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The Impact of Technology Adoption on the Operational Efficiency of Commercial Banks in Southeast European Countries

Saimir Dinaj, Fisnik Morina*

Business Management, Haxhi Zeka University, 30000 Peja, Kosovo

* Correspondence: Fisnik Morina (fisnik.morina@unhz.eu)

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Abstract: This research investigated the impact of investments in physical banking facilities, specifically the quantity of automated teller machines (ATMs) and branch locations, on the operational effectiveness of commercial banks in 14 Southeast European countries. By employing various analytical techniques such as panel methods (both fixed and random effects), dynamic panel estimation (Arellano-Bond), and population-averaged estimation generalized estimating equation (GEE), it is discovered that on average, an increase in the number of ATMs and branches correlated with a reduction in Bank Net Interest Margin (BankNIMRatio). Specifically, models that account for the overall population indicated that each additional ATM corresponded to a decrease of approximately 0.0945 percentage point in NIM, while each extra branch was linked to a decrease of around 0.1332 percentage point. The results from the Arellano-Bond method lost their statistical significance when dynamic factors were taken into account, implying that some of the observed cross-sectional relationships were influenced by historical performance and persistence. The originality of this study stemmed from (1) its focus on Southeast Europe, a diverse region that is rapidly embracing digital technologies while still maintaining significant traditional branch networks; and (2) its use of multiple complementary econometric techniques to distinguish between immediate and dynamic relationships. The findings suggested important policy considerations, such as emphasizing digital channels in situations where cost-benefit evaluations predicted diminishing returns from additional physical assets, and establishing branches strategically in response to local market dynamics and characteristics of individual banks.

Keywords: Technology integration; Operational performance; Commercial banks; Southeast Europe

JEL Classification: G21; O33; L25; C23; E44

1. Introduction

The banking industry is a fundamental component of the global economy, as it is playing a key role in supporting financial stability and economic development. With continuous evolution of the banking environment due to technological advancement and changing consumer demands, it is increasingly important to understand the factors that affect the profitability of a bank. One of the most significant factors is technological innovations, particularly automated teller machines (ATMs) and expansion of branch networks; these have drawn considerable attention from both researchers and industry professionals.

The widespread use of ATMs has revolutionized how banks operate and interact with their customers. Initially designed to enhance convenience and accessibility, ATMs have evolved into an essential part of modern banking systems. They allow customers to perform a range of transactions independently, without the need for direct interaction with bank personnel, thus helping to reduce operational costs for financial institutions. However, the relationship between the number of ATMs and bank profitability is complex. While some studies suggested that increasing the number of ATMs could enhance customer satisfaction and potentially boosted revenue from transaction fees, others indicated that the operational costs associated with these machines might outweigh the benefits, leading to lower profitability.

Alongside the expansion of ATM networks, banks have also extended their branch networks to strengthen their market presence and improve customer service. Branches serve as critical points of contact for customers seeking assistance and personalized financial advice. However, managing an extensive branch network can be costly, especially at a time when digital banking solutions are becoming increasingly prevalent. The challenge for banks lies in finding a balance between the benefits of physical presence and the costs associated with operating these branches.

Previous studies have yielded mixed findings regarding the impact of ATMs and bank branches on key profitability indicators, particularly Bank Net Interest Margin (BankNIMRatio). For example, some research suggested that while ATMs could increase fee-based revenue, their overall impact on profitability remained uncertain, mainly due to significant maintenance costs. On the other hand, other studies emphasized that a larger number of branches was typically associated with higher profitability, as they provided essential services to enhance customer loyalty and retention.

Southeast Europe offers a unique environment for examining banking technology. The nations within this area vary significantly in terms of financial progress, digital capabilities, regulatory frameworks, and the remnants of their transitional histories. These differences, both among and within countries, lead to varying cost-benefit analyses regarding investments in ATMs and branches compared to those seen in more established markets. To the best of knowledge, there have been few comprehensive studies that explore the relationships among ATMs, branches, and net interest margins (NIM) across all Southeast European countries using both static and dynamic panel techniques. This research aims to address that gap by analyzing how physical banking infrastructure influences NIM in markets that are at different points of digital evolution and institutional maturity.

