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Impact of Operational Efficiency, Technological Adoption, and Risk Optimization on Bank Profitability: Evidence from Bangladesh

Abstract

This paper investigates how three elements, including operational efficiency, technology adoption, and optimization of risk, affect bank profitability in Bangladesh. Using panel data from 10 privately owned commercial banks over the period 2014–2023, various econometric models (including pooled OLS, fixed-effects, random-effects, FGLS, and DSGMM) were applied with controls for credit risk, bank size, equity ratio, GDP growth rate and inflation to analyze profitability measures such as Return on Assets (ROA), Return on Equity (ROE), and Net Interest Margin (NIM). The results show that operational efficiency plays a significant role, with lower cost-to-income ratios leading to reduced operational costs, thus enhancing profitability. Technology adoption is positively linked to bank profitability across all estimation methods, indicating the growing importance of digital transformation for banking performance. Capital adequacy, though essential for maintaining solvency and regulatory compliance, does not directly drive profitability but plays a key role in risk management. Again, credit risk negatively affects profitability, highlighting the importance of sound risk management. Overall, the study provides an integrated empirical framework that considers the combined effects of efficiency, technology, and capital management within a dynamic panel setting, thereby contributing to existing literature.

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1. Introduction

Bangladesh's banking industry is the heart of the national financial system, where deposits are mobilized and credit is released to productive sectors, which boost investment and economic growth. As a financial intermediary, the core goal of a banking establishment is to manage the assets of the bank effectively to make enough profits. Broadly, profits are required for two reasons: they are required for the payment of dividends to shareholders and to enable banks to survive through periods of economic downturn or uncertainty when the demand for credit intermediation may be interrupted (Mashamba and Chikutuma, 2023). Again, the sustainability of banking institutions enables the sustainability of the entire economy and leads to a higher degree of financial inclusion and resilience to both domestic and international economic and political shocks.

The banking sector in Bangladesh has been undergoing rapid development over the past ten years as it responds to evolving regulatory requirements, technological advances, and changing risk factors. More than 60 scheduled commercial banks exist within the banking sector under the direct oversight of the central bank (Bangladesh Bank, 2024). The challenges, however, include many structural issues such as low operating efficiencies, high NPLs, and an increasing number of cybersecurity threats. As a result, these challenges lead to lower profitability, and therefore, there is an urgent need to create efficiencies and implement better practices for managing the sector-specific banking risks.

One of the various factors of bank performance is operational efficiency. It is commonly expressed as the Cost to Income Ratio (CIR) and represents how well banks can maintain their costs in relation to their revenue. It is a sign of the quality of the management in the banking sector, and banks that operate efficiently have higher profit levels than inefficiently managed banks (Mashamba and Chikutuma, 2023). In a competitive environment such as the Bangladeshi banking system, where there are rising costs and shrinking interest rate spreads, efficient operation is even more important for maintaining profitability.

Due to the digital transformation and the rise of financial innovations in the global market for banking, the global banking system has evolved. The entry of neobanks and FinTech companies has changed the traditional models of banking (Boot et al., 2021) and has forced banks to implement modern, sophisticated technologies to remain relevant (Pierri and Timmer, 2022; Kwan et al., 2023). For emerging economies such as Bangladesh, digitalization represents both a challenge and an opportunity. On one hand, digitalization and fintech collaborations provide opportunities to improve customer service, accessibility, and efficiency through digital platforms (Ren et al., 2024; Farhood, 2024), but require significant investments and represent risks to technology and regulatory issues. Data from Europe, Africa, and China clearly demonstrate that digital transformation can lead to improved performance and profitability of business operations (Farhood, 2024; Ren et al., 2024; Ebissa and Lakew, 2025). However, this also depends significantly upon the readiness of the institution and the strategic integration of technology (Ebissa and Lakew, 2025).

The concept of capital adequacy (also referred to as the capital adequacy ratio, CAR) is traditionally used to measure a bank's competence to absorb losses and conserve solvency. By maintaining adequate capital buffers, banks can manage their risk exposure and balance stability with profitability. In this context, we can explore the dual role of capital adequacy in not only meeting regulatory standards but also in managing financial risk to enhance profitability. In terms of the Basel II and Basel III systems, banks must maintain an appropriate level of capital holdings as a proportion of risk-weighted assets (Mathuva, 2009; Ho and Hsu, 2010). Properly capitalized banks will generally provide greater stability and better be able to withstand financial shocks than under-capitalized banks. Additionally, the cost of funding for properly capitalized banks will generally be less than it would be for under-capitalized banks (Alkhazali et al., 2024). While the equity ratio ensures financial stability, it is capital adequacy that directly links to risk optimization, making it the key focus of this study.

Studies from various developing countries, including India, Kenya, and Nigeria, have revealed that maintaining optimum levels of capital results in improved efficiency and profitability (Lotto, 2018; Ogunmola et al., 2022). Implementing Basel III in Bangladesh has led to an increase in the capital requirements of banks in Bangladesh; hence, they now have greater financial capability. Nonetheless, while increased capital adequacy leads to improved solvency, the cost associated with holding this excess capital could have been utilized for other potential revenue-generating activities, such as lending or investing. Simultaneously, adapting to the emerging trends of digitalization (such as mobile financial services, cloud infrastructure, etc.) in order to maintain a competitive edge will require costly investments during the near term. Yet, ultimately, these investments are key to sustaining both efficiency and competitiveness in the long run (Farhood, 2024).

