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Abstract

The rapid development of information technologies and high adoption have significantly impacted not only on our lives but also businesses in different industries, especially banking, requiring them to be more innovative and adaptive to change. This thesis investigates the impact of digital transformation on the operations of commercial banks in the European Union. Panel data regression analysis is utilized to investigate the effects of investments in information technologies and electronic banking exposure on operational performance indicators. The empirical results from static Fixed-Effects regression model showed negative instant effect of digitalization expenditures on financial results. Furthermore, the System Generalized Method of Moments captured temporal dynamics of digital transformation and provided an evidence of significant positive impact in a long term perspective. Moreover, while the raise in usage of digital banking services showed weak positive immediate effect, it does not contribute to the financial performance over time, suggesting more complex interrelationship with banks operations. These findings provide valuable insights into the strategic planning and technological investments of banks in the current digital age.

Keywords: Digital transformation, banking, financial performance, dynamic panel

Kurzfassung

Die rasche Entwicklung der Informationstechnologien und deren hohe Akzeptanz haben nicht nur unser Leben, sondern auch die Geschäftswelt in verschiedenen Branchen, insbesondere im Bankwesen, erheblich beeinflusst und fordern von diesen eine erhöhte Innovationsfähigkeit und Anpassungsfähigkeit an Veränderungen. Diese Arbeit untersucht die Auswirkungen der digitalen Transformation auf die Geschäftsabläufe kommerzieller Banken in der Europäischen Union. Zur Untersuchung der Effekte von Investitionen in Informationstechnologien und der Nutzung elektronischer Bankdienstleistungen auf die Leistungsindikatoren wird eine Panel-Daten-Regressionsanalyse verwendet. Die empirischen Ergebnisse aus dem statischen Fixed-Effects-Regression-Modell zeigten einen sofortigen negativen Effekt der Digitalisierungsausgaben auf die finanziellen Ergebnisse. Darüber hinaus erfasste die verallgemeinerte Methode der Momente (Generalized Method of Moments) die zeitlichen Dynamiken der digitalen Transformation und lieferte Belege für eine signifikante positive Langzeitwirkung. Ferner zeigte der Anstieg in der Nutzung digitaler Bankdienstleistungen einen schwach positiven Soforteffekt, trug jedoch nicht zur finanziellen Leistung über die Zeit bei, was auf komplexere Wechselbeziehungen mit den Bankoperationen hinweist. Diese Erkenntnisse liefern wertvolle Einblicke in die strategische Planung und technologische Investitionen von Banken im aktuellen digitalen Zeitalter.

Stichworte: Digitale Transformation, Bankwesen, Finanzleistung, dynamisches Panel

Contents

1 Introduction

During the last decades, the banking industry significantly increased the value and importance of information and communication technologies. Digitalization, digitization, and modern technological advancements are playing a vital role and serving as a basis for the current changes in the market. Digital Transformation is changing the shape of our world, transforming society, industries, and economies by reinventing traditional business models and creating new ones. Organizations, especially from traditional industries, recognize that digitalization offers more than just technical challenges, they perceive it as a transformation opportunity (Westerman et al., 2015). To adapt to this progressive environment, the banking industry is developing new operating models or at least upgrading the existing ones.

The banking industry has undergone fundamental changes in recent years as a result of the digital revolution. Digital technologies have transformed and redefined the way banks interact with their customers and run their operations, potentially improving efficiency and creating opportunities for revenue generation. However, the question of to what extent digital transformation impacts a bank's financial health remains a topic of ongoing debate and analysis among scholars and banking industry experts. The topic of digitalization and its impact on various industries including banking has been investigated from different perspectives in recent years. Researchers have explored various aspects of digital transformation, including its definition, key drivers, challenges, and potential benefits. Relevant literature, academic research and various reports related to the digital transformation in the context of banks have been reviewed, with a focus on the works of Liu et al. (2011), Baculard (2017), King (2018), Mikalef et al. (2019), Ziyadin et al. (2020) and Savić (2020). However, while the digital banking and financial services industry has attracted the interest of several scholars and practitioners, and the money that has been spent on improving the quality of services in the banking sector is increasing, empirical research on the digitalization of financial institutions is limited to a certain degree.

This thesis is focused on exploring the impact of digital transformation on the operations of commercial banks in the European Union. Publicly available financial reports, along with data from the S&P SNL Financial, Eurostat and World Bank is utilized to analyze the financial

performance of banks considering their digital technology implementations. In the empirical analysis part, multiple hypotheses tested with regard to relationship between digitalization and operational performance to answer following research questions:

1. What is the immediate impact of current investments in information technologies and penetration of digital banking on the operational performance of commercial banks?

2. How do previous investments in information technologies and penetration of digital banking influence subsequent operational performance of commercial banks?

It is important to mention that the study's outcomes are impacted by the availability and quality of financial data. In addition, there is a fundamental challenge of not being able to control for all external factors influencing digitalization and operational performance. Methodologically, this research accounts on specific statistical methods and theories (various statistical inference methods and testing, panel data analysis, static fixed-effects, dynamic unobserved effects modelling using Arellano-Bover system generalized method of moments) to specify and determine a relationship between a bank's digital transformation journey and its operational performance. This relationship is deduced by regressing contemporary and lagged variables, which signify a bank's profitability, against selected components of digital transformation.

The significance of this thesis lies in its contribution from empirical perspective to the literature on the topic of digitalization in the banking industry and helps to understand the challenges and financial impact of digital transformation for banks. In addition, this thesis provides valuable insights for the banking and financial industries, policymakers, and academics. Firstly, the findings of the study can help banks to understand the impact of digital transformation on their operational performance and to make informed decisions regarding digitalization strategy. Secondly, policymakers can use the findings of the study to develop policies that promote the adoption of digital technologies in the banking industry. Finally, the study contributes to the academic literature on the impact of digital transformation on financial performance in the banking industry, specially from the empirical perspective.

2 Background

This chapter provides a fundamental background and explains what digital transformation is, with a focus on its impact and challenges within the banking sector across European Union. It shows the transition from traditional to digital banking paradigms, supported by empirical data, highlighting adoption rates across countries within the European Union. The chapter navigates through the aspects, drivers, challenges, and regulatory frameworks shaping digital transformation, further venturing into the integration of modern digital technologies in banking operative models.

2.1 Aspects of Digital Transformation

Digital transformation is a complex and multidimensional process that involves the integration of digital technologies and organizational changes to enhance the operational efficiency of businesses (Ziyadin et al., 2020). Nowadays, digital transformation has become a driver of economic growth and competitive advantage in the global marketplace. It refers to the foundational restructuring of an organization's operations, aiming to enhance customer experiences and reduce expenses through the consistent integration of technology at a large-scale (McKinsey & Company, 2023). The digitalization of business processes has led to increased automation, better data management, and improved customer experiences (Savić, 2020).

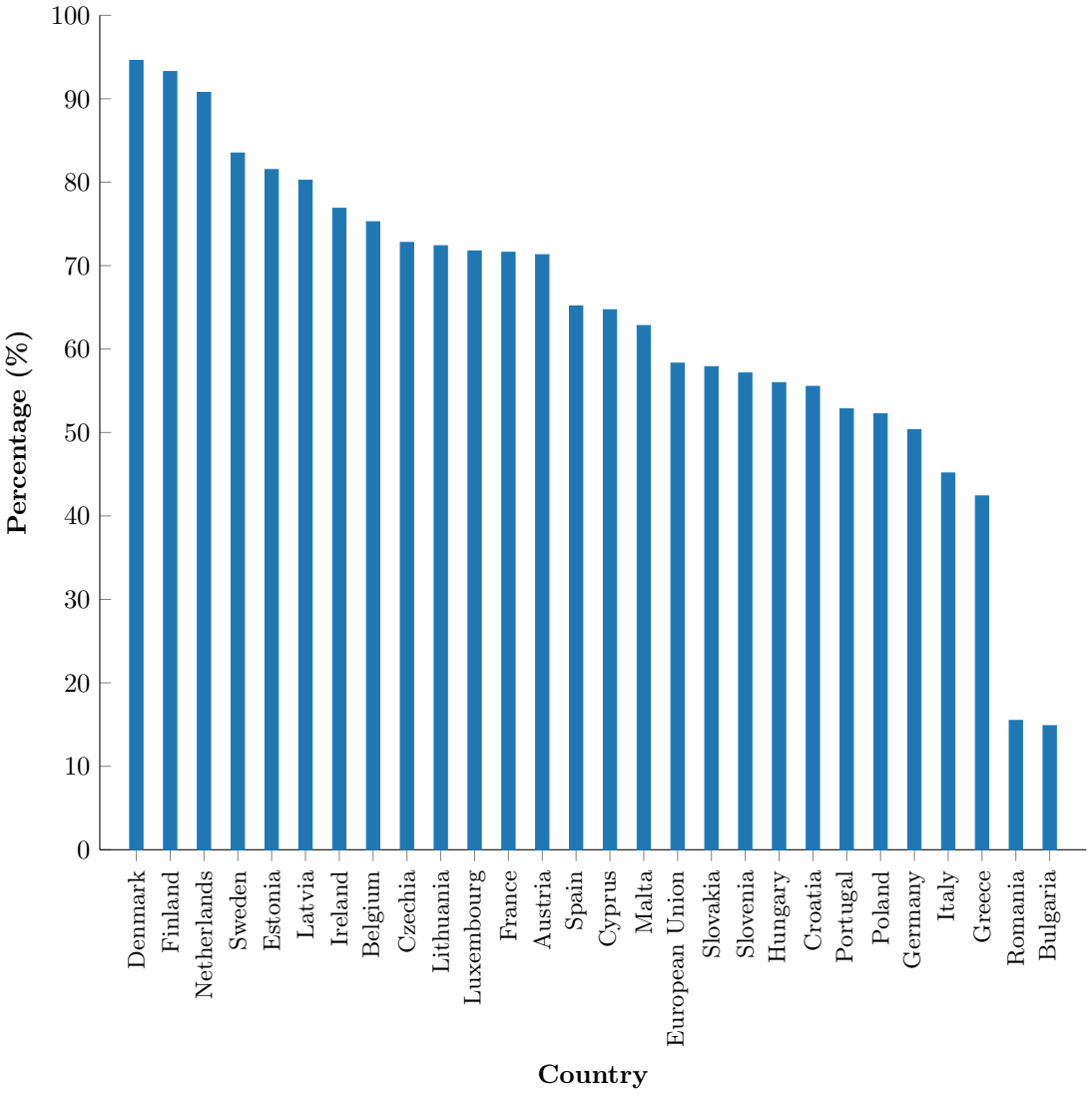
Key trends that led to the rapid adoption growth of digital transformation and in general digitalization of financial services are well-tracked based on statistics provided by Eurostat. The data shows the current trend in all European countries (Eurostat, 2022).

