accepted payment option within the EA, aligning with Europe's long-term economic and geopolitical interests.

With this institutional backing and strategic motivation in place, it is essential to analyse the practical implications the Digital Euro could bring upon the financial system. The following section expands on the foreseen impacts of Digital Euro.

2.2. Implications of the Digital Euro

This section explores how Digital Euro is being conceived to strengthen retail payments, foster competitiveness and innovation, and safeguard the financial stability and sovereignty of the EA, by assessing its potential to modernise payments and financial operations across member states.

Enhancement of Retail Payments

The ability of the EU to keep control over its payment systems and lessen dependency on non-European service providers is known as strategic autonomy in the payments sector. According to Article 127[3] of the Treaty on the Functioning of the European Union (TFEU), the ECB and the European System of Central Banks (ESCB) have the mission to guarantee "the smooth operation of payment systems" (European Union 2016). This duty is reinforced in Article 22[4] from the Statute of the ESCB and the ECB, clearly stating that the ECB and national central banks can and should establish policies and services that ensure that payment and money

transfer systems operate consistently and smoothly both inside the EU and with other nations (European Central Bank 2011). In short, these articles mandate the ESCB - which includes the Eurosystem - to promote efficient and secure payment systems, as well as to implement the necessary regulations to do so, with the goal of safeguarding the stability and integrity of the EA's payment structure.

CBDCs offer a secure, flexible and efficient form of digital currency, allowing seamless integration into existing financial systems (Ulrich Bindseil, Panetta, and Terol 2021). By adopting CBDCs, central banks can ensure that their monetary systems remain resilient and adaptable to technological advances. Today, the infrastructure supporting international payments and transfers remains fragmented, ineffective and expensive, resulting in significant delays and high charges. One of the key potential applications of CBDCs is in cross-border payments. An EA CBDC could represent the much-needed solution and help to streamline these processes, thereby reducing costs and fostering greater integration of the global financial system. The efficiency of worldwide trade as well as economic cooperation would increase, benefiting both consumers and businesses, if an EA CBDC is able to facilitate seamless cross-border transactions (European Central Bank 2020).

Promotion of Competition and Innovation

The current European payment's structure is heavily dependent on non-European providers, as expressed several times by the ECB (European Central Bank 2022). Global payment services providers (e.g., Visa, Mastercard, and American Express) easily dominate digital payments within the EA and have control over a significant share of cross-border transactions and card payments (European Central Bank 2019). These non-European card and mobile/online payment providers are currently the only ones to facilitate cross-border euro transactions inside the monetary union (Mai 2023). Euro cash is the only truly European solution that functions throughout the union, but cash usage is declining (Khiaonarong & Humphrey 2022, 3) .

The institution of a CBDC is designed to foster greater competition within the retail payments market. Presently, the market is dominated by a few key players in the private sector, which can result in inefficiencies, high fees, and limited consumer choice (Wong and Maniff 2020). On the authority of the European Central Bank, the advent of a public digital currency could serve to diversify the market by introducing a new, state-backed player. Such a measure may contribute to a reduction in market concentration, thus fostering a more competitive environment that benefits consumers through a reduction in transaction costs, an improvement in service quality, and an expansion of access to payment services (European Commission 2023; European Central Bank 2020).

The advent of Digital Euro also represents a monumental opportunity for the advancement of financial inclusion within the European Union and beyond. It is estimated that a significant proportion of the population is still unable to access fundamental financial services (WSBI-ESBG 2022), a shortcoming that could potentially be addressed through the introduction of CBDCs (Lannquist and Tan 2023, 37 While the Payment Accounts Directive (Directive 2014/92/EU 2014) has the goal to guarantee all individuals have access to fundamental financial services, encompassing payment accounts, the Digital Euro builds upon this directive by including several measures to address broader barriers to financial inclusion. These include an offline functionality, which enables access in areas with poor internet connectivity, as well as compliance with the European Accessibility Act (Directive (EU) 2019/882 2019) to ensure usability for individuals with disabilities, and the availability of a physical payment-card for those with low digital literacy or without smartphones. Additionally, onboarding processes through public entities (e.g.: postal offices) will facilitate access for unbanked and vulnerable populations, while support in all EU languages and a universally designed app will further increase accessibility (European Central Bank 2023a).

It is reasonable to assume that the implementation of the digital euro will play an instrumental role in the advancement of these objectives, offering enhanced and secure means of payment.

Safeguarding Public Money as the Monetary System Anchor

The issuance of public money by central banks has long been regarded as a fundamental component of the monetary system. Its distinctive attributes, most notably its legal tender status and the absence of default and liquidity risks, contribute to its reputation as the safest form of money. In this context, the inception of a Digital Euro is regarded as a crucial milestone in safeguarding the role of public money in the financial system. Such a measure would help to maintain the convertibility of private bank deposits at par with public money, which is essential for maintaining the trust of the public in the currency and the stability of the financial system (Ulrich Bindseil, Panetta, and Terol 2021).

Furthermore, CBDC could strengthen the resilience of the monetary system by ensuring a stable and secure digital alternative to private money during times of financial instability. In periods of crisis, confidence in commercial banks may erode, leading to runs on deposits. Without the availability of central bank money, such scenarios could lead to significant liquidity shortages and threaten financial stability. A CBDC would offer a digital haven for public savings, mitigating the risk of destabilizing shifts between private and public money and reducing the likelihood of large-scale bank runs (Ulrich Bindseil, Panetta, and Terol 2021).

Preservation of Financial Stability

The Digital Euro may bolster monetary sovereignty through the reinforcement of the Euro's dominance in the EU and countering displacement by private digital currencies. As a state-backed, risk-free alternative, it enhances financial stability by reducing dependence on volatile private digital assets (Lambert et al. 2024).

