3 CAN BANKS USE ENVIRONMENTAL, SOCIAL AND GOVERNANCE FACTORS AND BOARD GENDER DIVERSITY TO INCREASE EFFICIENCY?

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Abstract

Banks play a vital role in the global economy but face a challenge of complying with regulations regarding board gender diversity and environmental, social, and governance (ESG) practices while maintaining cost efficiency. Applying a two-stage modified Data Envelopment Analysis (DEA) cost efficiency model with Simar-Wilson bootstrap-based truncated regression procedure and the instrumental variable (IV) Tobit robustness checks, this study analyzes the associations among board gender diversity, ESG performance scores, and bank efficiency across 94 Asian banks from 2010 to 2020. The empirical results show that female directors are positively associated with bank efficiency while exhibiting an inverted U-shaped diminishing marginal return. Environmental performance is positively associated with efficiency, whereas social performance is negatively related, and governance performance exhibits an insignificant relationship. Furthermore, the interaction between gender diversity and each ESG performance pillar exhibits a positive relationship with bank efficiency. The findings suggest an optimal threashold of 10%-13% for female board representation. Banks may consider gender diversity as a strategy to implementing ESG initiatives, and ultimately correspond with a positive association with higher cost efficiency.

Keywords: *bank; efficiency; board gender diversity, ESG performance*

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1. Introduction

Financial institutions play a crucial role to the global economy. Banks act as intermediaries between individuals with excess funds and those who need loans. Consequently, banks strive to

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sustain their long-term performance. Cost efficiency is the primary way of assessing bank performance. Thaker *et al*. (2022) assessed bank cost efficiency by comparing bank inputs against bank outputs. Given identical inputs, higher outputs represent greater bank cost efficiency. Examples of bank inputs include labor, cost of assets, and borrowed funds. Outputs comprise loans, investments, and income-generating assets. Maintaining bank cost efficiency is essential for economic stability because bank failures could lead to the breakdown of the national economy. As a result, banks must incorporate corporate governance and sustainability practices into their operations to mitigate the risk of bank runs.

As part of corporate governance, gender diversity began to prevail in developed countries after the 2008 global financial turmoil. For example, Norway pioneered gender quota in 2008, mandating that companies elect at least 40% female directors on their boards (Ramly *et al*., 2017). Subsequently, other European countries demanded a quote of 30% to 40% female representation on the boards of listed companies. In contrast, non-European countries without government mandates saw a lower percentage of female directors on the corporate boards (Lavin and Montecinos-Pearce, 2021).

Shakil *et al*. (2021) asserted that board gender diversity enhances bank transparency. A well-balanced board of any bank consists of directors with diversified backgrounds, experience, and professional knowledge, benefiting a wide range of stakeholders. Kanter (1977) proposed the critical mass theory that highlights the need for a minimum number of female participants in a group. Kanter (1977) argued that when the percentage of women falls below 20% in any group, they are perceived only as tokens without significant influence. Therefore, achieving a threshold of 20% female participants is essential for them to influence the group decisions.

Aligned with corporate governance, the United Nations (UN) released the Principles for Responsible Investment (PRI) in 2005 to address three crucial issues: environmental, social, and governance (ESG) aspects (UN, 2020). In 2015, the UN further promulgated the 17 Sustainable Development Goals (SDGs) as part of the 2030 agenda. Avrampou *et al.* (2019) emphasized that the banking sector plays a pivotal role in helping various organizations accomplish the UN's SDGs.

Financial institutions develop both internal and external ESG policies. Internally, banks establish guidelines to reduce carbon dioxide emissions, promote renewable energy use, and provide community services (Buallay *et al*., 2022). Externally, banks offer loans to firms that comply with ESG regulations (El Khoury *et al*., 2021). Conversely, neglecting ESG requirements can jeopardize bank's reputation and long-term sustainability.

Asian economies, particularly Japan, India, and Singapore, have been among the key drivers of the global economy, achieving an average growth rate of 4% between 2010 and 2020 (Buallay *et al*., 2022). Banks in this region supported such growth by providing essential financial services to businesses and individuals. Notably, more than 40 of the 100 largest banks in the world by assets are based in Asia. Moreover, the Asian banking industry experienced an approximately 5% growth from 2010 to 2020, surpassing the growth rate of European and the U.S. banks (El Khoury *et al*., 2021). By integrating ESG guidelines, the Asian banks could help governments address critical issues such as global warming, carbon dioxide emission, and social inequality, thereby accelerating compliance with the UN's SDS globally. However, Asian banks may still overlook ESG practices due to their lower priority compared to normal banking operations.

Specifically, the Asian banking industry has lagged behind the developed countries in ESG practices. The percentage of female members on corporate boards in Asia has been lower than that of Europe. Traditionally in Asia, female workers are often perceived as less assertive, decisive, and powerful, with their roles seen as supportive rather than opinionated (Adusei, 2019). Men have predominantly occupied board positions in financial institutions across Asia, rendering the participation of women on bank boards less common. Similarly, Asian banks began adopting

ESG programs later than their counterparts in developed nations such as Europe and the U.S. (Andries *et al*., 2024). Under government oversight, Asian banks face the dual challenges of fulfilling ESG requirements while sustaining operational efficiency (Manta *et al*., 2020; Ramly *et al*., 2017).

A research gap exists in the literature regarding whether Asian banks can increase their operational efficiency while practicing gender diversity and ESG activities. Prior studies examined gender diversity and ESG practices in banks in developed countries (Andries *et al*., 2024; Adeabah *et al*., 2019; Adusei, 2019). Scant research focused on the Asian bank industry, which plays a vital role in the global economy. Given the traditional view of Asian women as less articulate and assertive, their social status is somewhat tied to their family background. Consequently, the presence of Asian women on bank boards could be less pronounced. The extant literature has rarely investigated the ways in which gender diversity and ESG activities affect bank performance in Asia. This study aims to fill this research gap by focusing on the Asian banking industry, where ESG requirements were implemented later and the proportion of female board members is lower compared to advanced countries such as those in Europe and the U.S.

This study investigates the association between board gender diversity and bank efficiency, the association between ESG performance and bank efficiency, and the relationship between the interaction of board gender diversity and ESG performance, and bank efficiency across East and Southeast Asia. Employing a two-stage modified Data Envelopment Analysis (DEA) cost efficiency model with Simar and Wilson (2007) bootstrap based truncated regression procedure and instrumental variable (IV) Tobit model for a robustness check, this study analyzes data across 94 Asian banks from 2010 to 2020. This timeframe is selected because it marks the period when Asian governments began recognizing the importance of ESG practices and requiring their adoption by financial institutions.

The empirical evidence shows that board gender diversity is positively associated with bank efficiency, though the relationship is nonlinear and follows an inverted U-shaped pattern, implying diminishing marginal returns. Among the individual ESG dimensions, environmental performance is positively associated with bank efficiency. Social performance is significantly and negatively associated with efficiency. Governance performance shows no significant correlation. However, when board gender diversity interacts with each ESG dimension, the combined effects show a significantly positive correlation with bank cost efficiency.

These results suggest that environmental initiatives tend to mitigate the cost burden of banks, creating financial benefits for them. The interaction of board gender diversity and environmental performance sustains such positive correlation. In contrast, social performance alone is negatively associated with bank performance. However, the interaction of board gender diversity and social performance are likely to strengthen bank efficiency.

Overall, the findings of this study imply that inclusive boards tend to be better positioned to implement ESG practices in ways that may ultimately strengthen efficiency.

Based on these findings, we recommend that bank leaders and policymakers view board gender diversity favorably. While ESG adoption is increasingly mandated in the banking sector, board gender diversity may serve as a complementary strategy for potentially enhancing both ESG performance and cost efficiency across East and Southeast Asia. Moreover, banks that align and disclose board gender diversity alongside ESG performance in their financial reports may also become more appealing to investors who favor institutions committed to ESG improvement (Thaker *et al*., 2022).

This paper contributes to the bank management literature in three ways. First, to the best of our knowledge, it is among the earliest studies to jointly examine the effects of board gender diversity and ESG factors on the efficiency of financial institutions. Second, it focuses on East and Southeast Asian banks, which is a region characterized by rapid economic growth yet lagging

progress in board gender diversity and ESG implementation. Third, it employs a methodology integrating the improved DEA cost efficiency model, Simar and Wilson (2007) bootstrap truncated-regression procedure, and the IV Tobit estimation model. Fourth, this research incorporates gender diversity, ESG performance, and bank-specific variables to provide a comprehensive analysis of bank efficiency.

The remainder of this paper is organized as follows. Section 2 reviews prior literature and develops hypotheses. Section 3 describes the data and methodology. Section 4 presents empirical results and discusses their implications. Section 5 concludes the study with limitations and suggestions for future research.

2. Literature Review and Hypothesis Development

The extant literature describes the relationships among gender diversity on bank board of directors, ESG, and efficiency of banks. The details are discussed below.