According to the Figure 1, Norway and Denmark are the most advanced countries with overall Internet banking usage estimated at 95.84% and 94.59% respectively. On the other side, Romania and Bulgaria with only 15.49% and 14.87% stay on the lower end. These two countries are the only exceptions from the overall picture given the average of 59.66% in European Union.

Analyzing the uptake of digital banking services across different European regions, it's evident that there has been a notable discrepancy in the rate of adoption. Nordic countries like Denmark and Finland have been front-runners, with Denmark's digital banking usage growing from 56.8% in 2007 to 94.59% by 2021 and Finland not far behind with a rise from 66.45% to 93.26% over

Figure 1

Percentage of Internet Banking Usage in the European Union, 2021



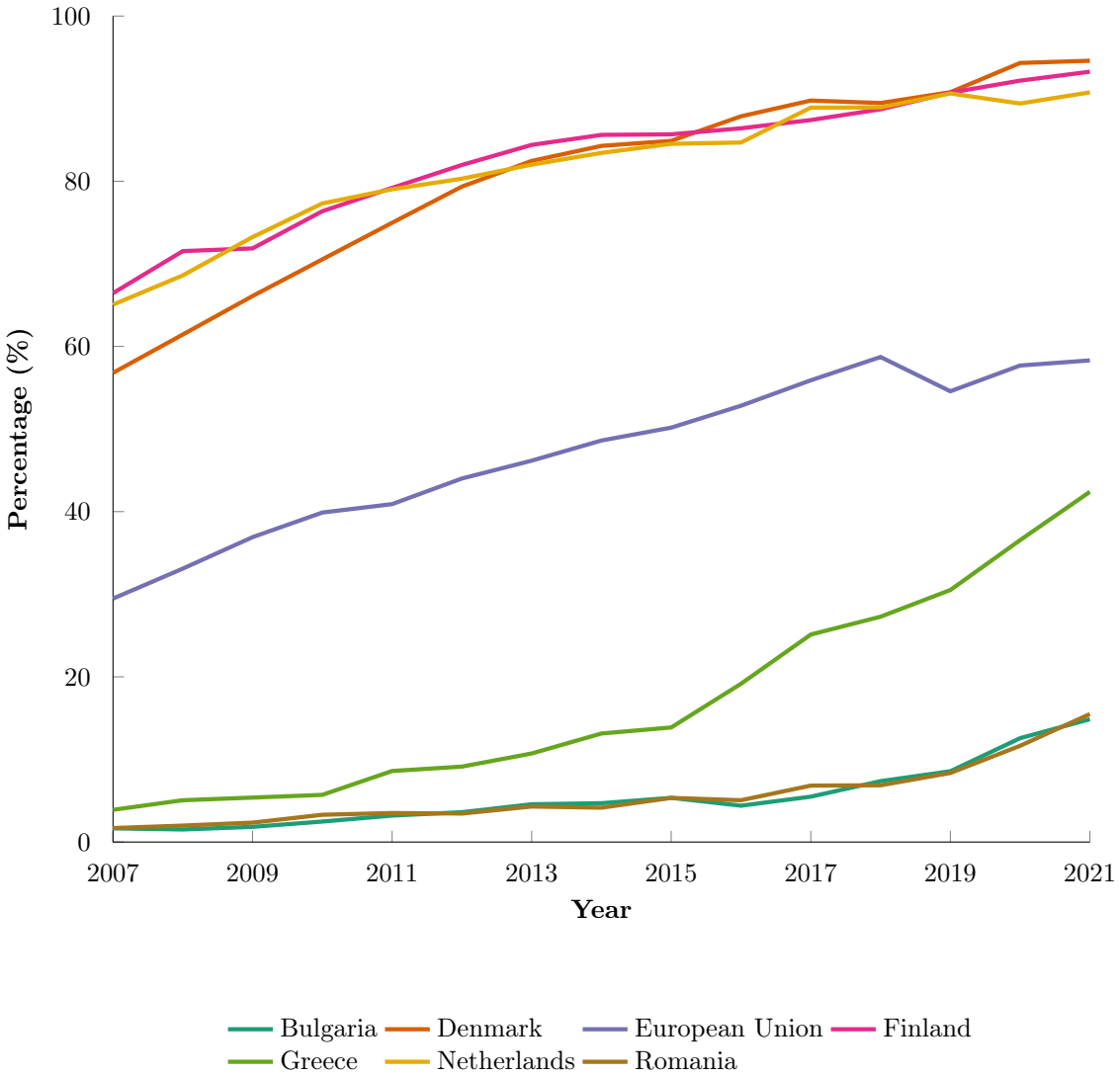
Note. Data source: Eurostat (2022).

the same period. Besides, countries such as Bulgaria and Romania started from a much lower base, with Bulgaria moving from 1.66% in 2007 to 14.87% in 2021, and Romania from 1.69% to 15.49%.

Aggregated data for European Union emphasizes a progressive and sustained increase in digital banking integration. According to the Figure 2, effects of digital transformation are significant and visible in the entire European banking sector. Factors such as regional characteristics, the robustness of technological infrastructure, and established banking regulations have played major roles in this transformation. Data highlights the significant impact

Figure 2

Trends in Internet Banking Adoption as a Percentage of the Adult Population in Selected European Countries, 2007-2021



Note. Data source: Eurostat (2022).

of digital transformation on banking services across European Union, with varying degrees of adoption. Overall, the usage of Internet banking in European Union rose from 29,47% in 2007 to 58,31% in 2021.

Given the significance of statistics it is important to understand what digitalization means. Term digital transformation refers to the process of incorporating digital technologies into the core business processes of an organization to improve performance and effectiveness (Ziyadin et al., 2020). In essence, it involves the implementation of technologies such as mobile, social,

cloud services, big data, internet of things, blockchain, and artificial intelligence. Digital transformation is not just about digitization or digitalization, it is also about transforming the entire organization to become digitally mature.

Even though digitization and digitalization are terms that are often used interchangeably, it is important to differentiate them. Digitization is the process of transforming information from analog or manual to digital format. Digitalization, on the other hand, is the process of automating the business processes and operations of the organization. It involves the integration of digital technologies into the core business processes of an organization thus digitalization is the foundation of the digital transformation (Savić, 2020). It enables businesses to streamline their processes and optimize their operations, leading to increased efficiency and reduced costs. Digitalization is not a consequence of digital transformation but a prerequisite for it.

Digital transformation is a break of template for existing business frameworks and changes the ways businesses operate and develop. The market makes it necessary for organizations to be on the edge between the classic business operations and consistent adoption of cutting-edge technologies, setting the stage for a comprehensive digital overhaul of the broader economy. Through these technological enhancements, ways of engagement among banks, government authorities, and prospective clients are redefined, as evidenced by the improved interactions facilitated by digital technologies (Aker, 2017; Galazova & Magomaeva, 2019; Vives, 2020). Besides, digital transformation boosts the broad-scale incorporation of modern banking services and forces the implementation of innovative technological advancements, which stand as a cornerstone for banks, fostering sustainable and lasting efficiency gains. Moreover, digital transformation has become a fundamental strategic goal globally in all industries, especially in banking supported by the evolving financial technologies steering this sector's transformation.

2.1.1 Key Drivers of Digital Transformation

There are four main forces that are driving the trend of digital transformation: customer experience, technological advancements, economic benefits, and global disruption (Bollard et al., 2017; Dias et al., 2017; Katz & Callorda, 2020; Westerman et al., 2014; Ziyadin et al., 2020).

In the current digital era, customer experience plays a crucial role in the digital

transformation process. Different tech giants like Apple, Alphabet, and Amazon create high expectations for the digital experience that customers have with a company or brand across various touch points Bilotta and Romano (2019). They want easy-to-use interfaces, personalized services, and seamless experiences across different platforms. The same applies to legal entities, to be competitive and meet these expectations. Digital transformation enables and pushes businesses to do automation, collect and analyze data, and gather feedback to perform continuous iterative improvements by using agile methodologies for product development (Bossert et al., 2015; Dias et al., 2017).