There is considerable evidence globally that operational efficiency and technological advancements contribute significantly to a bank's ability to improve profitability. Furthermore, though capital adequacy may be vital to the regulatory and operational stability of banks, effective management of risk enabled by capital adequacy and other operational improvement capabilities ensures sustained profitability. However, in the past, studies have generally examined individual predictors of profitability that do not allow policymakers and managers to create strategies for achieving a balance between efficiency, innovation, and stability. This paper aims to address this gap by examining the combined effect of these three dimensions, i.e., operational efficiency, technology adoption, and risk optimization, on the profitability of Bangladeshi banks. Moreover, the investigation takes into account several critical elements like credit risk, the size of banks, equity ratios, GDP growth, and inflation to provide a thorough understanding of both internal and broader economic influences on profitability. Lastly, using dynamic panel data methodologies, the paper attempts to establish strong and stable results to reflect the persistence in profitability.

The relevance of this study comes from its contribution to theory, context, and practice. From a theoretical standpoint, the study contributes to an integrated framework for examining efficiency, digitalization, and capitalization. From an empirical viewpoint, the study adds a rapidly developing and digitally evolving country (Bangladesh) adopting Basel III standards, which will fill a critically important gap in comparative finance literature. Methodologically, the use of the dynamic econometric method is helpful to increase the reliability of the findings through addressing the issues of contemporaneous correlation and firm-specific effects. Practically, the study has implications for bank managers and regulatory bodies that need to achieve a balance between cost-effectiveness, investment in technology, and capital management to enhance sustainable development and financial stability of banks in Bangladesh under a changing environment where there is a need to balance prudential regulatory requirements and profit maximization goals.

2. Literature Review

Bank profitability has been widely examined through bank-specific, industry-specific, and macroeconomic determinants, but the relative importance of these factors varies across institutional and regulatory settings. According to Akther et al. (2023), both micro and macro elements that affect a bank's profit margin include bank-specific characteristics and country-wide economic conditions. Additionally, studies led by Abbas et al. (2019) find that banks should implement new technologies, innovations, and customer service communications to enhance their banking services and performance. Evidence from Bangladesh reveals that both internal bank characteristics and macroeconomic conditions matter for profitability, although bank-specific components often play the dominant role. At the same time, cross-country studies suggest that profitability dynamics differ across banking systems because competition, regulatory structures, risk exposure, and management quality are not uniform across countries. For instance, each study examining banking performance in different countries, including Bangladesh (Bose et al., 2017; Robin et al., 2018); China (Tan, 2016; Tan et al., 2017); Tunisia (Bougatef, 2017); and India (Singh and Sharma, 2016; Almaqtari et al., 2019), has agreed that factors contributing to bank profitability will vary based upon the economy and regulatory setting in which they operate. Within this broader literature, operational efficiency, technology adoption, and risk optimization have become especially important in recent years as banks face digital transformation, tighter prudential regulation, and persistent asset-quality pressures in emerging markets such as Bangladesh.

The theoretical foundation of this study entails a multi-theoretical approach that brings together the hypotheses on efficiency structure, resource-based view, and risk-return trade-off to explain how operational efficiency, technology-related spending, and capital management interact to determine the level of bank profitability. The efficiency view is cost control and resource use as determinants of performance (Berger, 1995), the resource-based view is the important strategic role of technology in competitive advantage (Barney, 1991), and the risk–return trade-off is how credit risk and capital structure determine the profitability of banks (Athanasoglou et al., 2008). Last but not least, capital adequacy theory posits that, whereas increased capital enhances financial stability and low insolvency risk, high capitalization can inhibit profitability, as it implies less leverage (Berger, 1995; Athanasoglou et al., 2008).

2.1 Operational Efficiency and Bank Profitability

The efficiency structure hypothesis is a perspective widely used in explaining operational efficiency, which postulates that a bank that manages its operations more efficiently is more likely to make high profits than other banks because it incurs less operational waste and makes more effective use of resources. Here, the cost-to-income ratio (CIR) is a crucial measure of operational efficiency, with a lower ratio showing that the company is more efficient with its cost management and thus more efficient. In line with this perspective, more efficient banks are expected to perform much better in financial terms, because of better use of resources and less operational waste. This relationship is substantially supported by

empirical evidence, but its strength can depend on the conditions in the institutions and on the market. To illustrate, Dietrich and Wanzenried (2011) indicate that operational efficiency has a positive effect on bank profitability among the Swiss banks. In a similar report, Mashamba and Chikutuma (2023) state that cost efficiency is highly associated with ROA and ROE in Banks in Zimbabwe. Cost control is yet another example of a profitability force described by Lamers et al. (2022) in the European Union. Further, Ayinuola and Gumel (2023) record the relevance of the CIR with regard to the performance of banks in Nigeria, whereas the inquiry by Al-Sharkas and Al-Sharkas (2022) demonstrates that the cost-income dynamics continue to be in the focus of profitability in emerging economies. Such results imply that cost rationalization and disciplined operation continue to be critical in maintaining profitability, particularly within banking systems where spreads are narrowing, and compliance costs are on the increase. Nonetheless, there is evidence that the relationship can be different across settings. Higher operating costs in developing economies can either be due to expansion plans or investing in infrastructure, but not inefficiency (Flamini et al., 2009). This indicates that the efficiency–profitability nexus may be influenced by market structure and institutional factors.