2.1 Bank Board Gender Diversity and Efficiency

The agency theory highlights the conflict between managers (known as the agents) and shareholders (known as the principals) because the two groups of individuals do not share a common goal (Jensen and Meckling, 1976). Managers may prioritize their own interests. After the 2008 global financial crisis, governments urged listed companies to establish corporate governance functions, such as diversifying board members and adding independent directors, to ensure that managers' acts align with shareholders' interests (Rooh *et al.*, 2021). Changes in board composition led to increased gender diversity, enriching the decision-making process by incorporating diverse perspectives. Consequently, board gender diversity has become essential in the banking industry to protect the interests of a large number of depositors and borrowers (Manta *et al.*, 2020; Ramly *et al.*, 2017).

Kanter (1977) initiated the critical mass theory, arguing that women can impact organizational by proving new perspectives and competencies only when their participation in a group reached the 20% threshold or critical mass. Similarly, Owen and Temesvary (2018) asserted that banks with boards comprising 13% to 17% of female directors outperformed those with a lower percentage of women directors. Other researchers found that a 30% threshold is necessary for women directors to be influential in banks' decision-making processes.

The literature reported a positive impact of gender diversity on the boards of European banks, attributed to the high percentage of women on these boards (Adeabah *et al.*, 2019; Adusei, 2019). Consistent with this view, prior studies found evidence among European banks. Andries *et al.* (2024) revealed that greater female representation on the boards of 128 banks across 17 Central and Eastern European countries is significantly associated with both cost and technical efficiency, especially in smaller banks. Thaker *et al.* (2022) uncovered that India banks are linked positively to technical and cost efficiency. Delgado-Piña *et al.* (2020) claimed that greater female representation on boards may be linked to higher bank productivity and efficiency.

In contrast, Adams and Ferreira (2009) examined the U.S. firms and argued that although female directors tend to strengthen corporate governance and board monitoring, enhanced monitoring is not always associated with firm efficiency. In well-governed firms, excessive monitoring may even reduce firm value and performance. Kirsch (2018) conducted a review of 310 academic articles published between 1981 and 2016. Although this paper shows mixed effects of female board of directors on firm financial performance, the evidence showed that firms with more gender-diverse boards tend to engage more in stakeholder-oriented practices and improve monitoring mechanism.

Based on the low participation and role of female directors on bank boards in Asia, we developed Hypothesis 1 (H1) as follows:

H1: Board gender diversity is positively associated with bank efficiency.

2.2 ESG Performance and Bank Efficiency

The following section reviews the literature on the relationship between individual ESG dimensions and bank efficiency.

2.2.1 Environmental Performance and Bank Efficiency

Banks are required to execute both internal and external environment policies. Internally, banks can reduce carbon emissions and waste, though such practices often involve additional costs. Externally, banks may reject loans to businesses that harm the natural environments, which can potentially lower profits. Both types of policies may reduce short-term earnings but benefit financial institutions in the long run (Birindelli *et al.*, 2019).

Despite these concerns, prior studies largely reported a positive impact of environment efforts on bank performance. Shakil *et al.* (2019) identified a significant positive association between environmental performance and return on equity of banks across emerging markets. Similarly, Qureshi *et al.* (2020) examined 812 listed firms in 22 European countries. These authors found that environmental efforts were positively related to firm value efforts and firm value represented by stock price (Qureshi *et al.*, 2020).

Moreover, Rooh *et al.* (2021), focusing on 17 public and private commercial banks in Pakistan, also reported that environmental endeavor are positively linked to bank performance. Notably, the Asian banking industry began practicing environmental activities later than banks in advanced countries (Kyaw *et al.*, 2017). Therefore, we postulate Hypothesis (H2) as follows:

H2: Environmental performance is positively associated with bank efficiency.

2.2.2 Social Performance and Bank Efficiency

The Asian banking sector began engaging in corporate social responsibility (CSR) practices in 2012, well before actively integrating environmental preservation and corporate governance into their operations (Qureshi *et al.*, 2020). Asian banks widely published their social efforts in their annual reports, describing activities charitable donations, community care for the needy, and large-scale employee wellness programs (Forgione *et al.*, 2020).

Despite bank efforts on social initiatives, the literature revealed mixed results regarding the relationship between social activities and firm performance. Buallay *et al.* (2020) examined 59 conventional banks in emerging countries and found that social performance exerts a negative effect on profitability and firm value. Similarly, Rooh *et al.* (2021) indicated that social activities demonstrate the weakest relationship with firm performance among ESG factors. In addition, López-Penabad *et al.* (2022) investigated bank efficiency across 21 European countries and identified a U-shaped relationship between social practices and efficiency. These authors uncovered that banks with either low or high levels of social engagement achieved higher efficiency, whereas those with moderate social performance exhibited lower efficiency (López-Penabad *et al.*, 2022. Furthermore, Wasiuzzaman and Wan Mohammad (2020) found an insignificant influence of social disclosure on bank outcomes in Malaysia.

Although few previous researchers indicated a positive overall effect of ESG on bank efficiency across the U.S. and Europe (Athar and Chughtai, 2021; Alazzani *et al.*, 2017; Forgione *et al.*, 2020), these authors similarly indicated that social performance exhibits the weakest link with firm performance relative to other ESG dimensions.

Based on the literature, we propose Hypothesis 3 (H3) as follows:

H3: Social performance is negatively associated with bank efficiency.

2.2.3 Governance Performance and Bank Efficiency

Prior studies largely rejected the notion that corporate governance benefits banks' operating results. Despite the claim by Lavin and Montecinos-Pearce (2021) that independent directors positively influence ESG factors, most authors found that corporate governance exerted an insignificant impact on bank performance in developed countries. For example, EL Khoury *et al*. (2021) reported that corporate governance, management oversight, and protection of shareholders' rights produced a non-significant influence on the financial results of banks in emerging markets. Similarly, Wasiuzzaman and Wan Mohammad (2020) uncovered that although banks implemented corporate governance, these institutions did not increase efficiency. The literature generally indicated that corporate governance did not increase bank efficiency primarily because these efforts are internal and not visible to the public (Wasiuzzaman and Wan Mohammad, 2020). The objective for improving corporate governance is mainly to comply with the government regulations, not to improve customers service (El Khoury *et al*., 2021).

The Asian bank industry began following corporate governance principles later than developed countries, due to the slow and progressive demands of governments (Lavin and Montecinos-Pearce, 2021). Although the Asian banking industry publishes corporate governance efforts in their annual reports, these internal changes produced little impact on customer choice. Therefore, corporate governance is unlikely to help banks improve business operations in Asia. Therefore, we develop Hypothesis 4 (H4) as follows:

H4: Governance performance is negatively associated with bank efficiency.

2.4 Interaction of Gender Diversity and ESG Performance on Bank Efficiency

2.4.1 Interaction of Gender Diversity and Environmental Performance

The literature on the European banks supported the postulation that gender diversity and environmental initiatives produce a significant dual impact on banks. Qureshi *et al*. (2020) examined European companies and found that the participation of female board members enhanced firm value through compliance with environmental regulations. The presence of women on bank boards could also raise the awareness of environmental issues, thereby strengthening environmental performance. Additional studies showed consistent findings that female directors are linked to higher environmental performance within organizations (Alazzani *et al*., 2017; Bear *et al*., 2010; Ismail and Latiff, 2019). This improvement occurs because the objective views provided by female directors tend to align managerial decisions with shareholder interests. Therefore, we propose Hypothesis 5 (H5) as follows:

H5: The interaction of board gender diversity and environmental performance is positively associated with bank efficiency.

2.4.2 Interaction of Gender Diversity and Social Performance

The literature also articulated the impact of board gender diversity on social efforts and organizational performance. Ismail and Latiff (2019) reported a positive link between gender diversity on corporate boards and enhanced social performance among Malaysian publicly listed firms. Similarly, Ouni *et al*. (2020) examined Canadian companies and found that board gender diversity influences firms to engage in social activities. Consequently, the financial performance of these firms improved. Furthermore, Shakil *et al*. (2021) analyzed 37 U.S. banks and argued that female directors' perspectives and values enhance social performance in banks despite relative low female representation. Therefore, we develop Hypothesis 6 (H6) as follows:

H6: The interaction of board gender diversity and social performance is positively associated with bank efficiency.

2.4.3 Interaction of Gender Diversity and Governance Performance

Combining critical mass theory with agency theory sheds light on the challenges faced by Asian bank boards. The interaction of gender diversity and governance principles may compel traditional Asian banks to transform their organizational culture and internal mechanism to achieve greater efficiency (Rooh *et al*, 2021; Thaker *et al*., 2022). When Asian banks are mandated to integrate both gender diversity and ESG programs, they may elect or add younger and more professionally qualified women to meet these requirements (Buallay *et al*., 2022). Heightened government regulations further necessitate effective changes within banks, and women directors significantly enhance governance transparency (Delgado-Piña, *et al*., 2020; Wasiuzzaman and Mohammad, 2019). The convergence of gender diversity and governance regulations could ultimately drive Asian banks to improve business practices, such as accelerating digital services and reducing electricity consumption. Consequently, banks may become more efficient. Based on the above literature, we develop Hypothesis 7 (H7) as follow:

> H7: The interaction of board gender diversity and governance performance is positively associated with bank efficiency.

Moreover, the extant literature examined other governance practices by the board of directors. Examples include the audit committee, compensation committee, independent director, and the number of board meetings (Ismail and Latiff, 2019; Ramly *et al*., 2017; Thaker *et al*., 2022). Other bank-specific variables are also located in the literature, namely, capital adequacy ratio, cost-to-income ratio, and asset size (Ismail and Latiff, 2019, Owen and Temesvary, 2018). Additionally, prior studies suggested that banks in developed countries perform better than their counterparts in emerging markets in cost-to-income ratios (Chang *et al*., 2021; Ramly *et al*., 2017).