During periods of economic stress, a digital euro mitigates risks of depositors shifting funds to private or foreign assets, preserving bank liquidity. Safeguards, such as holding limits, are necessary to prevent significant outflows from commercial banks, ensuring stability while limiting large-scale withdrawals (Lambert et al. 2024).

The following section oversees the possible impacts on financial stability, considering the chance of bank disintermediation.

3. Impact on Financial Stability: Bank Disintermediation

3.1. Substitutability between the Digital Euro, cash and deposits

The Digital Euro will behave as a store of value instrument and a means of exchange. Taking that into account, a competitive dynamic between the Digital Euro, the physical Euro and deposits will emerge. Because of this, substitutability among the three assets is estimated to certain degree (Adalid et al. 2022, 7; Burlon et al. 2022, 7; Huynh et al. 2020, 22; Jiang 2020, 3-5; Lambert et al. 2024, 4; Li, Usher, and Zhu 2024, 24-26).

The substitutability between the physical and the digital Euro represents merely the transformation of one type of central bank money – coins and banknotes – into another–digital money. In this scenario, a decline in Euro coins and banknotes and an increase in Digital Euro will be registered on both households and Eurosystem balance sheets. In this context, banks' balance sheet will be not affected (Bindseil 2020, 9; Bindseil and Panetta 2020, 2; Lambert et al. 2024, 4).

By contrast, the substitutability between deposits and the Digital Euro will pose implications for banks' balance sheet via a decrease in deposit funding (Adalid et al. 2022, 7-12; Burlon et al. 2022, 4-5; García et al. 2020, 1; Li, Usher, and Zhu 2024, 23-26). Considering the case of

the Digital Euro, which is most likely to be non-interest bearing and available only for use by natural persons, it is expected to decrease demand deposit funding provided by retail customers (García et al. 2020, 2; Gorelova, Lands, and teNyenhuis 2022, 2; Meller and Soons 2023, 4; Usher et al. 2021, 7).

Besides the Digital Euro's direct competition with retail demand deposits, its attractiveness over other types of retail deposits should also be acknowledged. This will depend on the prevailing interest rate environment. A non-remunerated Digital Euro would be less attractive than savings and term deposits in a positive interest rate environment but much more desirable during periods of low or even negative interest rates (Adalid et al. 2022, 7). With that in mind, different levels of substitutability may occur across different macroeconomic cycles *ceteris paribus*[4] (Li, 2021; Nocciola and Zamora-Pérez 2024).

3.2. Structural bank disintermediation: a definition

The substitutability between retail deposits and the Digital Euro naturally leads to 'bank disintermediation' – a process characterized by the shrinking of banks' balance sheet due to a decrease in retail deposits (Carapella and Jean Flemming 2020)

Assuming banks behave as intermediaries in the distribution of the Digital Euro, this reduction in retail demand deposit funding is paired with a decrease in banks' own excess reserves (Figure 1). In more detail, banks acquire the Digital Euro by purchasing it from the Eurosystem using their own reserves. Subsequently, they facilitate the exchange of demand deposits for the Digital Euro with retail customers (Adalid et al. 2022, 15-16).

[4] Apart from the remuneration earned, other factors – such as perceived acceptance, privacy, branch network, possibility of obtaining complementary financial products – may influence the level of substitutability between deposits and the Digital Euro (Li, 2021; Li et al., 2024; Nocciola and Zamora-Pérez 2024).

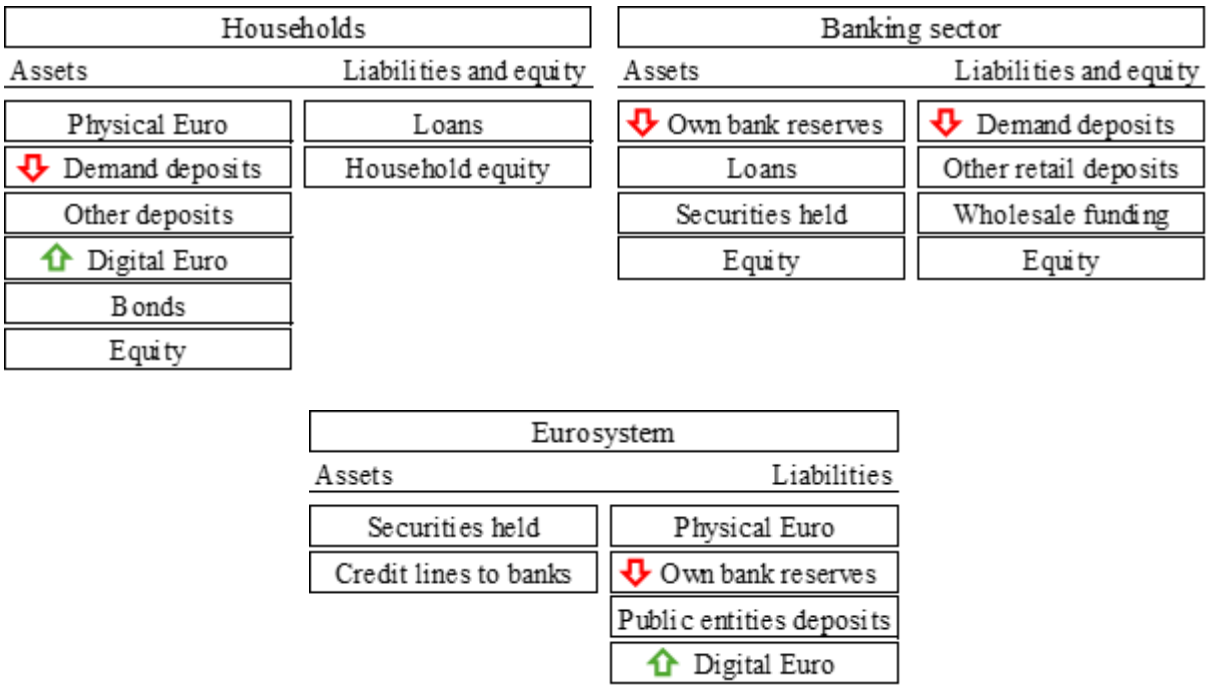

Figure 1 - *Bank disintermediation mechanism*

Source: Own elaboration

The concept of bank disintermediation can be categorized into two facets: (i) structural disintermediation, which refers to the one-off decrease in deposits by the inception of the CBDC; and (ii) cyclical disintermediation, where banks suffer further deposit outflows throughout periods of financial distress (Adalid et al. 2022, 35-43; Bindseil 2020, 13-16; Carapella et al. 2024, 16-18; Landau 2021, 16; Williamson 2022).