Rapid advancements in digital technologies have made it easier and more affordable for businesses to enable digital transformation. The availability of cloud computing, artificial intelligence, and the Internet of Things has made it easier for businesses of all spheres to integrate these technologies into their daily operations (Ziyadin et al., 2020). The technological push that happened in the twenty-first century is not just a driver of digital transformation but a key component of business success. Companies that are not following these trends and rely on the old ways of work, risk falling behind their competitors and going bankrupt (Bonnet et al., 2015). Nevertheless, it is important to mention that the commercial usage and adoption of technologies among the world's population also drive businesses to create innovative products and services and deliver superior customer experience so they can gain a competitive advantage in the market.

Digital transformation leads to significant economic benefits for businesses. By automating and optimizing business processes, digital transformation increases productivity and gives the possibility for employees to focus on more complex and valuable tasks. It also opens opportunities for businesses to create new operating models, decreasing the need for physical presence and infrastructure thus reducing costs and enabling new revenue streams (McKinsey & Company, 2023).

The adoption of digital technologies has led to global disruption which reshaped entire industries and societies. Digital disruptors are challenging traditional business models and innovating faster than established companies (Baculard, 2017). One prominent example is Facebook's deal to buy messenger WhatsApp in 2014 for $16 billion, at a time when WhatsApp already had a user base of more than 450 million people (Facebook, 2014). With this deal,

Facebook disrupted the whole industry, expanded its presence in the new market, and challenged the domination of Alphabet in the advertising market (Bradley et al., 2015).

2.1.2 Challenges of Digital Transformation

Although digital transformation offers many benefits, it also poses a significant challenge for organizations (Ziyadin et al., 2020). As businesses more and more rely on digital technologies, they are also becoming significantly vulnerable to cyber threats (Maurer & Nelson, 2021). Data privacy and security are critical issues for businesses so they need to ensure that customer information is protected and secured as mandated by key regulations including the General Data Protection Regulation and the regulation concerning data processing by Union's institutions (European Parliament & Council of the European Union, 2016, 2018). These aspects are particularly affecting financial institutions like banks since they store and collect very sensitive client data due to regulatory requirements like Know-Your-Customer (KYC) and provide various digital financial services that can be misused in case of unauthorized access (European Parliament & Council of the European Union, 2015b).

Another core challenge of digital transformation is a cultural shift within the organization (Foerster-Metz et al., 2018). Employees need to be trained to work with modern technologies, processes, and approaches which can be a difficult and time-consuming activity. There may also be resistance to change from employees who are comfortable with the old ways of doing things, especially in organizations with complex structures and a high-level of regulatory control from the authorities. At the same time, digital transformation requires businesses to keep up with technological trends. They need to invest in training and development programs to ensure that their employees have the necessary skills and mindset so that the organization can be sure that employees follow and bring ideas on the latest technological advancements and practices (Knight, 2015).

As stated by Melvin E. Conway (1968), "Any organization that designs a system will inevitably produce a design whose structure mirrors the organization's communication structure". This principle, known as Conway's Law, represents a link between organizational communication and system design. The law incorporates the importance of social and cultural

aspects within the organization, highlighting how crucial it is to have a common language and understanding in communication across all nodes of the organizational tree. Big and old corporations that have people working in their positions for many years struggle the most since they consider these employees as very experienced and valuable assets in specific fields, missing the fact that digital transformation requires new ways and approaches in business (McKinsey & Company, 2023).

When businesses are starting with digital transformation, it is crucial to make sure that the digital solutions can cover the current size and needs of the company and will not interrupt their undergoing operations. Moreover, new digital solutions must be integrable with existing systems and accommodate all the regulatory requirements and laws which may vary by country, region, and industry (Ahmed et al., 2021). All mentioned factors create significant challenges and affect all aspects of the business, bringing fundamental changes in the day-to-day business, and high-costs. Digital transformation requires careful strategic planning, management, and implementation considering all the challenges and numerous benefits organizations may face (Kane et al., 2015).

2.2 Specifics of Digital Transformation in Banks

In recent years, digital transformation has become a very popular topic among businesses as they seek to adopt and leverage digital technologies to transform their operations and customer experiences. The financial sector in particular has witnessed significant transformation, and banks have not been left out in this race to digitalize their operations. The importance of digital transformation in the banking sector has been widely recognized by industry experts and policymakers, with McIntyre et al. (2019) noting that digital transformation is crucial for banks to remain competitive and meet the changing needs of customers. Similarly, Kitsios et al. (2021) and Pagella and Iyer (2021) have highlighted the potential of digital technologies to enhance operational efficiency and reduce costs in the banking industry.

As digital transformation continues to accelerate in the banking sector, it is becoming extremely important for banks to understand the needs of their customers and offer the most modern and advanced services to remain competitive. With the widespread implementation

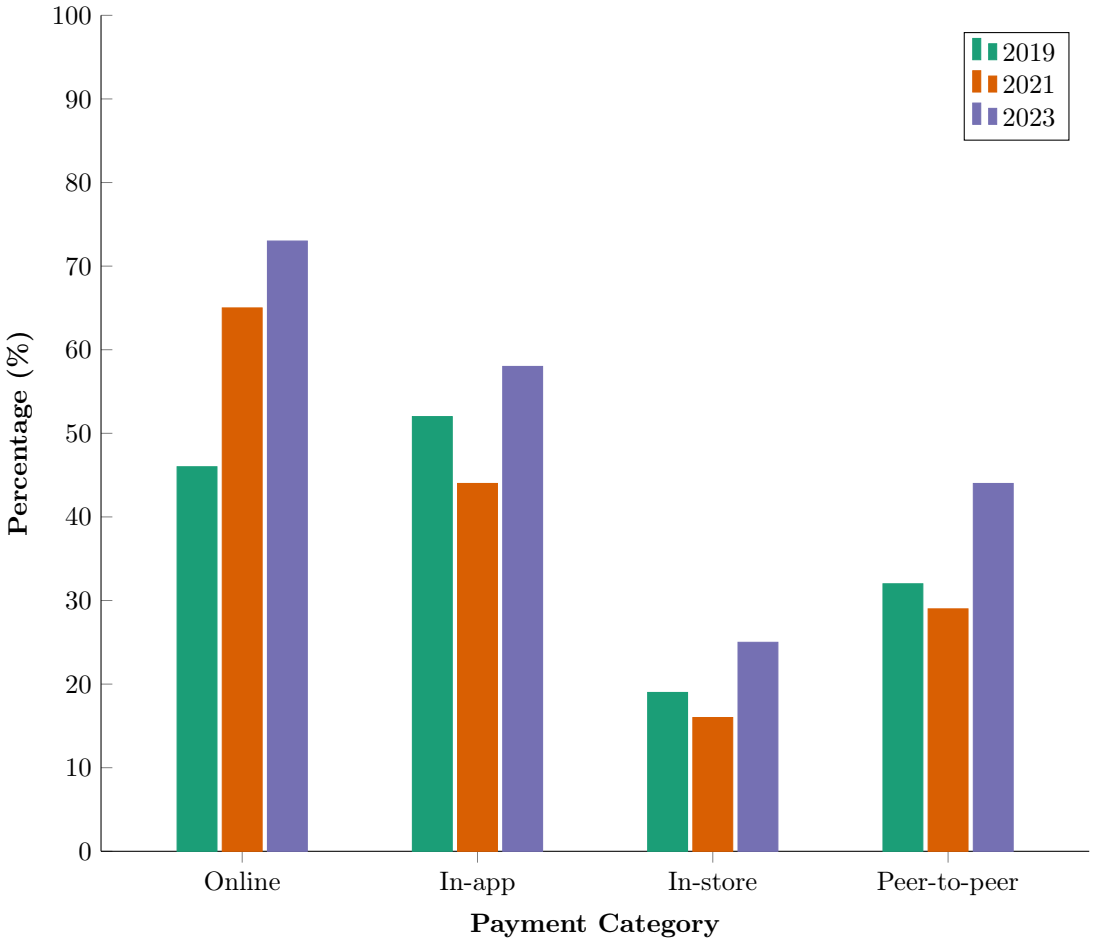
of modern methods of providing banking services, there has been a reduction in the number of bank branches, and many services have been transferred to online platforms, especially in areas such as payments, loan applications, fund investments, and account opening (Galazova & Magomaeva, 2019). However, digital payments are an add-on and cannot exist without a classic banking methods, since customers need to go through KYC process, open an account and get a bank card. According to the zeb and Oesterreichische Nationalbank (OeNB) (2022), Germany and Austria known as a cash-heavy countries had an increase of 20% and 12% respectively of card payments in 2020. Moreover, in a period from 2014 to 2019, average annual growth of card payments in most European Union countries was estimated at 12%. Based on Chen et al. (2023), 80% of consumers used at least one type of digital payment methods in 2021. In addition, in-store digital transactions by interacting with a terminal raised from 19% in 2019 to 25% in 2023, indicating that consumers transfer their behavior from online to physical purchasing by digitizing bank cards and using them digitally. The overall distribution suggests growth and high adoption rate in all four most common categories of retail digital payments as illustrated in the Figure 3.