This study contributed to the ongoing discussion about the impact of ATMs and bank branches on BankNIMRatio among commercial banks in Southeast Europe. The methodology employed involved a range of econometric techniques such as fixed effects models, random effects models, dynamic panel estimation using the Arellano-Bond method, and Generalized Estimating Equations (GEE). This research provided a deeper understanding of the impact of technological investments on operational efficiency, given the unique economic landscape of Southeast Europe, where banking systems are still developing alongside rapid technological advancement and shifting consumer preferences. Understanding the relationship between technology adoption and bank performance will not only inform banking strategies, but also provide valuable insights for policymakers seeking to create a more efficient banking ecosystem.

The findings of this study carried significant implications for bank management regarding investment decisions on technology and infrastructure. As banks navigate the complexities of modern financial environment, the insights gained from this research will be crucial in shaping strategic efforts aimed at improving operational efficiency and profitability. Ultimately, this study aims to shed light on the critical link between technology adoption in the banking sector and its impact on financial performance, thus contributing both to academic discourse and practical applications in the industry.

2. Literature Review with Meta-Analysis

The interaction between technology adoption and operational efficiency in the banking industry has increasingly attracted the attention of researchers, particularly when financial institutions seek to enhance their performance in the face of intense competition. A range of studies has examined the impact of technology on various aspects of banking efficiency and has highlighted significant findings to guide this research.

A key conclusion from the existing literature is that banks implementing advanced technologies, such as online banking and mobile applications, has experienced substantial benefits from operational efficiency. According to Akhter & Khalily (2020), these digital tools not only reduced transaction costs but also improved customer satisfaction, ultimately leading to a better income-to-expense ratio. This perspective aligns with the idea that the cost-to-income ratio is a vital measure of banking performance, where lower ratios indicate improved efficiency (Khan et al., 2019). The use of this metric allows researchers to effectively compare the performance of different banks over various periods.

Furthermore, the benefits of investments in information technology (IT) have been extensively studied. Research by Al-Shammari & Al-Am (2018) indicated that banks allocating resources to IT experienced higher profits and lower operational expenses. This improvement primarily stemmed from streamlined processes that reduced dependence on physical branches, thereby lowering overall costs. Additionally, digital banking solutions have proven effective in increasing customer engagement and retention, leading to higher revenue (Tarawneh et al., 2024). Actively engaged customers tend to utilize more additional services offered by banks, further enhancing financial performance.

The regulatory environment significantly influences the pace of technology adoption. Well-structured regulations provide essential guidelines to ensure security and consumer protection, thus encouraging banks to invest confidently in new technologies (Zhang et al., 2024). In a competitive environment, banks are motivated to innovate and embrace new technological advancement; El-Kassar & Singh (2019) emphasized that those failing to adapt to risks would lose market share to technologically superior competitors.

However, not all financial institutions have equal opportunities to adopt new technologies. Smaller banks often face challenges such as limited funding and a lack of specialized expertise (Abdul Basit et al., 2024). Overcoming these challenges is crucial to ensuring that every bank can benefit from technological advancement. Another important aspect to be considered is the impact of technology on non-performing loans. Research by Yu et al. (2021) showed that tools such as data analytics enabled banks to reduce bad loans by refining their credit assessment methods. Improved credit evaluations resulted in more prudent lending decisions, thus enhancing the overall financial health of an institution.

