International Journal of Business and Technopreneurship
Volume 15, No 2, June 2025 [115-134]

Bidirectional Relationship Between Risk and Efficiency of Commercial Banks of Bangladesh

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Received 09th October 2024, Revised 12th April 2025, Accepted 09th May 2025

ABSTRACT

This study undertakes a comprehensive analysis of the bidirectional relationship between risk and efficiency in Bangladeshi commercial banks, addressing a significant gap in existing research. It explores how risk-taking behaviour impacts bank efficiency and, conversely, how efficiency affects risk levels. The study also investigates the effect of market competition and diversification in this relationship nexus. Asset and revenue diversification are considered to ensure a comprehensive analysis, and the Boone Indicator (BI) is used to measure market competition. We employ System Generalised Method of Moments (GMM) estimation on an extensive dataset of 818 bank-level observations from 2000 to 2022 for empirical validation. The findings reveal several significant insights. First, banks with higher credit risk exhibit greater efficiency; however, excessive risk-taking leads to decreased efficiency over time. Second, asset diversification positively influences the risk-efficiency relationship, whereas revenue diversification has a detrimental effect on risk and efficiency. Third, the non-linear impact of competition suggests that its effect varies depending on the level of risk and efficiency, revealing a heterogeneous relationship. Furthermore, the combined effect of competition and diversification significantly alters risk and efficiency dynamics. These findings have significant practical implications for risk management, regulatory policies, and strategic decision-making in Bangladesh's banking sector. Understanding the tradeoffs between risk and efficiency can empower policymakers and bank managers to design more effective regulations and strategies. This, in turn, can enhance banking stability, performance, and financial resilience.

Keywords: Bangladesh, Bank Diversification, Competition, Efficiency, Risk

1. INTRODUCTION

The economic development of a nation significantly relies on the effective operation of its financial system. Like other developing countries, Bangladesh's monetary system is also primarily bank-based. However, an increasing number of default loans and the rescheduling culture of classified loans draw researchers' attention to investigate the impact of risk on other aspects, like capital regulations and the efficiency of banks (Gupta & Yesmin, 2022). There is a debate on whether superior efficiency positively influences risk-taking or deteriorates the risk position. Therefore, it is worth considering the bidirectional relationship between risk and efficiency to pinpoint how efficiency affects risk and vice versa.

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Portfolio theories postulate the diversification of investment to manage risk (De Jong, 2018). However, banks are dealing with liquid cash. Increasing the weight of cash holding may hinder growth and profitability (Changjun, 2023). That may lead banks to increase investment and mobilisation of deposits. As banks deal with liquid cash, mobilising deposits to non-traditional sectors may hinder the organisation's objective. Therefore, although portfolio investment reduces the investment risk, as a bank financial organisation deals with public deposits, it is more sensitive than any other organisation's investment. Regulators and other stakeholders constantly monitor banks' investments and other activities. Thus, it is high time to survey whether diversification to manage risk enhances bank performance or deteriorates. Including a good number of banks every decade incorporates more generations of banks in the industry. That intensifies the market competition, which may also significantly influence banks' risk-taking and efficiency.

Therefore, a few specific research questions need to be addressed. These are: (a) How risk affects the efficiency of banks and vice versa? (b) How does the diversification of assets and revenue intermediate bank risk and efficiency? and (c) Does market competition stimulate risk-taking and enhance efficiency, or deteriorate? The study aims to investigate the concurrent association between risk and performance in the form of the efficiency of commercial banks in Bangladesh. Changjun et al. (2023), Changjun et al. (2018a), and Gupta and Yesmin (2022) addresses the effect of competition on risk and efficiency, and diversification on efficiency or risk. However, the influence of competition and diversification in the concurrent examination of risk and efficiency is scarce. This study tends to impart insights into the existing literature in multiple forms to fill this gap. Primarily, the study addresses the impact of cost and profit efficiency on risk-taking and vice versa, which is rarely discussed in the existing literature. The dynamic panel model of risk and efficiency investigates the impact of diversification in both forms of assets and revenue, covering the complete picture of banks' diversification over risk and efficiency. Moreover, the two-step GMM also delves into the impact of competition and the performance of banks. Finally, the non-linear impact of market competition, joint effect diversification and competition gives us the complete picture of diversification and competition on bank risk and efficiency performance.

2. LITERATURE REVIEW

This chapter focuses on four comprehensive areas of literature to address the literature survey relating to the subject study. These are the literature about the determinants of risk and efficiency, the empirical literature on risk, efficiency, competition, and diversification, and theoretical discussions related to these topics.

2.1 Determinants of Risk

Diversified literature addresses cause and effect with risk and other determinants. A good amount of literature pinpoints different regressors that identify banks' risk. Anwar et al. (2024) preach efficiency as a critical risk factor, which again depends on banks' cost and revenue status. Chowdhury et al. (2024) pinpoint capital as a risk-mitigating determinant of commercial banks. Thus, adequate capital is treated as the most risk-extenuating tool. Literature and research outcomes also support the regulators' implementation of capital directives to control commercial banks' risk-taking (Zheng et al., 2024). Previous literature also supports banks' inverse association of risk and capital (Moudud-Ul-Huq et al., 2022; Shabir et al., 2023; Srivastava et al., 2023). Ahamed (2021) advocates liquidity, profitability, and capital as essential determinants of risk. However, competition and ownership also intermediate the association of risk and other determinants (Chowdhury et al., 2024). Besides other determinants, macroeconomic variables are equally significant as risk determinants (Zheng et al., 2024). Supporting the findings, Raiter (2021) also provides evidence of the association between macroeconomic variables and bank risk. The author opines those macroeconomic factors, including interest rate, inflation, and unemployment, positively impact banks' risk, while Gross Domestic Product (GDP), efficiency, and size inversely affect banks' risk. Therefore, it is apparent from the literature survey that in

risk determination, bank-level variables such as size, capital, efficiency, ownership, etc.; macroeconomic variables like GDP, inflation, etc.; and industry-level variables like competition, banking sector development, etc. are worth considering (Changjun, 2023).