3. Data and Methodology

This section describes the data and methodology.

3.1 Data

The data sample comprises 94 Asian banks during the period 2010 – 2020 and is collected from two databases: the Refinitive DataStream and Bank Focus. These banks are divided into two regional groups. The first group of banks covers the East Asian regions, including twenty-two banks from Japan, seven banks from Korea, twenty-six banks from China, twelve banks from Taiwan, and four banks from Hong Kong. The second group of banks encompasses the Southeast Asian region, including three banks from Singapore, another three from the Philippines, four banks from Indonesia, five banks from Malaysia, and eight banks from Thailand. Most of the governments in these countries require the listed companies to report their corporate governance mechanism and ESG activities based on the Organization for Economic Co-operation and Development's (OECD) corporate governance framework along with ESG investing guidelines (Buallay *et al*., 2022).

3.2 Variables

We first select the inputs and outputs. Then, we explain the board gender diversity, ESG, and other corporate governance and bank-specific control variables below.

3.2.1 Bank Input and Output

Based on the literature, this study selects three inputs: deposit, labor, and net fixed assets, and three outputs: loans, investments, and non-interest income. In addition, we include the prices of the three inputs: the price of deposits and borrowing (funding), the price of labor, and the price of the net fixed assets (Huang, 2005; Chang *et al*., 2021). The input prices are calculated as follows. Price of deposit and borrowing (funding) is calculated as interest payments divided by deposits.

Price of labor is calculated as total payroll divided by total assets which are used to replace number of employees. Price of net fixed assets is computed as operating expenses divided by net fixed assets.

3.2.2 Board Gender Diversity

Board gender diversity is measured by the proportion of women directors on the bank board. First, we determine whether bank boards have any female board members. If the answer is yes, we then compute the percentage of the female board of directors at a bank.

3.2.3 ESG Pillars

The database of DataStream contains the ESG scores, designed and offered by Refinitiv Company, a London Stock Exchange Group business, to measure the level of commitment and effectiveness of a company using three ESG pillars (environmental, social, and governance). The ESG pillars describe specific activities used by firms to develop and implement their ESG plans.

Control variables of audit committee, CEO duality, compensation committee are given a value of either "0" or "1". The value of "0" means that this variable does not exist on the bank board. The value of "1" indicates that the existence of such a variable on the bank board. The dummy variable of developed/emerging markets has a value of either "0" or "1". The value of "0" means that the bank is located in an emerging market. The value of "1" represents a bank in a developed country.

Table 1. Definitions of Dependent Variables (Inputs, Outputs, and Price of Inputs)

Dependent Variable	Definition	Data source
Efficiency		
Input		
Deposit (X1)	Includes checking accounts, saving accounts, time deposits, and amount of money borrowed from other financial institutions.	BankFocus
Labor (X2)	Represented by total bank assets, as a positive relationship exists between total bank assets and number of employees.	
Net fixed assets (X3)	Gross fixed assets at cost minus accumulated depreciation.	
Output		
Loan (Y1)	Short-term and long-term loans	BankFocus
Investment (Y2)	Short-term and long-term investment	
Non-interest income (Y3)	Includes transaction fee and service fee income	
Price of inputs		
Price of deposit and borrowing (funding) (P1)	Interest payments divided by deposit	BankFocus
Price of labor (P2)	Payroll divided by total assets (in place of the number of employees)	
Price of net fixed assets (P3)	Operating expenses divided by net fixed assets	

Moreover, the variables of audit committee, compensation committee, percentage of independent directors, number of board meetings, capital adequacy ratio, and dummy variable (developed/emerging market) are expected to show a positive sign (+). These variables are

anticipated to increase bank efficiency with higher values. However, the variable of cost-to-income ratio is expected to show a negative sign (-). A higher cost-to-income ratio should decrease the efficiency of banks. Table 1 provides definitions and data sources for the dependent variables used to calculate bank efficiency, specifically inputs, outputs, and the price of inputs.

Table 2 outlines the definitions and data sources for the independent variables used to calculate bank efficiency, including variables of interest, governance variables, and control variables.

Table 2: Definitions of Independent Variables

Independent variables	Definition	Data source
Variables of Interest		
Gender Diversity (GD)	Calculated by the number of female directors divided by total number of board members.	DataStream
Environmental (E)	Includes Resource Use, Emission Reduction, and Innovation	DataStream
Social (S)	Includes Work Force, Human Rights, Community, and Product Responsibility	DataStream
Governance (G)	Includes Management, Shareholder, and CSR Strategy	DataStream
Governance Variables		
Compensation committee (*CPC*)	Indicates whether the bank has established a compensation committee. “0” = no. “1” = yes.	DataStream
Percentage of independent directors (*IDB*)	The proportion of independent directors on the board.	DataStream
Number of board meetings (*BM*)	The number of board meetings per year.	DataStream
Control Variables		
Capital adequacy ratio (*CAR*)	The percentage of bank capital in the total risk-weighted assets.	BankFocus
Cost-to-income ratio (*CIR*)	The percentage of bank operating expenses in the total operating revenue.	BankFocus
Bank size (*SCALE*)	The natural logarithm of the total assets of a bank	BankFocus
Developed/emerging market (*DE*)	Indicates whether the bank is located in a developed or emerging market. “0” = emerging market. “1” = developed country.	World bank

3.3 The Two-Stage Regression Method

We use a two-stage regression method to analyze the data. During the first stage, we apply the modified cost efficiency model proposed by Tone (2002) in DEA to compute bank cost efficiency (output/input). During the second stage, we utilize the Simar-Wilson bootstrap based truncated regression procedure to identify the correlations among board gender diversity, ESG performance, and bank efficiency derived from the first stage.

The first stage of our regression analysis is based on past research. Banker, Charnes, and Cooper (1984) modified the traditional constant-returns-to-scale (CRS) model to allow for variable returns to scale (VRS). This adjustment allows efficiency to vary with the size of a business operation, reflecting real-world scenarios. In addition, this model adopts the widely used intermediation approach in banking industry, which assumes that the main objective of a

commercial bank is to create output using inputs (Ahn and Le, 2014; Liang *et al.*, 2018). Consequently, this study employs the VRS model along with the intermediation approach to measure the cost efficiency of decision-making units (DMUs).

During the second stage of the analysis, we utilize the bootstrap based truncated regression procedure proposed by Simar and Wilson (2007) to first identify the correlation of board gender diversity, ESG performance, and bank efficiency derived from the first stage. Then we examine whether the interaction of board gender diversity and ESG performance score is associated with bank efficiency (Adusei, 2019; Pasiouras, 2008).

To check the reliability of our results, we re-perform the analysis using the IV Tobit model (Wintoki, Linck and Netter, 2012). This method alleviates the endogeneity concerns by accounting for possible reverse cause-and-effect problems and considers that DEA efficiency scores are bounded in a range and often serially correlated. Hence, the IV Tobit model reduces bias and yields valid inferences.

3.3.1 Modified Cost Efficiency Model in DEA

During the first stage of the DEA analysis, we apply the modified cost efficiency model to compute bank cost efficiency. Tone (2002) identified a notable property of traditional cost efficiency models, which arises when input unit prices vary among banks and price adjustments are not feasible. Consequently, Tone (2002) developed the new-cost model which employes the cost-based production possibility set P_c as expressed by equation (1):

$$P_c = \{(\bar{x}, y) | \bar{x} \geq \bar{X}\lambda, y \leq Y\lambda, \lambda \geq 0\} \tag{1}$$

where, $\bar{X} = (\bar{x}_1, \ldots, \bar{x}_n)$ with $\bar{x}_j = \left(c_{1j}x_{1j}, \ldots, c_{mj}x_{mj}\right)$.

$$\begin{aligned} [NCost] e\bar{x}_0^* = \min_{\bar{x},\lambda} & \; e\bar{x} \\ \text{subject to} \quad & \bar{x} \geq \bar{X}\lambda \\ & y_0 \leq Y\lambda \\ & \lambda \geq 0 \end{aligned} \tag{2}$$

Where e is a row vector with all elements equal to 1. Let the optimal solution of the above linear programming be $\bar{x}_0^*$. Then, the new cost efficiency, $\overline{\gamma^*}$, is computed using equation (3):

$$\overline{\gamma^*} = e\bar{x}_0^* \,/\, e\bar{x}_o \tag{3}$$

3.3.2 The Simar-Wilson Bootstrap Truncated Regression

During the second stage, we examine the correlations among gender diversity, ESG performance, and bank efficiency. Because the DEA-based efficiency scores are bounded between zero (0) and one (1), the ordinary least squares estimation is unsuitable. Furthermore, female board representation and ESG performance may also suffer from endogeneity arising from reverse causality, simultaneity, or omitted variables. To address these concerns, we use two complementary approaches: the bootstrap based truncated regression procedure developed by Simar and Wilson (2007) as our baseline model, and an IV Tobit regression model as a robustness check.

