# DIGITALIZATION AND BANKING PERFORMANCE IN THE EUROPEAN UNION: AN EMPIRICAL OUTLOOK ON NPL, ROA, ROE AND DESI INDEX

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***Abstract***

*This study examines the relationship between digitalization and banking performance across European Union member states, integrating national digital maturity, measured through the Digital Economy and Society Index (DESI), with key financial indicators such as Return on Assets (ROA), Return on Equity (ROE) and Nonperforming loans to total gross loans (NPL). The research aims to assess whether differences in digital readiness translate into measurable variations in profitability and asset quality, thereby providing insights into how digital progress shapes the resilience and efficiency of EU banking systems. The methodological approach relies on descriptive statistical comparisons and preliminary correlation patterns, with econometric analyses to be developed subsequently. The conceptual framework is grounded in three hypotheses which posit that higher DESI scores are associated with increased profitability, lower credit risk and differentiated effects across low- and high-DESI economies. The findings of the study suggest that digital maturity may represent a structural determinant of banking performance, although its impact is likely to vary according to national digital infrastructure and institutional conditions. Beyond its immediate analytical contribution, this research offers a foundation for future empirical work, including panel regressions, nonlinear specifications and comparative analyses aimed at capturing the complex interactions between digitalization, macroeconomic factors and banking sector performance. The results therefore highlight the relevance of digital readiness in shaping the future trajectory of European banking.*

***Keywords:*** *digitalization, banking performance, DESI, ROA, ROE, NPL*

***Clasificare JEL:*** *G21, C80*

## 1. Introduction and context of the study

Over the past decade, the banking industry has experienced a profound wave of digital transformation, fundamentally reshaping organizational structures, operational processes and traditional business models. Advances in information technologies, data analytics and digital platforms have altered the way banks deliver financial services, manage risks and interact with customers. As a result, digitalization has evolved from a supportive function into a strategic pillar of banking activity, influencing both efficiency and long-term competitiveness.

In parallel with these developments, European Union member states have intensified their efforts to foster digitally oriented economies, supported by coordinated policy initiatives and substantial investments in digital infrastructure and skills. However, the pace and depth of digital transformation remain uneven across countries, leading to significant differences in national digital maturity. In this context, understanding how variations in digital readiness at the country level influence banking sector performance becomes increasingly important, particularly in a highly integrated financial system such as the European Union.

Using the Digital Economy and Society Index (DESI) as a measure of national digital maturity, this study examines whether differences in digital development across EU member states are reflected in key banking performance indicators, namely Return on Assets (ROA), Return on Equity (ROE) and the ratio of non-performing loans (NPL). By linking a macro-level indicator of digitalization to core measures of profitability and asset quality, the analysis seeks to capture the broader structural effects of digital progress on banking systems.

By analyzing EU-level data, the present work aims to identify how digital advancement shapes banking profitability and credit risk, and whether these relationships differ systematically between low- and high-DESI economies. In doing so, the study emphasizes the existence of

heterogeneous and potentially nonlinear effects of digitalization, suggesting that digital maturity may act as a conditioning factor rather than a uniform determinant of banking performance. This approach provides a comparative framework for assessing the role of digital readiness in shaping the resilience, efficiency and stability of banking sectors across the European Union.

The importance and originality of this study derive from its comparative and macro-level approach to assessing the relationship between digitalization and banking performance within the European Union. Unlike much of the existing literature, which focuses primarily on bank-level digital adoption or individual technological tools, this paper emphasizes national digital maturity as a structural determinant of banking outcomes. A key element of originality consists in the explicit distinction between high-DESI and low-DESI economies, allowing for the identification of heterogeneous and potentially nonlinear effects of digitalization on profitability and asset quality. By combining DESI with complementary indicators of digital inclusion and internet banking usage for the most recent years, the analysis captures both structural and behavioral dimensions of digitalization. This approach provides new insights into how advanced digital ecosystems contribute to banking stability and resilience, while lower levels of digital maturity are associated with higher volatility and delayed efficiency gains, thereby extending the empirical understanding of digital transformation in European banking.

The article is structured as follows. The Introduction presents the research context and objectives, emphasizing the importance of national digital maturity in shaping banking performance across the European Union. The Literature review examines the main theoretical and empirical contributions on digitalization and banking performance, with a particular focus on profitability, efficiency and credit risk, and highlights the gaps that motivate the present study. The Methodology and results section outlines the analytical framework and describes the empirical findings, integrating DESI indicators, measures of internet and internet banking usage and key banking performance variables in order to compare high- and low-DESI economies over the analyzed period. Finally, the Conclusions section summarizes the main results, discusses their implications for banking resilience and digital policy and suggests avenues for future research, including the use of more advanced econometric approaches to further explore the complex interaction between digitalization and banking performance.

## 2. Literature review

The findings of Saidov et al. (2025) show that digital transformation, captured through the expansion of remote banking services, has a substantial positive impact on bank profitability, outperforming traditional determinants such as asset size and equity returns. This reinforces the view that digital service development is a core driver of operational efficiency and financial performance.

Drawing from recent empirical evidence showing that digitalization enhances operational efficiency, credit monitoring quality and the ability of banks to assess borrower risk, this paper investigates whether these benefits translate into lower NPL ratios in countries with higher DESI scores. According to some research, banks with higher IT intensity tend to record lower levels of non-performing loans, reinforcing the view that the use of digital footprints and data-driven tools enhances credit monitoring and borrower selection processes, thereby contributing to improved asset quality (Berg et al., 2020; Pierri and Timmer, 2022).