2.2 Determinants of Efficiency

A bank's performance evaluation is worth considering when trading off with risk and other determinants. Efficiency is key to banks' performance (Changjun et al., 2018a). Generally, efficiency refers to the optimal tradeoff of outputs-inputs. Different efficiencies are observed in the literature when determining bank efficiency. Most used is technical efficiency Farrell (1957), cost efficiency (Kasman & Yildirim, 2006; Tan, 2016), revenue efficiency (English et al., 1993; Isik & Hassan, 2002), and profit efficiency (Tan, 2016).

Diversified determinants are pinpointed in the literature on efficiency. Miah and Sharmeen (2015) identify market competition as a significant determinant of efficiency. Tecles and Tabak (2010) trace the association between ownership and efficiency. They divulge that the size of banks intermediates the efficiencies. On the contrary, public banks can improve their cost efficiency but cannot manage their profit efficiency. The study indicates the impact of ownership on the banks' efficiency. According to Manlagnit (2015), efficiency does not depend on the authoritative supervisory action; it is closely related to the capital requirement. Chortareas, Girardone and Ventouri (2012) opine that authoritative guidance can improve the efficiency of banks rather than the self-interest managerial decision. Size is addressed as an impactful determinant of efficiency in literature as well (Mester, 1996; Nguyen & Nghiem, 2015).

Debates from different corners also add multiple determinants. Profitability as the efficiency measurement tool has an inverse relationship with bad loans. The empirical investigation of Kolapo et al. (2012) divulges that banks with high credit risk perform more efficiently than those with low credit risk counterparts. Reboredo (2004) points out a close connection between solvency and efficiency. In this study, the author tries to postulate that solvency is ensured by proper risk-return tradeoff that provides a bank's efficiency but does not lead to the ultimate destination in the future. Again, Barra et al. (2016) state that strict regulations sometimes hinder efficient banking performance. The effect of ownership in efficiency measurement is not out of the debate. Dong et al. (2016) preach ownership as an essential consideration for efficiency. Overseas banks dominate the local banks in cost efficiency, whereas domestic banks dominate their foreign counterparts in profit efficiency. Again, Majeed and Zanib (2016) pinpoint the conventional and Islamic banking systems as efficient deviators. Again, Maji and De (2015) trace the performance deviation between public and private banks. The authors evidence the superior efficiency performance of private banks than public banks. Unlike other literature, Battaglia et al. (2010) advocate ecological factors as cost and profit efficiency stimuli. They argue that a favourable environment can increase cost and profit efficiency. Girardone et al. (2004) state that banks' efficiency closely depends on a bank's capital structure and regulations. Ariff and Can (2008) also studied the factors of size, ownership structure, risk, profitability, and environment as dependent variables for banks' efficiency.

Therefore, the dominant efficiency determinants are market competition, capital requirement, ownership structure, legal condition, bank size, profitability, regulations, interest, and exchange rate movement.

2.3 Risk, Efficiency, Competition and Diversification

There is a general phenomenon that risk and efficiency are closely related, and efficient banks are in a better risk position than inefficient banks (Changjun et al., 2017). However, different authors differ on the risk-efficiency nexus. Literature such as David and Ernest (2017), Fiordelisi et al. (2011), Delis et al. (2017), Allen et al. (1997), Deelchand and Padgett (2009), Simon and Robert

(1997), and Nguyen and Nghiem (2015) among others opines that high risk-taking banks are less able to manage their efficiency substantially. On the contrary, Isshaq et al. (2012), Chan et al. (2014), Tan and Floros (2013), Niţoi and Spulbar (2015), Miah and Sharmeen (2015), amongst others, evidence positive association.

Human capital is also worth considering, and human resources efficiency plays a vital role in increasing human capital, influencing bank diversification and performance (Suryaning et al., 2023; Changjun et al., 2018a).

Siddique et al. (2022) found that nonperforming loans, cost efficiency, and liquidity position inversely affect banks' profitability, while capital adequacy and lending rate are negatively associated with banks' performance. Wu et al. (2020) opine that the benefit of greater diversification to bank stability is countered by the indirect benefit of higher diversification's resultant lowered efficiency, which makes banks riskier. Thus, the tradeoff between the two opposing pressures determines the overall effects of bank business diversification on bank stability. Abbas and Ali (2021) showed that the banks' risks are reduced (increased) by funding and asset (revenue) diversity. The authors preach that asset diversification positively affects banks' stability, whereas income diversification has a significantly adverse effect. Moudud-Ul-Huq et al. (2020) pinpoint that nonperforming loans are one of the most critical factors in banks' instability. Their study further highlights that emerging economies can leverage portfolio diversification as an effective risk management strategy to improve bank performance during financial crises. The authors emphasise the role of size in maximising the benefits of income diversification while advising caution regarding systematic risks. Adesina (2021) argues that human capital efficiency enhances banks' performance; however, increased diversification lowers it.

Dutta and Saha (2021) contend that competition and stability are inversely related, with efficiency as a mediating factor in this dynamic. Berger et al. (2004) show there is less risk of bank failure and more excellent financial stability when there is limited competition and high concentration. Rakshit and Bardhan (2022) pinpoint that bank profitability is hampered by the rising prevalence of credit risk for all banks, regardless of ownership. On the other hand, they also found that bank performance positively correlates with increased profit and cost-effectiveness. Sahul and Ibrahim (2020) and Adesina (2021) evidenced the association of efficiency and diversification. Adesina (2021) points out the positive effect of human capital efficiency in offsetting the inverse impact of diversification. Alhassan (2015) suggests that banks with greater income diversification are less vulnerable in emerging markets. Wang and Lin (2021) pinpoint that, in general phenomena, highly income-diversified banks are less risky. However, Wu et al. (2020) highlight a dual effect of diversification on commercial banks, revealing that while increased diversification reduces risk-taking, it also leads to a decline in efficiency.