To mitigate simultaneity bias, board gender diversity and ESG performance variables enter the model with a one-period lag. To account for a potential nonlinear relationship, we additionally incorporate the squared term of gender diversity ($GDSQ_{it-1}$). Finally, we perform regression

analysis to examine the associations among board gender diversity, ESG performance, and bank efficiency, as specified in equation (4).

$$EFF_{it} = \beta_0 + \beta_1 GD_{it-1} + \beta_2 GDSQ_{it-1} + \beta_3 E_{it-1} + \beta_4 S_{it-1} + \beta_5 G_{it-1} + \beta_6 AUDIT_{it} + \beta_7 CPC_{it} + \beta_8 IDB_{it} + \beta_9 BM_{it} + \beta_{10} CAR_{it} + \beta_{11} CIR_{it} + \beta_{12} SCALE_{it} + \beta_{13} DE_{kt} + \varepsilon_{it} \quad (4)$$

where:

EFF_{it} denotes bank efficiency, where $i = 1, \ldots, N$, N denoting the number of banks, and $t = 1, \ldots, T$, T denoting the time period.

GD_{it-1} denotes board gender diversity, and $GDSQ_{it-1}$ denotes its squared term. E_{it-1}, S_{it-1}, and G_{it-1} denote environmental, social, and governance (ESG) performance, respectively, all measured with a one-period lag.

Corporate governance control variables include: $AUDIT_{it}$ (audit committee), CPC_{it} (compensation committee), IDB_{it} (percentage of independent directors on the board), and BM_{it} (number of board meetings).

Bank-level control variables include: CAR_{it} (capital adequacy ratio), CIR_{it} (cost-to-income ratio), $SCALE_{it}$ (bank size), and DE_{kt}, a dummy variable equal to 1 if the bank is located in a developed country and 0 if it is located in a developing country.

ε_{it} denotes the residual term.

We also examine the interactive effect of board gender diversity and ESG performance on bank efficiency, as specified in equation (5):

$$EFF_{it} = \beta_0 + \beta_1 GD_{it-1} + \beta_2 GDSQ_{it-1} + \beta_3 E_{it-1} + \beta_4 S_{it-1} + \beta_5 G_{it-1} + \beta_6 (GD_{it-1} \times E_{it-1}) + \beta_7 (GD_{it-1} \times S_{it-1}) + \beta_8 (GD_{it-1} \times G_{it-1}) + \beta_9 AUDIT_{it} + \beta_{10} CPC_{it} + \beta_{11} IDB_{it} + \beta_{12} BM_{it} + \beta_{13} CAR_{it} + \beta_{14} CIR_{it} + \beta_{15} SCALE_{it} + \beta_{16} DE_{kt} + \varepsilon_{it} \quad (5)$$

where $GD_{it-1} \times E_{it-1}$, $GD_{it-1} \times S_{it-1}$, and $GD_{it-1} \times G_{it-1}$ are the interaction terms between board gender diversity and each ESG pillar; all other variables are defined as in equation (4).

3.3.3 The IV Tobit Regression Model

As a robustness check, we employ the IV Tobit specification to address the potential endogeneity of board gender diversity and ESG performance. Because DEA-based efficiency scores are bounded in the interval [0, 1], we specify a two-limit Tobit model with lower and upper censoring limits set at 0 and 1, respectively. To account for endogeneity, we instrument the contemporaneous values of board gender diversity and each ESG pillar using their respective one-period lagged values and estimate the model by IV Tobit, as specified in equations (6) and (7).

$$EFF^*_{it} = \beta_0 + \beta_1 GD_{it} + \beta_2 GDSQ_{it} + \beta_3 E_{it} + \beta_4 S_{it} + \beta_5 G_{it} + \beta_6 (GD_{it} \times E_{it}) + \beta_7 (GD_{it} \times S_{it}) + \beta_8 (GD_{it} \times G_{it}) + \beta_9 AUDIT_{it} + \beta_{10} CPC_{it} + \beta_{11} IDB_{it} + \beta_{12} BMI_{it} + \beta_{13} CAR_{it} + \beta_{14} CIR_{it} + \beta_{15} SCALE_{it} + \beta_{16} DE_{it} + \varepsilon_{it} \quad (6)$$

with the observation rule

$$EFF_{it} = 0, \quad \text{if } EFF^*_{it} \leq 0;$$
$$EFF_{it} = EFF^*_{it}, \quad \text{if } 0 < EFF^*_{it} < 1;$$
$$EFF_{it} = 1, \quad \text{if } EFF^*_{it} \geq 1.$$

where:

where EFF^*_{it} denotes the latent (uncensored) efficiency index of bank *i* at time *t*, and EFF_{it} denotes the observed (censored) efficiency score, bounded in the interval [0, 1]. GD_{it}, $GDSQ_{it}$, E_{it}, S_{it}, and G_{it}, together with the governance-related and bank-specific control variables $AUDIT_{it}$, CPC_{it}, IDB_{it}, BMI_{it}, CAR_{it}, CIR_{it}, $SCALE_{it}$, and DE_{it}, are defined as in equation (4). ε_{it} is the structural error term.

To address the potential endogeneity of GD_{it}, $GDSQ_{it}$, E_{it}, S_{it}, G_{it}, $GD_{it} \times E_{it}$, $GD_{it} \times S_{it}$, and $GD_{it} \times G_{it}$ arising from reverse causality, simultaneity, or omitted variables, each endogenous regressor is instrumented by its own one-period lagged value. These lagged values are assumed to be correlated with the corresponding endogenous regressor (relevance) but uncorrelated with the contemporaneous structural error term ε_{it} (exogeneity), thereby satisfying the standard conditions for valid instruments. Equation (7) presents the first-stage specification for GD_{it}; analogous first-stage equations are estimated for each of the remaining endogenous regressors.

$$GD_{it} = \gamma_0 + \gamma_1 GD_{i,t-1} + \gamma_2' Controls_{it} + \nu_{it} \quad (7)$$

where $Controls_{it}$ denotes the vector of governance-related and bank-specific control variables defined in equation (4), γ_2 is the corresponding coefficient vector, and ν_{it} denotes the first-stage error term.

4. Results and Implications

4.1 Descriptive Statistics

The descriptive statistics of bank efficiency, gender diversity, each ESG pillar, other corporate governance characteristics, and bank-specific control variables are presented in Table 3.

Based on Table 3, bank efficiency ranges from 8.11% to 100% with a mean value of 60% and a standard deviation of 23.99%. These values suggest that Asian banks vary largely in efficiency. Gender diversity ranges from 0% to 57.14% with a mean value being 12.43% and a standard deviation being 9.86%. The results indicate that on average, women consist of 12.43% of directors on the bank board, which is below the 13% threshold suggested by Owen and Temesvary (2018) and the 20% minimum by Kanter (1977).

The proportion of female directors (GB) has a mean of 12.43% (with a median of 10.00%), ranging from 0.00% to 57.14%. This result indicates that while some banks have achieved board gender diversity, the phenomenon of all-male boards remains prevalent across Asian banks.

Table 3 also exhibits the descriptive statistics for the ESG performance scores of the sample banks. Regarding environmental performance, the scores range from 0.00 to 92.54, with a mean of 32.68 and a standard deviation of 24.94, highlighting a large variation across banks. Although the mean score of 32.68 falls within the third tier (25 to 50), representing moderate performance and disclosure transparency, it leans toward the lowest tier (0 to 25), suggesting that banks perform less satisfactorily in environmental protection.

Regarding social performance, the scores range from 0.96 and 93.14, with a mean of 42.76 and a standard deviation of 23.50. Although this mean score also falls within the third tier (25 to 50), representing moderate ESG performance and disclosure transparency, it leans toward the second tier (50 to 75), suggesting that Asian banks perform better in the social pillar than in the environmental pillar.

Regarding governance performance, the scores range from 5.7 to 94.97, with a mean of 53.29 and a standard deviation of 22.01. The mean score falls within the second tier (50 to 75), representing good ESG performance and disclosure transparency. The overall results indicate that Asian banks perform best in governance and worse in the environmental pillar.

Table 3. Descriptive statistics

Variable Name	Symbol	Mean	Standard Deviation	Minimum	Medium	Maximum	Observation
Efficiency (%)	EFF	60.00	23.99	8.11	57.80	100	1034
Gender diversity (%)	GB	12.43	9.86	0.00	10	57.14	1034
Environmental (0-100)	E	32.68	24.94	0.00	27.56	92.54	1034
Social (0-100)	S	42.76	23.50	0.96	42.30	93.14	1034
Governance (0-100)	G	53.29	22.01	5.70	53.09	94.97	1034
Audit committee (0/1)	AUDIT	0.67	0.47	0	1	1	1034
Compensation committee (0/1)	CPC	0.59	0.49	0	1	1	1034
Independent director (%)	IDB	38.79	18.67	0	36.50	92.31	1034
Board meeting		12.15	5.15	4	12	38	1034
Capital adequacy ratio (%)	CAR	8.08	3.00	2.34	7.40	23.47	1034
Cost-to-income ratio (%)	CIR	49.74	14.04	23.16	48.62	115.46	1034
Bank size (in millions of USD)	SCALE	11.62	1.45	5.29	11.38	15.45	1034
Developed/emerging market (0/1)	DE	0.49	0.50	0	0	1	1034

Note: (%): Indicates the efficiency percentage of banks. Gender diversity (%): Percentage of female directors on the board. Environmental (0-100): Environmental performance score on scale from 0 to 100. Social (0-100): Social performance score on a scale from 0 to 100. Governance (0-100): Governance performance score on a scale from 0 to 100. Audit Committee (0/1): Indicates whether the bank has an audit committee (0=No, 1=Yes). Compensation Committee (0/1): Indicates whether the bank has a compensation committee (0=No, 1=Yes). Independent Director (%): The proportion of independent directors on the board. Board Meetings: The number of board meetings held per year. Capital Adequacy Ratio (%): The percentage of bank capital in total risk-weighted assets. Cost-to-Income Ratio (%): The percentage of bank operating expenses in total operating revenue. Bank Size (in millions of USD): The total assets of a bank, measured in millions of USD. Developed/Emerging Market (0/1): Indicates whether the bank is located in a developed or emerging market (0=Emerging market, 1=Developed country).

