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The impact of digital transformation on financial performance in public banks, development banks, and private banks in Türkiye

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Abstract
The aim of this study is to examine the impact of digital transformation on the financial performance of banks in Turkey. An exploratory design of the mixed research method was applied in the study. A digital transformation (DT) ratio was developed from banks through content analysis of the qualitative analysis methods. This ratio was then added as variables to causality test. The study's analysis covers the period from 2005 to 2023. The research include ROA, ROE, capital adequacy ratio (CAR), and the DT ratios developed for research is used as the variables. A negative correlation was found between DT and ROA, ROE, and CAR in public and development banks, whereas a positive correlation was observed between DT and ROA, ROE, and CAR in private banks. The relationship between DT and ROA, ROE, and CAR in public banks, and the relationship between DT and CAR in private banks, were found to be significant. The hypothesis that there is a causality from DT to CAR in public banks was rejected, while other hypotheses were accepted.

Keywords: banking sector, digital transformation, financial performance, Dumitrescu Hurlin panel causality test

Introduction[1]

Digital technological developments such as artificial intelligence, big data, 5G, and blockchain have steered the global economy and society towards a digital era (Li et al., 2020; Shanti et al., 2023). The advancement of digital technology has transformed both social and industrial activities, making digitalization an inevitable reality today. During the COVID-19 period, characterized by intense physical constraints, the development of digital technology accelerated the digitalization processes in the manufacturing, healthcare, education, economy, and finance sectors (Shanti et al., 2023). According to a study by the International Data Corporation

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[1] This study was partially presented at the VII-th International Conference on Economics on May 31 -June 2, 2024, and published online as a short abstract.

(IDC), by 2024, more than 50% of global economies and over 90% of businesses will have a digitalized structure (Yu & Yan, 2022).

Digital transformation is defined by Gartner as the enhancement of business models, the creation of new revenue types, and the generation of opportunities for added value to production or business through the development of digital technology (Diener & Špaček, 2021). In this context, digital technology encourages businesses and industries to offer new or improved services, transforms the ways businesses operate, and provides increased added value to enterprises (Dwivedi et al., 2022).

Today, businesses and industries need to adopt the intensive use of digital technology to strengthen their market positions. By advancing their use of digital technology, businesses and industries can enhance their capabilities related to optimal operations, improve their business processes, and gain a competitive advantage in the digital economy (Shanti et al., 2023).

One of the driving forces behind the development in the digital economy alongside digital technology is the finance sector (Diener & Špaček, 2021). Within the finance sector, the traditionally structured banking sector is considered a pioneer in information technology (Wang & Wang, 2022). Digital transformation in the banking sector refers to technology-based banking services (Theiri & Hadoussa, 2023). With the digitalization of the banking sector, new digital financial services such as smart asset management, fund scanning, online credit issuance, and online account managers have been introduced to customers (Bian et al., 2015). Moreover, digitalization is expected to increase interest and non-interest incomes in commercial banks (Bian et al., 2015; Jameaba, 2020) and enhance the efficiency of providing credit to customers through optimized credit processes, leading to an increase in the number of customers using bank loans (Zhou & Li, 2023). Additionally, digital transformation is significant in terms of costs. Providing services without physical branches facilitates customer access and increases operational cost efficiency (Kitsios et al., 2021). Thus, management and operating expenses are reduced (Zhu & Jin, 2023). Effectively managing digital processes will also strengthen banks' competitive power (Li et al., 2022). Increased competitive power and internal efficiency will directly impact the financial performance of banks (Chen et al., 2021; Dwivedi et al., 2022).

There is a limited number of studies in the literature investigating the impact of digital transformation on the financial performance of banks. In this context, the findings from this research provide evidence regarding the relationship between digital transformation and financial performance, thereby filling a gap in the literature. Accordingly, this study addresses how market-oriented digital transformation is handled in the non-financial reports of the Turkish banking sector and the extent to which it affects financial performance. Three primary research questions have been developed for this purpose.

- Can a 'Digital Transformation (DT) Score' be developed using content analysis techniques with key terms related to digitalization from the explanations of digital transformation efforts in the non-financial reports of banks?
- Is it possible to establish a relationship between the developed DT Score for banks and their financial performance?
- Does the developed DT Score for banks affect their financial performance?

The purpose of this study is to examine the relationship between the statements regarding digital transformation in the non-financial reports of Turkish banks and their financial performance. The contribution of this study to the literature is the application of content analysis to explore the extent to which Turkish banks address digital transformation in their non-financial reports. Existing research has examined the impact of quantitative data, such as the number of digital customers and digital application usage, on other quantitative financial performance indicators. Unlike previous studies, this research investigates the relationship between quantitative data derived from qualitative data (the digital transformation 'DT' score developed for this study) and the quantitative financial performance indicators.

A significant portion of research on the financial performance of banks is conducted without categorizing banks into distinct groups (such as ownership structure, type, etc.). For instance, when examining deposit banks, public, private, or foreign capital deposit banks can be considered within the same group. When public capital banks are investigated, both deposit banks and participation banks, as well as development and investment banks, can be studied together. The same situation may apply to private or foreign capital banks. This circumstance can hinder the ability to make comparisons within groups based on the ownership structure and type of banks. In this context, this research analyzes the impact of digital transformation on financial performance according to the ownership structures and types of banks, while also enabling comparisons between these groups. Therefore, in the study, public and private capital deposit banks, as well as development and investment banks, are treated as separate groups. This approach allows for a clear observation of the effects of digital transformation explanations on the financial performance of each group. Furthermore, the banks included in the study were selected from among the top 10 banks with the largest asset size in the Turkish Banking Sector.

The research is organized as follows. After the introduction, Section 1 reviews the literature on digital transformation and its application in the banking sector, and hypotheses are developed. Section 2 explains the research design, presenting the statistical methods used, data sources, and secondary data processes. Section 3 interprets analysis of findings. Section 4 discusses findings and then provides the conclusions.