The rise of digitally native competitors, such as FinTech firms and neobanks, has disrupted established banking dynamics and intensified competitive pressure, compelling traditional banks to undertake strategic digital investments in order to preserve market relevance and operational efficiency (Boot et al., 2021; Pierri and Timmer, 2022). This transformation has been further accelerated by exogenous shocks and regulatory developments. During the COVID-19 pandemic, European Union member states prioritized digital transformation initiatives, which, together with shifting consumer preferences, significantly increased reliance on digital banking channels as the primary mode of customer interaction (Savvakis et al., 2024; Kwan et al., 2023). In parallel,

regulatory frameworks such as the revised Payment Services Directive (PSD2) have facilitated the expansion of open banking, fostering greater competition, innovation and security within the European banking system (ECB, 2018).

The investments of banks in digital transformation are often associated with improved banking performance, as evidenced by recent empirical research. Wu and Cheng (2024) document a positive link between digital transformation and bank revenues in China, noting that this relationship becomes stronger in regions where public policies actively support digitalization. In a similar vein, Porfírio et al. (2024), using survey-based evidence from the Portuguese banking sector, show that digital transformation exerts a favorable impact on both business expansion and overall organizational performance.

According to Berg et al. (2020), investments in digital transformation can enhance multiple banking processes and operational functions, particularly by improving efficiency and strengthening monitoring capabilities.

Spulbar and Cărbune (2025) highlight the relevance of Open Banking and artificial intelligence as complementary technologies that foster financial innovation in the banking sector. By enabling rapid access to standardized customer-level and transaction-based data, these technologies support the development of more accurate predictive models for credit scoring, risk monitoring and service personalization. Their relevance for banking profitability stems from the enhanced use of granular micro-level information in decision-making processes, which improves operational efficiency, resource allocation and the effectiveness of digital banking strategies.

Existing empirical evidence suggests that banks with a higher degree of IT adoption tend to exhibit superior management efficiency, reflected in significantly lower cost-to-income ratios, primarily driven by reductions in both staff-related and non-staff operating expenses (Citterio et. all, 2024).

Building on recent empirical literature, this study examines the impact of digital transformation on banking performance from a macro-level, cross-country perspective within the European Union. Focusing on national digital maturity as measured by the DESI index, the analysis links digitalization to key banking indicators, ROA, ROE and NPL and explores whether these relationships differ between high- and low-DESI economies.

## 3. Methodology and results

The study adopts a cross-country empirical approach, using EU member states as the unit of analysis and integrating DESI scores with banking performance indicators (NPL, ROA, ROE). The conceptual framework is grounded in three hypotheses exploring the relationships between digital maturity and financial outcomes. The methodology is designed to rely on descriptive comparisons, correlation patterns and regression-based insights that will be developed subsequently. Given existing evidence in the literature, it is expected that countries with higher DESI scores will demonstrate stronger profitability and improved asset quality, while less digitalized economies may experience weaker or more ambiguous relationships. In addition, nonlinear effects are anticipated, as structural differences across EU countries may moderate the impact of digitalization on performance indicators.

Based on the existing literature on digitalization and banking performance and also, on the conceptual framework of this study, the empirical analysis is guided by the following research hypotheses:

*H1: Higher levels of national digital maturity, as measured by the DESI index, are associated with improved banking profitability, reflected in higher ROA and ROE.*

*H2: Higher digital maturity is associated with improved asset quality in the banking sector, as reflected by lower non-performing loan (NPL) ratios.*

*H3: The relationship between digitalization and banking performance differs between high-DESI and low-DESI economies, indicating heterogeneous and potentially nonlinear effects.*

Within this analytical framework, the empirical investigation proceeds in a stepwise manner. In the first stage, the study examines the Digital Economy and Society Index (DESI) at the level of European Union member states over the 2017-2022 period, for which harmonized and comparable data are available across all countries. DESI is employed as a comprehensive measure of national digital maturity, capturing multiple dimensions of digital development, including connectivity, digital skills, the integration of digital technologies and digital public services. The analysis of DESI scores allows for the identification of persistent cross-country differences in digital readiness and supports the classification of EU member states into high-DESI and low-DESI economies, reflecting structural disparities rather than short-term fluctuations.