Another significant direction of the bank's evolution is the transformation of the banking management model. Carson et al. (2021) suggests that new technologies and artificial intelligence will help companies, especially banks, to use new business and management models to reduce risks, costs, and increase productivity. While discussing the limitations of medium-sized and small banks in emulating large banks by creating financial ecosystems and transforming into IT companies, it is noted that they can instead engage in partnerships with other banks and fintech companies (King, 2010, 2013). The concept developed by Brett King, a recognized American innovator and banker, highlights the decline of traditional banking practices and the significant shifts toward digital transformation within the banking industry (King, 2010, 2013). King's studies describe the transition from conventional to digital banking, with the introduction of new business models and strategies (King, 2010, 2013).

Furthermore, King (2018) study of the impact of digital transformation on risk management gives emphasis to the potential benefits of digital technologies in enhancing risk identification and mitigation. This research emphasizes the necessity of a cultural shift within organizations to

Figure 3

Digital payments adoption by category in the United States



Note. Data source: Chen et al. (2023).

support digital initiatives and the need for leadership commitment to drive change. Specifically focused on risk management in the banking industry, King (2018) suggests that digital transformation can enable banks to identify and mitigate potential risks more effectively, thereby improving their financial performance. Basically, this points on the importance of digitalization in the banking sector, with concrete examples of numerous benefits, but also challenges and requirements for the successful application.

Besides, some of the first adopters of modern digital technologies and serious competitors in the financial markets are fintech companies. Yet, their spread and swift developments have also driven banks to develop and implement innovative technological solutions, gradually transforming them into IT companies with banking licenses. Consequently, banks are evolving,

improving the quality and spectrum of their services, and gradually expanding their functions (Zavolokina et al., 2017). However, the digital transformation of banks has not been without its challenges, particularly for the older generation which may not keep up with the acceleration of digital development (Alderman et al., 2021). Thus, complete abandonment of traditional ways of doing business is usually not an end goal for banks, even though they tend to go completely online, with some banks working exclusively on mobile digital platforms, also known as neobanks which offer financial services solely through mobile applications or online platforms (Srinivas & Wadhwani, 2019). Neobanks, such as Moven in the US, Stripe and N26 in Europe, are challenging traditional banks with their agility, personalized customer experiences, and lower fees (N26, 2022; Plesser et al., 2019). These neobanks have significantly reduced the cost of banking services by eliminating the need for physical branches, and their success has led to the emergence of banking as a service (BaaS) providers who offer their digital banking infrastructure to other businesses (Bradford, 2020).

Apart from that, blockchain technology has the potential to transform the banking industry by reducing operational costs and enhancing security and transparency (Higginson et al., 2017). With blockchain, banks can provide more efficient and secure payment processing and reduce the risk of fraudulent transactions. Moreover, blockchain-powered smart contracts can automate the execution of contracts, reducing the need for intermediaries, and lowering transaction costs.

The revised Directive on Payment Services (PSD2) reveals new perspectives for financial institutions and their customers (European Parliament & Council of the European Union, 2015a). The PSD2 directive has pushed banks to develop and use innovative mobile and online payment methods such as open banking and provide better protection for customers' rights. Additionally, the emergence and increased relevance of Application Processing Interfaces (APIs) highlight the potential of streamlining financial services, reinforcing the adoption of innovative methods and the potential of fintech teams in addressing challenges within the banking sector (Brodsky & Oakes, 2017). This has also allowed non-banks to perform part of the traditional banking services within this regulation, leading to the question of clarifying the concept of what a "bank" is. At the current stage of development, a bank looks like a technological company licensed to conduct banking services, which actively enters dialogue and cooperation with partners who perform

similar functions or own the same consumer segment in the financial market.

The General Data Protection Regulation (GDPR) has played a significant role in shaping banks' digital transformation and ensuring the privacy and security of personal data. The GDPR regulates the processing of personal data of individuals in the European Union, and it has pushed businesses, especially banks, to implement strong data protection measures, such as data encryption and access control (European Parliament & Council of the European Union, 2016). On the other hand, the aforementioned PSD2 mandates banks to provide third-party providers access to customers' account information and payment services, enabling the development of innovative financial services and products.

2.2.1 Digital Technologies in the Banking Industry

Banks in essence have very complex environments which on the one hand makes digital transformation challenging and on the other hand, incorporates a broad variety of technologies used in the financial industry. The core objective of digital transformation in banks is to enhance operational efficiency, customer experience, and revenue generation while reducing costs and risks (Campbell & Frei, 2010). Several advanced digital technologies have been identified as key drivers of digital transformation in the banking industry, including mobile and online banking, digital payments, business process automation, big data and cloud computing (Koteshov, 2023; Pollari et al., 2019; Whitfield, 2023).

The adoption of mobile internet, smartphones, and social networks is directly and indirectly related to the likelihood of using modern technologies. These perhaps turned out to be the largest impact on the transformation and development of digital banking and payments. A large segment of population in modern times utilizes smartphones, banks have also focused on digital payments, providing deep integrations of electronic payment methods on websites, applications, and digital wallet services. The literature suggests that developing new digital channels for customer interaction is a vital aspect of digital transformation in banks and can improve customer experience and financial performance (Mbama et al., 2018). Digital channels enable customers to access banking services from anywhere, anytime, enhancing convenience and accessibility. Already now, banks all over the world allow their retail and corporate customers to

go through the Know-Your-Customer (KYC) process, open an account, request loans, perform trade finance transactions, and utilize or amend their limits via digital channels (Raiffeisen Bank International AG, 2020). The HSBC bank has gone even further by establishing integration with the SWIFT KYC Registry and Compliance Analytics through APIs, which has enabled the completion of due diligence processes significantly faster, often without requiring any kind of outreach (Swift, 2021).

Big data analytics and usage of cloud computing services have the potential to enhance operational efficiency and risk management in the banking industry since both technologies provide more room for banks to achieve even more efficient automation of manual processes, improved services, and reduced risks. According to the Nassr and Patalano (2021), the application of these technologies can help banks detect potential fraud, improve security, and reduce transaction costs. One of the prominent examples on how cloud computing allowed a leading North American bank BMO to significantly increase data capacity management and deliver business objectives faster to meet regulatory market risk requirements reviewed in the case study by the Amazon Web Services (AWS) (2023). The AWS solution allowed BMO to build robust, scalable and modern risk platform as part of its business digitalization strategy. Besides, nowadays banks have the possibility to analyze customer behavior and preferences, enabling new opportunities to provide more personalized services and products. The case study by Villar and Khan (2021) demonstrates that automation of organizational business processes improves the accuracy of risk assessments, minimizes the likelihood of errors, boosts operational efficiency, and reduces costs in the long-term perspective.

There are two key takeaways in this chapter regarding digital transformation and its specifics in the banking sector. The first crucial observation is the fundamental role of digital transformation as a medium for enhancing operational efficiency, strengthening customer engagement, and remaining competitive in a dynamic market. The adoption of digital practices across banks is not merely a trend, it represents an essential shift towards digital proficiency to meet the changing demands of consumers. The second insight is the recognition of innovative practices within banks, which highlights the significant benefits and robust financial stability that digital transformation can provide. Various research and case studies mentioned, provide the

evidence of necessity for banks to not just adopt but to seamlessly incorporate digital technologies within their operational models.

3 Empirical Analysis

Despite high complexity and significant expenses associated with the digital transformation, banks are proactively investing in information technologies to utilize competitive advantage, enhance their efficiency and ultimately achieve better financial performance. To investigate the connection between the performance of banks and their investments in information technology, this study adheres to the approaches and frameworks previously established in the academic literature. Yet, the results are varying with different scientific studies suggesting positive and negative effect on the profitability of banks. Mallick and HO (2008) investigates impact of IT spending on profitability of 68 US banks over 20 years using feasible generalized least squares (FGLS). The result shows that while IT investments allow banks to stay more competitive and reduce costs, it negatively affects performance. Similar findings are presented in the study on relation of categorized investment in IT with profitability of 737 European banks done by Beccalli (2007). Author concludes that even though banks are one of the biggest investors in IT for strategic reasons, on average for the banking sector it does not lead to improved operational performance. On the contrary, Do et al. (2022) evaluates consequences of digital transformation on the operational efficiency of Vietnamese commercial banks through the application of the system generalized method of moments (SGMM). The findings indicate a positive correlation, with larger banks experiencing a more pronounced effect of digitalization. Moreover, the study suggests that the efficiency of digital transformation may vary according to the size of the bank. Bassani et al. (2019) supports the same results also suggesting that efforts banks put into the digital transformation are crucial to compete on the market especially with fintech and big tech companies. Another research by Romdhane (2013) shows that it is in the interest of banks to invest in IT since there is a positive and significant effect on the cost efficiency. Ultimately, results provided an evidence that the positive effect can only be achieved in synergy of investments into hardware, software and digital services.

