APTISI Transactions on Technopreneurship (ATT)
Vol. 8, No. 1, March 2026, pp. 351−364
E-ISSN: 2656-8888 | P-ISSN: 2655-8807, DOI:10.34306

Integrating Green Banking into Sustainable Development Strategies for Commercial Bank Efficiency

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Article Info

Article history:

Submission June 09, 2025
Revised August 06, 2025
Accepted December 24, 2025
Published February 20, 2026

Keywords:

Digital Banking
Sustainable Business
Green Banking
Efficiency
Foreign Ownership

ABSTRACT

Digital banking is rapidly transforming commercial bank operations by improving efficiency, service quality, and sustainability orientation. Banks face increasing pressure to balance financial performance with environmental and social responsibility. In Indonesia, this transformation is closely linked to Green Banking (GB) practices and operational efficiency to support sustainable business performance. **This study examines the effect** of digital banking on the sustainable business performance of Indonesian commercial banks and investigates the mediating roles of GB and efficiency, as well as the moderating role of foreign ownership. **The population** includes all KBMI 3 and 4 banks, totaling 13 commercial banks. A saturated sampling technique was used, and the data were analyzed using EViews 12. **Digital banking significantly** enhances sustainable business performance and promotes GB and efficiency. GB positively affects sustainability and mediates the digital banking sustainability relationship. Efficiency (measured by BOPO) improves sustainability but does not mediate the effect. Foreign ownership does not moderate the relationship. **Digital banking contributes** to sustainability mainly through strengthening GB rather than efficiency alone. The absence of mediation by efficiency and moderation by foreign ownership represents an important boundary condition and a key contribution of this study.

DOI: https://doi.org/10.34306/att.v8i1.759

1. INTRODUCTION

Sustainable business has become a central issue in the global business environment, as organizations are increasingly required to balance economic performance with social equity and environmental preservation [1]. The intensification of global challenges such as climate change, environmental degradation, and social inequality has shifted corporate priorities from short-term profit maximization toward long-term value creation. This shift is closely aligned with the United Nations Sustainable Development Goals (SDGs), particularly SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 13 (Climate Action), which encourage businesses to integrate sustainability into their core strategies. Consequently,

the integration of Environmental, Social, and Governance (ESG) principles into corporate strategies and operational decision-making has become essential for ensuring long-term organizational resilience and legitimacy.

In the banking sector, sustainability holds a particularly strategic role because banks act as key financial intermediaries that influence investment flows, industrial development, and economic stability. As a result, banks are expected not only to maintain sound financial performance but also to support sustainable development by financing responsible business activities and promoting inclusive economic growth [2]. In line with SDG 10 (Reduced Inequalities) and SDG 17 (Partnerships for the Goals), banks are encouraged to facilitate financial inclusion and support sectors that contribute to social welfare and environmental protection. Thus, the role of banks extends beyond profit generation toward fostering a financial system that supports sustainable and equitable development.

In the Indonesian banking sector, sustainability initiatives are increasingly influenced by rapid digital transformation and the growing adoption of GB practices. Digital banking enables banks to deliver financial services through digital platforms such as mobile banking, internet banking, and automated systems, which significantly improve operational efficiency, service accessibility, and customer experience [3]. These technological advancements reduce transaction costs, minimize operational errors, and expand financial inclusion, particularly for underserved communities, supporting SDG 9 and SDG 10. Moreover, digitalization contributes to environmental sustainability by reducing paper consumption, lowering energy use, and decreasing reliance on physical branch infrastructure. These environmental benefits are strengthened through GB practices, which encourage environmentally responsible lending, integrate environmental risk assessments into credit decisions, and support financing for sustainable and green projects, directly supporting SDG 12 (Responsible Consumption and Production) and SDG 13.

Operational efficiency remains a fundamental component of banking sustainability, as it reflects a bank's ability to manage resources effectively while maintaining competitiveness and resilience in a highly regulated and dynamic environment [4]. Efficiency improvements driven by digital transformation can enhance profitability and cost control, thereby strengthening financial performance. However, efficiency gains do not inherently lead to better sustainability outcomes. When efficiency strategies are narrowly focused on short-term cost reduction, they may limit investments in social responsibility, environmental initiatives, and human capital development [5]. Consequently, efficiency may generate conflicting effects on sustainable business performance, underscoring the importance of examining its role not only as an outcome of digital banking but also as a potential mediating mechanism that shapes sustainability outcomes in support of the SDGs.

2. LITERATURE REVIEW

2.1. Sustainable Business

The term "sustainable business" describes an organization that conducts its operations in a way that is socially just, ecologically conscious, and financially feasible to maintain long-term viability while reducing adverse effects on the environment and society. The idea is based on the Triple Bottom Line (TBL), which emphasizes the need to balance social equality, economic prosperity, and environmental sustainability. By adopting sustainable practices, businesses aim to meet present needs without endangering the ability of future generations to meet their own. This strategy facilitates long-term profitability and growth, enhances the company's reputation, and fosters innovation and operational effectiveness. Due to issues such as resource depletion, social injustice, and climate change, sustainable business practices are becoming increasingly important [6]. A bank's sustainable operations can be assessed using three metrics, namely economic, social, and environmental performance.