1. Literature review and hypothesis development

In the banking sector, digital transformation has been found to have a significant impact on banking operations, facilitating and simplifying processes (Bhutani & Paliwal, 2015), and reducing costs (Warner & Wager, 2019). Digitalization in banking provides numerous advantages, including the monitoring and control of operations, enhancement of product and service quality, and improvement of risk management (Sloboda et al., 2018). Within the framework of the information asymmetry theory, the digitalization of banks reduces information asymmetry in financial statements for stakeholders (Zhu & Jin, 2023). Despite this, there are limited sources in the literature concerning the digital transformation of the banking sector. According to Heredia et al. (2022), the reason for the lack of substantial evidence to establish a positive or negative relationship between digital transformation and financial performance is the limited number of studies explaining these mechanisms.

Mahboub (2018) examined the impact of information and communication technology investments on the performance of Lebanese banks, finding that digital services such as ATMs, internet, phone banking, and POS did not significantly affect the banks' performance. Ky et al. (2019) concluded in their study that financial technology had a strong positive impact on bank performance in East African countries. In their research on the correlation between determinants and performance in Russian banks, Koroleva and Kudryavtseva (2020) found that, with digital transformation and communication through digital channels with customers, banks in Russia performed better. Dong et al. (2020) examined the impact of internet financing on the financial performance of Chinese banks and found that internet financing had a positive effect on bank profitability. Zuo et al. (2021) highlighted several studies that found a positive relationship between the digital transformation of banking in China and the increase in bank efficiency, noting the need for more research to determine the impact of IT (computer technology) investments on financial performance. Potapova et al. (2022) investigated the relationship between digital transformation and financial performance in Russian commercial banks and found no significant relationship between digital transformation and profitability. Jikrillah and Fadah, (2022) examined the relationship between digital transformation and financial performance in Indonesian banks and found no significant relationship between digitalization and return on assets or net profit margin. Doran et al. (2022) found that digital transformation positively affected return on assets and return on equity in banks in Central and Eastern European countries. Zhu and Jin (2023) examined the relationship between digital bank transformation and commercial bank operating capabilities, as well as the impact of COVID-19 on this relationship, finding that digital transformation improved operational capabilities but was negatively affected by COVID-19. Mavlutova et al. (2023) found an increase in digital payment intensity in financial institutions in the EU and a close relationship

between digital payments and the operational efficiency of financial institutions. Shanti et al. (2023) investigated the impact of digital transformation on bank profitability in seven banks in Indonesia, concluding that there was a U-shaped relationship between digital transformation and bank profitability, suggesting that digital transformation supports bank profitability in the long term while causing a decline in profitability in the short term due to significant investments. Theiri and Hadoussa (2023) researched the impact of digital transformation on financial performance in Tunisian banks, finding that digital transformation had a positive effect on return on assets and return on equity.

However, in particular, studies on financial market volatility, geopolitical risks, and monetary policy could provide a supportive framework for understanding the impact of digital transformation in banking. In this context, Alptürk et al. (2021) examined the impact of Turkey's geopolitical risk on Credit Default Swap (CDS) premiums between March 2010 and October 2020, highlighting the importance of assessing the countries' risk status in terms of financial markets. According to their findings, changes in geopolitical risks significantly affect CDS premiums, whereas changes in CDS premiums do not influence geopolitical risk. Gürsoy and Kılıç (2021) investigated the effects of global markets' economic and political uncertainty on financial markets in Turkey using monthly data from March 2010 to October 2020. Their findings indicate that the volatility of CDS and banking variables exhibits a persistent effect, and that there is a volatility interaction from the Global Uncertainty Index to CDS. Additionally, there is a volatility interaction and transmission from CDS to the Global Uncertainty Index, as well as a volatility interaction from banks to the Global Uncertainty Index. Furthermore, there is a volatility interaction and transmission from the Global Uncertainty Index to banks, which has a mitigating effect on this interaction. Doğan et al. (2022) analyzed the impact of wind and geothermal energy consumption on financial and economic development in Germany, Iceland, Italy, Japan, Mexico, New Zealand, Portugal, Turkey, and the USA for the period from 2016-M1 to 2020-M11. Their findings suggest that geothermal energy consumption has a positive effect on financial development for the country group, while both geothermal and wind energy consumption negatively impact economic growth. Causality results indicate a unidirectional relationship from financial development to wind and geothermal energy consumption. Additionally, a unidirectional causality from wind and geothermal energy consumption to economic growth was identified. However, no statistically significant causality was found from wind and geothermal energy consumption to financial development or from economic growth to wind and geothermal energy consumption. Shahbaz et al. (2023) investigated the effects of financial development and economic growth on the ecological footprint by using annual data from China, the USA, India, Japan, Brazil, Indonesia, Mexico, Korea, Turkey, and the UK for the period 1992-2017. Their findings reveal that financial development, economic growth, and non-renewable energy consumption increase

the ecological footprint, negatively affecting environmental quality. Conversely, the effect of trade openness on the ecological footprint is statistically insignificant. Additionally, there is a unidirectional causality from financial development to ecological footprint, while a bidirectional causality exists between economic growth and ecological footprint. Gürsoy et al. (2024) examined the interaction between climate policy uncertainty (CPU), green energy index (ENERGY), carbon emission permit prices (CARBON), and Bitcoin (BTC) returns between 2012 and 2022. Their findings indicate a positive relationship between BTC and CARBON, a positive relationship between BTC and CPU, and a negative relationship between BTC and ENERGY. In terms of causal relationships, a unidirectional causality was identified from CARBON to BTC, from BTC to CPU, and from BTC to the ENERGY variable.