3.1 Model Specification

To show the financial impact of digital transformation on the performance of banks, quantitative analysis is performed. Based on the previously reviewed financial, economic,

business, and IT concepts foundation is build up so that the testable hypotheses can be derived and justified based on different theories and academic papers. The main objective of the research is to investigate the link between digital transformation process and operations of banks in Europe. More specifically, this study explores the extent to which digital transformation relates to the performance of banks, testing the following hypotheses:

H1: *Investments in information technologies are positively associated with the return on assets of European banks.*

H2: *Investments in information technologies are positively associated with the return on equity of European banks.*

H3: *Investments in information technologies are positively associated with the net interest margin of European banks.*

H4: *Digital banking exposure is positively associated with the return on assets of European banks.*

H5: *Digital banking exposure is positively associated with the return on equity of European banks.*

H6: *Digital banking exposure is positively associated with the net interest margin of European banks.*

The choice of model variables is guided by the theoretical and reviewed empirical literature. A key indicator for measuring a bank's operational performance and efficiency is its profitability (Wozniewska, 2008). The most common profitability measures used among practitioners and academics are return on assets (ROA) (*roa*), return on equity (ROE) (*roe*), and net interest margin (NIM) (*nim*), thus these financial indicators are used as dependent variables to represent operations of the European commercial banks (Blatter & Fuster, 2022; Dietrich & Wanzenried, 2010).

Banks are unique types of financial institutions, combining various strategies, models, and primary business areas. Moreover, banks are quite different in terms of size, geographical location, and as a consequence regulatory frameworks they operate. In the analysis, banks

of all sizes are considered, since quantitative data per segment of digitalization such as the number of ATMs, coverage of internet banking, and number of accounts opened digitally are not provided. Additionally banks are not separating data by customer segment like retail, corporate, and institutional clients. European Union was chosen for analysis due to its consistent geographic area and its similar integration of political, economic, and regulatory systems.

Digitalization efforts and commitments are represented by the investment in IT that refers to the combination of different hardware and software systems defined as computers, telecommunications, microelectronics, databases, networks, and others (Cosker, 2023). IT investments rate (*it_investment_rate*) indicate investment rate in innovation and business digitalization as part of bank's strategy and operations relative to the total revenue. It allows to observe more precisely commitment of banks towards digital transformation, regardless of their size and economic environment. Moreover, the study of Tunay et al. (2015) suggested that in Euro Area Countries usage of internet banking significantly contribute to the profitability of banks. As shown in Section 2.1, the penetration of the digital baking had significantly grown in the European area within the last decade. Moreover, the rise of digital banking can be explained by an increase of digital payment solutions and change in the customer behaviors and preferences, with more consumers choosing digital transactions over cash. Given that, the exposure of the internet banking (*ebanking_exposure*) is considered as good proxy to capture macro impact on the bank's financial and operational efficiency.

To fully capture the effect of digital transformation on the operations of banks, micro and macro control variables are introduced. Control variables are exogenous factors that have a relationship with the financial performance of the bank, however not determined by it. They are used to isolate the effect of main variable of interest and acquire unbiased and more efficient estimates. Macroeconomic and industry specific control variables added in the model specification are selected based on the academic studies focused on the banks operational performance, namely profitability.

A study by O'Connell (2022) suggests a positive relation between profitability and size, providing evidence that larger banks enable economies of scale effect and increase the scope of services they can provide. Another variable is derived based on the study of Loderer and Waelchli

(2010), that focused on the relationship between the age of organization and its performance, the older organization becomes, the poorer its profit margins get. The natural logarithm of a bank's total assets (*size*) is utilized as one of the control variables, addressing the potential non-linear relationship between a bank's size and its performance (Neves et al., 2020). This method ensures that the size and investment in information technology, which is positively skewed, are proportionately represented, enabling an accurate comparison among the banks included in the data set. This approach considers that larger banks might benefit from economies of scale, enhancing efficiency and their size of investments. In a similar manner the natural logarithm of the bank's age (*age*) is used to control for the maturity of the bank.

Additionally models incorporated in this thesis account and isolate the digital transformation effects from the influence of bank's credit risk, operational management and overall financial state. The non-performing loans (NPL) ratio (*npl_ratio*) indicates the bank's credit risk and reflects the proportion of loans that are in default or close to being in default. The Cost to income (CIR) ratio (*cir*) represents how efficiently bank is managed, where banks with higher efficiency generate higher profits. The loans to assets ratio (*loans_to_assets*) serves as a liquidity indicator showing what strategy banks have with regard to lending and liquidity management, that influence revenues and profitability. The stability of the bank is controlled by the tier one capital ratio (*tier_one_ratio*). Based on de Bandt et al. (2017), banks with solid capital structure which allows to withstand potential shocks and losses, are tend to be more profitable. Moreover, there are several macroeconomic and sector-specific variables that are used in this thesis. The growth rate of gross domestic product (GDP) (*gdp_growth*), inflation rate (*inflation*) and banking concentration (*banking_concentration*) represent external factors that can significantly affect financial performance of banks, regardless of their individual operational decisions. Such external control variables are reflecting to the overall economic environment where banks are operating and competitive dynamics of it. A detailed summary of the variable definitions can be found in Table A1 in the Appendix.

This study utilizes both static and dynamic panel data approaches to examine the impact of digital transformation on various profitability indicators across banks. The generalized form of the static bank's profitability equation for empirical model is specified as follows:

$$\pi_{it} = \sum_{j=1}^{J} \beta_j X_{j,it} + \sum_{k=1}^{K} \gamma_k Control_{k,it} + \mu_i + \nu_{it} \tag{1}$$

where: π_{it} represents the profitability of bank i at time t, $X_{j,it}$ denotes the j^{th} digital transformation indicator for bank i at time t, $Control_{k,it}$ represents the k^{th} control variable for bank i at time t, μ_i is individual effects, ν_{it} is the error term, β_j, and γ_k are parameters to be estimated.

Although, static models focused more on the immediate effect within a specific point in time, there is an evidence in the literature that past efficiency of bank's operations significantly influence current and future values (Horobet et al., 2021). Similarly, the effect of digital transformation presumably not immediate, especially in banks since they gradually adjust to new business models, processes and changing market conditions. Assuming that initial high upfront investments in digitalization negatively impact profitability in the short term, yet might yield positive effects on operations over time. Thus, to capture real-world dynamics, lagged dependent and independent variables are added in the original model specification, to reflect the autoregressive nature:

$$\pi_{it} = \rho\pi_{it-1} + \sum_{j=1}^{J} \beta_j X_{j,it} + \sum_{j=1}^{J} \delta_j X_{j,it-1} + \sum_{k=1}^{K} \gamma_k Control_{k,it} + \mu_i + \nu_{it} \tag{2}$$

where: π_{it-1} is the lagged profitability, $X_{j,it-1}$ denotes the j^{th} lagged digital transformation indicator, ρ and δ_j are effects to be estimated.

3.2 Data Specification

Within the given thesis, several types of data are used. Theoretical data, or in other words non-numeric data, is the type of data that consists of theories, diagrams, and pictures. Quantitative data, or numeric data on the contrary include numeric data and serve as a basis for statistical research since for each data value a position on a numeric scale can be assigned thus increasing precision. Moreover, breaking it down more granular, researchers divide it into primary and secondary data. Primary data can be described as data collected manually by the researcher for instance through either experiments or interviews, whereas secondary data is data

that already exists and can be taken from public sources like research papers and databases (Saunders et al., 2019).

Quantitative data collected for the thesis comprises of 84 banks within the European Union within a period of 10 years (2012 to 2021) following theoretical background build previously. Based on the countries where identified banks are located, macro-indicators were collected for the same period. Only secondary data is used for the empirical analysis in the form of yearly financial metrics sourced from the S&P SNL Financial database, adjusted using banks annual financial reports and macro-indicators sourced from Eurostat and World Bank (Eurostat, 2022; S&P Capital IQ, 2022; The World Bank, 2022).

The initial dataset taken from the S&P SNL Financial database was incomplete and thus data cleaning was required. Data was revised and cleansed to get rid of *NA* values. In several cases, observations with outliers were omitted. Ultimately, all the banks with metrics that were faulty, contained lots of outliers, were fully missing, and do not go long enough back in time were removed. However, the remaining data set remained unbalanced due to inconsistency in reporting, so it was controlled for outliers and corrected using the bank's annual financial reports. The resulting panel data set used for the empirical analysis included 840 data points.

Table 1 represents descriptive statistics and correlations of variables used in the empirical analysis. The data set used is balanced panel, providing multiple observations over time without missing years for the cross-sectional units. This allows to control for certain unobserved effects and constructs a dynamic panel data model to consider lags resulting in different outcomes (Wooldridge, 2013).