We also test for multicollinearity among the variables by conducting Pearson correlation coefficient tests. The correlation matrix of the variables is shown in Table 4. Gender diversity and Blau Index are highly correlated (0.98), confirming that the Blau index serves as an appropriate alternative proxy for gender diversity in robustness checks. All other correlation coefficients remain below 0.71, indicating the nonexistence of the potential problem of multicollinearity among variables.

Table 4 Correlation matrix of the variables

	Efficiency	Gender diversity	Blau Index	Environ-mental	Social	Governance	Audit committee	Compensation committee	Independent director	Board meeting	Capital adequacy ratio	Cost-to-income ratio	Bank scale	Developed/ emerging market
Efficiency	1													
Gender diversity	-0.0084	1												
Blau Index	-0.0013	0.9793***	1											
Environmental	0.0644***	0.1354***	0.1061**	1										
Social	-0.2069**	0.1922***	0.1654***	0.6667***	1									
Governance	-0.0496	0.1181***	0.1022***	0.4517***	0.5468***	1								
Audit committee	0.0678**	0.1225***	0.1402***	0.2588***	0.2387***	0.2169***	1							
Compensation committee	-0.0656**	0.1542***	0.1561***	0.4047***	0.4295***	0.4081***	0.7056***	1						
Independent director	-0.3123***	-0.0198	-0.0355	0.2920***	0.5578***	0.4769***	0.0926***	0.2688***	1					
Board meeting	-0.2427***	0.0074	-0.0136	0.1779***	0.2926***	0.2119***	0.1898***	0.3123***	0.1701**	1				
Capital adequacy ratio	-0.1359***	0.0678**	0.0602*	0.0429	0.2619***	0.1876***	0.1948***	0.2611***	0.2744***	0.2010***	1			
Cost-to-income ratio	0.0690**	-0.3026***	-0.3082***	-0.0458	-0.1832***	-0.0492	-0.0218	-0.1725***	-0.1496***	-0.0874***	-0.1372***	1		
Bank scale	0.1845***	0.021*	0.0436	0.3030***	0.1547***	0.2198***	0.1809***	0.2046***	0.0618***	0.034	-0.3800***	-0.2116***	1	
Developed/emerging market	-0.3942***	0.3441***	0.3704***	-0.0234**	0.1497***	-0.0348	0.012	0.1574***	0.1126***	0.1884***	0.2234***	-0.5917***	0.0527*	1

*Note: ***1% significance level, **5% significance level, and *10% significance level.*

4.2 The Simar-Wilson Bootstrap Truncated Regression Results

This study applies the Simar-Wilson bootstrap based truncated regression procedure to examine: (1) the relationship between board gender diversity and bank efficiency; (2) the relationship between ESG performance and bank efficiency; and (3) how the interaction of board gender diversity and ESG performance is related to bank efficiency. The results are presented in this section.

4.2.1 Relationship between board gender diversity and bank efficiency

According to Table 5, board gender diversity (*GD*) is positively associated with bank efficiency. To capture potential non-linearities, Model 2 includes the squared term (*GDSQ*). Although *GDSQ* is insignificant in Model 2, it becomes consistently negative and statistically significant in Models 5 through 8 after controlling for ESG pillars and interaction terms, confirming a robust inverted U-shaped relationship.

Differentiating the efficiency equation with respect to *GD* yields an optimal threshold (*GD**):

$$\text{Optimal } GD = -\frac{\beta_{GD}}{2 \times \beta_{GDSQ}} = -\frac{0.003}{2 \times (-0.0001518)} \approx 9.88\%$$

Across alternative specifications, the implied optimal threshold remains stable at 9.88%-13.18%. In practice, this range of percentages translates to one (1) female director on a standard 9-to-11-member board, and one (1) to two (2) female directors on a 13-to-15-member board. These results suggest that appointing the first female director generates the largest marginal efficiency gain by overcoming tokenism, whereas representation beyond the 9.88%-13.18% threshold yields diminishing returns due to increased coordination costs among directors.

As shown in Table 6, replacing the female director ratio with the Blau index yields consistent results, further supporting the positive association between board gender diversity and cost efficiency.

As a result, H1 (board gender diversity is positively associated with bank efficiency) is supported.

4.2.2 Relationship between ESG performance on bank efficiency

Table 5 and Table 6 also present the relationship between each of the environmental, social, and governance performance pillars and bank efficiency. The results are described below.

As presented in Table 5, Models (3) through (8) reveal that the environmental pillar (*E*) is significantly and positively associated with bank cost efficiency. This result suggests that banks actively pursuing green operations, sustainable finance, and climate change mitigation tend to achieve higher cost efficiency. Furthermore, the robust estimates in Table 6 reconfirm this consistent positive relationship across alternative diversity specifications. Taken together, these empirical findings strongly support H2 (environmental performance is positively associated with bank efficiency).

Models (3) through (8) of Table 5 demonstrate that the social pillar (S) has a significantly negative association with bank cost efficiency, suggesting that banks' active engagement in social responsibility initiatives incurs additional operating costs that diminish efficiency. In Table 6, the social pillar (S) consistently exhibits a significantly negative association with bank cost efficiency, reaffirming that corporate social responsibility activities may impose immediate expenditure pressures with corresponding efficiency gains. Therefore, H3 (social performance is negatively associated with bank efficiency) is supported.

In Table 5, the governance pillar (G) displays an insignificant association with bank cost efficiency. In Table 6, under the Blau index specification, governance similarly shows a null effect in simpler models, but exhibits a significantly negative association in extended specifications, suggesting

potential compliance burdens on banks. Therefore, H4 (governance performance is negatively associated with bank efficiency) is not supported.

Table 5 Results of the Bootstrap Truncated Regression: Gender diversity

EFF	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
GD	0.003***	0.004***		0.003***	0.003***	0.003***	0.003***	0.003***
	(3.59)	(3.61)		(3.43)	(3.16)	(2.65)	(3.18)	(2.90)
GDSQ		-0.000		-0.000	-0.000**	-0.000**	-0.000*	-0.000**
		(-0.97)		(-1.56)	(-2.35)	(-2.16)	(-1.93)	(-2.27)
E			0.003***	0.003***	0.003***	0.003***	0.002***	0.003***
			(5.70)	(5.81)	(5.96)	(6.04)	(5.70)	(5.73)
S			-0.001**	-0.001***	-0.001**	-0.001**	-0.001**	-0.001**
			(-2.31)	(-2.68)	(-2.44)	(-2.47)	(-2.54)	(-2.36)
G			0.000	0.000	0.000	0.000	0.000	0.000
			(0.68)	(0.30)	(0.53)	(0.77)	(0.67)	(0.79)
GD×E					0.000***			0.000
					(3.89)			(1.64)
GD×S						0.000***		0.000
						(3.50)		(0.45)
GD×G							0.000***	0.000**
							(4.06)	(2.53)
AUDIT	0.081***	0.079***	0.087***	0.075***	0.070***	0.071***	0.065***	0.064***
	(3.39)	(3.31)	(3.67)	(3.32)	(3.04)	(3.10)	(2.90)	(2.78)
CPC	-0.034	-0.033	-0.056**	-0.054**	-0.053**	-0.057**	-0.046**	-0.048**
	(-1.43)	(-1.39)	(-2.33)	(-2.31)	(-2.23)	(-2.39)	(-2.01)	(-2.08)
IDB	-0.004***	-0.004***	-0.004***	-0.004***	-0.004***	-0.004***	-0.004***	-0.004***
	(-8.56)	(-8.90)	(-7.81)	(-6.84)	(-7.07)	(-6.78)	(-6.97)	(-6.80)
BM	-0.006***	-0.006***	-0.006***	-0.006***	-0.007***	-0.006***	-0.006***	-0.007***
	(-5.56)	(-5.41)	(-6.07)	(-5.45)	(-6.02)	(-5.75)	(-5.62)	(-6.14)
CAR	0.006*	0.006*	0.005	0.007*	0.006	0.005	0.007**	0.006*
	(1.65)	(1.76)	(1.35)	(1.85)	(1.63)	(1.29)	(2.09)	(1.76)
CIR	-0.005***	-0.005***	-0.006***	-0.006***	-0.006***	-0.006***	-0.006***	-0.006***
	(-7.31)	(-7.72)	(-8.44)	(-7.98)	(-8.20)	(-8.45)	(-7.80)	(-7.80)
SCALE	0.069***	0.068***	0.056***	0.058***	0.057***	0.057***	0.058***	0.057***
	(9.86)	(10.05)	(8.15)	(8.46)	(8.38)	(8.10)	(8.48)	(8.58)
DE	-0.315***	-0.319***	-0.283***	-0.307***	-0.305***	-0.303***	-0.304***	-0.303***
	(-13.63)	(-13.77)	(-13.66)	(-13.64)	(-13.47)	(-13.59)	(-13.79)	(-13.55)
_cons	0.355***	0.369***	0.552***	0.520***	0.551***	0.562***	0.497***	0.529***
	(3.40)	(3.54)	(5.03)	(4.59)	(5.04)	(4.99)	(4.57)	(4.77)
sigma	0.199***	0.199***	0.196***	0.194***	0.192***	0.193***	0.192***	0.191***
	(30.31)	(31.06)	(30.22)	(30.48)	(30.95)	(31.07)	(31.00)	(31.08)
N	907	907	907	907	907	907	907	907

