Regression Model Analysis of Risky Behaviors and Board Characteristics on Bank Performance Using Profit Frontier Approach in Banks Listed on the Tehran Stock Exchange

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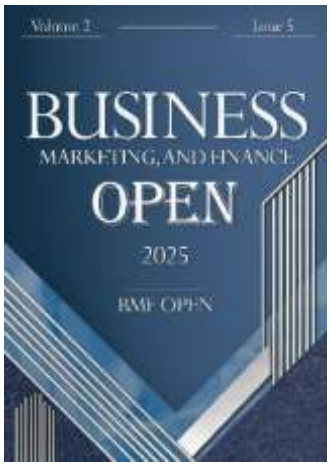

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Abstract: This study aims to analyze the impact of risky behaviors and board characteristics on the performance of banks listed on the Tehran Stock Exchange using the profit frontier approach. This applied study used panel data from all listed banks in Tehran Stock Exchange between 2014 and 2023. The dependent variable, bank performance, was estimated through a stochastic frontier model using a Cobb-Douglas production function. Independent variables included credit, liquidity, and operational risks, as well as board-related variables such as size, independence, ownership, tenure, education, gender diversity, and CEO duality. Fixed-effects panel regression models were estimated using EViews software. Results of the first model indicated that only board independence had a significant positive effect on bank performance. Other structural board characteristics were not statistically significant. In the second model, risky behaviors had a significant negative effect on performance, while none of the interaction terms between risk and board features showed a significant effect. These findings suggest that internal governance mechanisms alone may not be sufficient to mitigate risky behavior in banks. Effective risk management in the banking sector requires synergy between internal governance structures, external supervision, and regulatory instruments. Board independence remains one of the few variables significantly improving bank performance in Iran's risk-intensive banking environment.

Keywords: corporate governance, board of directors, credit risk, banking efficiency, profit frontier model, Tehran Stock Exchange

1. Introduction

In recent years, structural changes in banking systems, intensified competition, the complexity of financial instruments, and increased uncertainty in the economic environment have made it increasingly necessary to reassess the factors affecting bank performance. Among these, one of the most critical areas of study has been the examination of the relationship between board structure, risky behaviors, and financial performance of banks—especially through profit frontier models. This is because banks, as financial institutions, play a vital role in resource allocation, risk management, and maintaining economic stability. Bank governance structures, particularly board characteristics, can have a decisive impact on strategic orientations and risk-taking behavior [1, 2]. Accordingly, numerous studies have emphasized that risk management practices in banks are influenced by variables such as

board size, the degree of board independence, internal ownership, and gender composition—each of which may shape managerial behavior toward either risk-taking or risk aversion [3, 4].

According to agency theory, the conflict of interest between managers and shareholders is more pronounced in the banking sector than in other industries, given banks' greater reliance on deposit-based resources and access to high-risk financial instruments. Therefore, the quality of board oversight can play a deterrent role in this regard [5, 6]. On the other hand, empirical findings show that banks' risk-taking behaviors—particularly in loan disbursement, liquidity management, and asset portfolio composition—significantly affect their performance and can lead to decreased efficiency and higher default costs [7, 8]. In this context, regression models based on profit frontier analysis can serve as suitable analytical tools for evaluating bank performance, as they allow for the separation of technical inefficiency from random error and measure actual performance against a theoretical profit frontier [9, 10].

Studies on commercial banks across countries such as India, Pakistan, Indonesia, Germany, and the Eurozone have shown that board structure, along with indicators of operational, credit, and liquidity risk, are among the most important determinants of financial efficiency in banks [11-13]. Research in corporate governance indicates that increased board independence and the presence of institutional investors can curb managerial risk-taking and prevent deviations in resource allocation [3, 14]. Nevertheless, some banks continue to engage in high-risk behavior despite formal control structures, which may be attributed to weaknesses in operational oversight or internal conflicts of interest [15, 16].