In Bangladesh, according to Akther et al. (2023), cost inefficiency and a considerable magnitude of NPLs continue to hinder bank profitability. They report that bank-specific factors, including efficiency-related indicators, are important drivers of profitability. Similarly, Uddin (2022) finds that operating efficiency significantly affects the profitability of Bangladeshi commercial banks. Therefore, cost efficiency is a fundamental and ongoing challenge for banks in developing economies with unestablished managerial practices and productive systems.

2.2 Technology Adoption and Bank Profitability

The emergence of digital transformation has dramatically changed the way global banking operates. From the perspective of the resource-based view, investment in digital infrastructure and IT systems enhances banks' capability to deliver services efficiently and innovate to address changing customer needs. Along with the rapid change in how financial technology is used to improve the efficiency and competitiveness of Banks, it has also been accelerated by the COVID-19 Pandemic. As the International Monetary Fund (2022) states, the total assets of fintech banks grew 25% in the years 2020 and 2021 compared to 15% for traditional banks. Generally speaking, these investments in mobile banking, fintech platforms, and IT infrastructure are associated with greater operational efficiency, improved customer coverage, and higher profitability. This is further reinforced by empirical evidence. For instance, Dadoukis et al. (2021) show that embracing IT supported bank performance during the COVID-19 period. Pierri and Timmer (2022) further highlight the importance of technology in banking during crisis conditions. Moreover, Ren et al. (2024) show positive outcomes of digital transformation on the profit efficiency of Chinese banks, while Citterio et al. (2024) show similar results for European banks, Farhood (2024) for Arab banks, and Nguyen et al. (2023) in an emerging economy context. However, the effects of technology investment may

not be instantaneously observed. Beccalli (2007) shows that an investment in IT does not always increase performance in the short run. This indicates that the effect of technology may be subject to the quality of implementation and time span. Similarly, Branzoli et al. (2024) have observed decreasing returns to investment in technology, whereas Gupta et al. (2018) have found a U-shaped relationship of profits with respect to digital maturity stage, indicating an initial decrease and then an increase in profits. Thus, the relationship between the adoption of technology and profitability is highly circumstantial and likely to be influenced by factors such as governance capacity, readiness of the institution, and the stage of adoption. In Bangladesh, where FinTech and digital banking are growing quickly, the effect of technology-oriented spending on profitability has not received much attention.

2.3 Capital Adequacy and Bank Profitability

Capital adequacy serves as a key indicator for banks to manage risk, striking a balance between staying financially sound and making a profit. According to the risk-return trade-off theory, having more capital can provide the firm with greater stability, which will boost profits by lowering funding costs and reducing insolvency risks. Research has indicated across various settings that there's a link between how much capital banks have and their ability to turn a profit. For example, Dietrich and Wanzenried (2011) report that banks with better capitalization are likely to be more profitable. Alkhazali et al. (2024) unveil that bank capital played an important role in profitability during the COVID-19 period. According to Wanjagi et al. (2024), adequate capital levels improve the financial performance of commercial banks in Kenya. This is also demonstrated in other studies about Pakistan (Haris et al., 2020) and Ghana (Annor and Obeng, 2018).

However, as some studies note, the relationship between capital adequacy and profitability may be rather complicated. As noted by Ogunmola et al. (2022), adhering to Basel III regulations has indeed enhanced the efficiency of bank operations, but having too much capital can, in fact, be detrimental to profitability. Likewise, Poudel (2012) and Lotto (2018) have found that increased levels of CAR positively impact a bank's solvency; however, as CAR continued to increase, it ultimately decreased profitability. This helps explain why empirical studies often report mixed findings on capital adequacy and profitability, especially in banking systems undergoing regulatory transition.

2.4 Control Variables and Bank Profitability

In addition to the core drivers of bank profitability, other control variables that affect bank profitability include bank credit risk (non-performing loans ratio – NPLR), bank size (BS), bank equity ratio (ER), as well as external forces such as economic growth (GDP growth rate – GGR) and inflation (INF).

Bank credit risk has an inversely proportional association with bank profitability due to the direct proportionality of NPLs with provisioning costs and inversely proportional with income (Akther et al., 2023). Analogous evidence of adverse impacts of bank credit risk on bank profitability has been reported for Bangladesh (Uddin, 2022), India (Sing,

2016), Kenya (Kajirwa and Katherine, 2019), Turkey (Ekinci and Poyraz, 2019), Nepal (Bhattarai, 2016), and Sub-Saharan African banks (Flamini et al., 2009). On the other hand, the implication of bank size on bank profitability is controversial. Although the impact of bank size through the mechanism of economies of scale positively affects bank profitability, very large bank sizes can also lead to diseconomies of scale (Anbar and Alper, 2011; Zaman et al., 2011; Mirovic et al., 2024). Finally, the bank equity ratio improves bank financial stability by reducing the bank's default risk; however, excessive equity can negatively affect the bank's profit from leverage (O'Connell, 2023; Siddique et al., 2022). Here to clarify that while CAR is directly linked to risk optimization and regulatory compliance, the equity ratio, although important for stability, does not directly contribute to risk management or profitability in the same way as CAR.

