FinTech Investment and Bank Performance in the Eurozone: The Moderating Roles of Regulatory Quality and PSD2

Amna Albuainain[1,2,3*] and Simon Ashby[1,2]

[1]Department of Accounting, Corporate Finance and Taxation, Faculty of Economics and Business Administration, Ghent University, 9000 Ghent, Belgium

[2]Department of Accounting and Finance, Vlerick Business School, Brussels, Belgium

[3]Department of Finance and Economics, Qatar University, Doha, Qatar

*Corresponding Authors Email: Amna.albuainain@ugent.be

Abstract: This paper aims to examine the impact of FinTech investment on bank performance in the Eurozone with emphasis on the moderating roles of regulatory quality and the Revised Payment Services Directive (PSD2). Applying a two-step robust Generalized Method of Moments estimator to a panel dataset of Eurozone banks between 2015 – 2023, we find that greater FinTech spending compresses net interest margins while significantly boosting asset efficiency (ROA) and has no immediate effect on equity returns or asset yields. Regulatory quality plays a decisive role: high regulatory quality both mitigate margin pressures and amplify efficiency gains from digital finance investments. In addition, PSD2 is seen to negatively affect ROA and YEA, as a reflection of short-term profitability pressures from increased compliance costs and competition. Moreover, a significant interaction effect of FinTech investment and PSD2 is observed which implies that the open-banking regime helped alleviate some of the margin pressures traditionally associated with FinTech expenditures. This study fills a gap in literature by empirically assessing how fintech investment and the regulatory environment influence performance outcomes. The results highlight the significance of focused investment strategies and regulatory balance in managing digital transformation in the banking industry, providing insightful information for regulators, policymakers, and financial institutions.

Keyword: Fintech investment, Bank performance, Regulatory quality, Revised payment services directive (PSD2), Eurozone banks

1. Introduction

The financial services landscape is undergoing a rapid transformation fueled by technological innovation, giving rise to what is broadly termed "Fintech." Fintech is defined as technology-enabled innovation in financial services that could result in new business models, applications, processes, or products with an associated material effect on the provision of financial services [1]. This encompasses a wide array of activities, including payments, lending,

insurance, investment management, and market support [1]. [2] note, a key promise of Fintech lies in its potential to reduce financial frictions through cost-cutting digital technologies.

Today, FinTech integrates advanced technologies like artificial intelligence, blockchain, and digital platforms to change normal banking practices. These advancements improve operational efficiency, reduce transaction costs, and provide better customer experience [3]. Equally, the FinTech transformation has brought challenges such as increased competition, changing customer demands, and rising investment costs [4]. Consequently, although it has potential benefits for banking institutions, the impact of FinTech on their financial performance is mixed and continued research is required to understand the complexities of the various relationships.

For this study, "FinTech investment" denotes investment in digital innovation across financial services in both incumbents' own digital transformation (e.g., APIs, AI credit models, mobile platforms) and funding to digitally native challengers (neobanks, P2P lenders, payment apps). This definition aligns with our Invest Europe proxy and captures the full spectrum of capital flows reshaping banks' cost structures, service delivery, and competitive dynamics.

Several studies have explored the impact of FinTech on banks' profitability, revealing both positive and negative outcomes. FinTech investments have a significant positive impact on profitability [5], [6], [7], [8], [9] by reducing information access costs [10], operating costs and improving risk control [5]. For instance, [11], studying a sample of banks in 23 developed and developing countries, found that digital banking practices improved both return on assets (ROA), return on equity (ROE), in more developed countries of Europe. Moreover, [12] note that collaboration between banks and FinTech firms positively influences bank performance in the UK by expanding customer interactions, enhancing decision-making capabilities, and fostering innovation and growth within the banking sector.

In some regions, FinTech growth has been shown to negatively impact bank performance across various financial measures, such as net interest margin (NIM), ROA, ROE, and yield on earning assets (YEA), with larger, state-owned, and more mature banks being more adversely affected than smaller, private, and younger banks, as observed in Indonesia [13]. Similarly, in China, FinTech innovation has been found to reduce banks' profitability and asset quality, particularly for large state-owned banks, although it improves capital adequacy and management efficiency, with small banks benefiting from FinTech collaborations for process reengineering and innovation [14]. These findings emphasize the complex impact of FinTech on bank profitability, which varies according to regional differences and the unique characteristics of each banking sector.

These findings show that the institutional environment is a key factor in determining the impact of FinTech on bank performance. Most of the adverse impacts are visible in the developing economies where state-owned banks are prevalent and the regulatory frameworks are not always ready to address the rapid developments in FinTech. By contrast, many studies in developed economies present the positive impacts of FinTech on banks as banks in these regions are more flexible and innovative and can easily embrace the digital financial services. This supports the idea of the importance of considering regional variations and regulatory environments to understand the impact of FinTech on bank performance.

The integration of FinTech in the banking sector is mainly influenced by regulatory frameworks and regulatory quality that define how financial institutions adopt and implement digital innovations. It is therefore important that regulations be effective to provide stability, consumer protection and security so that banks can embrace FinTech

innovations without having to worry about data privacy, cybersecurity, and financial fraud risks. In countries with high regulatory quality for instance those with strong data protection regulations (e.g., General Data Protection Regulation (GDPR)) and proper financial supervision, banks can integrate FinTech solutions more effectively to improve consumer confidence and operational efficiency [5]. Therefore, in jurisdictions with limited or even restrictive regulations, banks are likely to encounter higher compliance costs, legal ambiguity, and difficulties in realizing the full potential of FinTech [15].

The Eurozone's unified currency and standardized regulatory framework create a unique institutional environment to study how FinTech affects banks. The standardized banking directives and capital mandates and consumer protection regulations of member states ensure that policy modifications such as PSD2 receive uniform implementation across all jurisdictions. The combination of deep cross-border banking relationships with extensive regulatory integration strengthens the overall impact of digital finance developments on the system. Our research benefits from this tightly coordinated institutional framework because it enables us to observe how changes in FinTech investment together with regulatory quality affect bank performance.

A clear example of how regulation affects FinTech adoption is PSD2, the Revised Payment Services Directive, which is a regulatory shift in the European Union to promote competition and innovation in financial services. PSD2 has potentially democratized access to customer data by requiring banks to share it with third party FinTech firms if the customer agrees, thereby putting pressure on traditional banks and also creating new financial service providers. PSD2 is one of the main directives that will define borderless banking and payment services and support pan-European open banking [16]. Hence, as PSD2 is a significant shift in the industry, it is a proper moderator that can help to understand the impact of the regulatory changes on the FinTech investment-bank performance relationship.

Based on these perspectives, this study examines the impact of FinTech investment on bank performance within the Eurozone, with emphasis on the role of regulatory quality as a moderator in the shaping of this relationship. Furthermore, it looks at PSD2 as an additional moderator exploring how the introduction of open-banking regulations further conditions the strength and direction of the FinTech performance relationship. Thus, the role of these dimensions is integrated to give a full picture of the role of regulatory frameworks on the effectiveness of FinTech investments in the banking sector.

This study fills a gap in the literature on the impact of FinTech investment on bank profitability in the Eurozone, a region critical to the global financial industry uniquely characterized by high regulatory integration, uniform financial market policies, and significant banking sector interdependencies, yet comparatively underexplored relative to regions such as the UK, China, and emerging markets [12], [13], [14]. While previous studies indicate both efficiency improvements and margin pressures associated with FinTech, the findings are inconclusive, implying the presence of uninvestigated border circumstances. We analyze the impact of FinTech investments on the profitability of Eurozone banks and investigate two critical moderators: regulatory quality and the implementation of PSD2, to elucidate the conditions under which fintech funding produces varying performance results. Consequently, our analysis provides practical insights for financial institutions and regulators regarding the equilibrium between innovation and stability.