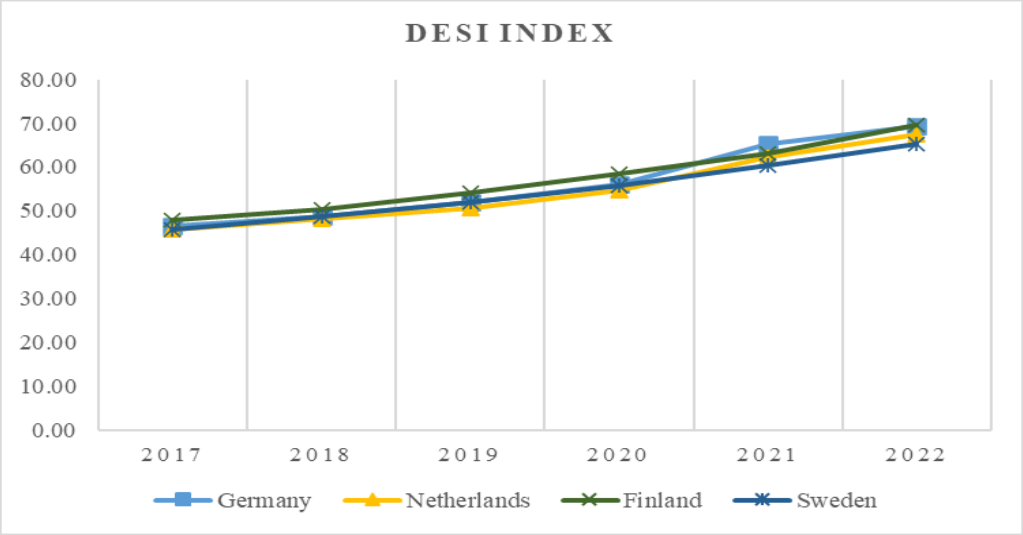


**Figure 1 – DESI Index in High-DESI Economies**
Source: Author's contribution based on data extracted from Eurostat

Figure 1 illustrates the evolution of the DESI index in selected high-DESI economies, Germany, Netherlands, Finland and Sweden, over the 2017–2022 period. Throughout the entire timeframe, all four countries consistently record DESI scores above the EU-27 mean, indicating a structurally higher level of digital maturity. While the EU average increased steadily from approximately 34 points in 2017 to over 52 points in 2022, the high-DESI economies started from substantially higher initial levels and experienced a more pronounced absolute increase. Finland and Sweden exhibit particularly strong digital performance, maintaining a clear lead relative to the EU average, while Germany and the Netherlands also demonstrate sustained convergence toward the upper range of digital maturity.

The widening gap between these countries and the EU mean after 2020 suggests that advanced digital ecosystems were better positioned to accelerate digital transformation during periods of heightened reliance on digital services. Overall, the trajectories observed confirm that high-DESI economies benefit from persistent and cumulative digital advantages, reinforcing their role as benchmarks for digital development within the European Union.

Figure 2 depicts the evolution of the DESI index in selected low-DESI economies, Bulgaria, Greece, Poland and Romania, over the 2017-2022 period. Although all four countries display a positive upward trend, indicating steady progress in digitalization, their DESI scores remain consistently below both the EU-27 average and the levels observed in high-DESI economies. Poland records the highest values within this group, reflecting relatively stronger digital advancement, while Romania persistently exhibits the lowest DESI scores, pointing to enduring structural constraints. The gap between low-DESI economies and the EU average narrows only modestly over time, suggesting that convergence in digital maturity has been gradual and incomplete. These patterns highlight the persistence of digital divides within the European Union

and underscore that, despite overall improvements, lower digital readiness may continue to limit the capacity of banking systems in these countries to fully benefit from digital transformation.

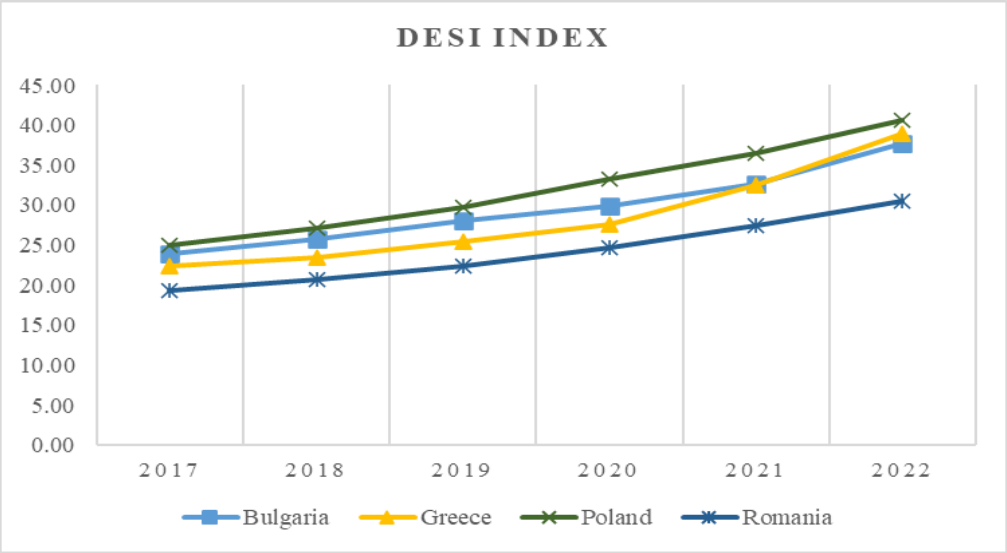


**Figure 2 – DESI Index in Low-DESI Economies**
Source: Author's contribution based on data extracted from Eurostat

For the subsequent period, 2023-2024, when aggregated DESI values are no longer available, the analysis shifts toward two alternative indicators that are directly related to the degree of digitalization at the national level: the share of individuals using the internet and the proportion of individuals who use internet for banking services. These indicators are selected due to their strong behavioral and functional relevance, as they reflect both general digital inclusion and the effective adoption of digital financial services by households.