Moreover, in financial literature, bank performance is not only influenced by governance variables but is also heavily affected by risk-related characteristics and the composition of their financial resources. Specifically, banks aiming to increase returns may be inclined toward riskier assets, especially when regulatory oversight and governance mechanisms are weak [17, 18]. In this vein, profit frontier models—where the output function is represented by actual bank cash flows and the inputs include cost-related variables such as cost of goods sold, working capital, administrative expenses, and loans—offer a more precise framework to assess the relationship between governance quality and financial performance [9, 19].

Recent research also indicates that in some emerging markets, the impact of banks' behavioral and structural variables on efficiency varies depending on the regulatory and cultural environment. For example, a study on Indonesian banks found that even banks with strong board structures exhibited high risk appetite in the absence of strict regulatory policies [4, 20]. Conversely, some banks have shown better performance in risk management and internal oversight by leveraging modern technologies such as artificial intelligence [21, 22]. Additionally, environmental factors such as tax policies, banking regulations, and executive compensation laws also play a significant role in shaping banks' risk tolerance. For instance, the introduction of a tax on bank assets in some countries has led to a reduction in risk-taking levels [7].

In the field of banking performance and its relationship to risk-taking behaviors, profit frontier models are considered valuable tools in econometric analysis. Unlike traditional methods such as Data Envelopment Analysis (DEA), they offer the advantage of separating inefficiency components from random error [9]. This advantage has popularized the use of profit frontier models based on the Cobb-Douglas function in recent studies to evaluate actual bank performance in terms of operational inputs and outputs [23]. From this perspective, a simultaneous analysis of behavioral variables (e.g., credit risk) and structural variables (e.g., board composition) with efficiency performance provides a comprehensive approach to assess causal relationships between governance structures and financial outcomes.

Furthermore, in many countries, professional ethics and moral hazard in banking processes have also emerged as major concerns. Studies have shown that government support or deposit insurance can encourage banks to take on more risk—a phenomenon known as "moral hazard" [14, 24]. In this regard, capital regulation and liquidity requirements imposed by central banks have been attempts to curb such behavioral deviations [11, 25].

In conclusion, given the increasing importance of integrated analysis of risk indicators, governance structures, and banking performance, the present study aims to conduct a regression-based analysis of the impact of risky behaviors and board characteristics on bank performance using the profit frontier model.

2. Methodology

This applied research seeks to analyze the effects of risky behaviors and board characteristics on bank performance. The statistical population includes all banks listed on the Tehran Stock Exchange during a ten-year period from 2014 to 2023. Given the limited number of public banks and the full accessibility of the population, the study adopts a census approach, analyzing all active banks within this timeframe as the statistical sample. This approach was selected to avoid sampling error and to utilize all available data for a more accurate analysis of bank performance in relation to the target variables.

Two regression models were developed and applied to analyze the data. The first model assesses the direct effects of risky behaviors and board characteristics on bank performance, formulated as follows:

$$BP\_it = \beta_0 + \beta_1 RISKY + \beta_2 BSIZE + \beta_3 IND + \beta_4 PER + \beta_5 OWN + \beta_6 DUAL + \beta_7 NUM + \beta_8 EDU + \beta_9 GEND + \beta_{10} Size\_it + \beta_{11} LEV\_it + \varepsilon$$

The second model examines the interaction effects between risky behaviors and board characteristics:

$$BP\_it = \beta_0 + \beta_1(BSIZERISKY) + \beta_2(INDRISKY) + \beta_3(PERRISKY) + \beta_4(OWNRISKY) + \beta_5(DUALRISKY) + \beta_6(NUMRISKY) + \beta_7(EDURISKY) + \beta_8(GENDRISKY) + \beta_9 Size\_it + \beta_{10} LEV\_it + \varepsilon$$

In these models, bank performance (BP) is the dependent variable, measured using the Stochastic Frontier Analysis (SFA) method. The variable RISKY denotes credit-related risky behaviors, defined as the ratio of loans and receivables from non-governmental entities to total loans disbursed annually. BSIZE refers to board size; IND to the proportion of independent (non-executive) directors; PER to CEO tenure; OWN to board ownership percentage; DUAL to CEO duality (coded as 0 when the CEO is also the board chair, and 1 otherwise); NUM to the number of board meetings; EDU to board educational level (coded as 1 if the majority of members hold postgraduate degrees); GEND to the proportion of female board members. Control variables include Size, measured as the natural logarithm of total assets, and LEV, measured as the ratio of total debt to total assets as a proxy for financial leverage.