According to the descriptive statistics, there is a wide dispersion in ROE (M = 5.50, SD = 9.58) suggesting varied effectiveness in the equity management. At the same time ROA (M = .37, SD = 1.22) and NIM (M = 1.81, SD = .85) are pointing to the moderate variability in the operational activities of banks across the sample. Unexpectedly, the IT investment rate (M = 5.67, SD = 3.69) showing moderately high level of resources and efforts banks allocate into the digital transformation. The variation in this case can be described by the observed heterogeneity commitment to and available capacity for digital transformation challenges. Some banks are likely making significant investments to pioneer innovative banking technologies, while

Table 1

Descriptive Statistics And Correlations

Variable	N	M	SD	1	2	3	4	5	6	7	8	9	10	11	12	13
1. roa	840	0.37	1.22													
2. roe	840	5.50	9.58	.73** [.70, .76] $p < .001$												
3. nim	840	1.81	0.85	.06 [-.00, .13] $p = .065$	-.01 [-.08, .05] $p = .684$											
4. it_investment_rate	840	5.67	3.69	.01 [-.06, .08] $p = .714$	.06 [-.01, .12] $p = .109$	-.36** [-.42, -.30] $p < .001$										
5. ebanking_exposure	840	47.53	22.28	.11** [.05, .18] $p = .001$	.18** [.12, .25] $p < .001$	-.43** [-.48, -.37] $p < .001$	.56** [.51, .60] $p < .001$									
6. size	840	17.36	1.61	-.01 [-.08, .06] $p = .781$	-.01 [-.07, .06] $p = .869$	-.36** [-.41, -.30] $p < .001$	.09** [.03, .16] $p = .006$	.24** [.18, .30] $p < .001$								
7. npl_ratio	840	7.64	8.62	-.42** [-.47, -.36] $p < .001$	-.41** [-.46, -.35] $p < .001$	.38** [.33, .44] $p < .001$	-.35** [-.40, -.29] $p < .001$	-.51** [-.56, -.46] $p < .001$	-.12** [-.18, -.05] $p < .001$							
8. cir	840	61.02	14.76	-.27** [-.33, -.20] $p < .001$	-.39** [-.45, -.33] $p < .001$	-.16** [-.22, -.09] $p < .001$	.14** [.07, .20] $p < .001$	-.01 [-.08, .06] $p = .809$	-.07* [-.14, -.00] $p = .042$	.07* [.00, .14] $p = .045$						
9. tier_one_ratio	840	14.53	4.39	.23** [.16, .29] $p < .001$	.25** [.18, .31] $p < .001$	-.07 [-.13, .00] $p = .054$	.19** [.12, .25] $p < .001$	.12** [.05, .19] $p < .001$	-.19** [-.25, -.12] $p < .001$	-.19** [-.25, -.12] $p < .001$	-.14** [-.20, -.07] $p < .001$					
10. loans_to_assets	840	61.03	13.61	-.05 [-.12, .01] $p = .113$	-.14** [-.21, -.08] $p < .001$	.28** [.21, .34] $p < .001$	-.27** [-.33, -.21] $p < .001$	-.15** [-.21, -.08] $p < .001$	-.21** [-.28, -.15] $p < .001$	.12** [.05, .18] $p < .001$	.11** [.04, .17] $p = .002$	-.24** [-.31, -.18] $p < .001$				
11. gdp_growth	840	1.17	3.62	.14** [.07, .20] $p < .001$	.13** [.06, .19] $p < .001$	.11** [.04, .17] $p = .002$	.03 [-.04, .10] $p = .348$	.07 [-.00, .13] $p = .052$	-.06 [-.13, .00] $p = .065$	-.05 [-.12, .02] $p = .134$	-.01 [-.07, .06] $p = .853$	.07* [.01, .14] $p = .030$	-.04 [-.10, .03] $p = .277$			
12. inflation	840	1.27	1.29	-.03 [-.10, .04] $p = .422$	.00 [-.07, .07] $p = .958$	.00 [-.07, .07] $p = .990$	.12** [.05, .19] $p < .001$	.12** [.05, .18] $p < .001$	-.04 [-.11, .03] $p = .265$	-.20** [-.26, -.13] $p < .001$	.07* [.00, .13] $p = .050$	-.05 [-.12, .01] $p = .112$	-.01 [-.07, .06] $p = .877$	.19** [.12, .25] $p < .001$		
13. banking_concentration	840	67.22	13.28	-.06 [-.12, .01] $p = .096$	-.02 [-.09, .05] $p = .552$	-.27** [-.33, -.20] $p < .001$	.35** [.29, .41] $p < .001$	.51** [.46, .56] $p < .001$	.15** [.08, .21] $p < .001$	-.01 [-.08, .06] $p = .739$	.00 [-.07, .07] $p = .956$	.19** [.13, .26] $p < .001$	-.12** [-.19, -.05] $p < .001$	-.07* [-.14, -.01] $p = .031$	-.13** [-.19, -.06] $p < .001$	
14. age	840	4.10	1.08	-.02 [-.08, .05] $p = .655$	-.05 [-.12, .02] $p = .165$	-.16** [-.23, -.09] $p < .001$	.10** [.03, .16] $p = .005$	.17** [.10, .23] $p < .001$	.21** [.15, .28] $p < .001$	-.00 [-.07, .07] $p = .978$	.10** [.04, .17] $p = .003$	-.06 [-.13, .01] $p = .085$	.17** [.10, .23] $p < .001$	-.08* [-.15, -.02] $p = .014$	-.04 [-.11, .03] $p = .272$	.21** [.14, .27] $p < .001$

Note. N = number of cases. M = mean. SD = standard deviation. Square brackets = 95% confidence interval.
* indicates $p < .05$. ** indicates $p < .01$.

others may adopt a more cautious stance, gradually integrating digital solutions. Furthermore, value accounted for the ebanking exposure (M = 47.53, SD = 22.28) can be explained by the cross-sectional nature of the sample, since banks are located in different countries with unique customer demographics, strategic priorities and technological capabilities. Overall, data characteristics indicate the significant engagement of banks in the expansion of their services focusing on digitalization.

Furthermore, correlation analysis of variables related to the digital transformation shows crucial preliminary findings. Negative correlation for IT investment rate with NIM (r = -.36, $p < .001$) suggests that technological investments reduce interest income of the bank. Similar situation observed between ebanking exposure and NIM (r = -.43, $p < .001$). Nevertheless, positive correlation between ebanking exposure and ROA ($r = .11$, $p < .001$) hints at the strategic importance of incorporating digital technologies in the bank's business models. Likewise, a positive correlation between ROE and ebanking exposure ($r = .18$, $p < .001$) provides an evidence of beneficial impact of technological advancements on equity returns. Due to the modest size, it is not a main driver of the profitability ratios, however, the positive sign might indicate that efforts and resources banks allocate in the expansion of digital banking (e.g. marketing, technological infrastructure, digitalization of business processes) could potentially lead to higher financial results. The positive significant cross-correlation between ebanking exposure and it investment rate (r = .56, $p < .001$) is expected and can be explained by the integrated digital strategy of banks. By investing in digital transformation, banks are expanding their digital services and technical infrastructure to support them. Moreover, given the competitive market environment, banks need to continuously improve technological capabilities to retain and expand their customer base. Another interesting finding is how digital banking exposure correlated with the selected control independent variables, highlighting broad impact of digital transformation initiatives on bank operations. Strong negative correlation of previously mentioned digital banking exposure with NPL ratio (r = -.51, $p < .001$) requires more careful investigation. From the banking perspective, digital banking services not only provide to banks another channel to expand selling opportunities of their products. It also comes with the automation of internal risk management processes, potentially allowing for more precise screening and lower

default rates. On the macro level, ebanking exposure shows significant positive correlation with banking concentration suggesting that bigger banks may leverage digital banking more efficiently. Ultimately, descriptive statistics and correlation analyses results are inline with derived research hypotheses indicating existing economic impact of digital transformation factors on financial performance indicators.

3.3 Empirical Results

To select and construct an econometric model specification, that will be appropriate to fit collected data, various statistical tests are performed. As a first step, stationarity of the data is checked using Maddala-Wu unit-root test for panel data. The test's hypothesis suggesting stationarity accounting for cross-sectional dependence and heterogeneity across the panel confirmed stationarity of all variables. Following stationarity investigation, the Breusch-Pagan Lagrange Multiplier test for cross-sectional dependence across entities in panel data is performed. Such correlation might lead to biased standard errors, affecting reliability of hypotheses testing. Thus, if present, it must be considered during model specification process. The results of the Breusch-Pagan Lagrange Multiplier test indicate cross-sectional dependence in the panel data for all variables tested. These finding once again highlighting interconnection of banks within the European area in terms of policies, economic factors and technological advancements.

At first, all three static models (see 1) are defined:

$$\begin{aligned} roa_{it} = {} & \beta_1 it\_investment\_rate_{it} + \beta_2 ebanking\_exposure_{it} + \beta_3 size_{it} + \beta_4 cir_{it} + \beta_5 npl\_ratio_{it} \\ & + \beta_6 tier\_one\_ratio_{it} + \beta_7 loans\_to\_assets_{it} + \beta_8 gdp\_growth_{it} + \beta_9 inflation_{it} \\ & + \beta_{10} banking\_concentration_{it} + \beta_{11} age_{it} + \mu_i + \nu_{it} \end{aligned} \quad (3)$$

$$\begin{aligned} roe_{it} = {} & \beta_1 it\_investment\_rate_{it} + \beta_2 ebanking\_exposure_{it} + \beta_3 size_{it} + \beta_4 cir_{it} + \beta_5 npl\_ratio_{it} \\ & + \beta_6 tier\_one\_ratio_{it} + \beta_7 loans\_to\_assets_{it} + \beta_8 gdp\_growth_{it} + \beta_9 inflation_{it} \\ & + \beta_{10} banking\_concentration_{it} + \beta_{11} age_{it} + \mu_i + \nu_{it} \end{aligned} \quad (4)$$

$$nim_{it} = \beta_1 it\_investment\_rate_{it} + \beta_2 ebanking\_exposure_{it} + \beta_3 size_{it} + \beta_4 cir_{it} + \beta_5 npl\_ratio_{it}$$
$$+ \beta_6 tier\_one\_ratio_{it} + \beta_7 loans\_to\_assets_{it} + \beta_8 gdp\_growth_{it} + \beta_9 inflation_{it}$$
$$+ \beta_{10} banking\_concentration_{it} + \beta_{11} age_{it} + \mu_i + \nu_{it} \quad (5)$$