Table 1. Meta-analysis

Authors	Main Variables	Methodology	Key Findings	Limitations
Bourke (1989)	Return on assets (ROA), Total assets, Number of branches, Market share	Regression analysis	Banks with a higher number of branches show stronger profitability indicators, suggesting that physical presence supports customer loyalty and service delivery.	Early period data; excludes technological factors such as ATMs or digital banking; limited to developed markets.
Berger & Mester (1997)	Cost efficiency, Scale efficiency, Number of ATMs, Number of branches	Stochastic frontier analysis (SFA)	Increased ATM installations improve cost efficiency, although benefits vary depending on the operational context.	Focuses on U.S. data; does not address differences in the emerging markets or long-term digital effects.
DeYoung & Hasan (1998)	Efficiency scores, Number of branches, Bank size	Data envelopment analysis (DEA)	More branches increase efficiency scores, but gains diminish once branch networks become large.	Efficiency measured only through DEA; digitalization not considered; lacks dynamic effects.
Bai et al. (2018)	Bank NIM, Number of ATMs, Economic conditions	Panel data regression	ATMs enhance accessibility but reduce NIM because maintenance and operation costs outweigh benefits.	Sample limited to Chinese banks; short time frame; potential endogeneity not controlled.
Nguyen et al. (2016)	Customer satisfaction, ATM availability, Bank performance metrics	Structural equation modeling (SEM)	ATM availability raises customer satisfaction but does not significantly improve ROA or other performance indicators.	Focuses on customer perception; small domestic sample; no profitability dynamics tested.
El-Kassar & Singh (2019)	Operational efficiency ratios, Number of ATMs and branches	Multivariate regression analysis	Both ATMs and branches improve short-term efficiency, but their long-term impact depends on effective management.	Data limited to service firms; lacks regional diversity; does not isolate the banking sector.
Khan et al. (2019)	Bank profitability metrics, Number of ATMs and branches over the time	Time-series analysis	Profitability benefitted from branch networks have declined as digital banking becomes more prevalent.	National-level time series; excludes bank-level heterogeneity; causality not tested.
González-Serrano et al. (2020)	Bank profitability ROA, Number of branches, Economic indicators	Fixed-effects model	Branch expansion raises profitability in developing economies, but excessive expansion can reduce efficiency.	Limited samples from developing countries; ignores technological substitutes such as online banking.
Aisha & Rakesh (2022)	Customer usage patterns of ATMs and branches, Financial performance indicators	Quantitative survey analysis	Customer preference is shifting toward digital services; declining use of branches affects strategies of profitability.	Survey-based; perception data only; lacks financial panel data and causal tests.
Zhang et al. (2024)	Bank NIM, Technological adoption (ATMs, Digital platforms)	Generalized method of moments (GMM) estimation	Digital transformation significantly improves bank performance; results highlight the moderating effect of macroeconomic conditions.	Limited to Chinese banks; macro variables not detailed; Southeast Europe not represented.

Customer satisfaction also emerges as a key outcome linked to technology adoption. Wang et al. (2020)

recognized a positive relationship between technology usage and customer satisfaction levels. Satisfied customers are more likely to recommend banking services, thus potentially increasing the revenue for a financial institution. Moreover, mobile banking has played a crucial role in expanding financial access for marginalized communities (Cobla & Osei-Assibey, 2018). By addressing the needs of populations without financial services, banks can expand their customer base and increase deposits. This trend aligns with the broader movement toward using technology for operational risk management; Alhassan et al. (2019) highlighted that technological advancement enhanced risk management through real-time data analysis.

The existing literature suggested that banks integrating technology into their operations reported improvements in their return on assets due to increased efficiency (Naceur & Omran, 2011). A higher return on assets indicated effective utilization of resources, which is crucial for long-term sustainability. The implementation of artificial intelligence in banking processes enhances decision-making capabilities (Tarawneh et al., 2024), which could facilitate banks to analyze large datasets rapidly to make informed strategic choices.

Technology adoption brings numerous advantages, particularly in cost savings. According to Mishra & Kumar (2023), the introduction of automation significantly reduced expenses associated with manual operations. By automating routine tasks, financial institutions could redirect their workforce toward higher-value activities, thereby increasing overall productivity.

Furthermore, integrating customer relationship management (CRM) systems has proven effective in improving both service quality and operational efficiency (González-Serrano et al., 2020). These systems allow banks to personalize their offerings to meet the specific preferences of each client, thus fostering loyalty and encouraging repeat transactions. Additionally, technology has improved the efficiency of international banking; Buch et al. (2013) demonstrated that globally operating banks utilized technology to unify their operations across different markets. This unification simplified processes and enhanced the ability to navigate diverse regulatory frameworks effectively.