Researchers examining the impact of digitalization on the banking sector have obtained varying results. Some researchers have found a significant and positive effect between digitalization and financial performance (Dong et al., 2020; Doran et al., 2022; Koroleva & Kudryavtseva, 2020; Ky et al., 2019; Mahboub, 2018; Theiri & Hadoussa, 2023), while others have found no relationship or no significant relationship (Jikrillah & Fadah, 2022; Potapova et al., 2022).

This research builds on the studies by Dong et al. (2020), Doran et al. (2022), Koroleva and Kudryavtseva (2020), Ky et al. (2019), Mahboub (2018), and Theiri and Hadoussa (2023), who found a significant and positive effect between digitalization and financial performance, as well as those by Jikrillah and Fadah (2022) and Potapova et al. (2022), who found no relationship or no significant relationship. In line with the literature, this study uses ROA and ROE (Dong et al., 2020; Doran et al., 2022; Jikrillah & Fadah, 2022; Potapova et al., 2022; Theiri & Hadoussa, 2023) and CAR (Shanti et al., 2023). Additionally, unlike other studies, the independent variable digital transformation data (DT score developed for this research) is derived from the content analysis of the statements on digital transformation in the non-financial reports of Turkish banks. This study aims to examine the impact of digital transformation on financial performance in public banks, development banks, and private capital banks. By applying the exploratory design of mixed research methods, this study contributes to the literature by first using content analysis and then incorporating the derived data into the quantitative analysis as an independent variable. The Dumitrescu Hurlin Panel causality test is used to test the hypotheses developed to examine the relationship between the variables. Additionally, the study is significant in investigating the relationship between digital transformation and financial performance over the period from 2005 to 2023, providing new empirical evidence to past research.

Capital adequacy ratio and profitability ratios are among the measures that indicate the financial soundness of banks (Rahman, 2017). Accordingly, based on the literature and the context discussed, the following hypotheses have been developed.

H1a: There is a causality relationship between the DT score and ROA ratio in public banks.
H1b: There is a causality relationship between the DT score and ROE ratio in public banks.
H1c: There is a causality relationship between the DT score and CAR ratio in public banks.

H2a: There is a causality relationship between the DT score and ROA ratio in development banks.
H2b: There is a causality relationship between the DT score and ROE ratio in development banks.
H2c: There is a causality relationship between the DT score and CAR ratio in development banks.

H3a: There is a causality relationship between the DT score and ROA ratio in private banks.
H3b: There is a causality relationship between the DT score and ROE ratio in private banks.
H3c: There is a causality relationship between the DT score and CAR ratio in private banks.

2. Dataset and methodology

This chapter describes the research methodology and the types of analysis used in the research. In order to extend and strengthen the results of the research, the mixed method is used. The content analysis technique is used for qualitative analysis and The Dumitrescu Hurlin panel causality test is used for quantitative analysis. Additionally, this chapter explains how DT scores are developed for the investigation.

2.1. Dataset and methodology

In this research, the exploratory design of the mixed research method was applied. Within this exploratory design, the frequency analysis technique, a qualitative analysis method, was used. Through frequency analysis, a DT score was created from the statements on digital transformation provided by banks (developed for this research). Non-financial reports of the banks were used for data collection in the qualitative analysis. Subsequently, the Dumitrescu Hurlin Panel causality test was applied in the quantitative analysis. For the quantitative analysis, financial performance indicators from the Turkish Banks Association (TBA) website were utilized. The population of the study consists of all banks in the Turkish banking system, while the sample includes the nine banks with the largest assets. The analysis

covers the period from 2005 to 2023. Financial performance indicators used in the study are ROA, ROE, and capital adequacy ratio (CAR). The non-financial performance indicator is the level of information regarding digital transformation (DT score developed for the research) disclosed by banks. The analyses were conducted using 19 years of data from the nine banks, resulting in 57 firm-year observations for each group.

In this research, the reason for selecting a mixed research method is the simultaneous use of qualitative and quantitative data. Using the exploratory design of the mixed research method, quantitative data were generated from qualitative data through the content analysis technique, which is one of the qualitative analysis methods. In other words, the content analysis technique employed in the study was used to produce quantitative data from qualitative data to be added to the quantitative dataset of the research. This approach has facilitated the expansion and enhancement of the final results of the study. The reason for choosing the causality test by Dumitrescu and Hurlin in the research is to determine the directions in which the variables influence each other. Specifically, the causality test was applied to ascertain whether digitalization affects financial performance and, if so, whether the effect is bidirectional or unidirectional. Furthermore, the transition of banks in Turkey to digital transformation began in 2005. Since that date, banks have shown progress in digitalization each year to adapt to the competitive conditions within the sector and to the changing times. As of the date this research was conducted, the absence of disclosed data for the end of 2024 for banks has resulted in the research data covering the period from 2005 to 2023. Additionally, the ratios of ROA, ROE, and CAR are among the indicators used to determine the financial soundness of banks. In this context, this research examines whether these ratios, which indicate the financial soundness of banks, have been affected by digital transformation during the period from 2005 to 2023.

Dependent variables

Return on Assets (RO) shows the profit earned over the total assets of a business, making it an important indicator of a bank's efficiency as it demonstrates the extent to which each unit of average assets generates profit. The ROA ratio is calculated by dividing pre-tax profit by average assets. Therefore, ROA can measure how efficiently a bank is managed (Petersen & Schoeman, 2008).

Return on Equity (ROE) is calculated by dividing pre-tax profit by average equity. The lower the average equity value, the higher the ROE. Therefore, bank owners (shareholders) may not want to have excessive equity. However, due to capital adequacy regulations, it is not possible for equity to be too low, as the level of bank capital funds is subject to these regulations (Petersen & Schoeman, 2008).

Capital adequacy (CAR): this ratio is among the financial soundness indicators. Banks' capital adequacy ratios also provide information about the socioeconomic conditions of the countries in which they operate (Arzova & Şahin,

2023). The capital adequacy ratio is calculated by dividing a bank's total regulatory capital by its risk-weighted assets, measured as a percentage (Shanti et al., 2023).