2.4 Hypotheses and Theories Related to Risk, Efficiency, Diversification, and Competition

A competitive market environment leads banks to perform efficiently. However, banks' efficiency significantly impacts commercial banks' risk-taking in Bangladesh. Therefore, the association between efficiency and risk-taking has emerged as one of modern banking's critical issues. Studies uncover the area is mainly in developed economies and, lately, in emerging economies. Changjun et al. (2017) and Changjun et al. (2018b) conclude that risk and efficiency are contradicting issues to point out the bidirectional relationship. The literature presents several hypotheses regarding the connection between risk and efficiency. To formalise the relationship between risk and efficiency, Allen and Robert (1997) introduce four management hypotheses: bad management (Fiordelisi et al., 2011), moral hazard, bad luck, and skimping hypothesis (Allen & Robert, 1997). Fiordelisi et al. (2011) make bank risk a low-cost and revenue efficiency factor, evidencing the bad management hypotheses. Changjun et al. (2017) examined three emerging Asian economies and found that the bad management hypothesis holds. Simon and Robert

(1997), Tara and Carol (2009), and Zhang et al. (2016) cited the moral hazard hypotheses in the inverse association between risk and efficiency. By examining 66 banks from Middle Eastern countries, Colesnic et al. (2019) support the bad luck hypothesis.

Theories point out different types of diversification. Dhir and Dhir (2015) identified four primary types: horizontal, vertical, concentric, and conglomerate diversification (Ansoff, 1965; Dhir & Dhir, 2015). Firms operate in a similar pecuniary environment and are sensitive to business cycles and market competition in horizontal diversification (Dhir & Dhir, 2015; Laurila & Ropponen, 2003). Stimulating from the regulatory to market changes hierarchies paradigm proposes vertical diversification (Williamson, 1975). This diversification uses market power and financial intermediation costs to retrieve benefits. Significant factors of concentric diversification are network, resources of firms, systems, and processes, along with exterior influences like industry attributes, regulatory impact, etc. Finally, conglomerate diversification is primarily driven by antitrust legislation, efficiency, globalisation, and asymmetric information.

The impact of diversification on bank risk and efficiency has long been a topic of significant academic discussion. Following the global financial crisis, interest in exploring the effects of diversification on bank risk has grown, encompassing both developed and developing economies. There is a doctrine that diversification brings stability to banks by reducing risk (Gupta & Yesmin, 2022). However, studies in different countries make responsible diversification for creating systematic risk. Zhou and Li (2019) stress diversification as a double-sided sword in financial system risk management. Competition-efficiency and competition-inefficiency are two dominant hypotheses revealing the association between market competition and efficiency. Using the proposed structure of Demsetz (1973), Schaeck and Čihák (2008) explained the competition-efficiency hypotheses. They opine that banks are bound to control their service cost to cope with external market shocks like competition. It refers to competition in the market confirming the efficiency, whereas reverse causality happens in the case of the competition inefficiency hypotheses.

The literature also supports the connection between market competition and risk. The literature of Gupta and Istiaque (2023), Leroy and Lucotte (2017), Gupta and Yesmin (2022), and Hellmann et al. (2000), among others, are worth mentioning. Therefore, the relevant hypotheses of the study are given as:

- H_1: Risk significantly impacts bank efficiency.
- H_2: Efficiencies (cost and profit) significantly impact banks' risk-taking.
- H_3: Bank diversification negatively affects the risk and efficiency of banks.
- H_4: Market competition significantly impacts the risk-taking and efficiency of banks.
- H_5: The joint effect of competition and diversification significantly influences the risk-efficiency nexus.

3. METHODOLOGY

3.1 Scope and Sources of Data

Currently, 61 scheduled banks are opting to do business in the industry (Annual Report Bangladesh Bank, 2022-2023). We have selected 44 scheduled banks after adjusting missing data, outlier effect, and non-availability of data. To maintain the consistency of data, banks with at least five consecutive years of data were incorporated in the data file for study. This selection process resulted in an unbalanced panel dataset comprising 818 bank-years, covering 44 commercial banks from 2000 to 2022.

Bank-level data were sourced from the respective banks' audited annual reports, while macroeconomic data were obtained from the World Bank dataset. Industry-level market

competition was measured using aggregated market information and annual reports from the Bangladesh Bank, with additional industry-level data sourced from the World Bank dataset.

3.2 Definition of Variables Used in the Study

Building on the research of Kasman and Carvallo (2014), Gupta and Yesmin (2022), as well as Gupta and Moudud-Ul-Huq (2020), we evaluate bank efficiency through the application of Stochastic Frontier Analysis (SFA). Adopting the intermediation approach proposed by Sealey and Lindley (1977), we employ the translog cost function as outlined in studies by Tara and Carol (2009), Moudud-Ul-Huq (2020), and Zheng et al. (2017a).

$$\text{Ln TC} = \alpha + \sum_i \alpha_i \, lnQ_i + \sum_j \beta_j \, lnP_j + \tfrac{1}{2} \sum_i \sum_k \gamma_{ik} \, lnQ_i lnQ_k + \tfrac{1}{2} \sum_j \sum_h \delta_{jh} \, lnP_j lnP_h + \sum_i \sum_j \lambda_{ij} \, lnQ_i lnP_j + \varepsilon \quad (1)$$

Table 1 Description of Variables in Empirical Investigations

Variables	Acronym	Definition	References/Sources
Dependent Variables			
Risk – Credit risk	NPLTL	Non-performing loans to total loans	Changjun et al. (2023)
Efficiency-Cost	EFF_cost	Efficiency of cost measured through SFA	Gupta and Yesmin (2022)
Efficiency-Profit	EFF_profit	Efficiency of cost measured through SFA	Gupta (2018)
Independent Variables			
Size	Size	Logarithm of total assets	Bougatef and Mgadmi (2016)
Capital	Capital	Total eligible capital to Total assets	Gupta and Akter (2020)
Asset Diversification	AD	Non-interest-bearing assets to total assets	Edirisuriya et al. (2015)
Revenue diversification	RD	Non-interest revenue to total revenue	Chaibi and Ftiti (2015)
Net interest margin to total assets	NIMTA	Net interest margin to total assets	Das Gupta et al. (2021)
Macroeconomic Variables			
Growth of gross domestic product	GGDP	The growth of real gross domestic product.	Gupta and Istiaque (2023) Source: World Bank data
Inflation	Inflation	Inflation, GDP deflator (annual %)	Changjun et al. (2023) Source: World Bank data
Industry Level Variables			
Competition	BI	Boone Indicator:	Gupta and Moudud-Ul-Huq (2020). Measured by Authors
	LI	Lerner Index (inverse competition measure-Market power) Lerner Index LI_{it} = (Price of $output_{it}$ – Marginal $cost_{it}$)/Price of $output_{it}$	Gupta et al. (2021).
	5-Bank asset concentration	Large 5 banks assets to industry assets.	Kasman and Kasman (2015) Source: World Bank data
Banking Sector Development	BSD	Financial system deposit to GDP	Chowdhury et al. (2024). Source: World Bank data