Furthermore, the role of macroeconomic factors is also quite clear. Generally speaking, GGR is positively associated with bank profitability by increasing loan demand and investments. However, the relationship between bank profitability and inflation is indefinite (Ebenezer et al., 2017; Adewole et al., 2019; Sarkar and Rakshit, 2023; Doğan and Yildiz, 2023). For example, moderate inflation can enhance banks' net interest margins and returns, but high inflation will negatively affect the quality of banks' assets and increase operating costs (Ongore and Kusa 2013).

2.5 Research Gap and Contribution

The empirical studies conducted in both advanced and emerging countries provide evidence that the prerequisites of bank profitability and financial sustainability are efficient cost management, digitalization, and adequate risk management. Despite extensive research on bank profitability, existing studies often examine individual determinants in isolation. Therefore, limited attention has been given to the combined effects of operational efficiency, technology adoption, and risk optimization, particularly in the domain emerging economies. In Bangladesh, where existing studies have mainly emphasized traditional bank-specific (such as size, liquidity, and credit risk) and macroeconomic variables, relatively few have assessed these three dimensions jointly in a single empirical framework. This study attempts to bridge this gap by offering a unified analysis of these essential factors with the current panel data of selected Bangladesh private commercial banks. By synthesizing several theoretical positions and using strong econometric tools, the study gives a more detailed perspective of the factors influencing the bank's profitability in the fast-changing financial world, particularly in the changes in the regulatory and digital environment brought about by the implementation of Basel III.

3. Data and Methods

This paper has employed panel data of 10 privately owned commercial banks in the period 2014-2023. Although the number of samples is small, it constitutes a substantial portion of the banking industry in Bangladesh, producing invaluable information on whether the operational efficiency (cost-to-income ratio) and technology adoption (IT expense to operating expense ratio), as well as risk optimization (CAR), affect bank profitability. The study uses financial and macroeconomic variables to capture

both internal and external influences on the performance of a bank. Variables are measured yearly for every bank and give a complete view of banking performance determinants for the study period. Therefore, our data is mainly derived from the banks' yearly financial disclosures and other publicly accessible financial statements from the banks, which has helped to ensure the authenticity and comparability of the data across the entire sample of banks.

The following table outlines the key variables used in this study, categorized into dependent, independent, and control variables:

Table 01: Variables' Description

Variable Name	Variable Type	Notation	Measure	Sources
Return on Assets	Dependent	ROA	Net Income / Total Assets	(Almaqtari et al., 2019; Dsouza et al., 2022; Akther et al., 2023)
Return on Equity	Dependent	ROE	Net income / Shareholders' Equity	(Maiti and Jana, 2017; Annor and Obeng, 2018)
Net Interest Margin	Dependent	NIM	Net Interest Income / Average Earning Assets	(Mondol and Wadud, 2022; Gupta and Mahakud, 2020)
Operational Efficiency Ratio	Independent	CIR	Operating Expense/ operating income	(Islam, 2021; Al-Sharkas and Al-Sharkas, 2022; Ayinuola and Gumel, 2023)
Technology Adoption Ratio	Independent	TAR	IT Expenses/ Operating expense	(Dadoukis et al., 2021)
Capital Adequacy Ratio	Independent	CAR	(Tier 1 capital + Tier 2 Capital) / Risk Weighted Assets	(Islam et al., 2020; Million et al., 2015)
Non-Performing Loan Ratio	Control	NPLR	Non-performing Loans / Total Loans	(Uddin, 2022; Bhattarai, 2016)
Bank Size	Control	BS	Log natural (Total Assets)	(Gržeta et al., 2023; Gupta and Mahakud, 2020; Rahman et al., 2015)
Equity Ratio	Control	ER	Shareholder Equity / Total Assets	(Topak and Talu, 2017; Khatun, 2016)
GDP Growth Rate	Control	GGR	Annual percentage growth rate of Gross Domestic Product (GDP)	Akther et al., 2023; Francis, 2013)
Inflation Rate	Control	INF	Annual percentage change in the Consumer Price Index (CPI)	(Islam, 2019; Gupta and Mahakud, 2020)

Note: Authors' Compilation

The baseline specification of the model is constructed below:

$$ROA_{it} = \alpha + \beta_1 \text{CIR}_{it} + \beta_2 \text{TAR}_{it} + \beta_3 \text{CAR}_{it} + \beta_4 \text{NPLR}_{it} + \beta_5 BS_t + \beta_6 ER_t + \beta_7 GGR_{it} + \beta_8 INF_{it} + \mu_{it} \ldots\ldots\ldots (i)$$

$$ROE_{it} = \alpha + \beta_1 \text{CIR}_{it} + \beta_2 \text{TAR}_{it} + \beta_3 \text{CAR}_{it} + \beta_4 \text{NPLR}_{it} + \beta_5 BS_t + \beta_6 ER_t + \beta_7 GGR_{it} + \beta_8 INF_{it} + \mu_{it} \ldots\ldots\ldots (ii)$$

$$NIM_{it} = \alpha + \beta_1 \text{CIR}_{it} + \beta_2 \text{TAR}_{it} + \beta_3 \text{CAR}_{it} + \beta_4 \text{NPLR}_{it} + \beta_5 BS_t + \beta_6 ER_t + \beta_7 GGR_{it} + \beta_8 INF_{it} + \mu_{it} \ldots\ldots\ldots (iii)$$

Here, Here, ROA = Return on Assets of banks; ROE = Return on Equity for banks, and NIM = Net Interest Margin ratio of banks; α = Constant of the model; β = Coefficient of the explanatory variable; μ = Error term of the model.