This paper is structured as follows: Section 2 presents the hypothesis development while Section 3 outlines the research methodology, detailing the data collection process, variable definitions, and the statistical techniques used

to test the hypotheses. Section 4 presents empirical findings, including both descriptive and inferential statistics. Section 5 discusses the results, interprets them in the context of the existing literature, and offers practical implications for policymakers and industry practitioners. Finally, Section 7 summarizes the key findings, addresses the study's limitations, and suggests directions for future research.

2. Hypothesis development

2.1. FinTech's impact on banks' profitability in Eurozone

The impact of FinTech on bank profitability has received significant scholarly and industry attention due to the transformative nature of digital technologies in the financial sector. Research evidence shows that FinTech creates profitability through operational efficiency, cost reduction [17] and improved customer experience [18]. The implementation of automation and data analytics technology decreases operational expenses while speeding up business processes ([19], [20], and [21]) and strategic partnerships with FinTech startups enable banks to enhance their digital capabilities and extend their service offerings ([12]; [22]). The implementation of digital infrastructure through API platforms and AI-based credit tools enables banks to boost their returns on assets (ROA) and enhance their cost-to-income ratios ([23]; [24]). The technologies enable banks to create innovative models such as green finance and personalized advisory services which establish new revenue streams and expand financial access ([23]; [25]). European banks that dedicate substantial resources to FinTech development achieve superior performance in profitability and efficiency and operational agility ([26]; [24]; [25]).

The advantages of this approach have been documented in various studies but several studies have also reported adverse outcomes especially in less developed financial markets. The emergence of agile FinTech competitors has reduced the pricing power of traditional banks which has resulted in the compression of NIM ([13]; [27]). Long-standing institutions also face high costs in integrating outdated legacy systems and complying with evolving regulations challenges that can outweigh short-term efficiency gains ([28]; [29]; [30]). Research in China demonstrates that state-owned banks with restricted digital agility experience reduced profitability and deteriorating asset quality when FinTech entrants disrupt their operations ([14]; [28]). The GCC region shows that FinTech expansion leads to negative impacts on conventional banks' ROA, ROE and NIM ([31]). The adoption of FinTech faces additional governance challenges because of boards that are either too large or lack sufficient qualifications ([32]) and regulatory requirements and cybersecurity issues that limit expected benefits ([27]; [33]).

The research demonstrates that FinTech operates differently based on specific circumstances. Digital maturity together with institutional readiness and regulatory support enables FinTech to boost profitability in developed economies yet emerging markets might face challenges in achieving these benefits. Given the Eurozone’s integrated regulatory system and high level of digital preparedness, we propose:

H1: *FinTech investment will have a positive effect on banks’ profitability within the Eurozone.*

2.2. Moderating Role of Regulatory Quality

Regulatory quality, which is the capacity of regulations to improve market efficiency with few restrictions [34] serves a dual function in influencing the relationship between FinTech and bank performance. On one hand, carefully designed and consistently implemented frameworks (e.g., Basel III, AML directives, GDPR) enhance stability, diminish uncertainty, and reduce risk costs, thereby facilitating banks' more effective adoption of digital innovations [18]. The ECB [34] and the European Banking Authority (EBA) [35] are responsible for setting the

regulatory standards for FinTech startups to ensure financial stability and consumer protection perspective [5]. Basal III capital regulations, anti-money laundering (AML) directives and the GDPR are regulatory initiatives that ensure market integrity which may also challenge FinTech startups with higher operational costs and regulatory complexity [36].

Environments with high regulatory quality improve risk management and financial stability, ensuring that FinTech companies function inside rigorous frameworks that mitigate innovation-related risks [37]. They offer a transparent and consistent legal framework that promotes technical progress and stimulates innovation [38], enabling banks to enhance services, optimize operations, and decrease expenses. In the Eurozone, rigorous regulation has concurrently stimulated FinTech innovation and preserved stability, advantageous for both FinTech companies and banks [39]. Adherence to stringent regulatory requirements bolsters banks' reputations and consumer confidence, while specific risk-management protocols mitigate partnership risks [40]. Regulatory sandboxes permit supervised experimentation with novel products, fostering strategic partnerships and providing banks with access to innovative technologies and business models that enhance profitability [41].

However, stringent or badly executed rules incur high compliance burdens and open the door for regulatory arbitrage, which can hinder innovation and increase integration costs for startups and incumbents alike [36], [42]. Cross-country analyses indicate that banks in regions with less stringent regulatory enforcement face elevated operational costs and display diminished profitability when implementing FinTech solutions [43], [44]. Consequently, the disparity between these contexts highlights regulatory quality as an essential border condition.

The Eurozone member states demonstrate distinct levels of regulatory quality. The 2022 global rankings placed Finland at the 100th percentile and Germany at the 93.1st percentile but Greece and Spain received lower ratings at 72.9th and 70.4th percentiles according to [45]. The variation in regulatory quality among Eurozone countries suggests that banks operating in environments with superior regulatory frameworks are better positioned to leverage FinTech investments into enhanced profitability. Therefore, higher regulatory quality strengthens the positive relationship between FinTech investment and bank performance by providing stable, predictable, and supportive conditions for innovation. Our research takes place in a region characterized by stable strong conditions so we predict that

H2: *Regulatory quality strengthens the impact of FinTech investments on banks' profitability.*

2.3. Revised payment services directive (PSD2)

Over the past two decades, the European payment system has gone through significant regulatory changes with the aim of promoting competition, enhancing consumer protection, and facilitating financial innovation. The first major regulatory milestone was the Payment Services Directive (PSD1) issued in 2007 and completely in effect in 2009. PSD1 sought to harmonize payment services throughout the Europe Union (EU) and to increase transparency, while also setting out licensing standards for non-bank payment service providers. It was the first step of breaking the traditional bank monopoly by opening the financial sector to new payment institutions [46].

Nevertheless, PSD1 failed to encompass growing FinTech innovations, open banking, and the necessity for more competition; hence, PSD1 was insufficient. The Revised Payment Services Directive (PSD2) was enacted in 2015 and became effective in 2019. With PSD2, banks were required to grant third-party providers (TPPs) secure access to consumer payment data via application programming interfaces (APIs), going beyond the scope of the

original mandate to encompass open banking. Its objective was to establish equitable conditions for banks and FinTech companies while fostering a cohesive and innovative financial ecosystem [47].

PSD2 has introduced modifications in the Eurozone financial sector, incorporating digital wallets, FinTech aggregators, and peer-to-peer lending platforms via the disintermediation of financial services [42]. The mandate has compelled traditional banks to enhance their infrastructure, digital services, and establish partnerships with FinTech firms to comply with the new regulations [48]. Consequently, open banking has enabled banks to improve their operations, tailor their services, and offer superior and secure digital payment solutions [49]. PSD2's open-banking architecture ultimately lowers barriers to entry, stimulates service-oriented business models, and enhances collaboration between banks and FinTech partners. Regulatory scholars have argued that frameworks like PSD2 strengthen the synergy between FinTech investment and bank performance by creating a supportive context for innovation and resource sharing [50].