*Note: ***1% significance level, **5% significance level, and *10% significance level.*

Table 6. Results of the Bootstrap Truncated Regression: Blau Index

EFF	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Blau	0.239***	0.281	0.371**	0.404**	0.365**	0.375**	0.398**
	(3.82)	(1.48)	(2.00)	(2.18)	(1.98)	(2.06)	(2.14)
Blau_SQ		-0.100	-0.390	-0.528	-0.481	-0.468	-0.524
		(-0.24)	(-0.93)	(-1.25)	(-1.16)	(-1.16)	(-1.26)
E			0.003***	0.001	0.003***	0.003***	0.001*
			(5.87)	(1.61)	(5.94)	(5.73)	(1.83)
S			-0.001***	-0.001**	-0.003***	-0.001**	-0.001
			(-2.68)	(-2.37)	(-3.64)	(-2.57)	(-1.06)
G			0.000	0.000	0.000	-0.002***	-0.001**
			(0.32)	(0.48)	(0.61)	(-2.81)	(-2.07)
Blau×E				0.008***			0.006*
				(3.38)			(1.76)
Blau×S					0.007**		-0.002
					(2.52)		(-0.49)
Blau×G						0.011***	0.009***
						(4.07)	(3.04)
AUDIT	0.079***	0.078***	0.074***	0.071***	0.073***	0.065***	0.065***
	(3.35)	(3.27)	(3.12)	(3.01)	(3.14)	(2.79)	(2.85)
CPC	-0.034	-0.033	-0.054**	-0.054**	-0.057**	-0.046*	-0.046**
	(-1.40)	(-1.42)	(-2.19)	(-2.27)	(-2.41)	(-1.91)	(-1.96)
IDB	-0.004***	-0.004***	-0.004***	-0.004***	-0.004***	-0.004***	-0.004***
	(-8.54)	(-8.68)	(-7.30)	(-7.06)	(-7.06)	(-6.78)	(-6.73)
BM	-0.006***	-0.006***	-0.006***	-0.006***	-0.006***	-0.006***	-0.006***
	(-5.54)	(-5.53)	(-5.48)	(-5.86)	(-5.73)	(-5.56)	(-5.89)
CAR	0.006*	0.006*	0.007*	0.006*	0.005	0.007**	0.007*
	(1.73)	(1.71)	(1.88)	(1.67)	(1.52)	(2.01)	(1.94)
CIR	-0.005***	-0.005***	-0.006***	-0.006***	-0.006***	-0.006***	-0.006***
	(-7.47)	(-7.39)	(-8.11)	(-8.00)	(-8.38)	(-7.77)	(-7.83)
SCALE	0.069***	0.068***	0.058***	0.057***	0.057***	0.057***	0.056***
	(10.12)	(9.85)	(8.48)	(8.32)	(8.07)	(8.35)	(8.19)
DE	-0.318***	-0.319***	-0.306***	-0.307***	-0.305***	-0.303***	-0.305***
	(-14.31)	(-14.09)	(-13.91)	(-13.67)	(-13.77)	(-13.77)	(-13.74)
_cons	0.313***	0.313***	0.460***	0.486***	0.494***	0.449***	0.460***
	(2.97)	(2.94)	(4.14)	(4.37)	(4.38)	(4.07)	(4.07)
/sigma	0.199***	0.199***	0.194***	0.193***	0.193***	0.192***	0.192***
	(30.93)	(29.26)	(30.98)	(30.51)	(30.15)	(30.73)	(30.87)
N	907	907	907	907	907	907	907
R^2							

*Note: ***1% significance level, **5% significance level, and *10% significance level.*

4.2.3 Relationship between interaction of board gender diversity and ESG performance, and bank efficiency

We further test the impact of ESG performance on bank efficiency with board gender diversity playing the moderating role. The results of the interactive influence are discussed separately below.

Regarding the interaction between environmental performance and board gender diversity, Model (4) in Tables 5 and 6 show that the coefficient of $GD \times E$ is significantly positive. This outcome suggests that banks with a higher proportion of female directors are associated with more involvements in environmental protection and climate change initiatives. Therefore, H5 (the interaction of board gender diversity and environmental performance is positively associated with bank efficiency) is supported.

Regarding the interaction between social performance and board gender diversity, Model (5) in Tables 5 and 6 shows that the coefficient of $GD \times S$ is significantly positive. Notably, while the main effect of the social pillar (S) remains significantly negative across all models, the positive interaction term demonstrates a clear mitigation effect. The significantly positive $GD \times S$ indicates that banks with a higher proportion of female directors are correlated with efficiency gain from social activities. Therefore, H6 (the interaction of board gender diversity and social performance is positively associated with bank efficiency) is supported.

Regarding the interaction between corporate governance and board gender diversity, Model (7) in Table 5 shows a significantly positive coefficient for $GD \times G$. More crucially, this interaction remains significant even in the full specification (Model 8), which includes all interaction terms, exhibiting strong robustness. By contrast, the main association of the governance pillar (G) is insignificant in Models (1) through (8) of Table 5. In Model (6) of Table 6, the main association of G even turns significantly negative. In contrast, the interaction term remains positive. These findings suggest that banks with more female directors are associated with higher efficiency with sound governance practices. Therefore, H7 (the interaction of board gender diversity and governance performance is positively associated with bank efficiency) is supported.

Figure 1. Marginal Effect of Board Diversity across Environmental Levels

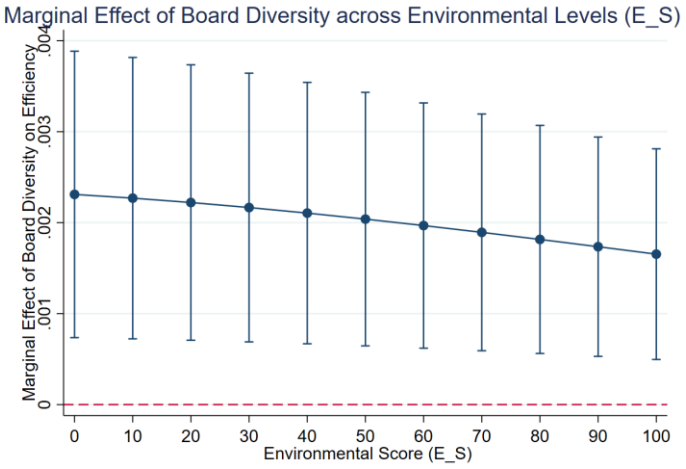


Figure 2. Marginal Effect of Board Diversity across Social Levels

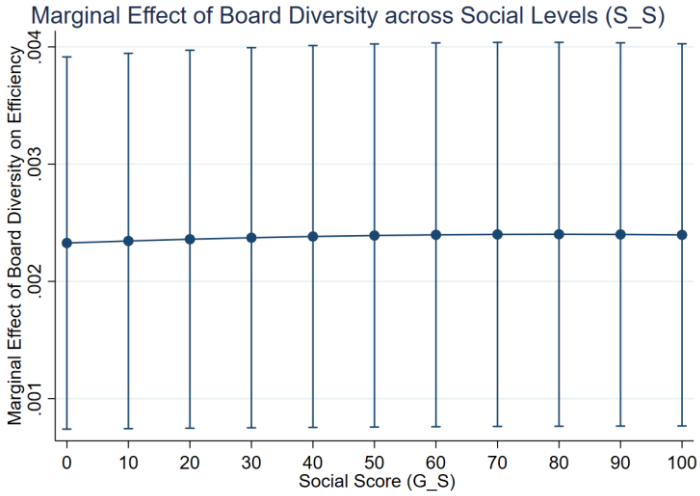
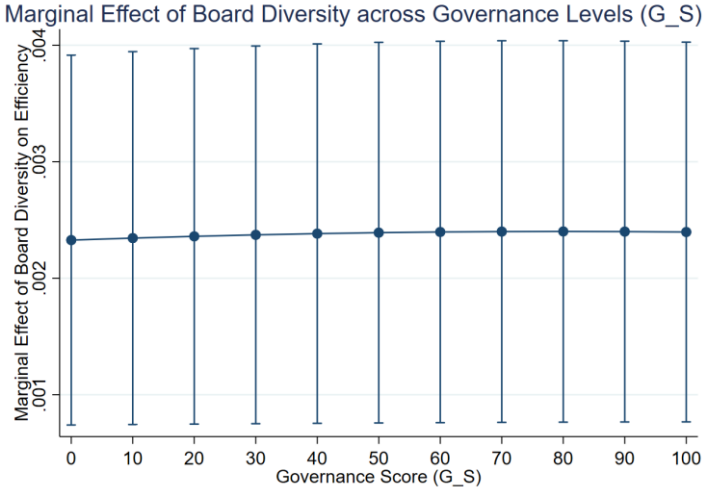


Figure 3. Marginal Effect of Board Diversity across Governance Levels



As shown in Figures 1, 2, and 3, regarding the environmental pillar (E_S), the marginal effect of board gender diversity on bank efficiency remains consistently positive and significant across the entire spectrum of environmental performance, with its magnitude further intensifying as environmental commitment increases. In contrast, for both the governance (G_S) and social (S_S) pillars, board gender diversity yields a remarkably stable and significantly positive marginal benefit on bank efficiency, regardless of the underlying levels of corporate governance or social responsibility.