4. INDIVIDUAL PART

4.1. Introduction on the impact of Digital Euro on deposits

As proposed by the European Central Bank (ECB), the introduction of a Digital Euro in the euro area is intended to serve as a complementary alternative to cash and deposits, with policy makers aiming to prevent any potential destabilising effects on the traditional banking sector's deposit base (Clemens, et al. 2021). Nevertheless, the introduction of a CBDC may result in a partial relocation of household and business deposits away from commercial banks, which could impact the structure of banks' liabilities and necessitate adaptations, potentially through increased deposit interest rates or alternative funding source (Brunnermeier and Niepelt 2019).

The following sections are focused on a central research question. The aim is to investigate how banks respond to a reduction in deposits and to analyse the implications of these responses in the context of the Digital Euro. The objective of this question is to identify the mechanisms through which banks adapt to changes in their funding structures when confronted with deposit outflows, a scenario that is likely to be exacerbated by the adoption of a central bank digital currency (CBDC). In particular, it will contribute to the existing literature by empirically investigating how banks have responded to deposit outflows in recent years (sample with data from 1995 to 2024).

Specifically, it will examine how deposit outflows have affected the non-performing loan (NPL) ratio, a critical indicator of credit risk and financial health. This will be achieved through the implementation of a regression model that quantifies the relationship between deposit outflows and changes in the NPL ratio, across a sample of European banks. This approach enables an examination of how liquidity constraints, stemming from fluctuations in deposits, impact a bank's loan portfolio and, subsequently, its overall stability.

Furthermore, the analysis is extended to encompass macroeconomic factors, such as GDP growth, in order to gain insight into the manner in which broader economic conditions interact with banks' responses to liquidity challenges.

4.2. Bank Reactions to Deposit Outflows and Systemic Risk

A significant concern associated with potential CBDC implementation is the possibility of deposit outflows from traditional banking institutions. This is due to the potential for consumer demand to shift towards a central bank-backed digital currency, driven by the perceived advantages in terms of liquidity and safety, over traditional forms of deposits. Such a shift could result in a fundamental alteration to the funding structure of banks, with significant implications for their liquidity, profitability and capacity to provide credit to the broader economy.

It is anticipated that this partial substitution will be tempered by the design of the CBDC, particularly in regard to potential holding limits and the differential between CBDC interest rates and those of commercial deposits. A number of studies have indicated that should the digital euro offer a competitive rate or become a close substitute for deposits, banks may be required to raise deposit rates in order to retain customers. While an increase in deposit rates may lead to an expansion in lending, it could also result in a rise in lending rates, potentially leading to a contraction in credit supply (Andolfatto 2021, Chiu, et al. 2019). As an alternative, banks may adjust their balance sheets through the utilisation of central bank funding or market funding, or by means of asset liquidations. However, these shifts have the potential to affect profitability or capital adequacy (Brunnermeier and Niepelt 2019).

This section will undertake a comprehensive review of existing literature, with a particular emphasis on three major areas: (1) the impact of CBDCs on deposit outflows from banks, (2)

alternative funding mechanisms that could replace lost deposits, and (3) the effects on banks' risk appetite and the discipline of the market.

The magnitude of potential deposit outflows depends primarily on the extent to which CBDCs can be considered as substitutes for traditional bank deposits. In the study conducted by Keister and Sanches (2023), the potential for CBDCs to become close substitutes for bank deposits is emphasised, particularly if they offer comparable liquidity services and competitive interest rates. In such scenarios, the advent of CBDC may prompt households to redirect a considerable portion of their deposits to these new alternatives, consequently diminishing the stability of banks' financial resources. The transition from deposit outflows to CBDC could prompt banks to elevate interest rates on deposits in an endeavour to maintain patronage, which could in turn augment banks' funding expenses and potentially diminish their net interest margins (Keister and Sanches 2023).

The framework in question has been significantly expanded upon in a study conducted by Chen and Filippin in 2023. In this work, the authors investigate the substitutability of central bank digital currencies (CBDCs) and traditional bank deposits. They find that even partial substitutability has the potential to result in significant outflows, particularly under specific conditions (Chen and Filippin 2023). In particular, the acceptance of CBDCs for retail transactions and their provision of secure, real-time settlement may encourage consumers to prefer holding their funds in CBDCs over bank deposits, particularly during periods of economic stress. It is during periods of financial crisis, in particular, that we might observe the most significant outflows from deposit accounts. This is because consumers may perceive central bank-backed CBDCs as a safer option than bank deposits, which are subject to a certain degree of credit risk (Chen and Filippin 2023).

As banks may potentially experience a reduction in deposits as a result of the introduction of CBDCs, it will be necessary for them to identify alternative sources of funding in order to replace the liquidity and stability that have traditionally been provided by deposits.

One potential solution to address the issue of deposit outflows is the pass-through Model, in which the central bank provides funding to banks in a manner that is proportional to the deposit shortfall that may result from the introduction of CBDCs. In their study, Brunnermeier and Niepelt (2019) posit that the central bank can offer loans on conditions analogous to those of deposits, thereby ensuring that banks can maintain their lending capacity and operations despite a reduction in deposits. In such scenarios, the central bank funding serves to replace the deposit loss, thereby preserving the ability of banks to create credit and support economic growth. The central bank would act as an agent between deposit holders and banks, providing stable funding without significantly altering the overall capital structure of the banking system (Brunnermeier and Niepelt 2019).