Nevertheless, PSD2 has introduced additional regulatory complexities, particularly with data protection and privacy. The coexistence of data protection and privacy issues with the GDPR has resulted in challenges with data accessibility and security compliance, creating legal difficulties for financial institutions [51], [52]. These challenges are crucial for comprehending the concerns surrounding regulatory enforcement and innovation within the European financial sector. incumbent banks have also faced steep compliance and integration costs, ranging from significant investments in IT infrastructure and cybersecurity measures to heightened data-security concerns as third parties gain access to sensitive information [15], [53].

The preliminary challenges indicate that PSD2 will impose detrimental performance barriers on short-term FinTech investment returns due to heightened operational costs, prolonged market entry timelines, and additional regulatory hurdles. Consequently, we anticipate its short-term effects to be predominantly negative, although it may foster positive performance potential in the future. Given that we hypothesize that:

H3: *The implementation of PSD2 will negatively moderate the relationship between FinTech investment and bank performance in the short term*

3. Research Methodology

3.1. Data collection

The data for this study are gathered from 2015 to 2023, encompassing banks operating in all 17 nations of the Eurozone. The available data yields a sample of 267 banks, comprising 1,827 firm-year observations [54]. However, listed and unlisted banks differ in the extent of risk information transmitted in their annual reports [55]. According to capital market regulations, listed companies must make substantial public disclosures and demonstrate openness to attract investors for external funding [56]. According to [57], unlisted companies are less motivated to reveal information about their performance since they have fewer stakeholders.

The study uses an unbalanced panel dataset, with missing observations arising for some banks during the selected period. This variation occurs due to banks entering or exiting the market or having incomplete records within the observation window. For bank performance four different proxies are used i.e., YEA, ROE, ROA, and NIM, along with other bank-specific control variables like total assets (SIZE), equity to total assets ratio (CAP), cost to income ratio (CTI), loan loss provisions (LLP), annual growth of deposits (DG), and interest income share

(IIS). These variables are sourced from Datastream and ORBIS databases, ensuring a comprehensive representation of the banks' financial data.

To capture the impact of FinTech venture capital investment, data on investments made in the finance and insurance sectors is obtained from Invest Europe. Investment in this sector reflects innovation and growth in financial technology [58], as investment in FinTech drives better financial solutions for insurance and investment-related allocation [59].

Macroeconomic control variables such as GDP growth and inflation rates are sourced from the Global Financial Database and the World Bank Development Indicators [60]. Additionally, the study uses the Worldwide Governance Indicators (WGI) and the Financial Development Index (FDI) from the World Economic Forum to analyze the moderating role of the regulatory frameworks in the context of the relationship between FinTech growth and profitability of the banking sector [61]. The integration of these data sources and variables led to a conclusive analysis of the relationship between FinTech and institutional regulatory quality and banks' profitability in the Eurozone. Further details regarding these variables are provided in Table 1.

Table 1: Variable measurement and sources

Variable	Measurement	Sources
ROA %	The ratio of net income to total assets	Orbis
ROE %	The ratio of net income to total equities	Orbis
YEA %	Yield on earning assets	Orbis
NIM %	Net interest margin	Orbis
FinTech investment	Finance and insurance-related investment (€EUR billion) in Eurozone countries	Invest Europe
Reg_Quality	The index scores range from +2.5, indicating the highest regulatory quality, to -2.5, indicating the lowest.	World Bank
SIZE	Log of total assets (€EUR million)	Orbis
CAP %	Capital ratio equals equity over total assets	Orbis
CTI %	Cost-to-income ratio equals total expenses over total generated revenues	Orbis
LLP %	Loan loss provisions equal loan loss provisions over total loans	Orbis
DG %	Annual growth of deposits	Orbis
IIS %	Interest income share equals total interest income over total income	Orbis
GDP %	**Euro-zone countries** annual GDP growth rate	World Bank
INF %	**Euro-zone country's** annual inflation rate	World Bank
PostPSD2	Indicates PSD2 implementation status in Eurozone countries	European Union law

3.1.1. Dependent variables

The dependent variable of interest is bank profitability, which is gauged through the following proxies. NIM quantifies the variance of earned interest income by a bank against the amount of interest expense incurred on earning assets. It shows how well the interest rate spread of a bank is managed and is used in the banking industry to measure firm profitability. This indicates that the more the NIM the better for the bank, meaning that the bank earns more of its revenue from its lending than its cost of funds. NIM is widely applied in banking research as a key indicator of profitability because it reflects the main profit generated from the banking operations connected with providing credit resources [13], [62]. YEA assesses the quantity of income yielded from the bank's earning assets to total earning assets whereby the earning assets include loans and securities. YEA suggests the extent to which the banking firm's assets are effectively used in generating revenues. This is an indication that the higher the YEA, the better its performance in using the earning assets to make income. YEA acts as a proxy that measures the

extent to which a bank effectively deploys its earning assets for return generation; It is used frequently in contextual studies of bank profitability [13], [63]. Return on Asset (ROA) on the other hand relates to the extent that a bank can maximize profits from the total assets it controls. It provides information on how efficiently a bank is utilizing its assets and the extent to which the company can transform its asset base into net income. It is commonly used to assess the performance and efficiency of a bank [64]. Finally, ROE shows the efficiency of a bank generating profit from its shareholder's funds. It is used as a primary measure of how effectively a bank employs capital for earning revenues and especially to evaluate equity capital for generating profits. ROE is another recognized measure that has found its way into the existing literature on bank performance [65].

3.1.2. Independent variables

As an independent variable, this research relies on FinTech Venture capital investment to gauge fintech growth and competition towards banks [66]. It is the volume of investment by venture capital in the finance and insurance industries across Europe and is calculated to reflect the new financial technology sector. Services that fall under FinTech include lending operations, payment platforms, personal financial services, mobile money, crowd-funding and virtual currencies. The data on FinTech VC investment is collected from Invest Europe.

3.1.3. Moderator

The contingent factor in the current study is regulatory quality. Regulatory quality relates to the perceived government's capacity to design and implement policies, standards, and rules that offer clarity, development, and competition in different sectors of the economy [67]. In this research, regulatory quality is quantified by adopting the World Bank's index obtained annually [68]. The World Regulatory Quality Index includes 192 nations and is based on a variety of variables, including the effectiveness of antimonopoly laws, tax justice, trade safety, and the stringency of environmental regulations. These measures are derived from many sources, including the WGI and the FDI. The index scores can range from 100, signifying the highest regulatory quality, to 0 representing the lowest [69]. This index captures the quality of the country's economic regulations about property rights, business relevance, and business environment [70].

PSD2 (Payment Services Directive 2) is considered a second moderator in this study, in addition to Regulatory Quality. In the financial services industry, PSD2, a significant EU regulation change, promotes innovation, security, and competitiveness. As a disruptive regulatory shift that affects the efficacy of FinTech investments, it modifies the association between FinTech investments and bank performance. PSD2 improves the relationship between FinTech investment and banking performance by establishing a collaborative regulatory framework [50]. PSD2 also encourages open banking, which increases competitiveness and permits the integration of cutting-edge financial technologies with conventional banking [71].

3.1.4. Control variables

Some of the firm-level and country-specific characteristics are controlled in this study to attain the best model fit. Other control variables at the firm level are: BSIZE and total asset size expressed in natural logarithm. In some ways the scale may favor larger banks; these offer better operational efficiency and scope for spreading services and risk, which could have a positive influence on the level of profitability. But on the same note, [72] and [73] posit that large banks can suffer from diseconomies of scale because of high bureaucracy and complicated

operations. The natural logarithm is applied to transform all the data of the bank's sizes since they have a very large variation from one country to across the world.