Source: Authors' compilation using the sources of data/literature references mentioned in the fourth column of the table

Profit efficiency is also measured using SFA by altering the error term to $V_n – U_n$ and using the equation as a production function, following the detailed estimation of Coelli (1996). The dependent variable of cost efficiency is the total cost, and profit efficiency is pre-tax profit. Inputs used in measuring efficiency are labour cost, cost of physical capital, and cost of funds, whereas

outputs are loans-advances and other earning assets. Risk competition and other measures of variables are given in Table 1.

3.3 Empirical Method

We utilise the System GMM to examine the risk efficiency linked to the effects of diversification and competition. After data filtering, we have 818 bank-level data of 44 banks from 2000 to 2022. To incorporate maximum data size and degrees of freedom, we structure unbalanced panel data to delve into the study. Following Blundell and Bond (2000), Arellano and Bover (1995), and Gupta and Istiaque (2023), we also applied System GMM for our dynamic panel data. We have used diagnostic tests to select the appropriate study method, such as rank and order condition determination, endogeneity, heteroscedasticity, autocorrelation, etc.

The model of the study can be given as:

$$Y_{i,t} = \beta_1 + \beta_2 Y_{i,t-1} + \sum_{r=3}^{4} \beta_r \, X_{i,r,t} + \sum_{p=5}^{6} \beta_p \, X_{i,p,t} + \sum_{q=7,10}^{9,11} \beta_q \, X_{i,q,t} + \varepsilon_{i,t} \quad (2)$$

'$Y_{i,t}$' represents the dependent variable Risk and efficiency. '$Y_{i,t-1}$ indicates the one-year lag-dependent variable. β_1 refers to the intercept of the equation, β_{2-n} denotes the coefficients of variables. Cross section dimension of different banks, denoted by subscripts' i' and 't' refers to time dimensions, whereas r,p, and q denotes macro-economic, industry-level, and bank-level control variables. Macroeconomic variables are inflation and Growth of Gross Domestic Product (GGDP), Banking Sector Development (BSD) and Market competition are industry-level variables. Bank-level variables for the equation are Asset Diversification (AD), Revenue Diversification (RD), and size. In addition to these, capital and Net Interest Margin to Total Assets (NIMTA) are also used as bank-level variables in the risk equation.

Ordinary least squares (OLS) estimation is unsuitable for dynamic panels because it may result in biased estimations. Diagnosis for method selection restricts the use of OLS due to autocorrelation and heteroscedasticity. Hausman specification test also suggests a fixed-effect model. System GMM opts for discrepancies and bias estimations to address the diagnosis issue. (Arellano & Bover, 1995; Blundell & Bond, 2000). Test results of AR(1) and AR(2) are similar to those of Nguyen and Nghiem (2020) and Changjun et al. (2018b), among others, rejecting the null hypotheses of no serial correlation. Applied models depict AR (2) in residuals as statistically insignificant, which is necessary for removing the time-dependent inconsistencies (Gupta & Yesmin, 2022). The study also addresses the non-linear effect of market competition and the joint impact of competition and diversification. The extended models are as follows:

$$Y_{i,t} = \beta_1 + \beta_2 Y_{i,t-1} + \beta_3 BSD_{i,t} + \beta_4 BI_{i,t} + \beta_5 BI_{i,t}^2 + \beta_6 BI^2 Diversification_{i,t} + \sum_{r=7}^{8} \beta_r \, X_{i,r,t} + \sum_{p=9,12}^{11,13} \beta_p \, X_{i,p,t} + \varepsilon_{i,t} \quad (3)$$

The risk equation consists of two models. One risk equation has cost efficiency as an independent variable, and another has profit efficiency as an independent variable.

4. FINDINGS

This section elaborates on the study's empirical findings. At first, descriptive statistics, multicollinearity, and unit root tests are performed to show the model and data appropriateness. Subsequently, we present the findings of the GMM estimators.

4.1 Descriptive Statistics and Multicollinearity Tests

The descriptive statistics for the variables included in the study are shown in Table 2. The mean risk ratio of 0.0826 refers to 8.26% of total loans and advances becoming default. The average cost and profit efficiency values are 1.3107 and 0.4781, respectively. The minimum value of profit efficiency is 0.00, meaning zero-profit banks exist in the industry. Assets and Revenue diversifications' average value is 0.3432 and 0.5105, respectively. It depicts that 34.32 % of assets and 51.05 % of average revenues are derived from non-interest-bearing assets and non-interest revenue incomes, respectively.

Table 2 Descriptive Statistics of the Variables

Variable	Observations	Mean	SD	Min	Max
Risk (NPLTL)	818	0.0826	0.1029	0.0000	0.5980
Cost efficiency	818	1.3107	0.1637	1.0109	2.0662
Profit efficiency	818	0.4781	0.2174	0.0000	0.7693
AD	818	0.3432	0.1169	0.0020	0.9956
RD	818	0.5105	0.2121	0.0000	0.9937
NIMTA	818	0.0201	0.0113	-0.0248	0.0770
Capital	818	0.0893	0.0739	-0.1533	0.8090
BI	818	-3.0396	2.6130	-8.6020	-0.0305
BSD	818	45.5904	4.9436	25.6644	51.1101
GGDP	818	6.1754	1.0965	3.4480	7.8819
Size	818	11.5653	1.2124	8.3667	14.4246
Inflation	818	6.7645	5.1624	3.2612	27.8507

The mean of NIMTA and capital are 0.0201 and 0.0893, demonstrating that the average net interest margin to a total asset is about 2.01% and eligible capital to total assets proportion is about 8.93%. The competition measure, BI, usually bears a negative sign. The mean competition ratio of the market is 3.0396. GGDP and Inflation averages are 6.1754 and 6.7645, respectively. GGDP refers to the economic growth ratio, and inflation depicts overall price hikes in the market. Although inflation rates are the outcome of the cumulative effect of previous years, they are a high rate for an investment market. The mean value of Banking Sector Development (BSD) is about 45.59, which refers to financial system deposits, which is 45.59 % of total GDP. The average size of banks is 11.5653.