Afterwards, they are estimated by ordinary least squares (OLS) for an initial assessment to test for individual and time effects using Breusch-Pagan Lagrange Multiplier test. Test results suggest that there are significant individual and time effects in the data for all three models. Since preliminary correlation analysis showed potential multicollinearity issues, variance inflation factors (VIF) are calculated. VIF test results are bellow 3 for all variables indicating low and acceptable correlation levels. Presence of individual and time effects in the OLS regression model suggest to use panel data methods such as Fixed-Effects (FE) and Random-Effects (RE) since they account for them (Wooldridge, 2010). To decide between the FE and the RE estimators, Hausman test is used to compare and select specification that fits best. It tests the null hypothesis that the individual effects are uncorrelated with the other regressors in the model, that is a key assumption of the RE model. The null hypothesis is rejected for all three models after performing the Hausman test, meaning that the FE model is more appropriate. While the RE model may be more efficient, the FE model provides consistent and unbiased estimates, which is crucial in inferential statistics. For further diagnostics, test for autocorrelation and homoscedasticity are performed, taking into consideration base line characteristics of the panel data set. The output from the Durbin-Watson test for serial correlation rejects the null hypothesis indicating that there is a significant evidence of autocorrelation in all three models. Similarly, the Breusch-Pagan test rejects the null hypothesis of equal variances across entities implying the heteroscedasticity. To account for the identified autocorrelation and heteroscedasticity, the robust version of FE model with Driscoll and Kraay corrected standard errors is used (Hoechle, 2007). Ultimately, it would be better to proceed with the FE model for ROA, ROE and NIM for further analysis and hypothesis testing. The results of the full sample FE regressions are presented in Table 2.

The estimated results are showing similarities across all three models. The overall significance and robustness of the findings is confirmed by the F Statistics for each model. The R^2 is 21.4% for ROA, 25% for ROE and 18.3% for NIM models respectively. IT investment rate has significant

Table 2

Results of robust twoways fixed-effects regression models

	Dependent variable:		
	roa	roe	nim
it_investment_rate	-.111*** (.024)	-.774*** (.169)	.008 (.007)
ebanking_exposure	-.017 (.011)	-.054 (.079)	.010*** (.003)
size	-.171 (.214)	2.694* (1.531)	-.527*** (.063)
cir	-.018*** (.004)	-.259*** (.030)	-.010*** (.001)
npl_ratio	-.090*** (.010)	-.481*** (.068)	.019*** (.003)
tier_one_ratio	.057*** (.015)	.546*** (.107)	-.009** (.004)
loans_to_assets	-.008 (.007)	.002 (.050)	.002 (.002)
gdp_growth	.044* (.025)	.099 (.178)	.014* (.007)
inflation	-.048 (.053)	-.488 (.376)	.019 (.016)
banking_concentration	.006 (.007)	.027 (.051)	.006*** (.002)
age	.565** (.225)	.703 (1.606)	.038 (.067)
Observations	840	840	840
R^2	.214	.250	.183
Adjusted R^2	.104	.145	.068
F Statistic (df = 11; 736)	18.180***	22.319***	14.945***

Note. * indicates $p < .1$. ** indicates $p < .05$. *** indicates $p < .01$.

negative effect only on ROA and ROE, while ebanking exposure shows significant positive impact on NIM. This might seem counterintuitive, given the rapid adoption of digital technologies in the banking sector. The mixed impact of digital transformation is consistent with the previous studies of Beccalli (2007) and Mallick and HO (2008), additionally providing insights about the external digitalization effects. The initial negative impact of IT investment on bank's profitability can be explained by the significant upfront costs and the delay in return of it. However, in the long run efforts and commitments of banks towards digitalization might yield higher efficiency, lower costs and new revenue streams. Development of digital banking services allows banks to increase volumes of transactions and reduce their costs. In addition, through the digital banking banks get a golden opportunity to introduce completely new financial products and services, with minimal time to market for the larger customer base, realizing higher margins. This intuition is consistent with the positive impact of ebanking exposure on NIM.

Following the intuition of lagged profitability response on the digital transformation factors,

the dynamic model specification is incorporated to extend investigation of its relationships. Due to the dynamic factors, the OLS estimates based on 2 are biased since there is a correlation between the lagged dependent variable π_{it-1} and the error term ν_{it} (Nickell, 1981). The reasons for that are region specific individual effects and presence of endogeneity bias. The model includes lagged dependent variable among regressors, to account for the dynamic nature of bank performance. At the same time, potential delayed effect of digital transformation is represented by the included lagged independent variables $X_{j,it-1}$. The error term in endogeneity bias is unobservable, so there is no direct way to statistically test that an endogenous variable is correlated with the error term.

According to Wooldridge (2010) both serial correlation and heteroscedasticity generate biased and inefficient results, thus static fixed-effects and random-effects models can not be used for the estimation of dynamic specification. Another econometric technique, the generalized method of moments (GMM) estimator outlined by Arellano and Bond (1991) commonly used for dynamic panel data. It allows for the use of internal instrumental variables to address the endogeneity problem. Considering the nature of the research, endogeneity might arise if there are factors that influence both digital transformation and financial performance simultaneously. Potentially it might be the case, that banks with higher financial performance are more likely to have bigger opportunity to invest and realize gains from digital transformation. Moreover, it is effective in controlling for unobserved heterogeneity allowing to achieve unbiased and consistent estimates. Specifically the system generalized method of moments (SGMM) that improves efficiency of the standard GMM estimator, especially in small samples, by utilizing a system of equations that combines levels and first-differences of the variables (Arellano & Bover, 1995). Given the structure, dynamic nature and potential endogeneity problem in the panel data, the SGMM is considered as a best fit and primary method to assess dynamics in relationship between digital transformation and operational performance of commercial banks:

$$roa_{it} = \rho_1 roa_{it-1} + \beta_1 it\_investment\_rate_{it} + \delta_1 it\_investment\_rate_{it-1} + \beta_2 ebanking\_exposure_{it} + \delta_2 ebanking\_exposure_{it-1} + \gamma_1 size_{it} + \gamma_2 cir_{it} + \gamma_3 npl\_ratio_{it} + \gamma_4 tier\_one\_ratio_{it} + \gamma_5 loans\_to\_assets_{it} + \gamma_6 gdp\_growth_{it} + \gamma_7 inflation_{it} + \gamma_8 banking\_concentration_{it} + \gamma_9 age_{it} + IV(\delta_3 roa_{it-2} + \delta_4 it\_investment\_rate_{it-2} + \delta_5 ebanking\_exposure_{it-2}) + \mu_i + \nu_{it} \quad (6)$$

$$roe_{it} = \rho_1 roe_{it-1} + \beta_1 it\_investment\_rate_{it} + \delta_1 it\_investment\_rate_{it-1} + \beta_2 ebanking\_exposure_{it} + \delta_2 ebanking\_exposure_{it-1} + \gamma_1 size_{it} + \gamma_2 cir_{it} + \gamma_3 npl\_ratio_{it} + \gamma_4 tier\_one\_ratio_{it} + \gamma_5 loans\_to\_assets_{it} + \gamma_6 gdp\_growth_{it} + \gamma_7 inflation_{it} + \gamma_8 banking\_concentration_{it} + \gamma_9 age_{it} + IV\{\delta_1 roe_{it-2} + \delta_4 it\_investment\_rate_{it-2} + \delta_5 ebanking\_exposure_{it-2}\} + \mu_i + \nu_{it} \quad (7)$$

$$nim_{it} = \rho_3 nim_{it-1} + \beta_1 it\_investment\_rate_{it} + \delta_1 it\_investment\_rate_{it-1} + \beta_2 ebanking\_exposure_{it} + \delta_2 ebanking\_exposure_{it-1} + \gamma_1 size_{it} + \gamma_2 cir_{it} + \gamma_3 npl\_ratio_{it} + \gamma_4 tier\_one\_ratio_{it} + \gamma_5 loans\_to\_assets_{it} + \gamma_6 gdp\_growth_{it} + \gamma_7 inflation_{it} + \gamma_8 banking\_concentration_{it} + \gamma_9 age_{it} + IV\{\delta_3 nim_{it-2} + \delta_4 it\_investment\_rate_{it-2} + \delta_5 ebanking\_exposure_{it-2}\} + \mu_i + \nu_{it} \quad (8)$$

Table 3 represent SGMM regression results including Sargan test of overidentifying restrictions, AR(1) and AR(2) tests, Wald tests for coefficients and time dummies. According to the Sargan test, the instrumental variables are valid for all three models, as indicated by the test statistics and p-values: $\chi^2(52) = 57.286$, $p = .285$ for the ROA model; $\chi^2(52) = 54.630$, $p = .375$ for the ROE model; and $\chi^2(52) = 62.875$, $p = .144$ for the NIM model, suggesting that the instruments are not correlated with the error terms. In addition, the AR(2) test indicates no significant autocorrelation at the second lag for all three models (ROA: $AR(2) = .561$, $p = .574$; ROE: $AR(2) = -1.010$, $p = .308$; NIM: $AR(2) = 1.384$, $p = .166$), supporting correct model specification and the use of lagged levels as instruments. The AR(1) test suggests the presence of autocorrelation at the first lag (ROA: $AR(1) = -4.135$, $p < .001$; ROE: $AR(1) = -2.825$, $p =$

.004; NIM: *AR(1)* = -3.783, $p < .001$), which is expected and not a concern for the SGMM model specification. The overall significance and importance of the variables used are confirmed by the Wald test for coefficients across all three models, with test statistics indicating strong model fit (ROA: $\chi^2(14) = 384.459$, $p < .001$; ROE: $\chi^2(14) = 268.997$, $p < .001$; NIM: $\chi^2(14) = 4448.21$, $p < .001$). Interestingly, the Wald test for time dummies is statistically significant for the ROA model ($\chi^2(8) = 12.358$, $p = .136$) suggesting the presence of time-specific effects. However, it is not statistically significant for the ROE and NIM models, implying that these outcomes are not entirely explained by time-specific effects.