However, it should be noted that central banks typically impose collateral requirements when lending to commercial banks. These requirements could potentially result in additional constraints on banks' ability to secure central bank funding, particularly during periods of economic stress when the value of collateral may decline (Chen and Filippin 2023).

In the event of an insufficient level of central bank funding, banks may seek to utilise alternative private funding sources, such as wholesale funding or short-term debt, in order to replace the deposits that have been lost.

As observed by Piazzesi and Schneider (2022), the utilisation of wholesale markets can result in elevated liquidity risks, particularly in the context of volatile financial environments. In particular, market funding is more costly and less stable than retail deposits, resulting in

increased vulnerability to funding shocks that could compound systemic risks during economic downturns (Piazzesi and Schneider 2022).

A reliance on market funding could result in a vicious circle of rising costs. As banks are confronted with elevated funding costs in the wholesale market, they may impose these costs on borrowers through the imposition of higher interest rates. This could, in turn, result in more stringent credit conditions, which could have broader ramifications for the economy. Furthermore, the alteration in the sources of funding may result in an elevated level of risk-taking behaviour. Financial institutions, confronted with elevated funding costs, may be driven to pursue high-yield investments that could offset these costs, but at the expense of intensifying their exposure to credit risk. This response may give rise to a vicious circle, whereby banks become increasingly vulnerable to economic downturns, particularly if they engage extensively in riskier lending practices (Piazzesi and Schneider 2022).

In a recent publication, Keister and Sanches (2023) present a compelling argument suggesting that central bank or market-based funding may entail a higher cost compared to traditional deposit funding. This, they posit, could potentially lead to banks taking on riskier loans with the objective of maintaining profitability. Such a shift towards higher-risk assets has the potential to increase the likelihood of loan defaults, which could have a destabilising effect on both individual banks and the financial system as a whole (Keister and Sanches 2023).

Conversely, some studies theorise that central bank funding, in conjunction with the advent of CBDCs, could facilitate enhanced market discipline. In fact, Brunnermeier and Niepelt (2019) suggest that central bank funding, as a public good, might be combined with more stringent regulatory oversight, thereby encouraging banks to implement more cautious and risk-adverse lending practices, thus assisting in stabilising the financial system.

4.3. Methodology

The objective of this chapter is to outline the data used and the model employed to investigate how banks have responded to deposit outflows in recent years.
In particular, the goal was to examine how deposit outflows have affected the non-performing loan (NPL) ratio. This approach enables an examination of how liquidity constraints stemming from fluctuations in deposits impact a bank's loan portfolio and, subsequently, its overall stability.

4.3.1 Sample selection and data cleaning

The dataset employed in this study was sourced from Orbis Bank Focus, a comprehensive global financial database on banks.

The focus of this study is the banking sector within the Eurozone. To ensure consistency, all data has been reported in millions of euros (m EUR).
The sample period extends from 1995 to 2024, encompassing significant economic shifts, including the global financial crisis, the European sovereign debt crisis, and the impact of the SARS-CoV-2 pandemic. This temporal span offers insights into the influence of diverse economic and policy contexts on the structure and risk profile of banks.
To ensure the capture of individual bank-level data and to exclude effects associated with subsidiaries or affiliates, only those banks reported at the unconsolidated level were selected.
The initial dataset was subjected to several processes to ensure the consistency and reliability of the subsequent analysis. Initially, duplicate entries were identified and removed through the sorting of the Orbis ID number and Consolidation Code, with the first occurrence of each unique bank retained to guarantee that each observation represented a distinct entity.

The next step was to reshape the data set from a 'wide' format (in which individual year-specific variables were included) into a 'long' format. This allowed for the creation of a structured panel data set, which is ideal for capturing both cross-sectional and time-series elements of the data**.**

Furthermore, a number of variables were stored in a text format, which required conversion to a numerical format to enable statistical analysis. In instances where missing values occurred, a methodical approach was employed to prevent the emergence of biased results. Each variable was renamed and meticulously labelled, aligning them with the model's requirements to ensure consistency throughout the analysis.

The data preparation process resulted in the creation of a well-organised dataset (appendix 3), which was then suitable for further modelling and analysis. This process also served to minimise the noise and inaccuracies that are often associated with raw financial data.

4.3.2 The regression model

The objective of the empirical analysis is to gain insight into the relationship between bank funding structure, asset size, and non-performing loan (NPL) ratios, which serve as a measure of credit risk.

The primary model employed is a panel regression with fixed effects, which is used to control for unobserved heterogeneity across banks and years. This approach allows for the capture of the time-invariant characteristics of individual banks, such as management practices or regional economic conditions, as well as year-specific shocks affecting all banks, such as regulatory changes or macroeconomic events.

$$NPL\ Ratio_{it} = \beta_0 + \beta_1 Deposit\ Share_{i,t-1} + \beta_2 Total\ Assets_{i,t-1} + \alpha_i + \delta_t + \epsilon_{it}$$

Where:

- NPL Ratio $_{it}$ represents the non-performing loan ratio for bank i in year t, and is therefore a key indicator of the quality of its loan portfolio. This metric is employed for the purpose of measuring the extent of the bank's credit risk and the quality of its outstanding loans. A high ratio indicates that the bank is exposed to a greater risk of loss in the event of an inability to recover the outstanding amounts, whereas a low ratio suggests that the loans are relatively low-risk for the bank. The level of non-performing loans is of significant economic importance, as these loans have a detrimental impact on the profitability of banks and result in the absorption of valuable resources, thereby limiting the capacity of banks to extend new loans (ECB n.d.).
- Deposit Share $_{i,t-1}$ is the lagged share of customer deposits in total funding, a key measure of funding stability, as it reflects the stability of a bank's customer deposits relative to its total funding.
- Total Assets $_{i,t-1}$ is the lagged total asset size and it as it serves as a proxy for the bank's size, as it represents the overall magnitude of the banks' operations. Larger banks are typically more liquid and demonstrate greater financial stability as a result of their size. This could influence their lending practices and, subsequently, the probability of non-performing loans. If a bank is larger and more financially stable, it may possess the capacity to better withstand shocks and manage defaults.
- α_i represents of bank-specific fixed effects, which serve to control for unobservable characteristics that are unique to each bank, such as management style, risk appetite, or location, which remain constant over time.
- δ_t represents time fixed effects, which are employed to account for common shocks that affect all banks in a given year, such as macroeconomic changes or regulatory shifts.
- ϵ_{it} represents the idiosyncratic error term.

In order to address potential endogeneity concerns, lagged values of the independent variables are employed to ensure that the explanatory variables exert influence on NPL ratios without simultaneously exerting feedback effects. To correct for any potential autocorrelation or heteroskedasticity that may exist at the level of the individual bank, the regression employs clustered standard errors.

4.3.3 Results

$$NPL\ Ratio_{it} = \beta_0 + \beta_1 Deposit\ Share_{i,t-1} + \beta_2 Total\ Assets_{i,t-1} + \alpha_i + \delta_t + \epsilon_{it}$$

Results with COVID-19 data

Number of observation	3002
F(2, 501)	7,32
Prob > F	0,0007
R-squared	0,7326
Adjusted R-squared	0,6765
Within R-sqared	0,0202
Root MSE	3,4965

(Standard error adjusted for 502 clusters in bank_id)

Results excluding COVID-19 data

Number of observation	2580
F(2, 501)	6,88
Prob > F	0,0011
R-squared	0,7381
Adjusted R-squared	0,6735
Within R-sqared	0,0207
Root MSE	3,6383

(Standard error adjusted for 493 clusters in bank_id)

NPL Ratio	Coefficient	Robust standard error	P>|t|	[95% confidence interval]	
Deposits on funding share	-0,467777	0,0202901	0,022	-0,0866419	-0,0069135
Total assets	0,000385	0,0000119	0,001	0,0000151	0,0000619
Results excluding COVID-19 data					
Deposits on funding share	-0,0466919	0,0214603	0,030	-0,0888572	-0,00452
Total assets	0,000383	0,0000121	0,002	0,0000145	0,00006

Absorbed degrees of freedom

Absorbed FE	Categories	Redundant	Number of Coefs
bank_id	502	502	0 *
year	18	1	17

* = FE nested within cluster; treated as redundant for DoF computation

Excluding COVID-19 data, the categories of banck_id are 493

Figure 2 *- Results of the regression model*

The regression analysis yields valuable insights into the relationship between deposit funding structure, bank size, and credit risk, as measured by the non-performing loan (NPL) ratio.

The coefficient of the deposits share is -0.0468, indicating that one percentage point increase in the deposits' share of a bank's funding structure is associated with a 4.68 basis point reduction in the NPL ratio. The coefficient is statistically significant at the 5% level of confidence.

This indicates that the dependency on consistent funding sources, such as deposits, can mitigate credit risks by guaranteeing predictable liquidity and promoting healthier loan portfolios. In the context of the potential introduction of the Digital Euro, the reduction in customer deposits that would result from the adoption of the new digital currency could prompt banks to rely on less stable funding sources, thereby increasing credit risk.

The coefficient for total assets suggests that larger banks tend to have slightly higher credit risk exposure.

The findings highlight the significance of a stable deposit base in maintaining low credit risk. The introduction of a digital euro may result in significant deposit outflows, which could lead to increased funding instability and a subsequent reliance on wholesale markets or other costlier sources of funding. This could ultimately result in higher NPL ratios.

Furthermore, the positive correlation between bank size, as represented by total assets, and NPL ratios suggests that larger institutions are not immune to credit risk. This finding highlights the necessity for close regulatory monitoring of larger banks, particularly in the event of severe deposit outflows, which could potentially pose a systemic risk.

The conclusions presented herein remain valid even when the data pertaining to the COVID-19 pandemic are excluded from the analytical framework, specifically for the year 2021. Indeed, the advent of the COVID-19 pandemic has resulted in unparalleled disruptions across a multitude of industries, economies, and societal systems. Such disruptions frequently resulted in anomalous data patterns, including steep declines, sharp spikes, or irregular trends, which do not align with the typical patterns observed in the data. The exclusion of the years affected

by the pandemic ensures that the focus is on normal business operations, thereby reducing the potential for skewed analysis resulting from the influence of an outlier period.

The deposit funding share exhibits a negative and statistically significant correlation with the NPL ratio. Consequently, it may be inferred that a higher dependence on deposit funding as a source of capital is associated with reduced levels of non-performing loans in the subsequent year. From an economic standpoint, this is significant because deposit funding is regarded as a reliable and low-risk financing source, frequently associated with more conservative lending practices. A 10% increase in the share of funding derived from deposits is associated with an approximate 0.47 percentage point reduction in the NPL ratio. This represents a notable reduction in the risk profile for financial institutions with sizeable loan portfolios.

Conversely, the coefficient for total assets is positive and highly significant at the 1% level. This indicates that larger banks tend to exhibit slightly elevated NPL ratios, potentially due to their engagement in riskier lending practices to expand market share or because their size renders them more susceptible to systemic risks. Although the effect of total assets may appear to be relatively modest, it could potentially accumulate to a significant degree for very large banks. This result highlights the intricate relationship between scale and complexity in banking. While larger institutions may benefit from diversification, they also encounter heightened challenges in risk management.