Table 3 Multicollinearity Test (Pairwise Correlation)

	Risk	Eff_cost	Eff_profit	AD	RD	NIMTA	Capital	BI	BSD	GGDP	Size	Inflation
Risk	1											
Eff_cost	-0.0512	1										
Eff_profit	-0.5019*	-0.2337*	1									
AD	0.3140*	-0.0044	-0.2188*	1								
RD	-0.0299	-0.0703*	0.1653*	0.0224	1							
NIMTA	-0.5683*	-0.2304*	0.5237*	-0.3311*	-0.1483*	1						
Capital	-0.3387*	-0.1115*	0.2036*	0.2317*	-0.0875*	0.3173*	1					
BI	-0.0636	0.0883*	-0.0229	0.0082	0.0614	-0.0719*	-0.0264	1				
BSD	-0.1380*	0.2179*	-0.1574*	-0.0121	-0.0931*	0.0551	0.2970*	-0.0942*	1			
GGDP	-0.0371	0.1706*	-0.1101*	-0.1150*	-0.0932*	0.0826*	0.1017*	-0.2504*	0.3033*	1		
Size	0.1038*	0.6730*	-0.3698*	-0.1475*	-0.0641	-0.2554*	-0.2137*	0.1080*	0.4174*	0.2779*	1	
Inflation	-0.0434	0.0123	-0.0281	0.0398	-0.0138	0.0484	0.1157*	-0.3690*	0.3362*	0.2331*	0.0758*	1

Note: * refers to correlations that are significant at 0.05 level.

To identify the multicollinearity (if any), we perform pairwise correlation (Table 3) and Variance Inflation Factor (VIF) test (Table 4). From the correlation table, we did not find any value greater than 0.70 between the independent variables. Therefore, there is no severe multicollinearity problem. No pairwise correlation value is more than 0.80 refers that the econometric model does not possess any multicollinearity problem (Gujarati, 2009).

Table 4 also shows the VIF test for multicollinearity. VIF values are also less than 10, which means there is no multicollinearity problem (Thompson et al., 2017).

Table 4 Multicollinearity Test (VIF)

Variable	Risk Equation with Eff_Cost		Risk Equation with Eff_Profit		Cost Efficiency Equaiton		Profit Efficiency Equation	
	VIF	1/VIF	VIF	1/VIF	VIF	1/VIF	VIF	1/VIF
Cost efficiency	1.9	0.527586						
Profit efficiency			1.83	0.545326				
Risk (NPLTL)					1.23	0.813065	1.23	0.813065
Capital	1.56	0.64042	1.49	0.66923				
NIMTA	1.54	0.650141	2.07	0.483729				
AD	1.4	0.716424	1.35	0.742157	1.19	0.839759	1.19	0.839759
RD	1.05	0.954616	1.17	0.853107	1.02	0.98102	1.02	0.98102
BSD	1.69	0.590238	1.61	0.619528	1.48	0.674859	1.48	0.674859
BI	1.27	0.788884	1.3	0.768428	1.28	0.781569	1.28	0.781569
Inflation	1.31	0.76278	1.31	0.761389	1.31	0.76243	1.31	0.76243
GGDP	1.27	0.787216	1.25	0.798206	1.25	0.80207	1.25	0.80207
Size	2.72	0.368129	1.6	0.626294	1.43	0.697648	1.43	0.697648
Mean VIF	1.57		1.53		1.27		1.27	

Thus, from the pairwise correlation and VIF test investigation, it is apparent that the models do not suffer any multicollinearity problem.

4.2 Relationship between Risk and Efficiency: Examining the Impact of Competition and Diversification

Table 5 explains the impact of diversification and competition on the relationship between risk and efficiency. Risk is persistently determined from year to year and is expressed by a significant positive coefficient of the lag risk variable. A significant negative association between risk and efficiency reveals that the enhancement of efficiencies substantially manages risk. It refers that when cost and profit efficiency increase, the risk of banks is reduced. Efficiency results show the same pattern in association with risk.

However, AD preaches a positive association with risk, while RD shows a negative association. It demonstrates that more proportional non-interest-bearing assets of total assets increase the credit risk of banks, but the diversified revenue sector reduces risk significantly. These results are in line with the findings of Moudud-Ul-Huq et al. (2018). That means the RD of banks proves the portfolio investment theory (Gupta, 2018), although asset diversification opposes it. Banks emphasising non-interest-bearing assets may lead to more risk due to the non-expertise sector of asset generation, which may be one of the possible reasons. These findings oppose the previous findings of Moudud-Ul-Huq et al. (2018) and Gupta et al. (2021).

Table 5 Risk Equation Examining the Effect of Efficiency, Competition, and Diversification

Variables	NPLTL with Eff_cost	NPLTL with Eff_profit
Risk (-1)	0.665159***(148.08)	0.639612***(176.71)
Eff_cost	-0.06634***(-12.54)	
Eff_profit		-0.06161***(-18.6)
AD	0.046276***(9.12)	0.039381***(5.84)
Size	-0.006448***(-9.38)	-0.0019***(-3.48)
RD	-0.02032***(-14.72)	-0.01158***(-7.90)
NIMTA	-1.37911***(-21.62)	-1.04106***(-26.83)
Capital	-0.11347***(-10.06)	-0.1106***(-9.53)
BSD	-0.00073***(-6.54)	-0.00072***(-9.70)
BI	-0.00152***(-11.91)	-0.00154***(-11.88)
GGDP	0.003287***(14.99)	0.002452***(11.94)
Inflation	-0.00013***(-3.66)	-0.0001***(-3.41)
Constant	0.08014***(14.12)	0.117408***(11.86)
Hansen Test (P-value)	0.501	0.385
AR(1) (P-value)	0.076	0.080
AR(2) (P-value)	0.360	0.365
Observations	774	774

Note: t-values are reported in parentheses; level of significant at 0.01, 0.05, and 0.10 denoted by ***, **, and * , respectively. The dependent variable is NPLTL denotes the proxy measure of risk. p-value of the Hansen test refer to J-statistic. Instruments are not correlated with residuals denoted by Hensen test. The Arellano–Bond tests denoted by AR(1) and AR (2) for first-order and second-order autocorrelation are asymptotically distributed as N(0, 1).