For organizations to fully benefit from their technological investments, employee training on new technologies is essential (Khan et al., 2019). Well-trained employees can leverage technology more efficiently, leading to improved service delivery. However, since banks have increasingly relied on technology, there are concerns about threats imposed by cybersecurity (Qin et al., 2020). Addressing these threats is crucial to maintaining customer trust and protecting sensitive data.

Finally, the transition to technological solutions also promotes sustainable banking practices by minimizing paper usage and optimizing resource management (Fischer et al., 2023). Embracing sustainable practices not only enhances operational performance but also improves public perception of banks. In the future, innovative technologies such as blockchain are expected to significantly transform banking operations by improving transparency and reducing transaction costs (Catalini & Gans, 2016). Technological advancement is likely to further reshape the operational efficiency of the banking sector (Aisha & Rakesh, 2022).

Existing research indicated a strong connection between technology adoption and improvements in operational efficiency in the banking industry. As summarized in Table 1, prior studies suggested that investing in technological solutions could enhance key performance indicators, such as cost-to-income ratios of banks, while fostering innovation and increasing customer satisfaction. Since banks in Southeast Europe face an increasingly competitive environment, leveraging technology will be crucial for achieving sustainable growth and maintaining a competitive advantage. This review underscored the importance of continued research on the evolving role of technology in banking, particularly in underexplored regions such as Southeast Europe.

In general, the research presented a variety of findings. Studies that are cross-sectional or utilize static panels frequently indicate unfavorable or unclear impacts of ATMs and bank branches on profit margins. In contrast, research employing dynamic approaches or instrumental variable methods typically uncovers milder or insignificant immediate effects, implying potential issues with persistence or homogeneity.

3. Methodology

The objective of this research is to examine how the use of technology impacts the operational effectiveness of commercial banks in Southeast Europe. This study specifically analyzed the relationships among the number of ATMs, the number of bank branches, and BankNIMRatio. The methodology presented here detailed the research framework, data collection methods, considered variables, and analytical strategies applied to test the proposed hypotheses.

A quantitative approach will be used to investigate the defined hypotheses:

Hypothesis 1 (H1): An increase in the number of ATMs is associated with a decrease in BankNIMRatio for commercial banks in Southeast Europe.

Hypothesis 2 (H2): An increase in the number of bank branches is associated with a decrease in BankNIMRatio for commercial banks in Southeast Europe.

This methodology enabled a structured examination of the relationships between technology adoption indicators (such as ATMs and bank branches) and operational performance (measured through BankNIMRatio).

3.1 Data Collection

To validate these hypotheses, this study utilized secondary data obtained from various reliable sources. Financial databases such as the World Bank will provide extensive data on banking operations and indicators related to technology adoption. Industry reports highlighting technological advancement in the banking sector will also be included, to offer insights into indicators such as the number of ATMs per 100,000 adults, digital banking adoption rates, and other metrics reflecting technology usage.

The collected dataset covered several years, allowing a longitudinal analysis of trends and impacts over the time. A diverse range of commercial banks from different countries in Southeast Europe will be represented in the sample distribution map below.

The geographical coverage of the dataset is illustrated in Figure 1, which highlights the 14 Southeast European countries in this study. The map demonstrates the spatial distribution of sampled commercial banks across the region.

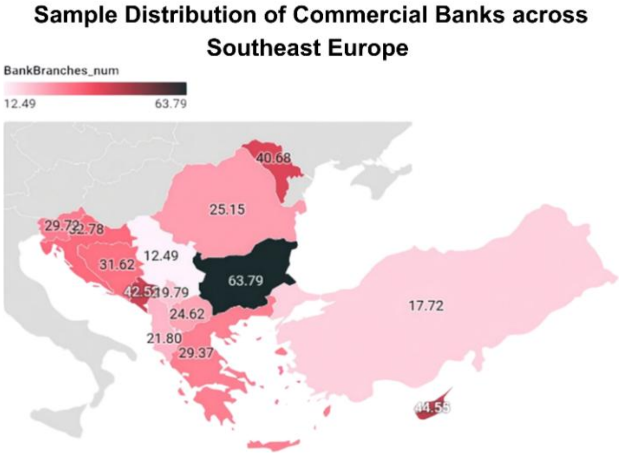

Figure 1. Sample distribution map

3.2 Key Variables

Dependent Variable: BankNIMRatio. This indicator serves as a measure of operational efficiency, calculated by dividing net interest income by earning assets. A lower value suggests a decline in profitability.