In brief, the following empirical models have been formulated to evaluate the potential effect of these factors that contribute as a proxy for measuring operational efficiency, technology adoption, and risk optimization as follows:

$$ROA_{it} = \alpha_{it} + \sum_{k=1}^{8} \beta_{it} X_{itk} + \mu_{it} \ldots\ldots\ldots\ldots (iv)$$

$$ROA_{it} = \alpha_{it} + \sum_{k=1}^{8} \beta_{it} X_{itk} + \in_{it} + \mu_{it} \ldots\ldots (v)$$

$$ROA_{it} = \alpha_{it} + yROA_{(t-1)} + \sum_{K=1}^{8} \beta_{it} X_{itk} + \mu_{it} \ldots\ldots\ldots (vi)$$

$$ROE_{it} = \alpha_{it} + \sum_{k=1}^{8} \beta_{it} X_{itk} + \mu_{it} \ldots\ldots\ldots\ldots (vii)$$

$$ROE_{it} = \alpha_{it} + \sum_{k=1}^{8} \beta_{it} X_{itk} + \in_{it} + \mu_{it} \ldots\ldots (viii)$$

$$ROE_{it} = \alpha_{it} + yROE_{(t-1)} + \sum_{K=1}^{8} \beta_{it} X_{itk} + \mu_{it} \ldots\ldots\ldots (ix)$$

$$NIM_{it} = \alpha_{it} + \sum_{k=1}^{8} \beta_{it} X_{itk} + \mu_{it} \ldots\ldots\ldots\ldots (x)$$

$$NIM_{it} = \alpha_{it} + \sum_{k=1}^{8} \beta_{it} X_{itk} + \in_{it} + \mu_{it} \ldots\ldots (xi)$$

$$NIM_{it} = \alpha_{it} + yNIM_{(t-1)} + \sum_{K=1}^{8} \beta_{it} X_{itk} + \mu_{it} \ldots\ldots\ldots (xii)$$

According to these equations, independent variables along with control variables are already described in the details of Table 1. To estimate the profitability of banks, ROA, ROE, and NIM ratios are used as dependent variables of three baseline models as mentioned earlier in equations 1,2 and 3, respectively.

This paper uses several different panel estimation methods to establish confidence in the findings. First, a pooled OLS approach is used as an initial step to estimate the effects of operational efficiency, technology adoption, and risk optimization on banks' profitability as per equations 4, 7, and 10, which is then followed by fixed-effects (FE) and random-effects (RE) approaches to capture unobservable bank-level heterogeneity. The RE method has been applied for estimating the coefficients of equations 5, 8, and 11. The Hausman test is also employed to determine whether to use either the FE or RE estimators. Additionally, given that there is evidence of heteroscedasticity and serial correlation in the data, FGLS is used to address these issues. At last, System-GMM was employed using a one-step procedure to address potential endogeneity and profit persistence as per equations 6, 9, and 12. Various diagnostic tests were administered to assess the appropriateness of the model's underlying assumptions, such as VIF, Breusch-Pagan heteroskedasticity test, Wooldridge autocorrelation test, and Ramsey RESET test.

4 Empirical Results and Discussion

The dataset of this investigation (Table 2) reveals that profitability is somewhat consistent (as measured by ROA) yet volatile (as measured by ROE) across banks. Bank efficiency in terms of cost also varies a great deal, as indicated by the large variance in CIR. The capital adequacy of the banks is generally very good. It plays a dual role in banking, i.e., ensuring solvency and regulatory compliance, while simultaneously acting as a critical tool for risk optimization. However, there is a very large variation in their credit risks based on the high variance of the banks' non-performing loan ratios. Thus, this dataset shows a mix of differences in bank operations and similarities in the macroeconomic environment to be estimated using a panel model.

Table 02: Descriptive Statistics of Model Variables

Variable	Mean	Std. Deviation	Minimum	Maximum	Observations
ROA	0.008676	0.00377	0.0010	0.0178	100
ROE	0.109086	0.04510	0.0008	0.2067	100
NIM	0.026125	0.01353	0.0057	0.0590	100
CIR	0.511151	0.09691	0.2864	0.7164	100
TAR	0.027115	0.01492	0.0039	0.0711	100
CAR	0.136442	0.02191	0.1003	0.2042	100
NPLR	0.060955	0.04846	0.0220	0.3307	100
BS	11.93588	0.67033	11.085	13.637	100
ER	0.076744	0.01491	0.0542	0.1212	100
GGR	0.064810	0.01179	0.0340	0.0790	100
INF	0.064321	0.01363	0.0550	0.0990	100

Note: Authors' Estimations based on the output generated from STATA

The following section reports full coefficient tables (coefficients with standard errors in parentheses) for the three profitability models, namely the ROA, the ROE, and the NIM model, as depicted below:

Table 03: Estimated Coefficients of ROA model (Dependent variable = ROA)