4.2.4 Bank-specific control variables.

We examine the effects of other corporate governance and bank-specific control variables on bank efficiency based on Tables 5 and 6.

Regarding the control variables, the results remain highly consistent and robust across all specifications. Specifically, the audit committee and bank size exhibit significantly positive impacts on bank efficiency at the 1% level. Conversely, independent director, board meeting, cost-to-income ratio, and the developed/emerging market indicator are significantly and negatively associated with bank efficiency across all models ($p < 0.01$). The compensation committee also shows a significantly negative effect in most specifications (Models 3 to 8). Finally, the Capital Adequacy Ratio displays a positive but somewhat inconsistent relationship, showing only marginal or no significance depending on the model.

4.3 Implication

The findings of this paper yield three implications derived from the relationships among board gender diversity, ESG performance, their interactions, and other corporate governance and bank-specific control variables, respectively.

First, the test results of H1 suggest that banks with more gender-diverse boards tend to exhibit higher efficiency.

This outcome supports the predictions of agency theory, which posits that greater board diversity enhances corporate governance, thereby alleviating principal-agent conflicts (Birindelli *et al*., 2019; Delgado-Piña, *et al*., 2020). Furthermore, these empirical results are also consistent with the findings of Andries *et al*. (2024), who argued that greater female representation on boards is positively associated with both cost and technical efficiency in banks across Central and Eastern Europe.

Similarly, the empirical evidence aligns with the critical mass theory, which states that a minimum threshold of female representation is required to influence board decisions. In our study, the optimal threshold for female representation (9.88%-13.18%) falls below the 13% to 17% range stated by Owen & Temesvary (2018), and is well below the 20% 20% proposed by Kanter (1977).

This study identifies the marginal effect on bank efficiency. Appointing the first female director generates the largest marginal efficiency gain by overcoming tokenism described by Kanter (1977). However, when the number of female directors increases beyond the threshold point, the association with efficiency diminishes.

Our findings diverge from that of Adams and Ferreira (2009). The findings of this study suggest that female directors in Asian bank probably engage more actively in board matters than traditionally anticipated, providing more oversight that correlates with higher bank efficiency (Delgado-Piña *et al*., 2020; Kirsch, 2018; Owen and Temesvary, 2018).

Second, the test results of H2, H3, and H4 reveal mixed results. Environmental performance is positively related to bank efficiency. This result aligns with prior research indicating that environment efforts tend to strengthen firm value and performance (Qureshi *et al*., Rooh *et al*., 2021, Shakil *et al*., 2019). Our findings imply that banks that engage in internal carbon dioxide reduction and offering green loans tend to mitigate environmental compliance costs without lowering income-generating abilities. Therefore, these banks appear to exhibit higher efficiency.

Social performance is negatively associated with bank efficiency. This result aligns with previous findings indicating a weak or insignificant link between social activities and firm performance (Buallay *et al*., 2020; López-Penabad *et al*., 2022; Wasiuzzaman and Wan Mohammad, 2020). This outcome is likely attributable to the condition that social initiatives require substantial costs but do not lead to immediate financial benefits (Forgione *et al*., 2020; Manta *et al*., 2020).

Governance performance is positively related to bank efficiency but insignificantly. This result corresponds with prior studies indicating an insignificant influence of corporate governance on firm performance (El Khoury *et al*., 2021; Wasiuzzaman and Wan Mohammad, 2020) This finding suggests that compliance with corporate governance requirements represent primarily internal adjustments rather than external events designed to appeal to clients. Furthermore, this phenomenon occurs probably because Asian banks are still in the early stages of enforcing corporate governance standards. Consequently, outward public effects and favorable performance outcomes would not materialize until later stage.

Third, the findings of this study reveal that the interaction between board gender diversity and each ESG performance pillar is significantly and positively associated with bank efficiency. Such results correspond to the literature indicating that greater female representation on corporate boards positively influence firm performance through greater monitoring (Andries *et al*., 2024; Kirsch, 2018). Moreover, women can bring their concerns to the boardroom, thereby enhancing transparency regarding environmental and social issues (Lavin and Montecinos-Pearce, 2021; Wasiuzzaman and Wan Mohammad, 2020). Female directors can help alleviate the negative effects associated with social issues, such as labor and community service challenges (Alazzani *et al*., 2017). Furthermore, the presence of female directors on the board better prepares firms to implement ESG programs, which may ultimately relate banks to higher efficiency (Giannarakis *et al*., 2014; Kyaw *et al*., 2017).

The findings of this study lead to the following recommendations. Leaders of financial institutions are encouraged to view the participation of female members on boards favorably. Although the implementation of ESG practices alone within the banking sector is unlikely to be related to higher cost efficiency immediately, board gender diversity could serve as a complementary strategy to amplify the benefits of ESG. Ultimately, a positive association with bank cost efficiency could perhaps be seen. Moreover, banks that align board gender diversity with ESG activities with proper disclosure on annual reports may also appeal to investors who prefer financial institutions engaged in ESG enveadors (Thaker *et al*., 2022).

5. Robustness Test

We check the robustness of the results using the IV Tobit models to address endogeneity issues.

5.1 Board Gender Diversity and Efficiency

The linear effect of board gender diversity (GD) on bank efficiency is significantly positive. Both methods used in this study, the Simar-Wilson bootstrap-based truncated- regression procedure and the IV Tobit model, show identical result, with the IV Tobit specifications yielding greater significance. The consistency of the results suggests that the positive association between female board representation and efficiency is not a matter of endogeneity bias, but rather a genuine relationship that persists even after accounting for potential biases such as reverse causality, simultaneity, and omitted-variable concerns.

The squared term for gender diversity (GDSQ), which tests whether the relationship is curvilinear rather than linear, is where the two models differ most. As shown in the baseline Simar-Wilson's bootstrap-based truncated regression model, the negative association only becomes apparent once all control variables are added, and even then, the association remains moderate. In contrast, the IV Tobit specifications show a stronger and more consistent negative effect across different specifications. These results indicate that once potential biases are addressed, the IV Tobit model reveals that an initial increase in female directors is associated with higher efficiency. However, when the number of female directors continue to rise, this positive association eventually ceases and moves toward a negative relationship. This phenomenon suggests that earlier estimates from the Simar-Wilson's regression procedure may have understated the non-

linear link between gender diversity and efficiency. Overall, the inverted U-shaped relationship is more robust once endogeneity is accounted for.

5.2 Blau Index and Efficiency

Both the Simar-Wilson bootstrap truncated regression and the IV Tobit model show a significantly positive link between board gender diversity and bank efficiency, confirming that the result is not an artifact of endogeneity bias. The two models differ more when the non-linear effect is tested: the squared term for gender diversity (GD^2) is stronger and more consistent in the IV Tobit model than in the Simar-Wilson model. This outcome signals that once endogeneity is properly controlled, the evidence for an inverted U-shaped relationship with the threshold point becomes clearer. However, the shape of this relationship depends how the relationship is measured. When using the Blau heterogeneity index, the squared term remains insignificant, indicating a straight, positive relationship rather than a curved one. Blau gender diversity sows a steady positive association with cost efficiency without the threshold effect seen in other models.

5.3 ESG Performance and Efficiency

The environmental performance dimension (E) is the most robust variable in the entire analysis, remaining significantly positive across virtually all specifications and under both estimation methods, indicating that its association with efficiency is unlikely to be driven by endogeneity.

The social performance dimension (S) is significantly negative under both methods, but the magnitude and precision of the estimated effect increase markedly under the IV Tobit model relative to the Simar-Wilson model. This pattern suggests that the adverse association between social performance and efficiency may be underestimated when endogeneity is left unaddressed.

The governance performance dimension (G) behaves differently depending on the diversity measure used in the model. The result is insignificant in the GD-based specifications under both methods, but turns significantly negative in the Blau-based specifications once the interaction terms are included, with this pattern holding consistently in both estimation approaches.

5.4 Interaction Effects and Efficiency

The interaction between board gender diversity and environmental performance is significant under the Simar-Wilson model but loses significance once endogeneity is corrected via the IV Tobit model, indicating that this moderating effect is sensitive to the choice of model and may not be robust. The interaction between gender diversity and social performance remains significant under both methods, although this significance is moderately attenuated in the IV Tobit model. The interaction between gender diversity and governance performance is the most robust moderating effect identified in the analysis, remaining highly significant under both estimation approaches and, notably, growing stronger after accounting for endogeneity.