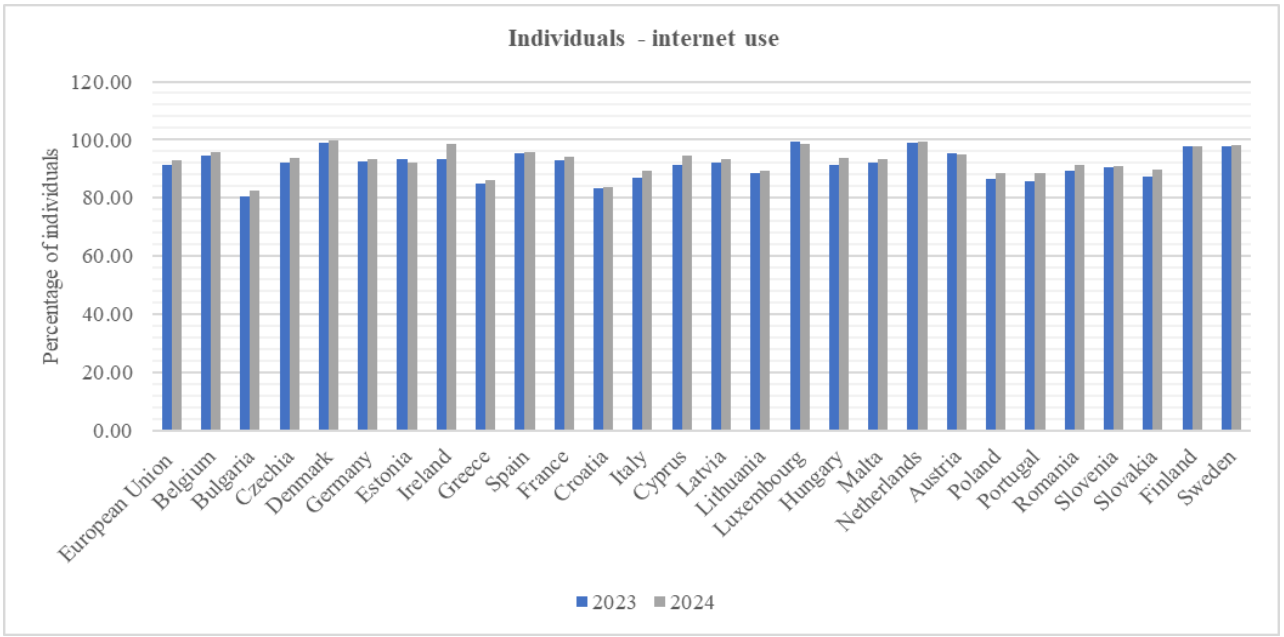


**Figure 3 – Individuals - internet use**
Source: Author's contribution based on data extracted from Eurostat

By integrating these complementary measures, the study ensures continuity in the assessment of digitalization dynamics while preserving analytical consistency across the entire sample period. This approach allows for the examination of whether digital divides identified through DESI persist in more recent years and whether they continue to shape banking performance outcomes.

Figure 3 illustrates the evolution of internet usage across EU member states in 2023-2024, highlighting a generally high and increasing level of digital inclusion at the European level. High-DESI economies continue to exhibit near-universal internet use, with countries such as Finland, Sweden, Netherlands and Germany recording consistently high percentages, close to full population coverage, thereby confirming the persistence of advanced digital environments identified in the DESI-based analysis. In contrast, low-DESI economies, while showing clear improvements between 2023 and 2024, still display comparatively lower internet usage rates, reflecting ongoing structural gaps in digital adoption.

While the general level of internet usage indicates a substantial reduction in digital disparities between high- and low-DESI economies, suggesting a broad convergence in basic digital access, this indicator captures primarily general digital inclusion rather than the effective use of digital financial services. Consequently, to obtain a more nuanced assessment of digitalization relevant to the banking sector, the analysis is further extended to the share of individuals using the internet for banking services (fig. 4).

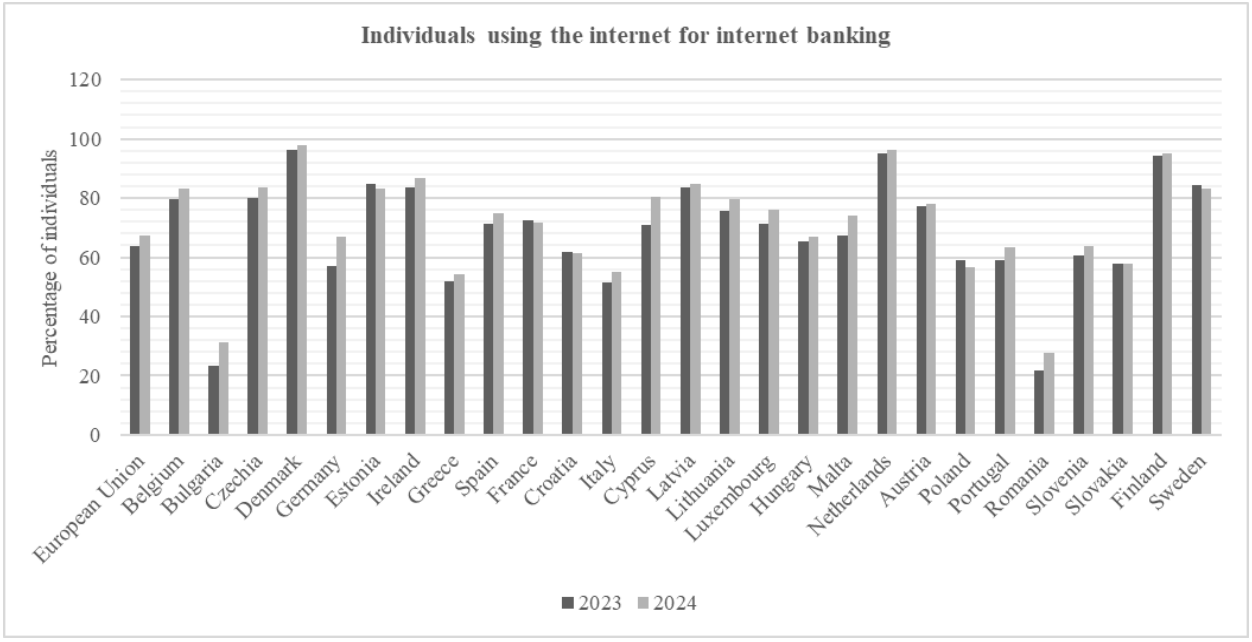


**Figure 4 – Individuals using the internet for internet banking**
Source: Author's contribution based on data extracted from Eurostat

This figure presents the evolution of the share of individuals using the internet for internet banking across EU member states in 2023-2024, revealing more pronounced differences between high- and low-DESI economies compared to general internet usage. High-DESI economies display consistently high and increasing levels of internet banking adoption, reflecting advanced digital financial ecosystems and strong user confidence in online banking services. In contrast, low-DESI economies record substantially lower participation rates, despite moderate improvements over the period. This divergence suggests that while basic digital access has become increasingly widespread, the effective use of digital financial services remains uneven across the EU. The persistence of these gaps underscores the relevance of internet banking usage as a more targeted proxy for banking-related digitalization and highlights its potential role in shaping cross-country differences in banking performance.