Variables	Pooled OLS	Fixed Effects	Random Effects	FGLS	System GMM
L.ROA					0.557250*** (0.12209)
CIR	0.008821** (0.00313)	-0.013115** (0.00413)	0.003057† (0.00352)	0.008821** (0.00299)	0.006286* (0.00320)
TAR	0.083439*** (0.02321)	0.067959** (0.02493)	0.076947** (0.02436)	0.083439*** (0.02214)	0.044257* (0.01994)
CAR	0.008445 (0.01497)	-0.012368 (0.01598)	0.009114 (0.01477)	0.008445 (0.01428)	-0.02091 (0.01727)
NPLR	-0.031456*** (0.00674)	-0.010031 (0.00578)	-0.023281*** (0.00647)	-0.031456*** (0.00643)	-0.01710† (0.00889)

BS	-0.001661** (0.00058)	0.000360† (0.00121)	-0.001225 (0.00066)	-0.001661** (0.00055)	-0.000090 (0.00065)
ER	0.142012*** (0.01826)	0.131242*** (0.02150)	0.150207*** (0.01908)	0.142012*** (0.01742)	0.060284† (0.03650)
GGR	0.038116† (0.02105)	0.012757 (0.01599)	0.031664† (0.01908)	0.038116† (0.02008)	0.016708 (0.01397)
INF	0.012003 (0.01915)	-0.001711 (0.01464)	0.007375 (0.01733)	0.012003 (0.01827)	0.018320 (0.01308)
Constant	0.008353 (0.00582)	0.000747 (0.01386)	0.005767 (0.00680)	0.008353 (0.00555)	-0.002734 (0.00515)

Note: Significance level is denoted by *** p≤0.001, ** p≤0.01, * p≤0.05, and † p≤0.10. Model specifications follow the Stata output: pooled OLS, fixed effects (FE), random effects (RE), feasible GLS (FGLS), and one-step system GMM

We have regressed ROA (Table 3) against operating efficiency, technological adoption, and risk optimization variables, where the cost-to-income ratio (CIR) and information technology expense to operating expense ratio show a proxy for operating efficiency and technological adoption, respectively, and are found statistically significant with positive navigation. A higher CIR generally reflects inefficiency, and therefore, the result may capture short-term effects of increased operational spending, such as investment in expansion or technology, rather than improved efficiency. That means, banks that spend more in terms of extending their operation generate more loans, fee income, enhanced customer volume, and stronger interest margins. As a consequence, ROA or profitability of the bank will be increased with the CIR. In addition, when banks invest more in technology adoption, they usually expand mobile with online banking, resulting in more transactions with low cost, more reach to unbanked people with reduced loan processing time, and improved customer retention (Dadoukis et al., 2021; Evian et al., 2021; Nguyen et al., 2023; Ebissa and Lakew, 2025).

Among control variables, the NPLR variable has a negative impact on ROA, as would be expected by Credit Risk Theory, also espoused by Bhattarai (2016), Topak and Talu (2017), Annor and Obeng (2018), and Gupta and Mahakud (2020). The equity ratio variable has a positive effect on ROA and therefore reflects the role of financial buffers in maintaining stability (Menicucci and Paolucci, 2016; Kawshala and Panditharathna, 2017). The macroeconomic variables exert a negligible and/or insignificant impact on the profitability of bank assets, indicating that it is bank-specific characteristics or decisions that are driving the differences in ROA among banks. These findings are also supported by Anbar and Alper (2011), Mondol and Wadud (2022), and Akther et al. (2023).

Table 04: Estimated Coefficients of ROE model (Dependent variable = ROE)

Variables	Pooled OLS	Fixed Effects	Random Effects	FGLS	System GMM
L.ROE					0.473813***
					(0.12268)
CIR	0.122759**	-0.216904***	0.044171	0.122759**	0.026527
	(0.04533)	(0.05907)	(0.050379)	(0.04324)	(0.05012)
TAR	0.866028*	0.593324†	0.780703*	0.866028**	0.992421***
	(0.33555)	(0.35629)	(0.351665)	(0.32010)	(0.29526)
CAR	0.012555	-0.28023	0.022279	0.012555	-0.03553
	(0.21649)	(0.22847)	(0.214412)	(0.20652)	(0.25449)
NPLR	-0.496577***	-0.19012*	-0.393773***	-0.496577***	-0.19913†
	(0.09746)	(0.08262)	(0.094363)	(0.09297)	(0.12088)
BS	-0.02243**	0.008222	-0.016633†	-0.02243**	-0.00307
	(0.00841)	(0.01733)	(0.009467)	(0.00802)	(0.01024)
ER	0.810057**	0.767453*	0.962336***	0.810057***	0.765617†
	(0.26402)	(0.30735)	(0.275218)	(0.25186)	(0.39885)
GGR	0.318611	-0.060350	0.235114	0.318611	0.172701
	(0.30431)	(0.22857)	(0.279686)	(0.29030)	(0.21485)
INF	0.264410	0.082760	0.212154	0.264410	0.183104
	(0.27688)	(0.20922)	(0.254077)	(0.26412)	(0.20474)
Constant	0.219373*	0.095249	0.182104†	0.219373**	-0.01269
	(0.08423)	(0.19806)	(0.096527)	(0.08035)	(0.08819)