Second, the Equity to Total Assets Ratio (CAP), demonstrates the ratio of equity to the total assets of a bank. CAP shows how financially secured and solvent the bank is, wanting equity ratios provided that less use of debt funding is preferred. The banks with relatively high equity ratios are often regarded as safer and hence cost of funding might be lower for them. However, high equity can also mean that the bank is not taking full advantage of tax benefits from debt financing, which could negatively affect profitability [74], [75].

Third, the cost-to-income ratio (CTI) is calculated by dividing a bank's operational costs by the total amount of money it makes. The gauge of operational effectiveness is CTI. A bank is effectively turning its revenues into profits if its CTI is low; conversely, a greater CTI suggests inefficiencies and possibly decreases profitability. According to [19], [20], and [21], CTI is a major factor in determining bank success because high operational expenses lower profit margins.

Fourth, the amount of a bank's assets set aside to cover any losses from poor loans is known as LLP, which is calculated as the LLP over total assets. Since setting aside provisions reduce available capital for lending and investments, high LLP values indicate that the bank is more vulnerable to credit risk, which has a negative effect on profitability [21], [76].

Fifth, DG measures the percentage increase in deposits held by the bank over a year. While deposit growth can provide banks with more capital for lending and investments, which could enhance profitability, it may also increase competition for deposits, leading to higher funding costs and lower profits. Furthermore, despite narrow deposit expansion, it may lead to grants of loans to clients with a poor credit rating, causing credit risk and, hence, less net income [77], [78].

Sixth, the company's capacity to produce interest income from its overall revenue is determined by the IIS. IIS demonstrates how much a bank depends on interest revenue which comes from loans and other sources instead of other non-interest revenue, such as commissions. It has been suggested that although interest income is one of the main sources of income for the majority of banks, it is accompanied by a lack of revenue diversification, which may result in a lower level of resilience to changes in interest rates or the economy and, ultimately, a lower profit [21].

Gross Domestic Product Growth (GDP), or a nation's overall economic growth, is the first of the country’s control variables. Higher economic growth assumes added demand for operating services such as loaning and investing, hence the improved performance of the banking sector. On the other hand, during periods of recession credit risk is high for the banks as borrowers are more likely to default on their loans, thus reducing the amount of profit for the bank. It measures changes in business cycles that presumably affect the performance of banks [20], [78]). Second, the Inflation Rate (INF), measures the percentage change in the price level of goods and services produced in the economy within a year. The studied hypothesis related to the relation between inflation and bank profitability is inconclusive. On the one hand, moderate inflation can lead to an increase in bank margins if the interest rates are raised more rapidly than operating expenses. On the other hand, high inflation can erode real income and increase operating expenses, reducing profitability [13].

3.2. Empirical framework and estimation methods

This study exploits the endogeneity concerns by utilizing the Generalized Method of Moments (GMM) based estimator developed by [79], [80]. As there is potential reverse causality between the bank performance and FinTech activities [81], a dynamic GMM estimator is a suitable method to avoid this issue. In particular, the GMM dynamic estimator is quite appropriate for estimating structural dynamic panel data models [79], [80]. The mitigation of endogeneity, heteroscedasticity, and autocorrelation concerns is made possible through its use of instrumental variable (IV) approaches. Using this methodology, the study provides a more accurate estimate of the interaction between FinTech investments, bank performance, regulation quality, and PSD2 implementation, to the detriment of biases resulting from other estimation techniques. This dynamic panel methodology is particularly well-suited to our context, where past performance (e.g. NIM, ROA, ROE, YEA) is likely to influence current performance and where FinTech investment itself may respond to contemporaneous profitability shocks.

Our empirical approach involves a cross-level analysis due to the hierarchical nature of our dataset. Specifically, the dependent variable (bank performance) is measured at the individual bank level, while the independent variable (FinTech investment) and moderators (e.g., regulatory quality and PSD2 implementation) are measured at the country or Eurozone level. The multilevel structure is methodologically justified because country-level FinTech investment functions as a macro-level condition which affects all banks operating within a specific national context. The theoretical framework supports the assumption that country-level regulatory frameworks and technological investments create uniform effects on all banks operating within the same regulatory and competitive environment.

Building on the strengths of this estimator, a stepwise-nesting approach is adopted to trace how the introduction of FinTech investment, regulatory quality, and PSD2 implementation incrementally alters bank performance. In the first step, a baseline model is estimated that includes only the lagged performance term, a full set of bank-level controls (such as size, capital adequacy, cost-to-income ratio, loan-loss provisions, deposit growth, and interest-income share), the World Bank's Regulatory Quality index, and a PSD2 implementation dummy. This baseline captures the persistence in performance and the direct effects of regulation and the open-banking shock prior to introducing FinTech-related terms. In the second step, the core independent variable, FinTech investment, is added to assess its marginal effect, conditional on the controls. The third and fourth steps introduce, respectively, the interaction of FinTech investments with regulatory quality and the interaction of FinTech investments with PSD2. Finally, the fifth step estimates the full model, which includes both interactions alongside the main FinTech term, thereby revealing how the regulatory context and PSD2 jointly moderate the relationship between digital investment and bank performance

Formally, for each bank, the following general dynamic panel model is specified as Eq. (1).

$$\begin{aligned} BPER_{i,t} = \beta_0 + \beta_1 BPER_{i,t-1} + \beta_2 FinTech_{Inv_{i,t}} + \beta_3 Reg_{Quality_{i,t}} + \beta_4 PostPSD2_{i,t} \\ + \beta_5 \left(FinTech_{Inv_{i,t}} x\, Reg_{Quality_{i,t}} \right) + \beta_6 \left(FinTech_{Inv_{i,t}} x\, PostPSD2_{i,t} \right) + lnSIZE_{i,t} \\ + CAP_{i,t} + CTI_{i,t} + LLP_{i,t} + DG_{i,t} + IIS_{i,t} + GDP_{i,t} + INF_{i,t} + \varepsilon_{i,t} \end{aligned} \quad (1)$$

In this analysis, *BPER* represents one of the selected bank performance indicators: NIM, ROA, ROE, or YEA. The coefficient β_2 captures the direct effect of FinTech investment on bank performance, while β_5 and β_6 represent

the moderating effects of regulatory quality and the PSD2-induced open banking regime, respectively. The model includes a comprehensive set of control variables encompassing bank-specific characteristics, such as size (log of total assets), capital adequacy ratio, cost-to-income ratio, loan-loss provisions, deposit growth, and interest-income share, as well as macroeconomic factors, specifically GDP growth and inflation.

The use of a stepwise-nested regression framework enables a systematic assessment of the incremental influence of FinTech investment and its interaction with the regulatory environment. This approach facilitates a clear evaluation of both the standalone impact of FinTech investment and the extent to which this relationship is shaped by institutional quality and the introduction of PSD2. By tracing the evolution of the FinTech–performance linkage across model specifications, the analysis provides nuanced insights into the dynamic interplay between digital innovation, regulation, and bank performance.

4. Results and Analysis

4.1. Descriptive statistics

The descriptive statistics presented in Table 2 provide an overview of the key variables used in the analysis, based on 1,827 bank-year observations. FinTech investment exhibits a mean value of approximately 215.7 units with a substantial standard deviation of 455.07, indicating considerable variation in the level of digital investment across banks. Among the bank performance indicators, NIM averages 6.48%, with a standard deviation of 3.57%, and a maximum value of 40.73%, suggesting significant differences in profitability related to interest-bearing assets. YEA and ROA have mean values of 2.84% and 6.26%, respectively, while ROE averages 8.59%. Notably, ROA and ROE display wide dispersion, with ROE ranging from -78.24% to 84.68%, reflecting divergent financial performance outcomes among banks in the sample.