Independent Variables: (1) ATMs: The total number of ATMs available per bank. (2) Bank Branches (BankBranches_num): The total number of physical bank branches managed by each financial institution.

Figure 2 showcases the theoretical framework of this research, to depict the expected connections between the key variables. In particular, it is suggested that the quantity of ATMs and bank branches may have an adverse effect on BankNIMRatio, thus highlighting the potential financial burdens associated with sustaining physical banking operations. To address the variations in institutions and surrounding conditions across Southeast European nations, control variables like bank cost to total income are incorporated.

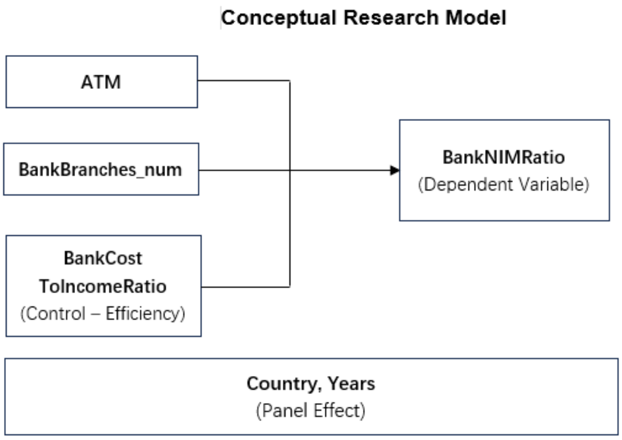

Figure 2. Research framework

3.3 Regression Analysis

Fixed Effects Regression: This model focuses on internal changes within each bank over the time, and control for any unobserved differences between banks. It is particularly useful when there are stable characteristics influencing operational efficiency.

Random Effects Regression: If it is determined that the unique characteristics of individual banks are not correlated with the regressors, this model will be applied to assess impacts while considering both within-group and between-group variations.

GEE: This approach is used to address potential correlations within different groups (such as countries), while simultaneously providing estimates that represent the overall population. The GEE model will help understand how changes in the number of ATMs and bank branches impact the BankNIMRatio.

3.4 Model Selection Methodology

This study started by utilizing pooled Ordinary Least Squares (OLS) for initial comparison, followed by fixed effects models, which aimed at accounting for unobserved variables that remained constant at the bank level over the time. Additionally, random effects models were employed to leverage both the variations between banks and those within the same bank. To ascertain the preferred model choice between fixed and random effects, the Hausman test was conducted. A significant Hausman statistic ($p < 0.05$) indicated a preference for fixed effects, as random effects would not yield consistent results. Having considered the correlation between bank profitability and investments in ATMs and branches, a dynamic panel estimator, specifically the Arellano-Bond method, was implemented.

This approach helped manage the persistence of NIM and addressed any potential endogeneity in the independent variables. The results of the Arellano-Bond AR (1) and AR (2) tests, along with the Hansen/Sargan over-identification test, was presented to evaluate the validity of the instruments. The use of GEE derived population-averaged estimates that were resilient to correlations within a country (data by country or bank was grouped where applicable), thereby providing additional insights alongside the fixed effects (within-bank) results.

This analysis incorporated standard controls at the bank and macroeconomic levels, such as total assets (in logarithmic form), capital adequacy ratio (CAR), non-performing loan ratio (NPL), and loan-to-deposit ratio (LDR). It also included a dummy variable for bank ownership (foreign/private), annual gross domestic product (GDP) growth rates, inflation, and the concentration of banking in the country. This was measured by the Herfindahl-Hirschman Index (HHI). These control variables assisted in isolating the specific impact of ATMs and branches on NIM.