Independent variables

DT Score: in this study, statements regarding digital transformation in the non-financial reports of banks were analysed using the content analysis technique. From the findings obtained, percentage values representing the DT score for each year of analysis for the banks were calculated. In the first stage, these values were obtained using a qualitative analysis method and, in the second stage, they were added as an independent variable to the quantitative analysis. Detailed information on the creation of the DT score will be provided in the methodology section.

Table 1. List of banks included in the analysis

Bank type	Banks
Publicly Owned Deposit Banks	Ziraat Bank
	Halk Bank
	Vakıflar Bank
Development and Investment Banks	İller Bank
	Türk Eximbank
	Türkiye Kalkınma and Yatırım Bank
Privately Owned Deposit Banks	İş Bank
	Yapı and Kredi Bank
	Akbank

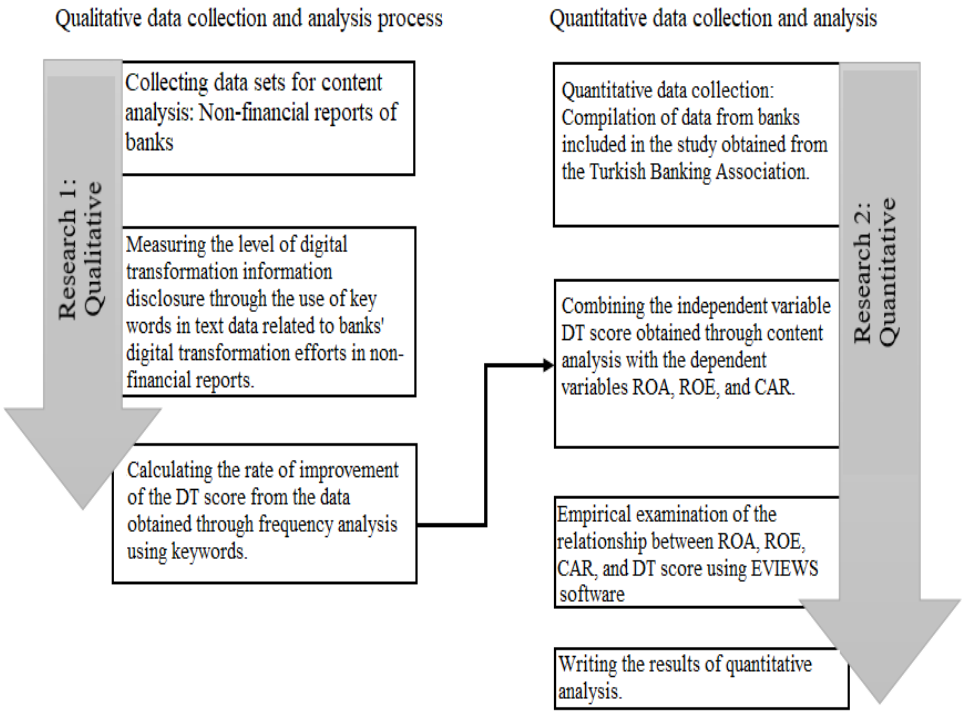
Source: author's representation

2.2. Mixed method

The concept of mixing different methods emerged when Campbell and Fisk used multiple methods in 1959 to investigate the validity of psychological traits. By the 1990s, the idea of mixing multiple methods progressed from the pursuit of convergence to the integration of quantitative and qualitative data (Creswell, 2009). The mixed method approach, which combines quantitative and qualitative analyses to obtain robust findings and achieve scientific rigor, allows for a richer understanding of the study phenomenon. Mixed method designs offer various advantages. Researchers can address "confirmatory and exploratory research questions", "provide stronger inferences than a single method", and "produce a wider range of different and/or complementary views" (Venkatesh et al., 2016, p. 437). In this study, an exploratory sequential mixed method design is followed to obtain exploratory insights into the phenomenon and to expand and strengthen the research results. Initially, a qualitative study was conducted to strengthen the research model and to develop the independent variable for testing the hypotheses (Study 1). The quantitative findings obtained from this qualitative study (the DT score developed

for the research) were then added to the financial performance indicators, and the analysis of the research was expanded through a quantitative study (Study 2). Figure 1 shows the different stages and flow of the research design.

Figure 1. Research diagram developed based on exploratory sequential design



Source: author's representation

2.3. Qualitative analysis of the research

Content analysis is widely used in the research related to environmental and social accounting. This method is a data collection technique that generates quantitative data from textual information through categorical coding (Parker, 2011; Pesci & Costa, 2014). Content analysis represents a mixed method that combines qualitative and quantitative research steps due to its position between qualitative and quantitative analysis types. The systematic nature of content analysis allows for free interpretation of the analysis results of textual data (Doğan, 2024). Pesci and Costa (2014) describe content analysis as a scientifically reliable, verifiable, and repeatable method. Researchers used content analysis to address a methodological issue in the corporate social and environmental reports of Italian Cooperative Banks, with the first based on narrative counting and the second on visual (pictures, graphs, and

tables) counting (Pesci & Costa, 2014). Using the content analysis technique, Mavlutova et al. (2023) investigated the literature on digital transformation and the impact of digital technologies on the sustainable development of businesses in the finance sector. In line with this information, content analysis was used in this research to develop the DT score.

2.4. Improvement of the digital transformation (DT) score

Digital transformation is a single, comprehensive variable that is difficult to measure (Guo & Xu, 2021), making the impact of digitalization challenging to assess. Therefore, despite its significant impact on banks, the effect of digital transformation has been examined in a limited number of studies (Kohli & Melville, 2019). Unlike the academic field, the industry focuses more on analysing financial indicators such as market value, revenue, and profitability to assess the impact of digital transformation on the financial performance of businesses. Currently, there is no conclusive evidence to fully explain the relationship between digital transformation and financial performance from all aspects (Fernandez-Rovira et al., 2021).