Note: Significance level is denoted by *** p≤0.001, ** p≤0.01, * p≤0.05, and † p≤0.10. Model specifications follow the Stata output: pooled OLS, fixed effects (FE), random effects (RE), feasible GLS (FGLS), and one-step system GMM

The results depicted in Table 4 show that CIR has a significant negative impact on ROE. Therefore, it supports the efficiency theory in which controlling costs is the most important factor in generating shareholder value, also supported by Mehta and Bhavani (2017), Topak and Talu (2017), Al-Sharkas and Al-Sharkas (2022), and Antwi (2019). The results of TAR demonstrate a strong positive relationship with all panel models and therefore support the hypothesis that digital integration strengthens profitability in terms of equity (Tran, 2025). The NPLR is found to have a negative relationship with ROE and therefore supports the risk and return trade-off model in which increased credit risk leads to reduced profits (Topak and Talu, 2017; Annor and Obeng, 2018; Ekinci and Poyraz, 2019; Al-Sharkas and Al-Sharkas, 2022). The results also show that the equity ratio consistently increases ROE and thus highlights financial solidity as a major driver of profitability (Menicucci and Paolucci, 2016). In addition, macroeconomic variables were generally found to be insignificant. These are also evidenced by Anbar and Alper (2011) and Islam and Nishiyama (2016).

Table 05: Estimated Coefficients of NIM model (Dependent variable = NIM)

Variables	Pooled OLS	Fixed Effects	Random Effects	FGLS	System GMM
L.NIM					0.751175*** (0.08908)
CIR	0.068875*** (0.01246)	-0.055431*** (0.01245)	-0.00685 (0.01435)	0.068875*** (0.01189)	0.014188 (0.01192)
TAR	0.201456* (0.09229)	0.199832** (0.07510)	0.255014** (0.09106)	0.201456* (0.08804)	0.167304* (0.07711)
CAR	0.000037 (0.05954)	0.022941 (0.04816)	-0.02290 (0.05464)	0.000037 (0.05680)	-0.01493 (0.04260)
NPLR	-0.07289** (0.02680)	-0.00020 (0.01741)	-0.02746 (0.02231)	-0.07289** (0.02557)	-0.01646 (0.02137)
BS	-0.00067 (0.00231)	-0.013635*** (0.00365)	-0.00178 (0.00307)	-0.00067 (0.00220)	-0.00147 (0.00181)
ER	0.303980*** (0.07261)	-0.00114 (0.06479)	0.208683** (0.07390)	0.303980*** (0.06927)	0.091143 (0.07847)
GGR	0.306839*** (0.08369)	0.175999*** (0.04818)	0.235341*** (0.06295)	0.306839*** (0.07984)	0.343168*** (0.04557)
INF	-0.06007 (0.07615)	-0.05073 (0.04410)	-0.07752 (0.05704)	-0.06007 (0.07264)	0.059709 (0.04555)
Constant	-0.04142† (0.02316)	0.200616*** (0.04175)	0.022583 (0.03331)	-0.04142† (0.02210)	-0.01846 (0.01774)

Note: Significance level is denoted by *** p≤0.001, ** p≤0.01, * p≤0.05, and † p≤0.10. Model specifications follow the Stata output: pooled OLS, fixed effects (FE), random effects (RE), feasible GLS (FGLS), and one-step system GMM

In Table 5, operating inefficiencies are shown to substantially reduce net interest margins for banks in fixed effects estimations supported by Mehta and Bhavani (2017) and Rahman et al. (2015). Technology is shown to have a positive impact on NIM as it increases pricing efficiencies and decreases costs, also espoused by Nguyen et al. (2023). The results show that credit risk has a negative effect on the margins of banks (Wani et al., 2018; Hossain and Ahamed, 2015) in both pooled and Generalized Least Squares (GLS) estimations. Results further show that a strong GDP growth rate positively affects NIM, due to an increase in lending opportunities available as economies grow. These results are also evidenced by Wani et al. (2018) and Gunter et al. (2013).

Overall, Technology and operating efficiency are identified as the primary determinants of bank profitability. Additionally, while credit risk has been shown to be a major constraint on the earnings resilience of banks, the evidence shows that risk mitigation through higher levels of equity (capital) can improve ROA and ROE levels; however, this does not appear to play a significant role in determining net interest margins. Therefore, policymakers may wish to place an emphasis on digital transformation, cost rationalization and credit risk management.

The results of the empirical analysis across the specifications are consistent: technology adoption (TAR) is positively and significantly related to profitability in nearly every model specification; operating efficiency (CIR) enhances profitability after controlling for unobserved bank-specific effects, and credit risk (NPLR) is negatively and significantly associated with profitability in every pooled and GLS model and in many panel models.

The model selection tests support the fixed-effect specification for both ROA and ROE. The Hausman tests reject the null hypothesis that there are no systematic differences between RE and FE estimates ($p < .001$) for both ROA ($\chi^2 = 63.85$, $p < .001$) and ROE ($\chi^2 = 109.67$, $p < .001$), indicating that bank-specific time-invariant factors are correlated with some of the explanatory variables and should be removed from the regression equation through the use of fixed effects. Similarly, the Hausman test supports the fixed-effects specification for NIM ($\chi^2 = 22.26$, $p = .005$) over the random-effects specification.