Several scenarios were specified to ensure robustness: (1) including models that normalize ATM counts per 1,000 customers or per 100,000 adults; (2) excluding extreme values from the analysis (top and bottom 1%); (3) conducting analyses on different subsamples (e.g., countries with high versus low rates of digital adoption); and (4) using lagged values of ATM and branch counts as instruments in the Arellano-Bond framework, while also reporting Hansen statistics to substantiate our findings.

4. Results and Discussion

This study on how ATMs and bank branches affect BankNIMRatio revealed significant insights into the operational efficiency of commercial banks. The established hypotheses were:

Hypothesis 1 (H1): An increase in the number of ATMs is associated with a decrease in BankNIMRatio.

Hypothesis 2 (H2): An increase in the number of bank branches is associated with a decrease in BankNIMRatio.

As highlighted in Table 2, the literature review and meta-analysis provided the theoretical foundation for these hypotheses, illustrating prior empirical evidence of how physical banking infrastructure influences profitability indicators such as NIM.

To improve visual presentation of the findings, Figure 3 illustrates the coefficient estimates derived from both the Fixed Effects (FE) Model and the FE Robust specification. This graph emphasizes the direction and statistical importance of the primary explanatory variables: ATMs, bank branches, and the cost-to-income ratio of banks. The consistently negative coefficients for both ATMs and branches in all models reinforced the reliability of their estimated impact on BankNIMRatio.

In examining the findings from both the population-averaged GEE and random effects models, the coefficients revealed modest economic significance that could hold importance when viewed collectively. To break down the coefficients: for ATMs, the random effects coefficient of −0.0945 indicated that the addition of one more ATM by a bank correlated with a reduction of 0.0945 percentage point in Bank NIM, which was translated to approximately 9.45 basis points. If the average NIM within the sample is around 3.0%, introducing an extra ATM would lower this figure from 3.00% to roughly 2.9055%. While this impact might seem minor, it becomes significant when applied across numerous ATMs or over the time. For bank branches, a random effects coefficient of −0.1348 suggested that adding another branch could lead to a decrease of 0.1348 percentage point in NIM, equating to about 13.5 basis points. Furthermore, the fixed effects estimate of −0.1877 implied that intra-bank growth could result in larger short-term cost implications, around 18.8 basis points.

Table 2. Results of the analyses

Methods	Variable	Coefficient	Std. Err.	*p*-Value	*R*-squared (within)	95% CI
Fixed effects regression	ATM	−0.1005	0.052	0.083	0.0506	(−0.202, 0.001)
	BankBranches_num	−0.1877	0.074	0.012		(−0.333, −0.042)
Random effects regression	ATM	−0.0945	0.046	0.043	0.0498	(−0.185, −0.003)
	BankBranches_num	−0.1348	0.066	0.045		(−0.265, −0.004)
Arellano-Bond estimation	ATM	−0.0543	0.078	0.487		(−0.207, 0.099)
	BankBranches_num	0.1392	0.095	0.145		(−0.048, 0.326)
GEE model	ATM	−0.0945	0.046	0.041	0.0528	(−0.185, −0.004)
	BankBranches_num	−0.1332	0.066	0.045		(−0.262, −0.004)