In this study, the DT score was developed using keywords derived from the research of Eremina et al. (2019), Guo and Xu, (2021), and Ionaşcu et al. (2022), by measuring the frequency values in the non-financial reports of banks. Frequency analysis was conducted with 124 keywords shown in Table 2, compiled from the studies by Eremina et al. (2019), Guo and Xu (2021), and Ionaşcu et al. (2022), across 171 non-financial reports of the banks included in the analysis. Since the keywords related to digital transformation were determined by consensus in previous research, no further consensus was deemed necessary for this study. Percentage values were calculated from the total digital transformation data obtained for each bank through frequency analysis. Thus, a scoring table showing the digital transformation scores (DT score developed for the research) of the banks was prepared. The steps for creating this score are explained below.

Step 1: The non-financial reports of the nine banks included in the analysis were uploaded to NVIVO 14 software in chronological order.

Step 2: The 124 keywords compiled from the studies by Eremina et al. (2019), Guo and Xu (2021), and Ionaşcu et al. (2022), as shown in Table 2, were translated into Turkish and scanned within the non-financial reports of the banks.

Table 2. Keywords used in content analysis

3D printing	data integration	image recognition	R&D
actuator	data lake	influencer	research
app	data management	informatization	robotics
artificial intelligence	data mining	informatized application	robotization
artificial reality	data monetization	informatized management	robots
asset tracking	data processing system	intelligent transportation	sensors
augmented reality	data science	innovation	sentiment analysis
automatic control	data storage	integration	server
automation	deep learning	intelligence	sharing economy
autonomous devices	digital	intelligent solutions	smart
autonomous technology	digital marketing	intelligent system	smart content
big data	digital strategy	intelligent things	smart devices
biometric	digital twin	interconnection	smart factory
biometrics	digitalization	internet	smart service
bitcoin	digitally	internet of things	smartphone
blockchain	digitization	machine learning	social media
business intelligence	data monetization	management informatization	social network
click through rate	e-catalogue	mass data	software
cloud computing	e-commerce	mobile internet	speech recognition
cloud platform	edge computing	natural language processing	technology
cloud services	e-government	networking	trade in data
cloud technology	e-mobility	neural network	user behaviour
cognitive computing	energy internet	new economy	V2V
computer	e-procurement	newsfeed	V2X
connected objects	e-publishing	online	vehicle to everything
connectivity	e-service	open source	vehicle to vehicle
cryptocurrency	e-travel	pattern recognition	virtualization
data analysis	FinTech	platform	web
data architecture	high tech	predictive analytics	web based
data capturing	Industry 4.0	programming	website
data center	IoT	proprietary algorithm	wireless

Source: Eremina et al. (2019); Guo and Xu, (2021); Ionaşcu et al. (2022)

Step 3: During the analysis phase, meaningless words or phrases within the raw data were reviewed and excluded.

Table 3. Examples of insignificant words

Keyword	Insignificant word
… analysis …	….. policy implementation
… data management …	… board of directors…
… e-service…	… this service …

Source: author's representation

Step 4: The results of the frequency analysis were transferred to an Excel spreadsheet.

Table 4. Reporting of frequency analysis in excel spreadsheet

Year	***Bank***	***Total Word Count***	***Year***	***Bank***	***Total Word Count***
2020	Akbank	7514	**2020**	Eximbank	2707
2021	Akbank	3661	**2021**	Eximbank	2847
2022	Akbank	9662	**2022**	Eximbank	2872
2023	Akbank	11095	**2023**	Eximbank	2957

Source: author's representation

Step 5: The ratio-proportion method was applied to the results of the frequency analysis to obtain the percentage values, as shown in the example in Table 5.

Table 5. DT scores of banks

Year	***Bank***	***DT Score***	***Year***	***Bank***	***DT score***
2020	Akbank	3.45	**2020**	Eximbank	6.04
2021	Akbank	10.72	**2021**	Eximbank	6.35
2022	Akbank	9.11	**2022**	Eximbank	6.41
2023	Akbank	10.47	**2023**	Eximbank	6.60

Source: author's representation

According to Table 5, 10.47% of the information disclosed regarding digital transformation in Akbank's non-financial reports from 2005 to 2023 pertains to the year 2023.

2.5. Quantitative analyses of the research

The correlation analysis was conducted to examine the relationship between various digital transformation developments in banks and their financial performance indicators. The correlation coefficients calculated through this analysis determine the strength and direction of the relationships between the variables. Mutual dependencies between variables can also be reflected through correlation analysis. This analysis was performed using 19 years of data from each group over the period from 2005 to 2023.

The Dumitrescu and Hurlin causality test, developed in 2012 by Dumitrescu and Hurlin, is an extension of the panel causality test initially introduced by Granger in 1969. The Dumitrescu and Hurlin causality test is designed to be robust against cross-sectional dependence, while also requiring that the beta values for each unit be heterogeneous. For this test to be applicable, the series must be stationary, and differencing may be necessary to achieve stationarity. If the findings of the Dumitrescu and Hurlin causality test show a probability value below a chosen significance level (e.g., 0.01, 0.05, or 0.10), the null hypothesis (H0) is rejected, and the alternative hypothesis (H1) is accepted. The test results can indicate bidirectional or unidirectional causality relationships between variables, or the absence of any relationship. Moreover, the Dumitrescu and Hurlin causality test can yield effective results regardless of whether the time dimension is smaller or larger than the cross-sectional dimension.

3. Findings

This section of the research presents the findings of the statistical analyses conducted, along with the interpretation and evaluation of these findings.

3.1. Findings of the normality test for banks

The normality test results for the variables related to the groups of public, development, and private banks in the study are presented in the tables below.