Table 2: Descriptive statistics

Variables	Observations	Mean	Std.	Min	Max
Fintech investment	1,827	215.706	455.070	0.000	2817.908
NIM (%)	1,827	6.476	3.569	0.000	40.731
YEA (%)	1,827	2.835	2.707	0.051	39.346
ROA (%)	1,827	6.261	10.021	-4.111	79.289
ROE (%)	1,827	8.592	10.472	-78.238	84.682
REG_Q	1,827	84.791	9.004	62.381	99.524
B. SIZE	1,827	5.711	2.594	1.058	9.485
CAP (%)	1,827	16.696	12.747	0.000	94.400
CTI (%)	1,827	52.152	22.538	-18.601	113.707
LLP (%)	1,827	8.507	9.812	0.000	81.672
DG (%)	1,827	3.439	13.646	-55.972	85.813
IIS (%)	1,827	4.458	4.509	0.000	19.815
GDP (%)	1,827	1.555	4.138	-11.600	18.733
INF (%)	1,827	2.875	3.024	-1.248	19.705
PSD2_Indicator	1,827	0.862	0.345	0.000	1.000

Note: Fintech denotes investment in finance and insurance. NIM (%): Net Interest Margin. YEA (%): Yield on Earning Assets. ROA (%): Return on Assets. ROE (%): Return on Equity. REG_Q: Institutional Regulatory Quality. B_SIZE: Bank Size. CAP (%): Capital Adequacy Ratio. CTI (%): Cost to Income Ratio. LLP (%): Loan Loss Provisions. DG (%): Annual Growth of Deposits. IIS (%): Interest Income Share. GDP (%): Gross Domestic Product growth rate.INF (%): Inflation rate. PostPSD2: time-specific variable capturing the PSD2 implementation across countries.

The average value of the regulatory quality index (REG_Q) is 84.79, with a relatively narrow standard deviation of 9.00, suggesting moderate variation in institutional quality across countries. Bank size, measured as the natural logarithm of total assets, shows a mean of 5.71, with values ranging from 1.06 to 9.49. Capital adequacy (CAP)

averages 16.70%. In comparison, the cost-to-income ratio (CTI) has a mean of 52.15%. However, it exhibits a wide range, including negative values, indicating the presence of outliers or specific accounting treatments in some observations. Loan-loss provisions (LLP) average 8.51%, reflecting the credit risk environment faced by the banks. Deposit growth (DG) and interest-income share (IIS) have means of 3.44% and 4.46%, respectively, but both exhibit high standard deviations, with DG ranging from -55.97% to 85.81%, underscoring volatile deposit trends in some markets. The macroeconomic variables, GDP growth and inflation, have means of 1.56% and 2.88%, respectively, again suggesting diverse economic conditions across the sampled countries. Finally, the PSD2 implementation indicator shows a mean value of 0.862, implying that the majority of observations occur after the implementation of the PSD2 directive, which facilitates an analysis of its potential effects on bank performance and FinTech interaction.

Table 3: Correlation matrix

	NIM	ROA	ROE	YEA	REG_Q	ln_SIZE	CAP	CTI	LLP	DG	IIS	GDP	INF	FINVM	PSD2_Indicator
NIM	1.000														
ROA	0.019	1.000													
	0.429														
ROE	0.118	0.559	1.000												
	0.000***	0.000***													
YEA	0.445	0.219	0.171	1.000											
	0.000***	0.000***	0.000***												
REG_Q	-0.198	0.138	0.017	-0.023	1.000										
	0.000***	0.000***	0.464	0.331											
ln_SIZE	-0.097	-0.596	-0.184	-0.225	-0.060	1.000									
	0.000***	0.000***	0.000***	0.000***	0.010**										
CAP	0.363	0.437	-0.007	0.245	0.074	-0.521	1.000								
	0.000***	0.000***	0.755	0.000***	0.002***	0.000***									
CTI	-0.126	-0.350	-0.160	0.013	-0.105	0.380	-0.308	1.000							
	0.000***	0.000***	0.000***	0.587	0.000***	0.00***0	0.000***								
LLP	0.121	0.484	-0.001	0.222	0.008	-0.536	0.587	-0.342	1.000						
	0.000***	0.000***	0.973	0.000***	0.736	0.000***	0.000***	0.000***							
DG	0.131	0.247	0.150	0.117	0.060	-0.219	0.256	-0.315	0.224	1.000					
	0.000***	0.000***	0.000***	0.000***	0.011**	0.000***	0.000***	0.000***	0.000***						
IIS	0.256	0.506	0.119	0.449	0.113	-0.546	0.573	-0.411	0.873	0.258	1.000				
	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***					
GDP	0.052	-0.043	0.039	0.001	0.041	0.040	-0.035	0.032	-0.036	-0.027	-0.035	1.000			
	0.027**	0.064*	0.100	0.967	0.079*	0.089*	0.130	0.172	0.128	0.246	0.135				
INF	0.049	-0.089	0.073	-0.013	0.030	0.088	-0.099	0.012	-0.129	-0.086	-0.090	0.302	1.000		
	0.038**	0.000***	0.002***	0.581	0.203	0.000***	0.000***	0.622	0.000***	0.000***	0.000***	0.000***			
FINVM	-0.224	-0.238	-0.080	-0.053	0.091	0.348	-0.303	0.190	-0.265	-0.131	-0.249	0.042	0.048	1.000	
	0.000***	0.000***	0.001***	0.023**	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.075*	0.042**		
PSD2_Indicator	-0.019	-0.364	-0.111	-0.105	-0.128	0.310	-0.307	0.230	-0.330	-0.130	-0.345	0.028	0.173	0.169	1.000
	0.410	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.227	0.000***	0.000***	

Note: ***,**,**indicate significance at 1%, 5% and 10% respectively*

4.2. Correlation analysis

Table 3 presents the correlation matrix for the key variables based on 1,827 bank-year observations. As anticipated, FinTech investment (FINVM) shows a negative association with all four performance indicators. The relationship is particularly pronounced with ROA and NIM, while the correlations with ROE and YEA are weaker. This pattern likely reflects the substantial costs associated with implementing digital technologies, including investments in infrastructure, compliance, and operational adjustments that may initially depress profitability. Regulatory quality is positively correlated with FinTech investment, suggesting that stronger institutional frameworks may foster a more conducive environment for digital transformation. Similarly, a positive relationship is observed between bank size and FinTech spending, indicating that larger banks are better positioned to allocate resources toward technological innovation, possibly due to economies of scale and broader strategic capabilities. Among the performance measures, NIM is positively associated with YEA, ROE, and capital adequacy, while showing a negative relationship with regulatory quality. YEA is positively linked to ROA and ROE but negatively associated with bank size, suggesting that smaller institutions may achieve relatively higher yields. ROA demonstrates a strong positive correlation with ROE and loan-loss provisions, and a negative relationship with the cost-to-income ratio, underscoring the role of operational efficiency and risk management in enhancing asset returns. Control variables such as deposit growth and interest-income shares display strong positive associations with profitability metrics, reinforcing their importance in driving financial performance. In contrast, macroeconomic indicators like GDP growth and inflation exhibit weak or negligible correlations with bank performance, highlighting the dominant influence of firm-level characteristics in this context.

Further, the variance inflation factor (VIF) analysis is conducted, and the results are illustrated in Table 4. A VIF value of 1 implies minimal or no multicollinearity, values between 1 and 10 are generally acceptable, and values above 10 indicate that multicollinearity may be a concern. The independent variables are not significantly correlated, indicating that the model's conclusions are stable and reliable. The results below indicate that the mean VIF of 2.410 suggests the model is well-specified, and multicollinearity is not a serious concern.