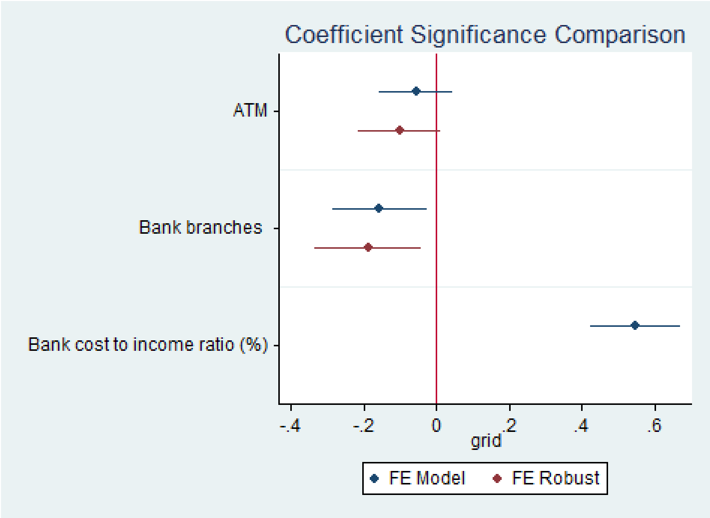

Figure 3. Comparison of coefficient significance across the model

Regarding dynamics as measured by the Arellano-Bond approach, the estimates showed no statistical significance for either ATMs or branches. This outcome suggested that, even after accounting for prior NIM and potential endogeneity, the current size of the physical network might not independently account for the present NIM level. The discrepancy observed between static and dynamic models indicated that some of the negative relationships highlighted in static analyses might stem from overlooked dynamic influences or reverse causation.

In terms of policy implications, the combined insights from static and population-average estimates pointed to the trend that expanding physical assets tended to yield slightly lower NIMs. On the other hand, dynamic models underlined the importance of historical performance and enduring characteristics of banks. Consequently, financial institutions should thoroughly assess the long-term benefits of expanding their infrastructure, considering both the short-term operational costs and potential future revenue opportunities such as cross-selling, which may not be immediately reflected in NIM measurements. Tests confirmed both Hypotheses 1 and 2, while demonstrating that ATMs and bank branches negatively impacted BankNIMRatio, as evidenced by the fixed effects and GEE analyses. However, the results from the Arellano-Bond estimation required caution and emphasized the evolving nature of these relationships over the time. These findings highlighted the need for banks to carefully assess their technological strategies, in order to align with profitability goals while effectively managing associated costs.

5. Conclusions

This research investigated the impact of physical banking facilities such as ATMs and branches on NIM of banks in Southeastern Europe. The findings from static and population-averaged analyses consistently revealed a negative relationship between the number of ATMs/branches and NIM. However, when employing dynamic panel estimation techniques (Arellano-Bond), these associations diminished to statistical insignificance. This trend offered two complementary interpretations. Firstly, the observed negative static relationship likely reflected immediate cost implications. The addition of more machines and branches incurred direct operational, upkeep, and staffing expenses, which in turn lowered profitability based on interest margins. Secondly, the weakening effects seen in dynamic estimations suggested significant roles played by historical performance, strategic decisions, and potential reverse causality, i.e., banks with high NIM opted to build more branches whereas banks with low NIM chose to downsize. Consequently, one should interpret the current cross-sectional relationship with caution.

When compared to prior discussions in the field, the present findings reveal that the operational costs associated with maintaining ATMs and physical branches tend to reduce profit margins for commercial banks. Moreover, they align with findings suggested that the advantages of infrastructure like customer loyalty and fee income might require more time to manifest or depend on the integration of digital solutions. The variations observed across different countries implied that the market structure and the degree of digital adoption influenced the relationship between ATMs/branches and NIM. In markets that are more advanced digitally, the incremental cost of adding a physical asset tends to be greater.

The limitations of this study include the reliance on aggregate bank-level data, which does not capture profitability at the branch level or the customer-level preferences for different channels. Additionally, measuring ATMs solely by their counts overlooks variations in transaction volumes and fee arrangements. While the Arellano-Bond method addresses some endogeneity issues, the validity of instruments is contingent on the sample size and lag structure. Hansen and AR tests could help demonstrate the robustness of our instrument strength.

Implications of these findings suggested that bank managers should focus on strategically rationalizing the set-up of branches while investing in digital platforms where cost-benefit evaluations implied unfavorable outcomes from expanding physically. Regulators must also be vigilant regarding the access to trade-offs: while consolidating branches can lower costs, it may simultaneously hinder access for under-serviced populations, thus indicating a need for differentiated regulatory support or incentives that promote digital inclusion.

Data Availability

The data used to support the research findings are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

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