Figure 5 illustrates the evolution of ROA in selected high-DESI economies over the 2017-2024 period. Return on Assets (ROA), computed as the ratio of net income to average total assets, measures a bank's efficiency in generating profits from its asset base. A higher ROA indicates more effective asset utilization and management, whereas a lower ROA may signal operational inefficiencies and/or constraints in revenue generation (Spulbar et al., 2025). Overall, these countries exhibit relatively moderate but stable profitability levels, reflecting mature banking systems operating in highly digitalized environments. The sharp decline in ROA observed in 2020 across all four countries can be largely attributed to the economic disruptions caused by the COVID-19 pandemic, which led to increased provisioning, lower lending activity and heightened uncertainty. However, the post-2020 recovery is gradual and sustained, particularly in Sweden and Finland, coinciding with advanced digital infrastructures and widespread adoption of internet banking services. The high degree of digital maturity, as captured by elevated DESI scores and near-universal internet and internet banking usage, appears to have supported operational resilience and efficiency, enabling banks to stabilize profitability rather than pursue high short-term returns. Germany and the Netherlands display lower ROA levels, yet their trajectories remain relatively smooth, suggesting that digitalization contributes more to profitability stability than to elevated ROA levels in highly developed banking systems.

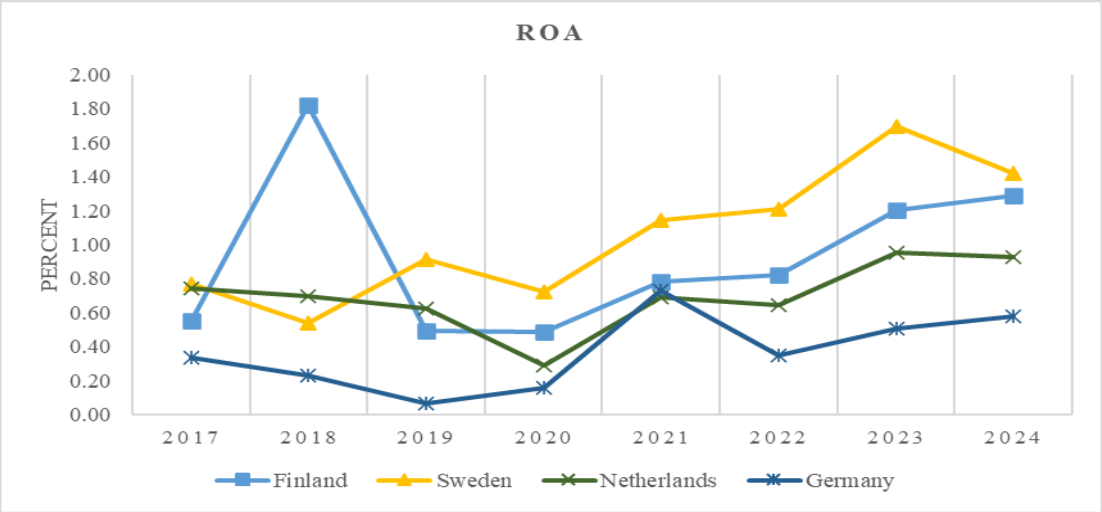


**Figure 5 – Return on assets in high-DESI economies**
Source: Author's contribution based on data extracted from IMF

Figure 6 presents the evolution of ROA in selected low-DESI economies, revealing higher volatility and more pronounced cyclical fluctuations compared to high-DESI countries.

The impact of the COVID-19 shock in 2020 is particularly evident, with Greece recording significantly negative ROA values, reflecting structural vulnerabilities and delayed recovery dynamics. Despite lower levels of digital maturity, the post-pandemic period is characterized by a strong rebound in profitability across all four countries, especially from 2021 onward. This recovery coincides with a rapid increase in internet usage and a notable expansion in internet banking adoption, as evidenced in the 2023-2024 indicators. While overall digital inclusion has improved substantially, the lower penetration of internet banking services relative to high-DESI economies suggests that profitability gains in low-DESI countries may be driven by cyclical catch-up effects rather than by sustained digital efficiency. These patterns indicate that, although digitalization supports recovery and modernization, limited digital maturity may result in higher ROA volatility and less predictable profitability outcomes.