The corresponding interactions using the Blau index show a broadly similar pattern for the governance pillar, where the diversity-governance interaction remains robustly significant, and its effect size increases under the IV Tobit model. However, the Blau-based interactions with environmental and social performance are considerably less robust: the environmental interaction loses significance after endogeneity correction, and the social interaction is insignificant under both methods.

Table 7. Results of the IV Tobit Regression: Gender diversity

EFF2	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
GD	0.003***	0.004***		0.004***	0.004***	0.003***	0.004***	0.003***
	(3.93)	(4.41)		(4.66)	(4.38)	(3.70)	(3.99)	(3.81)
GDSQ		-0.000		-0.000**	-0.000**	-0.000***	-0.000***	-0.000**
		(-1.63)		(-2.27)	(-2.50)	(-3.07)	(-2.76)	(-2.36)
E			0.003***	0.003***	0.003***	0.003***	0.003***	0.002***
			(5.83)	(6.01)	(5.97)	(5.91)	(5.52)	(5.42)
S			-0.003***	-0.003***	-0.003***	-0.003***	-0.003***	-0.003***
			(-4.36)	(-4.77)	(-4.71)	(-4.69)	(-4.31)	(-4.36)
G			0.001	0.000	0.001	0.001	0.001	0.001
			(1.41)	(0.90)	(1.03)	(1.29)	(1.23)	(1.30)
GD×E					0.000			-0.000
					(1.36)			(-1.37)
GD×S						0.000**		0.000
						(2.43)		(0.64)
GD×G							0.000***	0.000***
							(4.44)	(3.46)
AUDIT	0.032*	0.027	0.046**	0.032	0.030	0.029	0.022	0.024
	(1.69)	(1.46)	(2.33)	(1.64)	(1.54)	(1.47)	(1.18)	(1.26)
CPC	-0.025	-0.024	-0.045**	-0.043**	-0.043**	-0.045**	-0.033*	-0.033*
	(-1.33)	(-1.25)	(-2.22)	(-2.17)	(-2.18)	(-2.24)	(-1.70)	(-1.65)
IDB	-0.004***	-0.004***	-0.004***	-0.003***	-0.003***	-0.003***	-0.003***	-0.003***
	(-11.73)	(-11.47)	(-8.38)	(-7.37)	(-7.31)	(-7.02)	(-7.06)	(-6.90)
BM	-0.005***	-0.005***	-0.005***	-0.004***	-0.004***	-0.004***	-0.004***	-0.004***
	(-6.14)	(-5.05)	(-5.56)	(-4.59)	(-4.96)	(-4.78)	(-4.71)	(-4.31)
CAR	0.017***	0.017***	0.016***	0.018***	0.017***	0.017***	0.018***	0.018***
	(4.82)	(4.93)	(4.53)	(5.19)	(5.10)	(4.86)	(5.42)	(5.40)
CIR	-0.003***	-0.003***	-0.004***	-0.004***	-0.004***	-0.004***	-0.003***	-0.004***
	(-5.40)	(-5.52)	(-6.79)	(-6.25)	(-6.25)	(-6.58)	(-6.10)	(-6.17)
SCALE	0.048***	0.047***	0.036***	0.037***	0.037***	0.037***	0.038***	0.038***
	(7.87)	(7.67)	(5.31)	(5.42)	(5.36)	(5.46)	(5.64)	(5.85)
DE	-0.263***	-0.270***	-0.228***	-0.254***	-0.252***	-0.251***	-0.251***	-0.252***
	(-15.65)	(-15.37)	(-13.57)	(-14.23)	(-14.06)	(-13.90)	(-14.23)	(-14.30)
_cons	0.399***	0.423***	0.556***	0.526***	0.535***	0.544***	0.497***	0.486***
	(4.29)	(4.53)	(5.22)	(4.82)	(4.89)	(5.00)	(4.64)	(4.64)
N	940	940	940	940	940	940	940	940

*Note: ***1% significance level, **5% significance level, and *10% significance level.*

Table 8. Results of the IV Tobit Regression: Blau Index

EFF2	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Blau	0.242***	0.301*	0.395**	0.400**	0.399**	0.381**	0.344**
	(4.29)	(1.68)	(2.28)	(2.30)	(2.34)	(2.27)	(2.00)
Blau_SQ		-0.139	-0.374	-0.396	-0.461	-0.461	-0.304
		(-0.33)	(-0.90)	(-0.93)	(-1.14)	(-1.11)	(-0.72)
E			0.003***	0.003***	0.003***	0.002***	0.004***
			(5.97)	(4.45)	(5.90)	(5.48)	(4.99)
S			-0.003***	-0.003***	-0.004***	-0.003***	-0.002**
			(-4.79)	(-4.77)	(-4.94)	(-4.42)	(-2.41)
G			0.000	0.000	0.001	-0.002***	-0.003***
			(0.92)	(0.96)	(1.16)	(-3.58)	(-3.92)
Blau×E				0.001			-0.006*
				(0.38)			(-1.74)
Blau×S					0.004		-0.001
					(1.62)		(-0.16)
Blau×G						0.014***	0.018***
						(5.16)	(4.42)
AUDIT	0.029	0.028	0.032	0.031	0.031	0.025	0.026
	(1.55)	(1.48)	(1.61)	(1.60)	(1.55)	(1.31)	(1.39)
CPC	-0.025	-0.024	-0.042**	-0.043**	-0.044**	-0.033*	-0.029
	(-1.30)	(-1.26)	(-2.14)	(-2.14)	(-2.20)	(-1.68)	(-1.44)
IDB	-0.004***	-0.004***	-0.003***	-0.003***	-0.003***	-0.003***	-0.003***
	(-11.60)	(-11.05)	(-7.30)	(-7.26)	(-7.04)	(-6.94)	(-7.01)
BM	-0.005***	-0.005***	-0.005***	-0.005***	-0.005***	-0.005***	-0.004***
	(-5.59)	(-5.53)	(-5.29)	(-5.39)	(-5.42)	(-5.47)	(-4.93)
CAR	0.017***	0.017***	0.018***	0.018***	0.017***	0.018***	0.018***
	(4.89)	(4.91)	(5.20)	(5.16)	(4.97)	(5.33)	(5.50)
CIR	-0.003***	-0.003***	-0.004***	-0.004***	-0.004***	-0.003***	-0.003***
	(-5.45)	(-5.47)	(-6.18)	(-6.17)	(-6.38)	(-6.12)	(-5.86)
SCALE	0.048***	0.047***	0.038***	0.038***	0.038***	0.037***	0.038***
	(7.81)	(7.68)	(5.44)	(5.43)	(5.49)	(5.55)	(5.71)
DE	-0.267***	-0.268***	-0.251***	-0.251***	-0.250***	-0.248***	-0.249***
	(-15.64)	(-15.56)	(-14.27)	(-14.23)	(-14.06)	(-14.24)	(-14.48)
_cons	0.358***	0.358***	0.450***	0.452***	0.461***	0.435***	0.413***
	(3.80)	(3.80)	(4.10)	(4.11)	(4.18)	(4.06)	(3.91)
N	940	940	940	940	940	940	940

6. Conclusions

This study examines the associations among board gender diversity, ESG performance, bank cost efficiency, and their interactive terms. Using a two-stage DEA methodology with the bootstrap based truncated regression procedure (Simar and Wilson, 2007) and the IV Tobit model, we analyze data from 94 Asian banks spanning the period from 2010 to 2020.

The findings of the study indicate a positive association between board gender diversity and bank efficiency. However, this association is non-linear and exhibits an inverted U-shaped pattern with diminishing returns. Specifically, the optimal threshold identified in this study is approximately 10% to 13% female representation on bank boards.

The association between individual ESG performance pillars and bank efficiency shows mixed results. Environmental performance shows a positive association with bank efficiency. In contrast, social performance exhibits a negative association with bank efficiency, and governance performance reveals an insignificant relationship.

However, the interactions between board gender diversity and all three ESG performance pillars are positively correlated with bank cost efficiency.

Overall, the results of this study align with agency theory (Jensen and Meckling, 1976) and critical mass theory (Kanter, 1977), suggesting that a certain number of female directors may positively influence firm performance. Furthermore, the findings imply that inclusive boards tend to be better positioned to implement ESG practices, which may ultimately relate firms to higher efficiency.

Based on these findings, financial institution leaders and policymakers are recommended to adopt a favorable perspective on board gender diversity. While ESG requirements have become more prevalent within the banking sector, board gender diversity may function as a complementary strategy associated with the potential enhancement of both ESG performance and cost efficiency across firms. Furthermore, banks that align and transparently disclose board gender diversity in conjunction with ESG practices in their corporate reports tend to attract investors who favor institutions committed to ESG practices.

This study is limited to a sample of 94 Asian banks covering the years from 2010 to 2020. Future research could expand the dataset to include more banks and countries, and apply methods such as dynamic panel GMM or quasi-experimental designs to identify cause-and-effect relationships. In addition, future researchers might also consider using alternative measures, such as the Blau index, to provide additional perspective.

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