The adjusted R-squared value indicates that approximately 67% of the observed variation in the NPL ratio can be explained by the independent variables and the fixed effects. This indicates a high level of model fit; however, the within R-squared value suggests that the explanatory power of the model remains limited when considering variations within individual banks over time. This implies that while the model is able to capture cross-sectional differences between banks, other factors, such as macroeconomic conditions, borrower characteristics, and

sector-specific dynamics, may exert a greater influence on the observed changes in NPL ratios within banks over time.

4.3.4 The extended model

To provide further insights, the model was extended by including GDP growth as an additional explanatory variable. The inclusion of GDP growth also allowed for the examination of its interaction with the deposit funding share, yielding insights into the dynamics between economic conditions and banks' credit risk exposure.

$$NPL\ Ratio_{it} = \beta_0 + \beta_1\left(Deposit\ Share_{i,t-1} \times GDP\ Growth\right) + \beta_2 Total\ Assets_{i,t-1} + \alpha_i + \delta_t + \gamma_t + \epsilon_{it}$$

where $\left(Deposit\ Share_{i,t-1} \times GDP\ Growth\right)$ represents the interaction term between the lagged deposit share and GDP growth. The GDP growth was extracted from the International Monetary Fund (IMF) database.

The analysis of real GDP growth is of particular significance as it functions as a principal indicator of the overarching macroeconomic context within which banking institutions operate. The growth of the economy exerts a direct influence on the repayment capacities of borrowers, which in turn affects the quality of a bank's loan portfolio and its non-performing loan (NPL) ratio. In periods of robust economic growth, businesses and households are better positioned to meet their financial obligations, which in turn leads to a reduction in credit risk. Conversely, during periods of economic contraction, the probability of default rises, thereby amplifying credit risk and placing additional strain on banks' balance sheets.

Incorporating GDP growth into the model enhances the analytical process by capturing these macroeconomic effects, thus facilitating a more comprehensive understanding of the manner in which external economic conditions interact with internal bank-specific factors, such as

funding structures. Furthermore, the interaction term between GDP growth and the deposit funding share demonstrates how the stability afforded by deposits may fluctuate in accordance with the economic cycle. For instance, the stabilising effect of deposit funding on credit risk may be more pronounced during periods of economic contraction, whereby external funding sources are subject to greater volatility.

4.3.5 Results of the extended model

Number of observation	2570
F(4, 488)	17,13
Prob > F	0,0000
R-squared	0,7459
Adjusted R-squared	0,68833
Within R-sqared	0,0512
Root MSE	3,5877

(Standard error adjusted for 489 clusters in bank_id)

NPL Ratio	Coefficient	Robust standard error	t	P>|t|	[95% confidence interval]	
Deposits on funding share	-0,054614	0,0214295	-2,55	0,011	-0,0967194	-0,01250
GDP Growth	-81,68901	21,52122	-3,80	0,000	-123,9747	-39,403
Deposits on funding share # GDP Growth	0,4825665	0,238711	2,02	0,044	0,0135381	0,95159
Total assets	0,000381	0,0000104	3,66	0,000	0,0000176	0,00005

Absorbed degrees of freedom

Absorbed FE	Categories	Redundant	Number of Coefs
bank_id	489	489	0 *
year	17	1	16

* = FE nested within cluster; treated as redundant for DoF computation

Figure 3 *- Results of the extended regression model*

The results yield several noteworthy findings.

Firstly, the deposit funding share remains negatively and significantly associated with the NPL ratio, thereby confirming the hypothesis that banks with a higher reliance on deposit funding experience lower levels of credit risk. The results concur with the prevailing view that deposit-based funding, being more stable in comparison to other funding sources, provides greater financial resilience and reduces default risk.

Moreover, it was found that GDP growth is a highly significant determinant of the NPL ratio. This coefficient is strongly negative, indicating that periods of robust economic growth result in substantial reductions in NPL ratios. This can be explained by the fact that businesses and households are better positioned to meet their financial obligations during periods of strong economic growth. This finding emphasises the crucial influence of macroeconomic circumstances on the evolution of credit risk within the banking sector.

The interaction term between the deposit funding share and GDP growth is positive and statistically significant. This suggests that the beneficial effect of deposit funding on NPL ratio reduction is more pronounced in periods of economic weakness but diminishes as GDP growth improves. During periods of robust economic expansion, the overall reduction in systemic credit risk appears to diminish the relative importance of stable funding sources with regard to the management of default risk. In contrast, during periods of economic stagnation or contraction, banks reliant on a greater proportion of deposits may prove more capable of absorbing external economic shocks and maintain lower levels of non-performing loans.

The relationship between total assets and the NPL ratio remains positive and statistically significant. This finding indicates that larger banking institutions are marginally more susceptible to credit risk exposure, potentially attributable to their engagement in higher-risk lending activities or greater vulnerability to systemic shocks. Although this effect is statistically significant, its relatively small magnitude indicates that total assets play a secondary role in influencing the NPL ratio, with other factors exerting a greater influence.

The results of the model demonstrate an overall strong fit, indicating that approximately 68% of the observed variation in NPL ratios can be explained by the variables included in the model. The within R-squared, which quantifies the model's explanatory power for variations within

individual banks over time, is comparatively limited, indicating that a significant proportion of the observed variation is attributable to differences across banks rather than within them.

From an economic perspective, these results highlight the complex interplay between macroeconomic and bank-specific factors in shaping credit risk. In periods of economic expansion, the enhancement of systemic repayment capabilities serves to diminish overall credit risk, thus reducing the necessity for deposit financing as a means of risk mitigation. Conversely, during periods of economic decline, the role of deposit funding as a stabilising factor is amplified, enabling banks to maintain lower NPL ratios in the context of heightened financial stress.