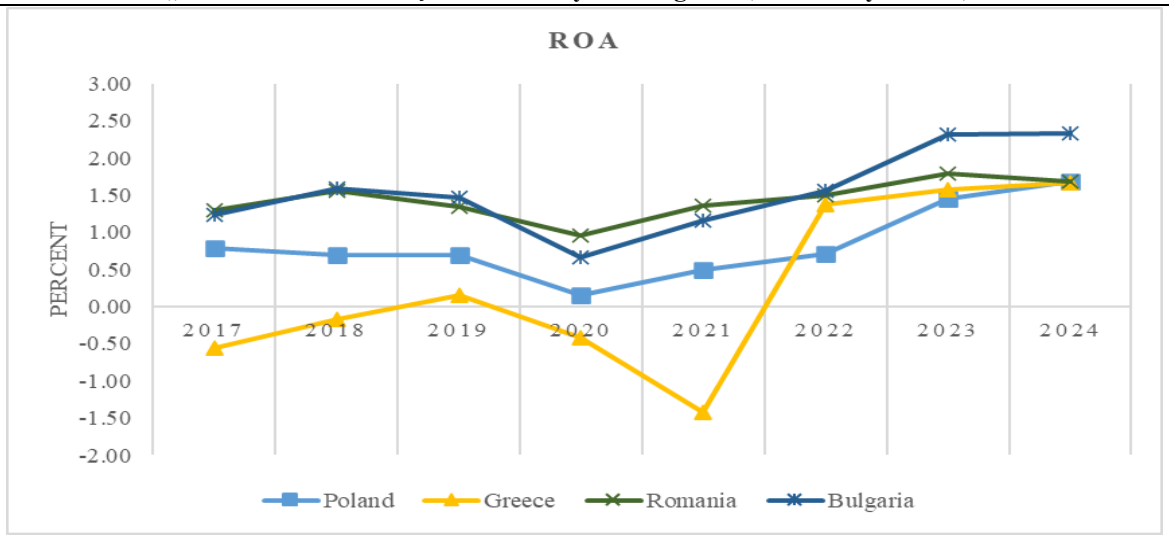


**Figure 6 – Return on assets in low-DESI economies**
Source: Author's contribution based on data extracted from IMF

Taken together, the ROA dynamics suggest that digital maturity influences not only the level but also the quality of banking profitability. High-DESI economies benefit from greater stability and resilience, supported by advanced digital ecosystems and widespread internet banking usage, while low-DESI economies experience stronger but more volatile profitability cycles, even as digital adoption accelerates in the post-pandemic period.

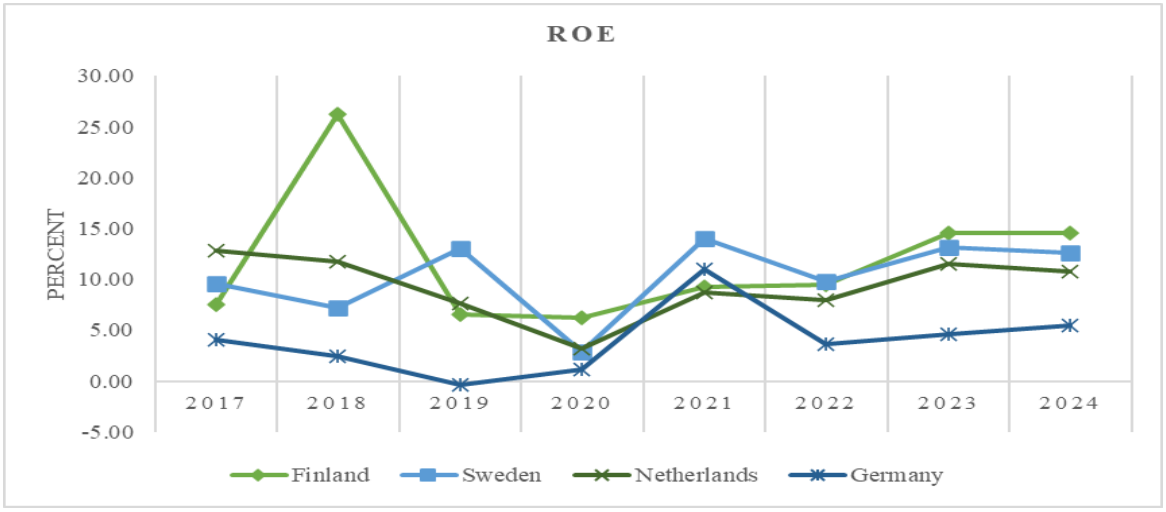


**Figure 7 – Return on equity in high-DESI economies**
Source: Author's contribution based on data extracted from IMF and ECB

Figure 7 illustrates the evolution of Return on Equity (ROE) in selected high-DESI economies over the 2017–2024 period. Overall, these countries display relatively stable and moderate ROE levels, consistent with mature banking systems operating in highly digitalized environments.

The sharp fluctuations observed around 2020 reflect the impact of the COVID-19 pandemic, which adversely affected profitability through increased provisions and subdued economic activity. From 2021 onwards, ROE shows a gradual and sustained recovery, particularly in Finland and Sweden, coinciding with advanced digital infrastructures and high levels of internet and internet banking usage. While Germany records comparatively lower ROE values, its trajectory remains smooth, suggesting conservative profitability strategies. It should be noted that ROE data for Sweden for the 2022-2024 period were sourced from the European Central Bank (ECB), as corresponding data were not available in the IMF database, while all other observations were obtained from the

International Monetary Fund (IMF). Overall, the patterns indicate that in high-DESI economies digital maturity supports profitability stability rather than exceptionally high equity returns.