Table 6. Normality test for publicly owned deposit banks

	ROA	ROE	CAR	DT
Skewness	0.098467	0.542158	3.039412	6.437944
Kurtosis	2.125897	2.476992	11.99022	46.40004
Jarque-Bera	1.906742	3.442037	279.7186	4867.211
Probability	0.385440	0.178884	0.000000	0.000000
Observation	57	57	57	57

Source: author' representation

To determine whether a series is normally distributed, its skewness, kurtosis, and probability values are examined. For a series to be considered normally distributed, the skewness value should be "0", the kurtosis value should be "3", and the probability value should be greater than 0.05 (Doğan, 2024). According to the findings in Table 7, the ROA and ROE ratios of public banks are normally distributed, whereas the CAR and DT ratios are not normally distributed.

Table 7. Normality test for development and investment banks

	ROA	**ROE**	**CAR**	**DT**
Skewness	2.825047	2.057189	6.063502	-0.186528
Kurtosis	14.14300	7.170628	42.46803	3.010157
Jarque-Bera	370.7136	81.51534	4048.874	0.330774
Probability	0.000000	0.000000	0.000000	0.847566
Observation	57	57	57	57

Source: author' representation

Upon examining development banks, it is observed that only the DT ratio is normally distributed, while the other variables in the series do not follow a normal distribution.

Table 8. Normality test for privately owned deposit banks

	ROA	**ROE**	**CAR**	**DT**
Skewness	-4.303263	-3.472639	0.064661	0.743750
Kurtosis	30.72131	25.61526	3.461207	2.629578
Jarque-Bera	2001.040	1329.257	0.544912	5.580931
Probability	0.000000	0.000000	0.761507	0.061393
Observation	57	57	57	57

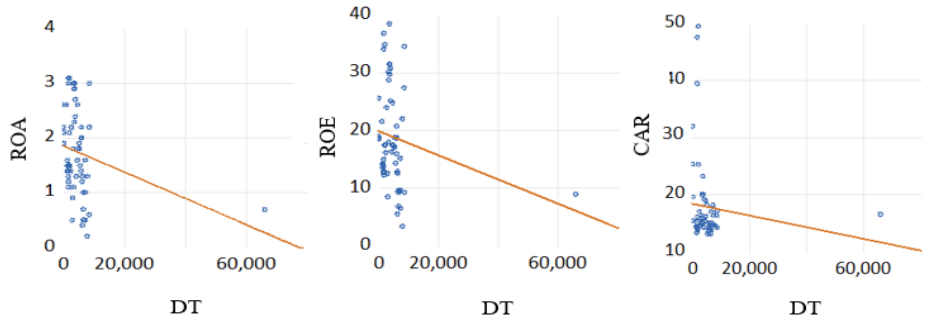
Source: author' representation

Finally, in private banks, it was determined that the CAR and DT ratios are normally distributed, while the other variables do not follow a normal distribution.

3.2. Findings from the scatter plot analysis for banks

The scatter plot is a type of analysis that provides general information to determine the direction and strength of the relationship between two variables. The scatter plot graphs below illustrate the weak/strong and positive/negative relationships between the variables for each bank group in the study.

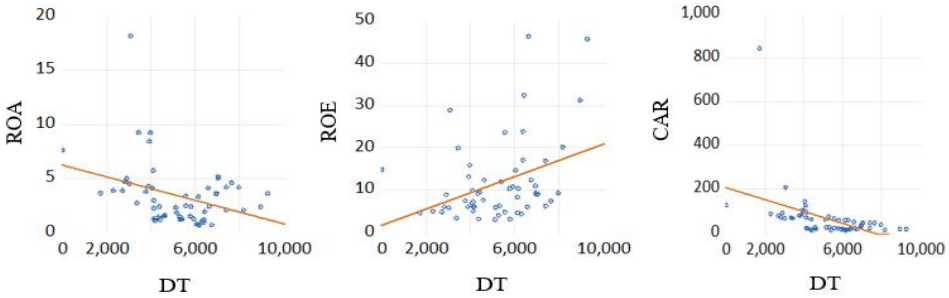
Figure 2. Scatter plot of publicly owned deposit banks



Source: author' representation

In public banks, each unit increase in the DT score does not result in a similar increase in the ROA, ROE, and CAR variables. According to the scatter plot, there is a 'weak negative relationship' between DT and ROA, while there is a 'strong negative relationship' between DT and both ROE and CAR. Accordingly, a one-unit increase in the DT score leads to a decrease in the ROA, ROE, and CAR ratios.

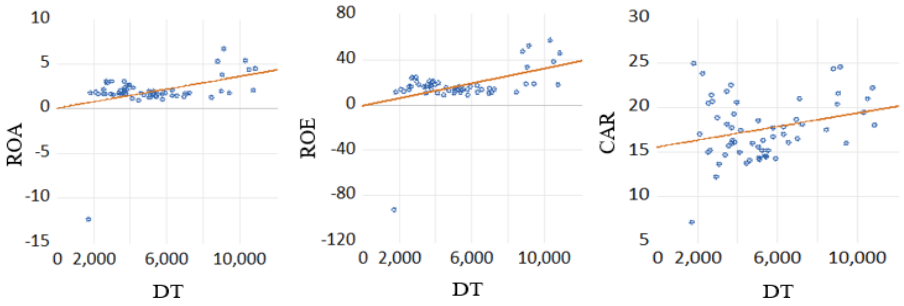
Figure 3. Scatter plot of development and investment banks



Source: author' representation

In development banks, a 'weak negative relationship' is observed between the DT score and ROA, while a 'strong negative relationship' is identified between the DT score and CAR. In other words, each unit increase in the DT score leads to a decrease in the ROA and CAR values. On the other hand, there is a 'strong positive relationship' between the DT score and ROE, meaning that each unit increase in the DT score similarly increases the ROE ratio.

Figure 4. Scatter plot of privately owned deposit banks



Source: author' representation

In private banks, a 'weak positive relationship' is observed between the DT score and both ROA and CAR, while a 'strong positive relationship' is identified between the DT score and ROE. In other words, each unit increase in the DT score results in an increase in the ROA, ROE, and CAR values.