Bank performance was assessed using a Cobb-Douglas production function within the stochastic frontier framework, where cash flow (CF_it) served as the output variable. The model included five input variables: cost of goods sold (COGS_it), retained earnings (RE_it), working capital (WCAP_it), selling, general, and administrative expenses (SG&A_it), and accounts receivable (REC_it). The model is specified as:

$$\ln(CF\_it) = \beta_0 + \beta_1 \ln(COGS\_it) + \beta_2 \ln(RE\_it) + \beta_3 \ln(WCAP\_it) + \beta_4 \ln(SG\&A\_it) + \beta_5 \ln(REC\_it) + v\_it - u\_it$$

Here, **v_it** denotes the random error term and **u_it** represents technical inefficiency. Using EViews software, inefficiency values were estimated for each bank, and by subtracting these from one, bank efficiency scores were computed. Compared to DEA, this method offers the advantage of isolating random error from inefficiency.

Control variables in this study include bank size and financial leverage. Bank size was assessed through the natural logarithm of total assets, reflecting operational scale and access to financial resources. Financial leverage was calculated as the ratio of total debt to total assets, indicating the bank's financial structure and risk exposure. All data were sourced from banks' financial statements and publicly available databases including the Codal system and Tehran Stock Exchange portal. Fixed-effects panel regressions with robust standard errors were used to account for cross-sectional heterogeneity and temporal autocorrelation.

3. Findings and Results

This section presents the descriptive findings and the results of regression model assumption testing, aimed at evaluating the reliability of the analytical models. First, the descriptive statistics of the study's main variables—including mean, median, minimum, maximum, standard deviation, skewness, and kurtosis—are reported in the table below:

Table 1. Descriptive Statistics of Research Variables

Variable	Mean	Median	Max	Min	Std. Dev.	Skewness	Kurtosis
Operational Risk	0.100	0.101	0.167	0.047	0.0281	0.123	2.594
Credit Risk	0.604	0.622	0.730	0.364	0.086	-0.867	3.210
Liquidity Risk	0.715	0.785	0.977	0.076	0.230	-1.795	5.060
Bank Efficiency	0.010	0.008	0.045	-0.046	0.016	-0.272	4.333
Board Size	3.976	4.000	7.000	2.000	1.214	0.245	2.628
Board Independence	0.450	0.501	0.972	0.030	0.249	0.0221	1.788
CEO Tenure	0.174	0.070	2.530	0.000	0.330	4.916	32.788
Board Ownership (%)	0.043	0.015	0.267	0.004	0.059	1.715	5.570
Bank Size (log assets)	12.637	12.306	16.006	10.565	1.250	0.602	2.857
Financial Leverage	0.642	0.639	1.031	0.183	0.151	0.084	3.442

As shown in the table above, the variable with the greatest dispersion is Bank Size (standard deviation = 1.250), and the least dispersion belongs to Bank Efficiency (standard deviation = 0.016). The skewness and kurtosis of most variables deviate from perfect normality, which will be further examined using statistical tests. CEO Tenure exhibits the highest skewness and kurtosis, indicating a significant leftward concentration in its distribution.

To assess multicollinearity among the independent and control variables, the Variance Inflation Factor (VIF) was used, with results presented below:

Table 2. VIF Results for Multicollinearity Diagnosis

Variable	VIF
Liquidity Risk	1.33
Credit Risk	1.54
Operational Risk	1.043
Board Size	1.054
Board Independence	1.045
CEO Tenure	1.035
Board Ownership	1.054
Bank Size	1.11
Financial Leverage	1.064

Since all VIF values are below 10, it can be concluded that the current regression model does not suffer from severe multicollinearity and the data are reliable in this regard.