Table 4: Variance inflation factor (VIF) analysis

Variable	VIF	1/VIF
IIS	7.380	0.136
LLP	6.310	0.159
ROA	2.910	0.343
ln_SIZE	2.020	0.496
ROE	1.930	0.519
CAP	1.850	0.539
YEA	1.700	0.587
CTI	1.480	0.676
FINVM	1.200	0.835
DG	1.180	0.849
REG_Q	1.150	0.872
INF	1.140	0.876
GDP	1.110	0.902
Mean VIF	**2.410**	

4.3. Empirical results

This section presents the results of the two-step System GMM estimations conducted for each bank performance indicator, NIM, ROA, ROE, and YEA, based on the stepwise nesting framework outlined in Section 4. The

complete estimation results are reported in Tables 6 through 9. The analysis begins by evaluating the direct effect of FinTech investment (H1), followed by an examination of the moderating influence of regulatory quality (H2) and PSD2 implementation (H3). The section concludes with a summary of the key effects observed for the control variables included in the model.

4.3.1. FinTech investment and bank performance (H1)

Hypothesis H1 proposed that greater FinTech investment improves bank performance. However, the results reveal a mixed pattern across performance indicators. In the case of NIM, Table 5 shows a consistently negative association. In the full specification, FinTech investment is negatively and statistically significant ($p < 0.05$), indicating that digital spending compresses interest margins, likely due to implementation costs and competitive pricing pressures; thus, H1 is not supported for NIM. For ROA, Table 6 indicates a statistically significant positive association with FinTech investment at the 10% confidence level in the full model, and at the 5% level in earlier specifications. This suggests that digital investment contributes modestly to improved asset efficiency, thereby providing support for H1 in the context of ROA. In contrast, ROE in Table 7 displays a relatively large point estimate of 0.103 for FinTech investment, but the result does not attain statistical significance in the full interaction model, implying that no firm conclusion can be drawn regarding equity returns. Similarly, Table 8 shows that the coefficient for FinTech investment on YEA is statistically insignificant, indicating no direct relationship. In summary, the evidence supports H1 for ROA, does not support it for NIM and YEA, and ROE.

4.3.2. The moderating role of regulatory quality (H2)

Hypothesis H2 posited that the quality of regulation moderates the relationship between FinTech investment and bank performance. The interaction term between FinTech investment and regulatory quality (FINVM × REGQ) provides nuanced insights. For NIM, Table 5 reports a positive and statistically significant interaction effect ($p < 0.05$), suggesting that strong regulatory frameworks help to mitigate the compression associated with FinTech investments. The interaction term for ROA in Table 6 is also positive and significant ($p < 0.10$), indicating that regulatory quality enhances the efficiency benefits of digital spending. Conversely, the interaction effect for ROE is negative and statistically significant ($p < 0.01$), as shown in Table 7, implying that strict regulatory environments may limit shareholder gains from FinTech innovations. A similar negative and significant interaction is observed for YEA ($p < 0.05$) in Table 8, reflecting a reduction in yield-related benefits under stricter regulation. These findings confirm H2 across all performance dimensions, although the direction of moderation varies, positive for NIM and ROA, negative for ROE and YEA.

4.3.3. The moderating role of PSD2 on bank performance (H3)

Hypothesis H3 suggested that the implementation of PSD2 moderates the impact of FinTech investment on bank performance. The findings indicate partial support for this hypothesis. Table 5 reports a statistically significant and positive interaction between FinTech investment and PSD2 ($p < 0.05$), implying that the open-banking regime helped alleviate some of the margin pressures traditionally associated with FinTech expenditures. However, the interaction effect in Table 6 for ROA is negative and statistically significant ($p < 0.10$), indicating that PSD2 weakens the efficiency benefits of FinTech investment on asset returns. For ROE, Table 7 shows coefficient is not statistically significant. The interaction for YEA in Table 8 is negative and statistically significant at the 10% level,

indicating a modest reduction in yield performance post-PSD2. Collectively, these findings support H3 for NIM, ROA, and YEA.

Table 5: GMM Results for NIM

	NIM	**NIM**	**NIM**	**NIM**	**NIM**
L.NIM	0 .614***	0.091	0.804**	0.538***	0.023
FINTECH INVESTMENT		-0.004***			-0.034**
FINVM* REGQ			-0.000**		0.006**
FINVM* PSD2				-0.002	0.034**
ln_SIZE	0.072*	0.112*	0.023	0.104**	0.069
CAP	0.034**	0.120*	-0.030	0.034	0.146**
CTI	0.012	0.018*	0.013	0.009	0.012
LLP	-0.058	-0.266*	-0.002	-0.117*	-0.231*
DG	0.105***	0.025**	0.111***	0.109***	0.017
IIS	0.030	0.533 *	-0.007	0.171	0.458 **
GDP	0.002	0.041**	-0.024	0.035 *	-0.018
INF	0.054	-0.049*	0.013	0.003	-0.017
REG_Q	-0.042***	-0.028	-0.090	-0.048	-0.004
PSD2_Indicator	-0.282*	1.433	1.704	-0.308**	1.713
Constant	4.850 ***	0.728	-0.751	1.559	-1.029
Prob > chi2	0.000***	0.000***	0.000***	0.000***	0.000***
AR(2)(Pr > z)	0.596	0.953	0.442	0.670	0.684
Hansen test (Prob > chi2)	0.148	0.245	0.112	0.748	0.521

Note: ***,**,**indicate significance at 1%, 5% and 10% respectively*

Table 6: GMM Results for ROA

	ROA	**ROA**	**ROA**	**ROA**	**ROA**
L.ROA	0.518***	0.620***	0.517**	0.318***	0.455***
FINTECH INVESTMENT		0.009**			0.032*
FINVM* REGQ			-0.011***		0.004*
FINVM* PSD2				0.001	-0.028*
ln_SIZE	-0.505***	-0.516**	-0.494**	-0.674***	-0.716***
CAP	0.017	0.040	0.026	0.029	0.059
CTI	-0.0260*	0.010	-0.018	-0.039	-0.006
LLP	0.162	0.029	0.182	0.206*	0.049
DG	0.0129**	0.042	0.019***	0.010	0.025
IIS	-0.029	0.192	0.145	0.017	0.203
GDP	-0.124***	-0.278*	0.031	0.073	-0.203*
INF	0.052	0.173	-0.289**	0.094	0.126
REG_Q	0.208**	0.235	0.043 *	0.061**	0.206
PSD2_Indicator	-0.184	0.291	13.42984*	-1.582705*	-1.419*
Constant	5.640***	2.067	-11.37323*	3.520	4.884 *
Prob > chi2	0.000***	0.000***	0.000***	0.000***	0.000***
AR(2)(Pr > z)	0.326	0.19	0.485	0.278	0.224
Hansen test (Prob > chi2)	0.241	0.167	0.364	0.115	0.186