A negative association of size and risk depicts that large banks are taking less risk than their sample-sized bank counterparts. More cost of financial intermediation (NIMTA) and capital play a positive role in managing the risk of banks. These results are similar to the findings of Rahman et al. (2018) and Das Gupta et al. (2021). The coefficient of the industry-level variable BSD shows a negative association with risk. It denotes that with banking sector development, the risk-taking of banks decreases. More experience and market development are possibly the reasons behind this. However, another industry-level variable market competition depicts a positive association with risk.

Since BI usually bears negative signs, the sign of coefficients will refer to the opposite meaning. It signifies that the escalation of market competition will enhance the risk-taking of banks (Changjun et al., 2017). The coefficient of GGDP asserts the positive association with the risk of banks. This is because, with economic progression, demand for loans increases, and proportionate investment in banks also increases, possibly leading to more risk. However, during an inflationary period, the risk of banks decreases. This is because loan servicing becomes cheaper in an inflationary period than in an average period of time. This finding reinforces the previous finding of Changjun et al. (2017).

4.3 Relationship between Efficiency and Risk - Examining the Impact of Competition and Diversification

In examining the bidirectional relationship between efficiency and risk, Table 6 explains the impact of risk, competition, and diversification on the efficiency of banks. Current year efficiency has a significant positive impact on last year's efficiency, as depicted by the lag efficiency variables.

Table 6 Efficiency Equation Examining the Effect of Risk Competition and Diversification

Variables	Efficiency of cost	Efficiency of Profit
Eff_csot (-1)	1.056638 ***(1.30E+04)	
Eff_profit (-1)		0.993999***(2038.10)
Risk	0.001368***(19.91)	0.005864***(20.25)
Size	-0.00023***(-29.92)	-9.69E-05*(-1.89)
AD	0.000884***(14.68)	0.004208***(13.00)
RD	-0.00012***(-6.53)	-0.00064***(-8.83)
BSD	9.62E-08(0.46)	-5.6E-05***(-18.01)
BI	9.00E-06***(26.76)	-4.04E-06*(-1.80)
GGDP	2.91E-05***(27.26)	-4.91E-05***(-8.76)
Inflation	-3.32E-06***(-31.65)	1.03E-05***(13.96)
Constant	-0.05698***(-776.01)	-2.38E-03***(-3.23)
Hansen Test (P-value)	0.179	0.288
AR(1) (P-value)	0.026	0.079
AR(2) (P-value)	0.321	0.157
Observations	774	774

Note: t-values are reported in parentheses; level of significant at 0.01, 0.05, and 0.10 denoted by ***, **, and * , respectively. The dependent variables are Eff_cost and Efff_profit denotes the proxy measure of Efficiency. p-value of the Hansen test refers to J-statistic. Instruments are not correlated with residuals denoted by Hensen test. Arellano–Bond tests denoted by AR(1) and AR (2) for first-order and second-order autocorrelation are asymptotically distributed as N(0, 1).

In the risk equation, we observed the negative effect of efficiency on risk (Table 5). However, as shown in Table 6, which examines the bidirectional association of efficiency and risk, we observe that risk has a positive effect on efficiency. It is precise that with the increase of risk, the efficiency of banks also increases. That means banks with more risk are confirming more cost and profit efficiency than low-risk counterparts. These results are in line with Gupta and Yesmin (2022). A negative coefficient of size depicts that large-size banks are less efficient than their low-size counterparts. The effect of diversification is the opposite of risk. This indicates that while asset diversification increases risk and efficiency for banks, revenue diversification tends to reduce their efficiency. The development of the banking sector does not significantly impact cost efficiency; however, profit efficiency tends to decline as the sector matures. Market competition positively influences cost efficiency but has a negative effect on profit efficiency. Economic growth, as reflected by the coefficient of GGDP, is associated with an increase in cost efficiency and a decrease in profit efficiency. Inflation, on the other hand, negatively impacts cost efficiency but has a positive effect on profit efficiency in the banking sector.

4.4 Non-linear and Joint Effect of Market Competition and Bank Diversification on Risk

This study also addresses the non-linear effect of market competition and the joint effect of competition and bank diversification. Table 7 presents the non-linear and joint effect on risk. Model 1 and Model 2 represent the risk equation with cost efficiency, and Model 3 and Model 4 demonstrate the risk equation with profit efficiency. Again, Model 1 and Model 3 address the effect of AD on the risk equation, whereas Model 2 and Model 4 examine the effect of RD on risk.

Table 5 shows that market competition is positively associated with risk. However, in Table 7, it is depicted that with the change in market competition, the risk of banks initially decreases and then increases in the long run. Since the competition variable, measured by the BI, consistently carries a negative sign, the interpretation of the linear term should be reversed, while the squared term refers to its exact meaning.