To verify homoscedasticity (equal variance of residuals), four tests were conducted: Breusch-Pagan, Harvey, Glejser, and ARCH. Results are shown in the following table:

Table 3. Homoscedasticity Test Results for Model Residuals

Test	F-Statistic	p-Value
Breusch-Pagan	3.124	0.12
Harvey	4.563	0.45
Glejser	2.934	0.38
ARCH	1.996	0.67

All four tests yielded p-values above 0.05, suggesting that the assumption of homoscedasticity holds and that alternative estimation methods like GLS or WLS are unnecessary.

To assess autocorrelation in the model residuals, the Durbin-Watson test was used:

Table 4. Durbin-Watson Test Results

Model	DW Statistic
1	1.88
2	2.033

Both DW statistics fall between 1.5 and 2.5, indicating no significant autocorrelation and supporting the assumption of independence among observations.

To test for normality in the dependent variable and residuals, the Jarque-Bera test was conducted:

Table 5. Jarque-Bera Normality Test Results

Variable	p-Value
Bank Efficiency	0.17
Model Residuals	0.11

Since p-values exceed 0.05 for both variables, the null hypothesis of normality is not rejected, allowing the use of linear regression for analysis.

In summary, diagnostic tests indicate that the dataset is free from significant issues related to multicollinearity, heteroscedasticity, autocorrelation, and non-normality. Therefore, the application of OLS regression models for hypothesis testing is statistically valid.

Before incorporating variables into the regression model, it is essential to test their stationarity. In applied econometrics, stationarity is a prerequisite, as non-stationary variables—those whose mean and variance change over time—can lead to spurious regressions and unreliable conclusions. To verify stationarity, the Levin, Lin, and Chu (LLC) unit root test was employed. Results are as follows:

Table 6. Levin, Lin, and Chu Stationarity Test Results

Variable	Statistic	p-Value
Risky Behaviors	3.234	0.00
Board Size	1.886	0.00
Board Independence	3.277	0.00
CEO Tenure	4.389	0.00
Board Ownership	3.556	0.00
Bank Size	2.876	0.00
Financial Leverage	1.995	0.00

Given the p-value of 0.00 for all variables, it can be concluded that all research variables are stationary and suitable for regression modeling.

To determine the appropriate panel data estimation technique, the Chow and Hausman tests were conducted. These tests assess whether fixed effects or random effects models should be used:

Table 7. Results of Chow and Hausman Tests for Panel Model Selection

Test	p-Value	Conclusion
Chow Test	0.000	Use Panel Data
Hausman Test	0.000	Use Fixed Effects Model

As both p-values are below 0.05, the results support the use of a fixed-effects panel data regression model for analyzing the research model. Accordingly, the first model was estimated using fixed-effects panel regression.

The results obtained from analyzing the first regression model are presented in the table below. The coefficient of determination (R^2) for the model is 0.151, indicating that approximately 15% of the variation in the dependent variable (bank efficiency) is explained by the independent and control variables in the model. Moreover, the F-statistic is 2.316 with a p-value of 0.041, which is below the 0.05 significance threshold. Therefore, the model is statistically significant, and the presence of a linear relationship between the independent variables and the dependent variable is confirmed.

Table 8. Regression Results for Model 1 (Fixed Effects Estimation)

Variable	Coefficient	t-Statistic	p-Value
Board Size	0.002246	1.559516	0.1229
Board Independence	0.019826	2.844617	0.0057
Board Ownership (%)	0.050258	1.709880	0.0913
CEO Tenure	0.001038	0.198012	0.8436
Bank Size	0.002172	1.510110	0.1351
Financial Leverage	0.003798	0.326326	0.7451
Constant	-0.039777	-1.899343	0.0612

R^2 = 0.151236

Adjusted R^2 = 0.085

F-statistic = 2.316390

Model p-value = 0.041311

According to the above table, board independence is the only variable statistically significant at the 1% level, with a coefficient of 0.0198 and a p-value of 0.0057. This finding suggests that an increase in the proportion of non-executive directors on the board is positively and significantly associated with improved bank efficiency. Other variables—such as board size, board ownership, bank size, and financial leverage—although having positive signs, are not statistically significant at the 95% confidence level. CEO tenure does not show a meaningful effect on bank performance.