ROA and NIM models captured dynamics of the historical performance in predicting future operational performance. This phenomenon can be explained by the fact that successful banks with strong and persistent operational performance are more likely to maintain it in the future periods. Banks achieve it by realizing positive effects of recognizable strong branding and reliable financial service provider reputation among customers. Non-significant results observed in ROE model suggests that the amount of generated returns for shareholders are not affected by the past values. The findings related to the digital transformation factors are similar with the results of static FE model and align closely with the established theoretical background. Like in the robust FE models, IT investment rate indicates negative significant effect on ROA and ROE. Nevertheless, this initial negative impact is followed by a positive effect, supporting the intuition of over time beneficial gains. By eliminating endogeneity bias, SGMM model shows surprizing results — both current and lagged ebanking exposure has no significant impact or mixed effects on the operations of banks. This suggests that dynamic relationship in this case is quite complex, since the effect of ebanking exposure on profitability could be dependent on the other factors like quality of implementation, customer's satisfaction and competitive environment on the market.

Both dynamic SGMM and static FE models provided mixed and complex insights with regard to the stated hypotheses. While both specifications suggest negative immediate effect of IT investments on ROA and ROE due to the high initial costs, lagged effects show improvement of the banks operations over time. Thus hypotheses H1 and H2 are not supported by the FE model specification, yet partially supported by the SGMM. Consequently, the hypothesis H5 is rejected by both specifications, implying no significant direct impact of IT investments on

Table 3

Results of two-ways effect two-steps system generalized method of moments regression models

	Dependent variable:		
	roa	roe	nim
lag(roa, 1)	.185*** (.072)		
lag(roe, 1)		.080 (.082)	
lag(nim, 1)			.869*** (.033)
it_investment_rate	-.225*** (.065)	-2.116*** (.506)	-.025 (.025)
lag(it_investment_rate, 1)	.175*** (.053)	1.784*** (.475)	.035 (.024)
ebanking_exposure	-.014 (.021)	-.090 (.202)	.010 (.008)
lag(ebanking_exposure, 1)	.018 (.023)	.107 (.216)	-.009 (.007)
size	-.021 (.031)	-.228 (.285)	.001 (.010)
cir	-.012*** (.004)	-.183*** (.037)	-.002* (.001)
npl_ratio	-.039*** (.010)	-.415*** (.105)	.008*** (.003)
tier_one_ratio	.029 (.018)	.309** (.149)	.006 (.007)
loans_to_assets	-.003 (.006)	-.065 (.057)	.004** (.002)
gdp_growth	.022 (.019)	.070 (.151)	.001 (.008)
inflation	-.048 (.062)	-.359 (.431)	.007 (.017)
banking_concentration	-.004 (.006)	-.021 (.058)	-.003 (.002)
age	.017 (.037)	.302 (.382)	-.023 (.019)
Sargan Test (chisq)	57.286 (52)	54.630 (52)	62.875 (52)
Sargan Test p-value	.285	.375	.144
AR(1)	-4.135	-2.825	-3.783
AR(1) p-value	$< .001$	.004	$< .001$
AR(2)	.561	-1.010	1.384
AR(2) p-value	.574	.308	.166
Wald Test for Coefficients (df)	384.459 (14)	268.997 (14)	4448.207 (14)
Wald Test for Coefficients p-value	$< .001$	$< .001$	$< .001$
Wald Test for Time Dummies (df)	12.358 (8)	14.427 (8)	36.707 (8)
Wald Test for Time Dummies p-value	.136	.007	$< .001$
Observations	84	84	84

Note. * indicates $p < .1$. ** indicates $p < .05$. *** indicates $p < .01$.

NIM. The influence of digital banking exposure on bank operations is less direct, due to the varying results between static and dynamic models. The FE model provides an evidence of positive significant relationship with NIM accepting the hypothesis H6. However, the SGMM model's findings are non-significant, bringing uncertainty into the interconnection of these two

indicators. The impact of ebanking exposure on ROA and ROE may be more complex and indirect, leading to the rejection of the hypotheses H4 and H5. Ultimately, findings derived in this study suggest that digital transformation positively affects the long-term operational efficiency of commercial banks in the European Union, although the immediate effects are mixed and have more sophisticated interconnection.

4 Conclusion

The main aim of this thesis was to evaluate the impact of digital transformation on the operations of commercial banks in the European Union. The theoretical background is built by reviewing the concept of digital transformation, considering its aspects, challenges, and opportunities that organizations may exercise from it. Banks are quite cautious and resistant to such changes since as financial institutions, they are heavily regulated and serve critical economic functions. The path of IT-enabled transformation for banks is full of caveats, including regulatory constraints, cybersecurity threats, and required changes in the mindset of people. However, banks that include digital transformation in their strategic agenda gain profound benefits of more efficient operations, improved customer experience, and higher financial performance. The adoption of digital technological advancements by banks is not merely a trend but a necessity to be competitive and grow in the current digital age.

To understand the effects of digitalization processes, panel data regression analysis is performed employing the static fixed-effects and dynamic system generalized method of moments estimation techniques. The analysis reveals that investments in information technologies do not bring immediate positive results but significantly contribute to a bank's long-term financial performance. Moreover, incorporated models provided mixed but weak results related to the other component of banking digitalization — ebanking exposure, suggesting that it possibly affects certain aspects of banking operations without an effect on the financial performance indicators. Overall, the empirical analysis performed in this thesis demonstrates that investments by commercial banks in the European Union in digital transformation positively impact operations over time, enhancing banks' ability to adapt to the disruptive financial environment.

There are several limitations in this thesis that must be considered. The empirical analysis is constrained by the sample of data used. Many banks were excluded due to the availability and quality of data sources. In addition, available data sources did not provide more detailed and granular data related to digital transformation indicators, which would allow capturing more nuanced effects. Finally, the analysis is focused on the European Union's banking sector, thus it is not possible to generalize the results and apply them to other regions with different regulatory and market dynamics.

As a practical recommendation based on the outcome of this thesis, banks must properly prioritize and include in their strategy investments in information technologies. This must be done in combination with promoting innovation and fostering cultural changes within the organizational structure. Stakeholders and investors should align their return on investment expectations with a long-term perspective, nevertheless still prioritize and possibly increase financing of digital transformation. Policymakers and regulators should foster the digital transformation process in the financial industry by providing a necessary environment and boosting digitalization in synergy on all levels. In further research on this topic, the recommendation is to explore other variables linked with digital transformation. In the dynamic specification, different lag structures can be incorporated by using broader time horizon to get deeper insights and confirm observed temporal dynamics of digital transformation indicators. The scope of the study can be extended by including banks from other regions to perform a cross-regional comparative analysis. Ultimately, banks' operations can also be observed from different angles, thus the suggestion is to examine how various digitalization factors influence specific areas like risk management, liquidity management, or compliance.

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Appendix

Table A1

Variable definitions

Variable	Definition	Source
Return on assets (ROA)	Net profit as a percentage of assets	SNL Financial
Return on equity (ROE)	Net profit as a percentage of equity	SNL Financial
Net interest margin (NIM)	Net interest income, on a fully taxable-equivalent basis if available, as a percent of average earning assets. If average earning assets is not available, average financial assets may be used	SNL Financial
IT investment rate	Rate of investments into communications, data processing and technology such as computers, software, information systems and telecommunications	SNL Financial
eBanking exposure	Penetration of digital banking services among population	Eurostat
Total assets	All assets owned as of the date indicated, as carried on the balance sheet and defined under the indicated accounting principles	SNL Financial
Size	Natural logarithm of total assets	SNL Financial
Years of operation	Number of years bank has been in operation	SNL Financial
Age	Natural logarithm of years of operation	SNL Financial
Non-performing loans (NPL) ratio	Non-accrual and restructured loans as a percent of total loans and leases	SNL Financial
Cost to income ratio (CIR)	Operating expense as a percentage of operating income	SNL Financial
Tier one capital ratio	Tier one capital as a percentage of total risk-weighted assets of bank	SNL Financial
Loans to assets ratio	Total loans as a percentage of total assets	SNL Financial
GDP growth	Annual percentage growth rate of GDP at market prices based on constant local currency	World Bank
Inflation	Harmonised Indices of Consumer Prices (HICPs) designed for international comparisons of consumer price inflation	Eurostat
Banking concentration	Assets of three largest commercial banks as a share of total commercial banking assets	World Bank

Note. This table provides definitions and sources for key variables used in the thesis.