It would be reasonable to hypothesise that the behaviour of deposit holders during periods of financial distress, particularly in the context of the digital euro, may warrant further investigation. It seems probable that the digital euro will be regarded as a secure asset, which may prompt depositors to withdraw funds from commercial banks during periods of heightened economic uncertainty. This could have a pro-cyclical effect, increasing financial instability by eroding the stabilising role of deposit funding. Rather than providing banks with a reliable source of funding during downturns, the shift of funds to the digital euro could intensify economic stress, reducing banks' liquidity and potentially deepening the crisis.

4.4. Implications of introducing Digital Euro

The advent of the digital euro marks not only a significant technological advancement but also a profound reconfiguration of the euro area's financial architecture. As evidenced by the findings of this thesis, the implementation of a digital euro could present significant challenges for the traditional banking sector, particularly in regard to deposit bases, funding structures, and credit risk. It is therefore essential to give careful consideration to the design parameters, regulatory frameworks and policy interventions that could be implemented in order to mitigate any potential adverse consequences.

The regression models indicate that customer deposits exert a stabilising influence on banks, contributing directly to lower non-performing loan (NPL) ratios. This highlights the significance of deposits as a reliable and consistent source of funding. However, the advent of a Digital Euro may prompt households and businesses to reallocate a proportion of their deposits to this novel form of central bank digital currency (CBDC). Should the Digital Euro offer similar levels of accessibility, security and potentially competitive interest rates, it may become a close substitute for traditional bank deposits, leading to substantial outflows from commercial banks.

The magnitude of any such outflows is contingent upon the specifics of the Digital Euro's design and policy features. In order to mitigate the possibility of disintermediation, it may be advisable to impose certain constraints upon the Digital Euro. These could take the form of holding limits, tiered remuneration systems, or restrictions on its usage as a store of value. Conversely, in the absence of such constraints, there is a heightened probability of a large-scale migration of deposits, which would impede banks' capacity to sustain their current funding structures.

The diminished reliance on secure deposit funding may encourage financial institutions toward more volatile and costly funding sources, such as wholesale markets or brief-term borrowing. As has been previously observed in the literature, this shift introduces an increased risk of liquidity and refinancing difficulties, particularly during periods of economic stress. Our findings suggest that the utilisation of such unstable funding sources could result in an elevated risk of credit default, as evidenced by elevated NPL ratios, thereby posing challenges to financial stability.

The results also indicate a significant relationship between deposit share and credit risk, thereby emphasising that a reduction in deposits could lead to an increase in credit risk for banks. The advent of a Digital Euro may necessitate a reorientation of credit portfolios by banking institutions in response to evolving funding dynamics. This could result in more stringent credit conditions, elevated lending rates, and a potential contraction in the availability of credit for households and businesses. It is possible that such developments may have a direct impact on economic growth, particularly in sectors that depend on affordable and accessible bank financing.

The extended model presented in this thesis further emphasises the relationship between macroeconomic conditions and credit risk. In periods of robust GDP growth, credit risks tend to decline as borrowers' repayment capacities improve. Nonetheless, in the event of an economic downturn, the joint impact of diminished deposits and augmented credit risk may serve to accentuate the inherent weaknesses of the banking system. It would be prudent for policymakers to exercise caution when contemplating the implementation of a Digital Euro in a macroeconomic environment that is characterised by fragility. Such a move could have the unintended consequence of intensifying liquidity and credit risks, with broader implications for financial stability.

4.5. Key takeaways

The model studied in this section has investigated the manner in which banks respond to instances of deposit outflow, with a particular focus on the implications of such responses for the stability of the financial system, particularly in the context of the Digital Euro. The findings underscore the intricate interrelationship between funding structures, macroeconomic conditions, and credit risk, with substantial implications for policymakers and financial institutions.

A principal outcome of the analysis is the positive and statistically significant interaction between the deposit funding share and GDP growth. This finding indicates that the beneficial impact of deposit funding on the reduction of the NPL ratio is more pronounced during periods of economic weakness but diminishes as GDP growth improves. During periods of economic expansion, the reduction in credit risk at the systemic level diminishes the relative importance of stable funding sources, such as deposits, in the management of default risk. Conversely, during periods of economic stagnation or contraction, banks that rely on a larger proportion of deposits are better equipped to absorb external economic shocks, maintaining lower levels of non-performing loans. This highlights the pivotal function of deposit funding as a stabilising element during periods of economic turbulence.

Furthermore, the analysis demonstrates that banks with a greater reliance on stable deposit funding typically exhibit reduced credit risk, as evidenced by lower NPL ratios. However, the advent of the Digital Euro could result in substantial outflows of deposits, compelling banks to pursue alternative, potentially less stable funding sources. Such a shift could intensify credit risk and systemic fragility, particularly during periods of economic stress.

The incorporation of GDP growth into the extended model has yielded significant insights into the broader macroeconomic context of deposit outflows. By illustrating the importance of

designing the Digital Euro in a way that minimises financial disruptions by capturing the interaction between economic cycles and funding stability, this study demonstrates the value of such an approach. For instance, the implementation of features such as holding limits, tiered interest rates, or restrictions on its use as a store of value could serve to mitigate the adverse effects of deposit migration.

To conclude, this research highlights the necessity of achieving a delicate equilibrium between financial innovation and stability. While the Digital Euro offers opportunities for modernisation, its design must consider the vital contribution that traditional deposit funding makes to maintaining the stability of the banking sector, particularly during economic downturns. Policymakers must prioritise measures that ensure the resilience of the banking sector while embracing the potential benefits of a Central Bank Digital Currency.

5. Conclusions

The present work project aims to explore the implications of the issuance of the Digital Euro, a retail non-interest-bearing CBDC, for financial stability in the Euro Area, with a specific focus on banks' balance sheet. As a premise for the research, it is assumed that there are no holding limits on the adoption and usage of the Digital Euro. To this end, the study examines the three fundamental components of banks' balance sheet: (i) funding structure, (ii) capital structure, and (iii) asset structure. The discussion considers the associated risks for each of these components – (i) liquidity risk for funding structure, (ii) capital adequacy for capital structure, and (iii) credit risk for asset structure – accompanied by a brief discussion of their implications for banks' profitability.