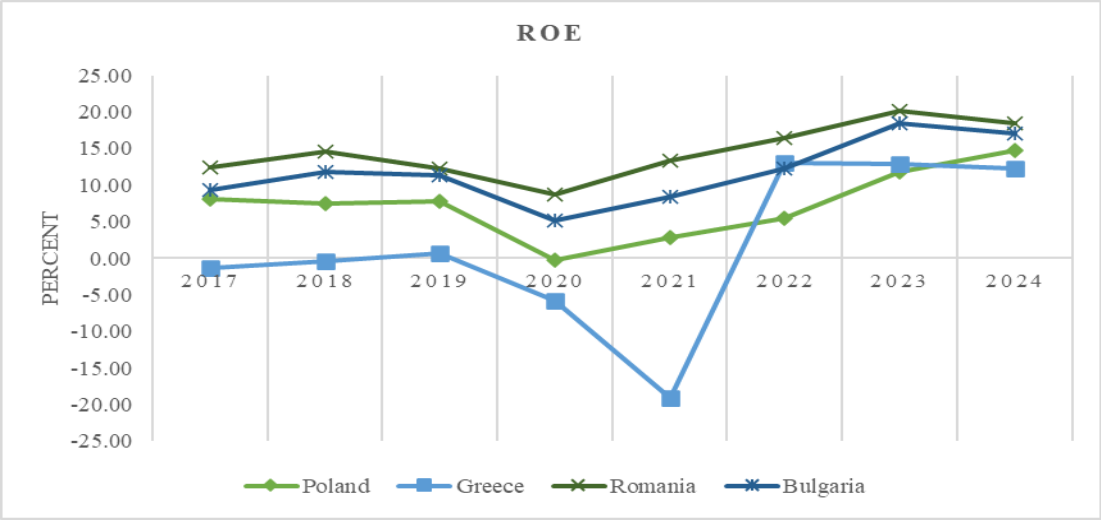


**Figure 8 – Return on equity in low-DESI economies**
Source: Author's contribution based on data extracted from IMF and ECB

Figure 8 presents the evolution of ROE in selected low-DESI economies, revealing higher volatility and more pronounced cyclical behavior compared to high-DESI countries. The negative ROE values recorded in 2020, particularly in Greece, highlight the strong impact of the COVID-19 shock on banking profitability in less digitally mature economies. However, the post-pandemic period is characterized by a rapid and robust recovery, with ROE levels increasing significantly from 2021 onward across all four countries. This improvement coincides with a marked expansion in internet usage and growing adoption of internet banking services, suggesting that accelerated digitalization has supported the recovery of banking performance. Nevertheless, the higher amplitude of ROE fluctuations indicates that profitability in low-DESI economies remains more sensitive to cyclical and structural factors, reflecting lower digital maturity and less entrenched digital banking ecosystems.

Taken together, the ROE dynamics reinforce the view that digital maturity contributes to the resilience and stability of banking profitability, while lower levels of digitalization are associated with higher volatility, even in the context of post-pandemic recovery.

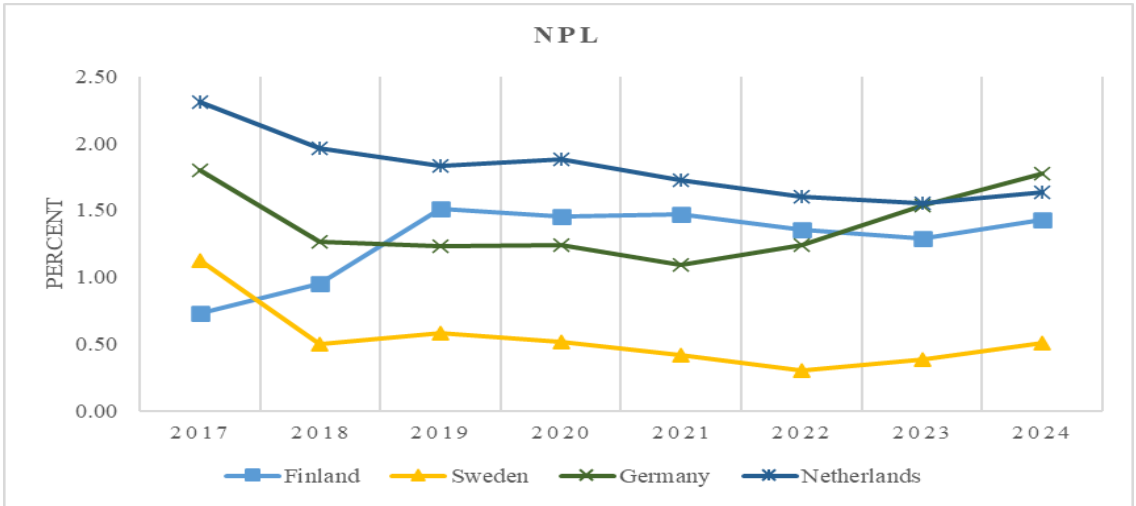


**Figure 9 – Nonperforming loans to total gross loans in high-DESI economies**
Source: Author's contribution based on data extracted from IMF and ECB

Figure 9 illustrates the evolution of non-performing loans (NPL) in selected high-DESI economies over the 2017-2024 period. Overall, these countries exhibit consistently low NPL ratios, generally below 2%, indicating strong asset quality and effective credit risk management. The absence of a pronounced increase in NPL during the COVID-19 shock in 2020-2021 highlights the resilience of banking systems operating in highly digitalized environments, where advanced data analytics, automated monitoring tools and widespread use of digital banking channels support early risk detection. Sweden and Finland maintain particularly low and stable NPL levels, while Germany and the Netherlands show slightly higher but still contained values. It should be noted that NPL data for Germany for the 2017-2021 period were sourced from the ECB, as corresponding data were not available in the IMF database, while data for the remaining years and countries were obtained from the IMF. Overall, the trajectories observed suggest that high digital maturity, as reflected by elevated DESI scores and extensive internet and internet banking usage, is associated with sustained asset quality and limited credit risk volatility.