Table 7 Non-linear and Joint Effect of Competition and Diversification on Risk

Variables	Model 1	Model 2	Model 3	Model 4
Risk (-1)	0.650131***(134.46)	0.664536***(0.0045)	0.637494***(136.62)	0.640402***(157.83)
Eff_cost	-0.06726***(-8.98)	-0.0618***(0.0078)		
Eff_profit			-0.06359***(-20.45)	-0.05853***(-12.85)
AD	0.080897***(20.77)	0.051751***(0.0073)	0.056532***(8.59)	0.047361***(5.32)
Size	0.005697***(6.06)	0.005269*** (0.0008)	-0.00341***(-8.31)	-0.00313***(-5.64)
RD	-0.01919***(-8.44)	-0.02891***(0.0017)	-0.01286***(-6.34)	-0.0192***(-13.17)
NIMTA	-1.34762***(-20.16)	-1.31055***(0.0765)	-1.00582***(15.24)	-1.01314***(-24.03)
Capital	-0.15947***(-10.70)	-0.13599***(0.0116)	-0.12998***(-11.61)	-0.12417***(-9.93)
BSD	-0.00063***(-4.03)	-0.00055***(0.0001)	-0.00053***(-6.34)	-0.00039***(-3.54)
BI	0.001599***(2.88)	0.002577***(0.0004)	0.000971**(2.10)	0.002502***(7.92)
BI^2	0.000663***(9.35)	0.000213***(5.48E-05)	0.000454***(5.27)	0.000209***(4.80)
BI^2×AD	-0.00082***(-3.79)		-0.00041**(-2.10)	
BI^2×RD		0.00066***(6.32E-05)		0.000609***(8.35)
GGDP	0.003564***(12.36)	0.00311***(0.0003)	0.002714***(11.44)	0.002561***(10.63)
Inflation	-0.00026***(-3.80)	-0.00032***(5.25E-05)	-0.00019***(-3.67)	-0.00033***(-7.64)
Constant	0.08084***(12.06)	0.089678***(0.0091)	0.12474***(18.88)	0.121447***(9.70)
Hansen Test (P-value)	0.471	0.510	0.361	0.327
AR(1) (P-value)	0.076	0.076	0.081	0.082
AR(2) (P-value)	0.35	0.39	0.359	0.39
Observations	774	774	774	774

Note: t-values are reported in parentheses; level of significant at 0.01, 0.05, and 0.10 denoted by ***, **, and * , respectively. The dependent variable is NPLTL denotes the proxy measure of risk. Model 1 & 2 refers the risk equation with cost efficiency and Model 3 & 4 denotes the risk equation with profit efficiency. p-value of the Hansen test refers to J-statistic. Instruments are not correlated with residuals denoted by Hensen test. Arellano–Bond tests denoted by AR(1) and AR (2) for first-order and second-order autocorrelation are asymptotically distributed as N(0, 1).

Although asset diversification leads banks to increase their risk, in the long run, risk decreases within a competitive market, as evidenced by the joint effect of competition and asset diversification. Revenue diversification behaves in the opposite manner of asset diversification. That means revenue diversification reduces the risk significantly initially; however, in the long run, in a competitive market situation, the risk of banks is enhanced with revenue diversification.

4.5 Non-linear and Joint Effect of Market Competition and Bank Diversification on Efficiency

The non-linear and joint effect of competition and diversification shows heterogeneous results, as illustrated in Table 8. Initially, increased market competition negatively impacts cost efficiency and positively affects profit efficiency; however, in the long run, with the change of market competition, banks' cost efficiency improves while profit efficiency declines.

Over the long term in a competitive market, asset diversification tends to reduce bank cost efficiency while enhancing profit efficiency. In contrast, revenue diversification decreases the bank efficiency in the long run under market conditions.

Table 8 Non-Linear Effect of Market Competition and Diversification on Efficiency

Variables	Model 1	Model 2	Model 3	Model 4
Eff_cost (-1)	1.0569***(1.00E+04)	1.057***(8148.87)		
Eff_profit(-1)			9.82E-01***(2611.68)	0.99411(2327.74)
Risk	1.18E-03***(10.07)	1.24E-03***(9.65)	-0.00601***(-16.13)	5.80E-03(16.77)
BSD	3.22E-06***(11.92)	4.36E-06***(15.20)	-9.24E-05***(-19.16)	-7.2E-05(-8.55)
Size	-0.00027***(-26.81)	-0.00028***(-23.38)	-0.0007***(-32.64)	-9.4E-05(-1.62)
AD	0.000996***(-3.45)	6.54E-04***(10.94)	-0.00033***(-2.64)	0.00425(9.39)
RD	-8.39E-05***(-3.45)	-7.82E-05***(-4.33)	0.000365***(3.79)	-0.00203(-5.45)
BI	8.01E-05***(19.51)	7.75E-05***(16.35)	-0.00039***(-19.88)	-0.00045(-9.80)
BI^2	1.11E-05***(14.74)	9.14E-06***(19.91)	-4.98E-05***(-21.22)	3.54E-05(4.71)
GGDP	2.30E-05***(25.37)	2.11E-05***(20.35)	-1.13E-04***(-20.64)	-4.1E-05(-3.64)
BI^2×AD	-6.68E-06***(-3.33)		1.54E-05***(10.37)	
BI^2×RD		-9.62E-07**(-2.13)		-2.02E-04***(-11.67)
Inflation	-4.92E-06***(-20.79)	-5.12E-06***(-23.46)	2.09E-05***(18.00)	4.12E-05(8.24)
Constant	-0.05686***(-577.63)	-0.05682***(-677.10)	0.014232***(43.22)	-0.00172(-2.43)
Hansen Test (P-value)	0.154	0.225	0.102	0.152
AR(1) (P-value)	0.097	0.102	0.002	0.001
AR(2) (P-value)	0.143	0.115	0.629	0.987
Observations	774	774	774	774

Note: t-values are reported in parentheses; level of significant at 0.01, 0.05, and 0.10 denoted by ***, **, and * , respectively. The dependent variables are Eff_cost (Model 1&2) and Efff_profit (Model 3 & 4) denotes the proxy measure of Efficiency. p-value of the Hansen test refer to J-statistic. Instruments are not correlated with residuals denoted by Hensen test. Arellano–Bond tests denoted by AR(1) and AR (2) for first-order and second-order autocorrelation are asymptotically distributed as N(0, 1).

4.6 Risk Equation Altering Boone Indicators (BI) as Lerner Index (LI)

A robust check is performed by altering the competition measure BI to the Lerner Index (LI). Comparable findings are evident in the robust regression based on the original equation. However, the LI shows that banks tend to reduce their risk-taking as market power increases, which contrasts with the results for the competition measure BI. Given that the LI is an inverse indicator of competition and a direct measure of market concentration, this outcome appears reasonable (Gupta et al., 2021).