Note: ***,**,**indicate significance at 1%, 5% and 10% respectively*

Table 7: GMM Results for ROE

	ROE	ROE	ROE	ROE	ROE
L.ROE	0.288***	0.415**	0.294 ***	0.336***	0.368
FINTECH INVESTMENT		0.002*			0.103
FINVM* REGQ			0.002		-0.007***
FINVM* PSD2				0.007**	-0.104
ln_SIZE	-0.216	-0.164	-0.182	-0.127	-0.082
CAP	-0.126***	-0.093*	-0.129***	-0.135***	-0.140**
CTI	0.018	-0.036	0.012	-0.135	-0.043*
LLP	-0.365	-0.086	-0.301	-0.297	-0.336
DG	0.182**	0.073***	0.174**	0.245**	0.094***
IIS	0.795	0.164	0.697	0.672	0.747
GDP	-0.024	0.167 **	-0.097	-0.196 **	0.214
INF	0.059	0.333**	0.124	0.214**	0.044
REG_Q	-0.003	0.609***	-0.067**	-0.152 ***	-0.106
PSD2_Indicator	-2.911***	0.141	-2.863***	-2.549***	-2.547*
Constant	9.966***	7.901*	15.549 ***	22.19854***	14.314***
Prob > chi2	0.000***	0.000***	0.000***	0.000***	0.000***
AR(2)(Pr > z)	0.968	0.893	0.980	0.889	0.933
Hansen test (Prob > chi2)	0.106	0.650	0.113	0.272	0.644

Note: ***,**,**indicate significance at 1%, 5% and 10% respectively*

Table 8: GMM Results for YEA

	YEA	YEA	YEA	YEA	YEA
L1. YEA	0.672***	0.658**	0.365**	0.335**	0.548***
FINTECH INVESTMENT		0.000			0.001
FINVM* REGQ			0.001		-0.003**
FINVM* PSD2				0.001	-0.001 *
ln_SIZE	0.081	0.014	-0.100	-0.164*	-0.006
CAP	-0.029***	-0.024	0.009	0.016	-0.002
CTI	.0121*	0.037	0.063***	0.065***	0.044 ***
LLP	-0.242	-0.421**	-0.354**	-0.309	-0.505 ***
DG	0.054**	0.007	0.057***	0.069**	0.011
IIS	0.643*	0.988**	0.903***	0.804**	1.244 ***
GDP	0.0312*	0.014	0.003	-0.002	-0.014
INF	0.006	-0.001	0.001	-0.007	0.034
REG_Q	-0.071**	0.027	-0.052*	-0.044	0.020
PSD2_Indicator	-3.050**	-9.269**	-0.296**	-0.310**	-4.847
Constant	2.049*	7.164**	-2.242***	-2.023 ***	3.029
Prob > chi2	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***
AR(2)(Pr > z)	0.245	0.893	0.115	0.152	0.101
Hansen test (Prob > chi2)	0.353	0.242	0.231	0.313	0.900

Note: ***,**,**indicate significance at 1%, 5% and 10% respectively*

4.3.4. Control Variables

The inclusion of lagged dependent variables across all performance models underscores a significant degree of performance persistence. In the NIM model, the lagged NIM (L.NIM) is highly significant in two specifications, indicating that past NIMs strongly predict current outcomes. Similarly, the lagged ROA (L.ROA) demonstrates robust significance with coefficients across all the models, suggesting moderate to strong persistence in ROA over

time. The ROE model also reveals significant positive associations through L. ROE. For YEA, the lagged term (L.YEA) is statistically significant at the 1% level in most cases, affirming the consistent influence of prior asset levels on current asset performance.

Bank size (ln_SIZE) demonstrates a differentiated impact across metrics: it is positively associated with NIM at the 10% significance level in some specifications, suggesting scale-related gains in interest-based profitability, but consistently exhibits a negative and significant effect on ROA, highlighting declining asset efficiency with size. Its impact on ROE and yield on YEA is largely insignificant or negative. Capital adequacy (CAP) shows a favorable and statistically significant association with NIM in multiple models, indicating that well-capitalized banks are able to enhance interest-based profitability. However, CAP negatively influences ROE and YEA in several specifications, possibly reflecting a more conservative risk profile that limits return maximization. The cost-to-income ratio (CTI) reveals mixed effects: while not consistently significant for NIM and ROE, it significantly increases YEA in certain models, potentially reflecting a trade-off between cost management and asset expansion. Loan-loss provisions (LLP) demonstrate a negative and statistically significant influence on NIM and YEA, reaffirming the adverse effects of credit risk on profitability and asset yield. In contrast, LLP's relationship with ROA and ROE appears insignificant or positive in some specifications, possibly due to provisioning strategies smoothing performance over time. Deposit growth (DG) remains a robust and positive determinant across most performance indicators, particularly NIM and ROE, suggesting that banks with stronger funding bases tend to perform better across key dimensions. Macroeconomic controls, including GDP growth and inflation, exert limited and inconsistent influence. GDP shows a negative relationship with ROA and ROE in certain models, while inflation's impact lacks statistical robustness. These findings underscore that firm-specific variables, especially those related to capital strength, credit risk, and funding growth, play a more decisive role in shaping bank performance within the Eurozone panel than do macroeconomic fluctuations.

The diagnostic test performed for all three hypotheses passed the [82] test suggesting the absence of 2nd order autocorrelation. Moreover, the Hansen test gives insignificant value, confirming the validity of the instruments utilized in all three models.

5. Discussion

This study used two-step System GMM estimations to assess how FinTech investment and its interactions with regulatory quality and PSD2 affect bank performance across four metrics (NIM, ROA, ROE, YEA), revealing a complex interplay of benefits and challenges that we explore in detail below.

The research hypothesis 1 predicted that higher FinTech investments would lead to better bank performance but our analysis of NIM reveals a different outcome. The data in Table 5 demonstrates that FinTech outlays decrease NIM because digital spending and its competitive forces reduce traditional interest-based revenue. The results match [29] and [83] by showing that banks need to decrease their lending rates because agile startups provide alternative services. The GCC research by [31] shows that FinTech startup expansion leads to reduced NIMs for banks. The transition from interest-based to fee-based and digital transaction models according to [84] makes margin pressure more severe. The implementation of automation and advanced analytics produces back-office efficiencies yet intensifies price competition in loan markets and strategic pricing for digitally savvy customers makes margin compression worse. The combination of these factors indicates that FinTech investment forces banks

to abandon their traditional interest-based revenue model which produces operational benefits while creating substantial margin challenges during the short term.

The positive effect of FinTech investment on ROA emerges from both Eurozone and emerging-market research findings. The research by [26] demonstrates that European banks achieve higher ROA through their FinTech-driven CSR and green-finance initiatives and [24] shows that a one-standard-deviation increase in per-bank FinTech spending leads to a 0.03 pp ROA increase because of analytics and platform deployment scale economies. [85] found that Bahrain's conventional and state-owned banks gain more ROA improvements from FinTech innovations than Islamic or private institutions. [86] prove that Jordanian banks increase both ROA and ROE through specific digital strategies and [87] demonstrate that Malaysian banks achieve ROA growth through their IT investments even when facing general competitive challenges. The research shows that European ([[26]; [24]) and international studies demonstrate how automation and data analytics and platform upgrades lead to improved asset efficiency.

Our research findings for ROE and YEA differ from what previous studies have shown. The research by [86] demonstrates that digital innovation initiatives lead to improved ROE and ROA performance in Jordanian banks. The research by [88] demonstrates that FinTech spending in Indonesia does not impact traditional profitability metrics such as ROE but affects performance through cost-to-income ratio and loan-to-deposit ratio (LDR) and macroeconomic indicators including GDP and inflation. The Eurozone banks seem to direct their digital investment returns toward operational efficiency improvements and funding metrics or they need extended time and additional fee-based services for shareholder returns and asset yields to show significant changes. The NIM and ROA results demonstrate FinTech's immediate efficiency-driven effects but the ROE and YEA findings indicate banks need to adapt their business models in more complex ways or over longer periods to achieve shareholder return and earning asset yield improvements.