3.3. Findings from the correlation analysis for banks

The scatter plot shows the direction and strength of the relationship between two variables but does not provide information about the intensity and significance levels of the relationships. Accordingly, the results of the correlation analysis, which indicate the strength and significance of the relationships between the variables, are presented in Table 9.

Table 9. Correlation analysis of bank groups

Example: 2005-2023 Observation: 57	***Publicly Owned Deposit Banks***	***Development and Investment Banks***	***Privately Owned Deposit Banks***
Correlation; t-Statistic Probability	DT	DT	DT
DT	1.000000	1.000000	1.000000
ROA	-0.261036 -2.005425 ***0.0498****	-0.347964 -2.752588 0.0080	0.387687 3.119108 0.0029
ROE	-0.208398 -1.580214 ***0.1198****	0.368275 2.937669 0.0048	0.450688 3.744211 0.0004
CAR	-0.117290 -0.875894 ***0.3849****	-0.445810 -3.693571 0.0005	0.276364 2.132626 ***0.0374****

Notes: p>0.01 (*), p> 0.05 (**), p> 0.10 (***)
Source: author' representation

As seen in the table, there is a weak negative correlation between the DT score and the ROA, ROE, and CAR variables in public banks. Specifically, a one-unit increase in the DT score results in a decrease of 0.26 in ROA, 0.21 in ROE, and 0.12 in CAR. Additionally, a significant relationship was found between the DT score and the ROA, ROE, and CAR variables. In development banks, a strong negative correlation was identified between the DT score and the ROA and CAR variables, while a strong positive correlation was found with the ROE variable. In other words, a one-unit increase in the DT score results in a decrease of 0.35 in ROA and 0.45 in CAR, but an increase of 0.37 in ROE. There is also a significant relationship between the DT score and the ROA, ROE, and CAR variables. Finally, in private banks, a strong positive correlation was found between the DT score and the ROA, ROE, and CAR variables. A one-unit increase in the DT score leads to an increase of 0.37 in ROA, 0.45 in ROE, and 0.28 in CAR. However, a significant relationship was found only between the DT score and the CAR variable.

3.4. Findings from the Dumitrescu Hurlin panel causality test for banks

The impact of the DT variable on the ROA, ROE, and CAR variables was analysed using the Dumitrescu Hurlin panel causality test. During the testing phase, four lags were considered to examine the possibility of a causality relationship between the variables. The findings are presented in the tables below.

Table 10. Causality test for publicly owned deposit banks

Dumitrescu Hurlin panel causality test (Sample: 2005-2023)					
Lags	**H_0: Null Hypothesis**	**W-Stats.**	**Zbar-Stats.**	**Probability**	**Result**
1	***DT to ROA***	3.26035	1.98195	***0.0475*****	***H_0: REJECT***
	ROA to DT	0.49406	-0.62077	0.5347	***H_{1a}: ACCEPT***
2	***DT to ROE***	10.0844	2.42170	***0.0154*****	***H_0: REJECT***
	ROE to DT	1.06724	-1.08496	0.2779	***H_{1b}: ACCEPT***
2	DT to CAR	2.20416	-0.64283	0.5203	H_0: ACCEPT
	CAR to DT	7.08360	1.25473	0.2096	H_{1c}: REJECT

Notes: p< 0.01 (*), p< 0.05 (**), p< 0.10 (***)
Source: author' representation

In light of the findings, the probability value indicating the causality relationship from DT to ROA and ROE in public banks being less than the significance level ($p < 0.05$) shows a unidirectional causality relationship between the variables. However, due to the probability (p) value for the relationship between DT and CAR being greater than the specified significance levels, there is no causality relationship between these variables.

Table 11. Causality test for development and investment banks

Dumitrescu Hurlin panel causality test (Sample: 2005-2023)					
Lags	**H_0: Null Hypothesis**	**W-Stats.**	**Zbar-Stats.**	**Probability**	**Result**
2	***DT to ROA***	13.6832	6.64871	***3.E-11****	***H_0: REJECT***
	ROA to DT	10.5841	4.82255	1.E-06	***H_{2a}: ACCEPT***
2	***DT to ROE***	10.8558	4.98262	***6.E-07****	***H_0: REJECT***
	ROE to DT	3.70076	0.76648	0.4434	***H_{2b}: ACCEPT***
1	***DD to CAR***	21.4682	19.1132	***0.0000****	***H_0: REJECT***
	CAR to DT	0.31970	-0.78483	0.4326	***H_{2c}: ACCEPT***

Notes: p< 0,01 (*), p< 0.05 (**), p< 0.10 (***)
Source: author' representation

According to the analysis findings for development banks, the probability values indicating the causality relationship from DT to ROA, ROE, and CAR being less than the significance level ($p < 0.01$) demonstrate a unidirectional causality relationship between the variables.

Table 12. Causality test of private equity deposit banks

Dumitrescu Hurlin panel causality test (Sample: 2005-2023)					
Lags	**H_0: Null Hypothesis**	**W-Stats.**	**Zbar-Stats.**	**Probability**	**Result**
2	***DT to ROA***	8.16622	3.39778	***0.0007****	***H_0: REJECT***
	ROA to DT	3.37125	0.57232	0.5671	***H_{3a}: ACCEPT***
2	***DT to ROE***	7.30226	2.88868	***0.0039****	***H_0: REJECT***
	ROE to DT	3.12206	0.42548	0.6705	***H_{3b}: ACCEPT***
2	***DT to CAR***	5.28012	1.69712	***0.0897*****	***H_0: REJECT***
	CAR to DT	0.22193	-1.28344	0.1993	***H_{3c}: ACCEPT***

Notes: p< 0,01 (*), p< 0.05 (**), p< 0.10 (***)
Source: author' representation

Finally, the analysis findings of private banks indicate that the probability values ($p < 0.01$ and 0.10) demonstrating causality from DT to ROA, ROE, and CAR are below the significance levels, suggesting a one-way causality relationship between the variables.