Table 9 Risk Equation Examining the Effect of Efficiency, Competition, and Diversification

Variables	NPLTL with Eff_cost	NPLTL with Eff_profit
Risk(-1)	0.654458***(175.81)	0.637483***(135.25)
Eff_cost	-0.06498***(-7.18)	
Eff_profit		-0.0615***(-13.32)
AD	0.033611***(7.47)	0.025474***(3.69)
Size	-0.007424***(7.92)	-0.0015**(-2.59)
RD	-0.01996***(-13.58)	-0.01166***(-6.44)
NIMTA	-1.48918***(-28.58)	-1.15019***(-34.86)
Capital	-0.12544***(-14.61)	-0.10182***(-7.53)
BSD	-0.00117***(-12.33)	-0.00114***(-14.08)
Lerner Index	-0.05048***(-27.01)	-0.05446***(-18.60)
GGDP	0.001024***(3.06)	0.000276(0.79)
Inflation	7.38E-05(1.95)	8.97E-05(2.49)
Constant	0.142675***(22.33)	0.186628***(12.81)
Variables	**NPLTL with Eff_cost**	**NPLTL with Eff_profit**

Variables	NPLTL with Eff_cost	NPLTL with Eff_profit
Hansen Test (P-value)	0.292	0.302
AR(1) (P-value)	0.074	0.080
AR(2) (P-value)	0.369	0.378
Observations	774	774

Note: t-values are reported in parentheses; level of significant at 0.01, 0.05, and 0.10 denoted by ***, **, and * , respectively. The dependent variable is NPLTL denotes the proxy measure of risk. p-value of the Hansen test refer to J-statistic. Instruments are not correlated with residuals denoted by Hensen test. Arellano–Bond tests denoted by AR(1) and AR (2) for first-order and second-order autocorrelation are asymptotically distributed as N(0, 1).

4.7 Efficiency Equations by Altering BI as 5-Bank Asset Concentration Ratio

By altering the competition measure as a 5-Bank asset concentration ratio, we also performed a robust check of the efficiency equation.

Table 10 Efficiency Equation Examining the Effect of Risk, Competition, and Diversification

Variables	Efficiency of cost	Efficiency of Profit
Eff_csot (-1)	1.057065***(1.30E+04)	
Eff_profit (-1)		0.99403***(1732.73)
NPLTL	0.001253***(13.44)	0.00565***(19.47)
Size	-0.00031***(-29.10)	0.00017***(3.18)
AD	0.000473***(16.31)	0.004399***(10.75)
RD	-4.5E-05***(-3.41)	-0.00096***(-11.79)
BSD	-1.4E-05***(-20.02)	3.29E-05***(12.49)
5-Bank Asset Concentration	-4.44E-06***(-24.13)	2.59E-05***(18.42)
GGDP	7.66E-06***(13.39)	2.72E-05***(3.57)
Inflation	-2.17E-06***(-18.05)	1.81E-06**(2.40)
Constant	-0.0555***(-592.97)	-0.01135***(-11.31)
Hansen Test (P-value)	0.238	0.327
AR(1) (P-value)	0.028	0.280
AR(2) (P-value)	0.143	0.212
Observations	774	774

Note: t-values are reported in parentheses; level of significant at 0.01, 0.05, and 0.10 denoted by ***, **, and * , respectively. The dependent variables are Eff_cost and Efff_profit denotes the proxy measure of Efficiency. p-value of the Hansen test refers to J-statistic. Instruments are not correlated with residuals denoted by Hensen test. Arellano–Bond tests denoted by AR(1) and AR (2) for first-order and second-order autocorrelation are asymptotically distributed as N(0, 1).

In the robust equation models demonstrate the same results as shown in the base models of efficiency in Table 6, except for one variable, BSD. In Table 6, BSD was observed to be insignificant in the efficiency of cost and negatively associated with the efficiency of profit. However, in a robust check (Table 9), BSD is significantly negatively associated with cost efficiency and positively associated with profit efficiency. Other than this, the exception results are similar to the baseline results of the robust check.

5. CONCLUSION

Banks are the dominant and major shareholders in the financial sector, accounting for more than sixty percent of total market shares (Gupta & Yesmin, 2022). Banks are the prime matchmakers of the economic flows and major intermediaries of the economy's circular flow. Thus, the attention of regulators and researchers is always on banks, how risk-taking behaviour changes, and how it affects and can be affected by other determinants. This study investigates the two-way association between the risk and efficiency of commercial banks. The study also takes into consideration market competition and diversification in the examination of the risk-efficiency nexus. The empirical investigations pinpoint a few significant insights. Banks taking more risks

are more efficient than their low-risk-taking counterparts; however, an inverse association between risk and efficiency was observed in reverse causality. That means that the risk to banks decreases significantly with the increase in efficiency. Asset diversification escalates risk and efficiency, whereas revenue diversification significantly reduces risk and efficiency. This means that although revenue diversification advocates the portfolio investment theory, it opposes asset diversification. The market competition also depicts mixed results like diversification. The incremental effect of market competition risk-taking of banks also increases, resulting in higher profit efficiency. However, banks' cost efficiency decreases with the increase of market competition. Extension of baseline models depicting heterogeneous outcomes. Market competition initially reduces banks' risk but enhances risk-taking tendency in the long run. Asset and revenue diversification also explored mixed results. Asset diversification manages the risk in a competitive market, whereas revenue diversification escalates it in the long run. Like diversification, the impact of market competition and diversification are also heterogeneous across banks' cost and profit efficiency. This investigation provides a foundational background for formulating policy related to risk and efficiency. The findings highlight that efficiency and risk behaviour vary depending on the types of diversification and the level of market competition. Therefore, uniform policies on diversification and market competition may not be suitable for managing risk and efficiency across all commercial banks. Future studies can be extended by exploring regional data, particularly from Asian countries or by exploring the influence of ownership dimension in a similar nexus.

ACKNOWLEDGEMENTS

This project is financed by the University Grants Commission of Bangladesh, grant memorandum no. 37.01.0000.072.14.021.22.154 dated 09-02-2023.

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