Regulatory quality emerged as a significant moderator across all performance metrics: it bolstered NIMs and amplified asset-efficiency gains from FinTech investments, yet it simultaneously restrained equity returns and yields on earning assets. The implementation of clear and consistent oversight practices reduces short-term margin and efficiency challenges from digital spending but establishes proper boundaries for high-risk high-return outcomes. The pattern aligns with research from sub-Saharan Africa which shows that strong governance maintains institutional stability during turbulent times by directing positive changes toward fundamental stability indicators instead of profit-oriented metrics [89]. The research demonstrates that banks need to design their FinTech approaches based on their regulatory framework to protect their margins and efficiency while acknowledging that strict oversight systems will slow down or reduce shareholder return and yield improvements.

The implementation of the Revised Payment Services Directive (PSD2) has likewise exerted a nuanced, predominantly adverse moderating effect on the FinTech–performance link, offering only partial support for H3. While PSD2's open-banking requirements help banks alleviate some margin pressure by enabling new fee-based services and more efficient pricing models, the directive's compliance and integration demands such as system upgrades, security enhancements, and API development appear to outweigh these benefits in other areas. Specifically, PSD2 weakens the efficiency benefits of FinTech investment on asset returns and modestly depresses yields on earning assets, without delivering immediate gains in shareholder returns. These results echo [90], who document that PSD2's compliance and integration expenses elevate operational costs and competitive pressures, thereby eroding profitability in the financial sector. Similarly, [91] argue that heightened market competition and

regulatory burdens initially depress bank performance, as legacy systems struggle to accommodate new API-driven services. Research by [92], [93] further underscores that, although PSD2 fosters openness, competition, and financial inclusion, it simultaneously imposes heavy compliance obligations system upgrades and security enhancements do not translate into immediate revenue gains. The European Central Bank [94] concurs, noting that open-banking mandates disrupt traditional revenue models by shifting market share toward third-party providers and FinTech entrants, forcing banks to reconfigure their income structures to remain competitive. [47] further highlight that PSD2's open-banking mandate obliges banks and third-party providers to implement extensive and often inconsistently defined security protocols, exacerbating the compliance burdens and technical complexities that contribute to the short-term performance drag we observe. Taken together, these findings suggest that PSD2's short-term impact on profitability is driven more by adaptation expenses and intensified competition than by revenue enhancement, underscoring the need for banks to manage these transitional costs before realising the directive's longer-term benefits..

6. Conclusion

In conclusion, our research shows that FinTech investment creates different impacts on bank performance through reduced NIMs while it slightly improves asset efficiency without affecting equity returns or asset yields. These findings suggest that there is a complicated link between bank profitability and FinTech investments, having both favorable effects on operational performance and unfavorable implications on conventional revenue models. The duality of this form mimics the ongoing transition of the banking sector, on the verge of being disrupted by FinTech solutions replacing traditional financial services. Further, the analysis shows that regulatory quality functions as a vital factor which reduces both margin and ROA pressures and reduces the high-risk high-return outcomes in ROE and YEA. The open-banking mandate of PSD2 creates additional challenges for banks because it protects margins through new fee-based offerings but requires significant compliance and integration expenses that reduce efficiency gains and yields without providing immediate shareholder return benefits.

This research contributes to literature through three major advancements. The research shows that FinTech investment produces different effects on specific metrics as it reduces NIMs but significantly boosts asset efficiency without changing equity returns or yields. The research demonstrates that superior monitoring acts as a moderating factor which both restricts and improves efficiency benefits and reduces negative margin pressures thus transforming regulation from a compliance expense into a strategic asset. The analysis of PSD2 as another moderator shows that open-banking reforms have dual effects on banks because they enable margin protection through new fee-based models yet create challenges for compliance and integration that reduce efficiency and yield improvements. Collectively, these findings provide a cross-level paradigm for comprehending the interaction between macro-level investments and policies in influencing bank performance.

6.1. Theoretical contributions

Our findings make three key contributions to the FinTech–bank performance literature. First, we confirm that country-level FinTech investment has a tangible, positive effect on firm-level performance: higher national digital finance spending is associated with improved efficiency (ROA) and conversely, with a reduction in NIM. Second, by conceptualizing regulatory quality as a moderating factor, we demonstrate that the institutional environment not only facilitates or restricts digital innovation but also actively influences its outcomes. Effective oversight enhances

the efficiency benefits of FinTech investments and mitigates short-term margin pressures, indicating that regulators may transform digital finance into a strategic asset rather than a simple compliance obstacle. Third, the incorporation of PSD2 as a secondary moderator elucidates a complex function of competition-enhancing reforms: while PSD2 aims to foster innovation, our findings suggest it may impose immediate limitations on banks, underscoring the necessity of balancing competitive access with transitional assistance. In this manner, we provide a methodological framework for future research, urging scholars to collaboratively examine national-scale policies, infrastructure investments, and firm-level outcomes, rather than perceiving the regulatory environment as a fixed variable

6.2. Regulatory and policy implications

The findings suggest that although PSD2 seeks to enhance competition and innovation within the financial industry, its execution has imposed short-term profitability challenges on traditional banks, mostly due to heightened compliance expenses and competitive pressures from TPPs. But far than being an existential threat, these issues show how important it is to have regulatory frameworks that strike a balance between financial stability and innovation. Policymakers should make sure that the criteria for compliance are reasonable and do not place an undue strain on established banks, especially smaller ones with fewer resources.

For regulators, this highlights the necessity to implement dynamic and flexible policies that foster FinTech innovation while ensuring the stability of the financial industry. A more sophisticated approach such as incremental deployment strategies, regulatory sandboxes, or incentive frameworks could assist banks in more effectively integrating FinTech technologies while preserving stability.

For banks, the findings indicate that they should not perceive legislative changes solely as constraints, but rather proactively modify their business models, diversify revenue methods, and enhance technical investments to capitalize on the potential offered by FinTech. Institutions that adeptly adopt open banking, digital collaborations, and data-centric financial services will be more strategically positioned to maintain competitiveness in the changing financial environment.

6.3. Limitations and future studies:

Although we control extensively for country and year fixed effects and include regulatory quality and other relevant covariates to mitigate bias, we recognize that unobserved differences in national innovation capacity could still confound our estimates. Future research might address this residual endogeneity by employing instrumental-variable strategies or alternative causal designs (e.g., difference-in-differences). Moreover, scholars should explicitly account for the cross-level structure of the data where country-level FinTech investment drives firm-level bank by using multilevel mixed-effects models to ensure that shared, nation-wide shocks do not inflate statistical significance.

Our analysis combines retail and investment banks with universal and specialized banks into one Eurozone sample which produces average results from various business models. Future research should include bank-type indicators or perform subgroup analyses to determine how different banking models react to digital finance investments. Moreover, the findings from our Eurozone institution study might not apply to emerging markets because these countries have different digital infrastructure and regulatory systems. Future Research studies that

compare multiple regions would reveal how institutional settings influence the relationship between FinTech and performance.

Finally, we rely on Invest Europe data covering broader banking and insurance industries, which may dilute the signal of pure FinTech investment; more specific datasets such as firm-level digital transaction volumes or dedicated FinTech funding registries could sharpen measurement precision. And because PSD2 remains in its infancy, our short-run analysis cannot capture its full economic impact. Longitudinal investigations are needed to trace bank performance trajectories post-PSD2 and to compare how different regulatory approaches (for example, sandbox environments versus stringent compliance regimes) moderate the relationship between digital finance spending and institutional outcomes.

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