To begin, sections 1 and 2 elaborate on the definition of the Digital Euro and the key advantages of its issuance, with particular emphasis on the enhancement of the current Euro Area payment system, which is highly reliant on non-European payment providers, and the safeguard of the Euro currency as public money in the digital era. Section 3 introduces the topic of financial stability, focusing on the impact of the Digital Euro on financial stability, particularly on banks' balance sheets through the disintermediation of deposits.

Based on the analysis of banks' funding structure and liquidity position (in section 4), savings and cooperative are the most likely to experience significant impacts on their funding structure with the launch of the Digital Euro. They rely heavily on retail demand deposits and dispose of relatively low levels of internal funds. Additionally, if they need to raise funding, their liquidity positions may be jeopardized. In that scenario, these are the types of banks most likely to require central bank funding, which while less damaging for their liquidity, is the most expensive funding option.

On the other side of the spectrum are non-banking credit and mortgage institutions, which have minimal reliance on retail demand deposits. However, if they need to raise funding, it is complex to evaluate the likelihood of borrowing from central banks, as their liquidity buffers are challenging to evaluate due to the small number of observations and high dispersion. The same limitation applies to investment banks and private banking institutions. While a comparative analysis allows to hypothesize about potential impacts on the funding structure of savings, cooperative and commercial banks, the same is not feasible to investment banks and private banking institutions. This highlights the limitations encountered in data collection, particularly for these types of banks.

The following segment explores the effect of the Digital Euro issuance through the endogenous lens of money creation. Capital adequacy emerges as a critical constraint, acting as both a regulator of banks' risk appetite through required buffers and a direct influence on credit and liquidity risks. This section concludes that the Digital Euro could theoretically exert a dual pressure on the Capital Adequacy Ratio and analyses in parallel European banks' current capital position (which stands at about 2,5 to 5 pp above the required), even considering recent macroeconomic challenges. Despite confirming banks' short-term capital resilience, the proposed strategies – prioritized by ease of implementation and historical precedence – offer a roadmap to strengthen banks' risk-adjusted capital ratios, addressing medium to long-term impacts on the balance sheet of banks. In terms of impact on profitability, the Digital Euro significantly introduces initial costs for banks but also creates opportunities for new revenue streams, such as fee-based services, enabling banks to optimize capital efficiency and offset early challenges.

The model examined in the last section highlights the crucial function of deposit funding in upholding financial stability, particularly during periods of economic stagnation or contraction. A larger proportion of deposit funding enables banks to withstand external economic shocks

more effectively, which in turn leads to a reduction in non-performing loans (NPLs) and an improvement in the management of credit risk. The findings of the analysis indicate that the stabilizing impact of deposit funding is most evident during economic contractions, a time when systemic credit risks are heightened. Conversely, its relative significance is diminished during periods of economic expansion. This dynamic emphasizes the critical interdependence between the structural characteristics of financial funding, macroeconomic conditions and the risk of credit default in guaranteeing the stability of the financial system.

The implementation of the Digital Euro may potentially disrupt this equilibrium, with the possibility of triggering significant deposit outflows on a large scale. Such a shift could necessitate that banks rely on alternative funding sources that are less stable, thereby intensifying credit risk and systemic fragility, particularly during periods of economic turbulence. To mitigate these risks, the design of the Digital Euro must prioritize measures that minimize disruptions to funding stability. Features such as holding limits, tiered interest rates, or restrictions on its use as a store of value could serve to mitigate deposit migration and thereby preserve the stabilizing role of traditional deposit funding.

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Appendix

Variable selection

The analysis included a number of variables that were deemed to be relevant to the performance of banks, the risks they face, and the sources from which they fund their activities. The abovementioned variables represent fundamental elements of a banking institution's balance sheet and funding structure.

- Total Assets (in EUR): The total assets of a bank represent a critical measure of its size, and are often correlated with a number of key financial variables, including economies of scale, capital adequacy, and systemic risk. The larger the bank, the greater the potential benefits of diversification, but also the greater the risks in the event of financial instability.

  This measure was subsequently transformed into the natural logarithm of total assets in order to account for non-linear scale effects associated with bank size and to address skewness in the distribution of bank size. This approach facilitates the normalisation of data, thereby enabling a more accurate interpretation of the effects of bank size across a range of differently sized banks.

- Profit (or loss) after tax (m EUR): This variable is used to measure the net profit of the bank, thereby capturing the overall profitability and operational efficiency of the institution.

- Gross loans and advances to customers (in millions of euros): This variable indicates the total lending volume, which represents a significant source of revenue for banks. The level of lending undertaken by a financial institution reflects both the inherent risk exposure and the business model employed. It is therefore reasonable to conclude that higher loan volumes are potentially associated with greater credit risk.

The proportion of customer deposits as a share of total funding provides insight into the stability of the bank's funding base. The proportion of customer deposits as a share of total funding provides an indication of the stability of the bank's funding base. A greater reliance on customer deposits is typically regarded as a more stable funding source than wholesale funding, given that deposits are often less volatile during economic downturns. The variable was renamed as "Deposit share".

NPL Ratio (Non-Performing Loan Ratio): This metric is employed for the purpose of measuring the extent of the bank's credit risk and the quality of its outstanding loans. A high ratio indicates that the bank is exposed to a greater risk of loss in the event of an inability to recover the outstanding amounts, whereas a low ratio suggests that the loans are relatively low-risk for the bank. The level of non-performing loans is of significant economic importance, as these loans have a detrimental impact on the profitability of banks and result in the absorption of valuable resources, thereby limiting the capacity of banks to extend new loans (ECB n.d.).