4. Discussion

The findings from the scatter plot and correlation analysis of the study reveal that both public and development banks exhibit generally negative correlations between DT ratios and the variables ROA, ROE, and CAR. Shanti et al.'s research suggests that technological advancements are not necessarily driving forces behind banks' financial performance. The researchers' findings align with the notion of a profitability paradox associated with technology investments, as they empirically

find no positive relationship between technology investment and profitability (Shanti et al., 2023). In line with these findings, the results of this study are consistent with Shanti et al.'s findings. Additionally, among the bank groups, significant relationships were observed across all variables for public banks, whereas only a significant relationship between DT ratio and CAR variable was found for private banks. These results are supported by previous studies such as Dong et al. (2020), Doran et al. (2022), Koroleva and Kudryavtseva (2020), Ky et al. (2019), Mahboub (2018), and Theiri and Hadoussa (2023). The inability to establish a significant relationship between DD ratio and all variables for development banks and between DT ratio and ROA/ROE variables for private banks is consistent with the findings of Jikrillah and Fadah, (2022) and Potapova et al. (2022). In conclusion, the findings suggest that the high cost of digital transformation for banks and the anticipated long-term benefits of digitalization may impact the profitability and capital adequacy ratios of these bank groups.

The findings of the Dumitrescu Hurlin panel causality test for banks indicate that only public banks do not exhibit a causality relationship from DT to CAR, leading to the rejection of hypothesis H1c. However, causality relationships were observed among all other variables, thereby confirming the acceptance of other hypotheses developed. Accordingly, the empirical findings of the study across bank groups suggest that digital transformation is an influential factor on asset profitability, equity profitability, and capital adequacy ratios. This implies that digital transformation does causally effect the banks' ROA, ROE and CAR ratios. In other words, the findings of the Dumitrescu Hurlin panel causality analysis conducted in the study support other research indicating and analysed by different methods that digital transformation does have a predicted effect on financial performance.

When considering the causality relationship between digital transformation and financial performance as indicated by correlation analysis, digitalization can be interpreted as increasing costs and, thereby, reducing profitability rates for public and development banks. Conversely, in private banks, this relationship may suggest cost reductions leading to increased profitability rates.

Conclusion

Banks within the financial sector have entered into a process of change and transformation with the advancement of digital technology. Especially during the intense constraints of the COVID-19 pandemic, the banking sector accelerated its digital transformation and implemented various innovations. Strategies and objectives aimed at innovative financial products and services compatible with digital transformation within the banking sector have provided various competitive advantages such as cost-effective services, reduction in branch numbers, and cost

savings. As a result of these developments and innovations, it has been noted that digitalization has certain effects on banks' financial performance.

There is limited research in the literature regarding the impact of digitalization on banks' financial performance. While some of the studies in the literature suggest that digitalization has no impact on financial performance, others have found a positive or negative relationship between digitalization and financial performance. In this context, this research examines the impact of digital transformation on financial performance in the banking sector. This study explored the relationship between digital transformation and asset profitability, equity profitability, and capital adequacy ratios using an exploratory research design incorporating mixed research methods. This is where the research differs from previous studies. Unlike previous studies, this research investigates the relationship between quantitative data derived from qualitative data (the digital transformation 'DT' score developed for this study) and the quantitative financial performance indicators. Accordingly, the digital transformation rates of banks were obtained through the qualitative analysis method by using the content analysis technique applied to the non-financial reports of banks.

According to the findings of this study, digitalization has become a key source for private banks in enhancing profitability and capital adequacy and reducing costs. On the other hand, for public and development banks, digitalization has the role of increasing efficiency as perceived by market participants. However, public and development banks are considered to be digitalizing due to competitive pressures. In this context, it is argued that digitalization has a negative impact on the profitability and capital adequacy of public and development banks. However, the most significant factor contributing to the financial impact differences among the bank groups included in the study is the methods of fundraising and fund allocation employed by these bank groups. In other words, each of the bank groups subject to the research has distinct methods for raising and distributing funds. Consequently, the cost of resources for these bank groups also varies. This situation leads to the emergence of profit differences among each bank group and affects the profitability levels of the bank groups. On the other hand, the services provided by the banking sector are increasingly differentiating from the traditional structure due to advancing technology and accelerating digitalization. With the development of internet usage, the adoption of mobile applications designed for the banking sector by bank customers is steadily increasing. These applications are leading to an increase in infrastructure-related investments for banks. The return of infrastructure investments to institutions as profit can span over a long period. According to the results of the correlation analysis of the research, it is observed that the digital transformation explanations of public capital deposit banks and development and investment banks negatively affect the financial soundness indicators of the banks. This may imply that the infrastructure investments of these two bank groups reduce their financial performance. In contrast, the digitalization explanations of private capital deposit banks appear to positively influence financial performance. This suggests that the

infrastructure investments of banks within the private capital deposit bank group yield returns sufficient to enhance profitability.

This study has some limitations. The study focused on the period from 2005 to 2023 for the analysed banks. Accordingly, the limited occurrence of digital transformation-related keywords in non-financial reports published by banks between 2005 and 2015 has impacted the research findings. Additionally, the selection of nine banks with the largest asset sizes trading on the Turkish market and ranking within the top ten has influenced the sample size of this study. Therefore, expanding the sample size in future studies may make the analysis results more reliable.

Future research could integrate both qualitative and quantitative data on the banks' digital transformation to examine their combined effects on financial performance. However, future research can be based on the research scope and specific conditions to add different dependent variables to more fully assess the impact of digital transformation on the banks' performance. Based on the results, it is recommended that, while considering digital transformation for achieving targeted profitability, banks should also consider factors such as IT investment costs, required time, and optimal strategies.

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