Table 06: Diagnostic and Specification Tests

Test	ROA model	ROE model	NIM model	Conclusion
Mean VIF	1.68	1.68	1.68	No multicollinearity
RESET (p-value)	0.0165	0.0695	0.0157	Misspecification in ROA & NIM model
Heteroskedasticity BP (p)	0.8484	0.8174	0.0471	Heteroskedasticity in NIM
Autocorrelation Wooldridge (p)	0.0025	0.1152	0.0001	Serial correlation in ROA & NIM
Hausman χ^2	63.85***	109.67***	22.26**	Fixed effects preferred

Note: ***, ** denote statistical significance at the 1% and 5% levels respectively. VIF values below 10 indicate the absence of multicollinearity. The Breusch–Pagan test examines heteroskedasticity; the Wooldridge test detects first-order autocorrelation in panel data. Ramsey RESET test assesses functional form misspecification. The Hausman test evaluates consistency between FE and RE estimators, where significant results favor FE.

According to Table 6, diagnostic tests suggest that the reliability of the inferences obtained from simple pooled OLS is likely compromised. Both the Wooldridge test for autocorrelation and the modified Wald test for heteroscedasticity (where applicable) reject the null hypotheses that the residuals are free of autocorrelation and homoscedasticity, respectively, for ROA and NIM (Wooldridge test: ROA p-value = 0.0025; NIM p-value = 0.0001; modified Wald test for group-wise heteroscedasticity: ROA p-value < 0.001; ROE p-value = 0.0045; NIM p-value < 0.001). As such, these diagnostic tests motivate the use of heteroscedasticity and autocorrelation-robust standard error estimators (such as cluster-robust SEs at the bank-level or Driscoll-Kraay SEs when applicable).

An additional robustness check is performed through System GMM to control for the possibility of endogeneity between profitability and internal bank decisions (efficiency, technology spending, and risk management) as well as to account for the possibility of profit persistence. All three GMM models show

strong evidence of profit persistence as the lagged dependent variable is positive and statistically significant. The Arellano-Bond tests for second-order serial correlation (i.e., the AR (2)) were not rejected (ROA p = 0.183; ROE p = 0.492; NIM p = 0.360), providing further support that the moment conditions were valid. Additionally, the Sargan tests did not reject the validity of the instruments (ROA p = 0.588; ROE p = 0.789; NIM p = 0.164). However, a caution exists in that the number of instruments (45) is higher than the number of banks (10), which can weaken the power of the over-identification tests and potentially lead to overfitting the endogenous variables. Therefore, one common strategy to refine this is to collapse the instruments and/or limit the lag depth so that the total number of instruments is reduced while still maintaining the same results.

5. Conclusion with Policy Implications

This study examines the impact of operational efficiency, technological adoption, and risk optimization on the profitability of commercial banks in Bangladesh, presenting strong empirical evidence of the effects of internal and external factors on bank performance during a ten-year time frame. The findings reveal that operational efficiency plays a significant role in enhancing profitability, while technology adoption is identified as the main factor that affects bank profitability through its positive relationship to ROA, ROE, and NIM in all model specifications used in this study. Hence, investment in technology must be regarded as one of the primary ways to enhance the quality of services and the bank's competitiveness. Whereas, capital adequacy while important for the viability of a bank and for satisfying regulatory requirements, does not directly influence profitability but serves as a means for the management of financial risk and for the optimal use of risk exposure. Again, the equity ratio as a control variable supports both ROA and ROE because it acts as a buffer against shocks, but has little impact on NIM. Thus, while managing capital is vital for financial stability, it is operational efficiency, not capitalization, that drives profitability. Also, credit risk is critical to bank profitability and, hence, to shareholder wealth creation as it reduces profit margins directly.

The findings of the study offer notable insights for stakeholders. Financial regulators need to encourage and support digital transformation within the banking industry through partnerships with fintech companies, a digital infrastructure upgrade, and a stronger cybersecurity framework. Banking models that utilize technology can enhance efficiency while expanding financial inclusion. Bank managers need to focus on restructuring the operations of their institutions via process automation, cost rationalization, and governance systems based on performance metrics that pursue aggressive digital transformation strategies to increase efficiencies in their operations through increasing competitiveness. Moreover, strengthening credit risk management frameworks is critical to achieving sustainable profitability. In addition, capital regulations should be designed to maintain optimal levels of capital buffers that strike a balance between financial stability and earnings potential as opposed to promoting overly conservative capitalization strategies that may limit the ability of banks to pursue intermediary functions.

Though the findings in this paper provide important insight, the study faces limitations, notably in the sample size, as it is based on data from 10 banks. Future studies may address the limitation of sample size through the extension of the dataset with attention to the diversity of institutions in Bangladesh's financial industry and inclusion of additional macro and bank-specific variables, which may affect profitability. Future studies can also examine which specific areas of fintech investment, such as mobile banking or the use of AI in loan processing, have a greater impact on the profitability of banks in developing countries such as Bangladesh. Overall, this research indicates that balancing the use of technology, operational efficiency, and sound risk management is highly required to help increase profitability in the Bangladesh banking industry. Since the industry is constantly evolving, aligning these factors with the market needs and regulations will be the defining factor in ensuring profitability and financial stability.

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