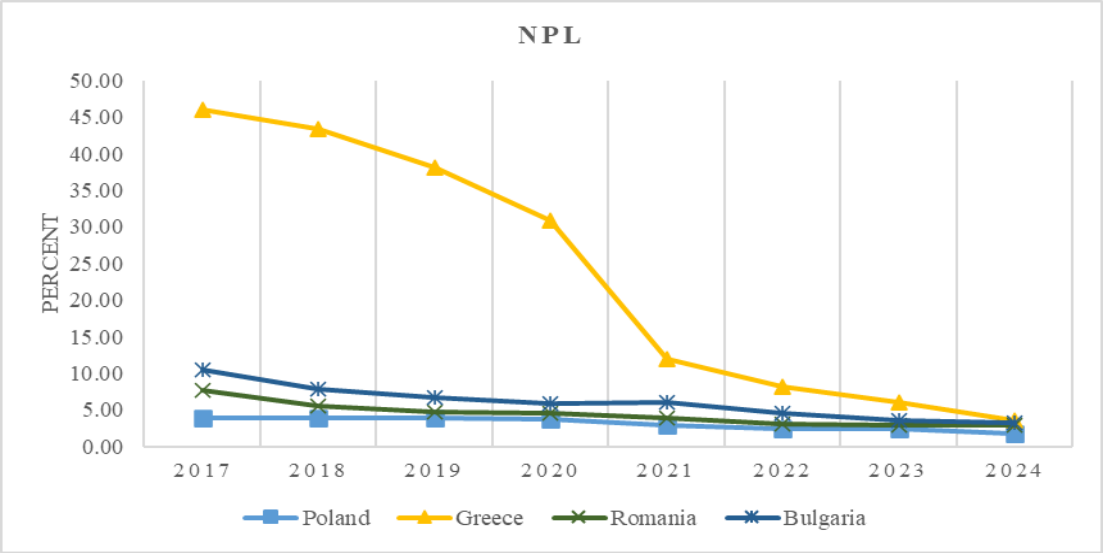


**Figure 10 – Nonperforming loans to total gross loans in low-DESI economies**
Source: Author's contribution based on data extracted from IMF and ECB

Figure 10 presents the evolution of NPL ratios in selected low-DESI economies revealing significantly higher initial levels and more pronounced adjustments compared to high-DESI countries. Greece stands out with exceptionally high NPL ratios in the pre-pandemic period, followed by a sharp and continuous decline, reflecting large-scale balance-sheet clean-up processes and regulatory interventions rather than gradual digital efficiency gains. Romania and Bulgaria also record elevated NPL levels at the beginning of the period, followed by steady reductions, while Poland exhibits comparatively lower and more stable values. Although the COVID-19 shock did not result in an immediate surge in NPL ratios, the adjustment paths in low-DESI economies are steeper and more volatile, indicating a stronger reliance on corrective measures. The more limited penetration of internet banking services in these countries, despite rising general internet usage, suggests that digitalization has played a supportive but secondary role in improving asset quality. These patterns underline that, while digital adoption contributes to risk mitigation, lower digital maturity is associated with higher initial credit risk and less preventive control mechanisms.

Taken together, the NPL dynamics reinforce the hypothesis that digital maturity primarily strengthens the preventive dimension of credit risk management, leading to lower and more stable NPL ratios in high-DESI economies. In contrast, low-DESI economies tend to exhibit higher initial levels of non-performing loans and rely more heavily on ex-post balance-sheet adjustment processes to restore asset quality.

## 4. Conclusions

This study examines how digitalization, measured through the DESI index, relates to key banking performance indicators in the European Union, highlighting that digital maturity can influence profitability and asset quality in different ways across countries. The findings provide a conceptual foundation for future econometric research, offering premises for analyses that may explore nonlinear effects, cross-country differences and broader macroeconomic interactions.

First, the findings offer partial confirmation of hypothesis H1, which posited a positive relationship between digital maturity and banking profitability. While high-DESI economies do not consistently exhibit higher ROA or ROE levels compared to low-DESI economies, they display more stable and resilient profitability patterns, particularly during periods of economic stress such as the COVID-19 pandemic. This suggests that digitalization contributes less to maximizing short-term profitability and more to enhancing the quality and sustainability of profits, through improved efficiency, cost control and operational continuity.

Second, the results provide strong support for Hypothesis H2, which hypothesized a negative relationship between digital maturity and credit risk. High-DESI economies consistently record lower and more stable NPL ratios, indicating superior asset quality and more effective preventive credit risk management. Advanced digital infrastructures, widespread internet usage and high penetration of internet banking services appear to facilitate earlier risk detection and monitoring. In contrast, low-DESI economies exhibit higher initial NPL levels and rely more heavily on ex-post balance-sheet clean-up processes, even though substantial improvements have been achieved over time.

Third, the analysis clearly confirms Hypothesis H3, highlighting the existence of heterogeneous and nonlinear effects of digitalization across EU member states. The impact of digital maturity on banking performance differs markedly between high- and low-DESI economies, reflecting structural differences in institutional quality, market development and digital adoption. Moreover, the comparison between general internet usage and internet banking adoption shows that while basic digital inclusion has largely converged across countries, significant gaps persist in the effective use of digital financial services, with important implications for banking efficiency and risk management.

Overall, the study demonstrates that digitalization acts as a structural conditioning factor rather than a direct determinant of banking performance. High digital maturity enhances resilience, stability and asset quality, while its effects on profitability are indirect and mediated by broader economic and institutional conditions. These findings provide a solid conceptual foundation for future econometric research, encouraging the use of panel data models, nonlinear specifications and interaction terms to capture the complex interplay between digitalization, macroeconomic factors and banking sector performance in the European Union.

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