In the next stage, the second regression model, which includes interaction terms between risky behaviors and board characteristics, will be analyzed. This analysis enables a deeper understanding of the structural dynamics between risk-taking and corporate governance quality in explaining bank performance.

In the second phase of regression analysis, the interaction effects between risky behaviors and various board characteristics on bank performance were examined. The objective of this analysis is to determine whether governance variables can play a moderating role in the relationship between bank risk-taking and performance. The results of Model 2 are presented in the table below:

Table 9. Regression Results for Model 2 (With Interaction Terms)

Variable	Coefficient	t-Statistic	p-Value
Risky Behaviors	-0.056396	-2.256762	0.0273
Board Size * Risky Behaviors	0.006296	0.105106	0.6289
Board Independence * Risky Behaviors	0.006222	0.485565	0.6108
Board Ownership * Risky Behaviors	-0.002444	-0.511365	0.2066
Bank Size	0.000971	0.631564	0.5298
Financial Leverage	-0.002624	-0.209727	0.8345
Constant	-0.039777	-1.899343	0.0612

$R^2 = 0.302193$

Adjusted $R^2 = 0.125137$

F-statistic = 1.706767

Model p-value = 0.063125

Analysis of Table 9 shows that in Model 2, only the variable for risky behaviors independently demonstrates a statistically significant negative coefficient at the 5% level ($p = 0.0273$). This suggests that as risky behaviors in banks increase—such as a higher proportion of non-performing loans—efficiency significantly declines. These findings align with theoretical expectations and prior research, which argue that excessive risk-taking in loan portfolios can lead to increased default costs, reduced cash flows, and deteriorated performance.

In contrast, none of the interaction terms introduced in the model—i.e., the interaction between risk and board size, board independence, or board ownership—are statistically significant. This implies that the governance variables examined in this study do not serve as effective moderators between risk-taking and bank performance. In other words, even in banks with larger or more independent boards, the negative impact of risky behavior on performance remains unchanged.

The R^2 for Model 2 is 0.302, which represents an improvement over Model 1, indicating better explanatory power. However, the adjusted R^2 is 0.125, suggesting that when considering the number of predictors and sample size, the model's true explanatory capacity remains limited. The F-statistic's p-value is 0.063—marginally above the conventional 0.05 threshold—indicating borderline statistical significance.

Overall, the results of Model 2 highlight the key negative role of risk-taking behaviors in undermining bank performance, while the interaction effects of board characteristics are statistically insignificant. This may suggest that the internal governance structures of banks alone are insufficient to manage credit and operational risks, underscoring the need for complementary oversight mechanisms at the regulatory and policy-making levels. A more detailed interpretation and comparison with prior studies are provided in the discussion section.

4. Discussion and Conclusion

The results from the estimation of the first model revealed that among all the independent and control variables examined, only board independence had a statistically significant and positive effect on bank performance under the profit frontier approach. This result suggests that the higher the proportion of non-executive members on the board, the greater the improvement in bank performance. This finding is consistent with agency theory, which emphasizes the monitoring role of independent directors in reducing conflicts of interest and preventing managerial opportunism. Previous studies have also indicated that board independence, by enhancing oversight and reducing decision-making risks, can improve bank productivity and profitability [1, 3]. This is particularly relevant in the Iranian banking context, which is marked by regulatory complexities and government

interventions—factors that make board independence a potentially effective tool for mitigating risk and improving efficiency.

On the other hand, in the first model, other variables such as board size, board ownership, CEO tenure, bank size, and financial leverage did not show significant relationships with performance. This may be attributed to structural factors specific to Iran's capital market and banking system, where decisions are often influenced by external (state or institutional) structures, thereby potentially diminishing the impact of internal variables. Nonetheless, the finding that board size does not significantly affect performance is aligned with studies from other countries such as India and Indonesia, where larger boards have not necessarily translated into more effective decision-making [2, 4].

In the second model, which examined the interaction effects between risky behaviors and board characteristics, it was found that risky behaviors alone had a significant and negative effect on bank performance. This confirms the notion that increases in credit, operational, or liquidity risk can decrease efficiency and move banks further from the optimal profit frontier. This result aligns with an extensive body of literature indicating that highly risk-tolerant banks, when lacking effective oversight, are more likely to suffer from rising default costs, reduced cash flows, and asset quality deterioration [7, 13, 26]. For instance, a study on Islamic banks in Indonesia showed that high credit risk in loan portfolios led to significant declines in return on equity [8].

A noteworthy point in the second model is that none of the interaction terms between board characteristics and risky behaviors were statistically significant. In other words, variables such as board size, independence, and ownership failed to moderate the relationship between risky behavior and performance. This finding suggests that formal governance structures in Iran's banking system have yet to exert effective control over banks' risk-taking behaviors. This aligns with research suggesting that the effectiveness of corporate governance mechanisms in developing countries is often limited due to weak regulatory institutions and legal gaps [6, 15].

These findings also correspond with studies that emphasize the greater influence of external institutions—such as central banks, governments, and institutional investors—on banks' risk behaviors, compared to internal governance mechanisms [16, 24]. Even when boards include independent or highly educated members, in the absence of binding regulatory frameworks and legal accountability, their ability to curb risky practices remains limited. In several countries, tools such as bank asset taxes, capital adequacy requirements, and executive compensation reforms have been effectively deployed to reduce risk-taking incentives [7, 9].

Additionally, the results showed that variables such as bank size and financial leverage had no significant effect on performance. While some studies have posited that larger banks benefit from economies of scale and reduced capital costs [11, 25], this finding may reflect ownership centralization or liquidity constraints in Iran's banking system, which may prevent banks from fully realizing these advantages.

Overall, the findings of this study suggest that structural characteristics of boards alone are insufficient to enhance bank performance in high-risk environments. Success in mitigating the negative effects of risk requires synergy between internal governance structures, effective regulatory oversight, and external institutional support. These results are consistent with prior research emphasizing the need for combining formal intra-organizational mechanisms with sector-wide supervisory frameworks for effective governance in banks [10, 20, 27].

One of the key limitations of this study was the lack of access to detailed data on executive compensation structures and board meeting contents, which could have helped explain the relationship between governance and risk-taking more comprehensively. Furthermore, the study focused exclusively on banks listed on the Tehran Stock Exchange, which may limit the generalizability of the findings to non-listed or smaller private banks. Another

limitation is the exclusive use of archival and formal data, without incorporating qualitative variables such as CEO leadership style or organizational culture, which could have significant effects on both risk and efficiency.

Future research can address these limitations by incorporating mixed-method designs (quantitative and qualitative) to investigate the mechanisms linking board characteristics and risk-taking more thoroughly. Exploring mediating variables such as risk culture, financial transparency, and the bargaining power of institutional shareholders may help refine the analytical models. Comparative studies between public and private banks or between large and small banks could also yield useful insights for policymakers.

In practice, banking managers and policymakers should not only focus on restructuring boards but also prioritize the design of anti-risk incentive policies, reasonable limits on executive bonuses, and enhanced transparency in credit decision processes. Regulatory bodies must also implement continuous risk assessment frameworks and develop smarter oversight tools to curb high-risk behaviors. Specialized training programs in risk management and corporate governance for board members can also play a critical role in improving decision-making effectiveness.

Authors' Contributions

Authors equally contributed to this article.

Ethical Considerations

All procedures performed in this study were under the ethical standards.

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Conflict of Interest

The authors report no conflict of interest.

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