2.2. Digital Banking

Digital banking refers to the utilization, comprehensive financial transaction process started by clients. It aims to maximize utility for customers in terms of accessibility, usability, and cost-efficiency, while also benefiting banks by reducing operational costs, minimizing errors, and enhancing service quality [7]. Moreover, digital banking denotes an institution's ability to leverage digital technology to enhance the efficiency and efficacy of internal operations and external market offerings. It also fosters creativity that surpasses organizational boundaries and assimilates into broader innovation networks [8]. The assessment of digital banking is often founded on the development of a digital banking index, comprising 21 factors as suggested by [9]. These indicators collectively capture the extent of a bank's digital integration and its operational transformation through technology.

$$\text{Digital Banking (DB)} = \frac{\sum_{i=1}^{n} d_i}{N} \times 100\%$$

2.3. Green Banking

GB indicates banking methods that are ecologically responsible. These operations are executed via efforts like the reduction of paper consumption (paperless banking), the facilitation of online transactions such as bill payments to preserve energy, and the provision of loans to environmentally responsible or "green" enterprises [10]. GB signifies an effort that financial institutions might adopt to demonstrate their dedication to environmental conservation within the banking sector. The adoption of GB is believed to play a vital role in halting environmental degradation and in creating a more livable ecosystem [11]. GB is closely related to the concept of green business, which is a profitable model that offers economies of scale and sustainable returns, thereby contributing significantly to long-term business continuity. GB is thus regarded as both a smart business strategy and an environmentally friendly approach one of the most promising developments of the 21st century. The implementation of GB can be assessed through a set of 16 indicators that reflect a bank's disclosure and commitment to environmentally sustainable practices.

$$\text{Green Banking (GB)} = \frac{\sum_{i=1}^{n} d_i}{N} \times 100\%$$

2.4. Operational Efficiency

The concept of banking efficiency was first introduced by [10], who defined efficiency as comprising two main components: technical efficiency and allocative efficiency. These two dimensions are combined into what is referred to as economic efficiency. A firm is considered economically efficient when it is able to minimize production costs to produce a given level of output using prevailing technology and market prices [12]. In the Indonesian banking sector, Bank Indonesia Regulation No. 14/26/PBI/2012, Article [13], mandates that bank efficiency be assessed by the Operating Expenses to Operating Income (BOPO) ratio. This ratio is widely recognized as a key indicator of efficiency, as it reflects a bank's ability to manage its operating costs relative to its operating income. Operating expenses include all costs associated with banking operations, while operating income consists of earnings derived from core banking activities [14]. According to [15], the BOPO ratio is determined by dividing operating expenses by operating income for the same period. A lower BOPO ratio indicates higher efficiency, as it demonstrates superior cost control and profitability. Accordingly, this study uses the BOPO ratio as a proxy for operational efficiency. Efficiency (EF) is measured by BOPO (Operating Expenses/Operating Income). Lower BOPO values indicate higher efficiency; therefore, a negative coefficient on BOPO implies an improvement in efficiency, while a positive coefficient indicates deterioration.

$$\text{BOPO} = \frac{\text{Operating Expenses}}{\text{Operating Income}} \times 100\%$$

2.5. Foreign Ownership

Ownership structure in the banking sector tends to change with the entry of foreign investors. Foreign ownership in banks may occur through direct public investment or through strategic partnerships such as mergers, acquisitions, and joint ventures [16]. The Financial Services Authority Regulation of Indonesia (OJK Regulation No. 12/POJK.03/2021) permits foreign firms to possess up to 99% of shares in Indonesian commercial banks. The minimum foreign ownership threshold is established at IDR 10 billion (excluding land and building values), accompanied by a minimum paid-up capital requirement of IDR 2.5 billion to be deposited with Bank Indonesia. Foreign ownership denotes the percentage of a bank's total outstanding shares that are possessed or funded by foreign persons, legal companies, institutions, or governmental authorities from abroad. This ownership proportion may grant a certain degree of control or influence over the management and strategic direction of the bank. The proportion of foreign ownership may be determined using the method presented by [17]:

$$\text{Foreign Ownership (\%)} = \left(\frac{\text{Total Shares Owned by Foreign Investors}}{\text{Total Outstanding Shares of the Company}} \right) \times 100\%$$

2.6. The Effect of Digital Banking on Sustainable Business

Technological advancements have compelled the banking sector to innovate and adapt. Currently, banking services are increasingly oriented toward digital banking, which leverages technology to enhance service delivery. [18] contend that innovation and technological advancement profoundly impact corporate sustainability. [19] similarly discovered that Industry 4.0 technologies significantly influence environmental sustainability. Based on these findings, the following hypothesis is proposed:
H1: Digital banking has a positive effect on sustainable business.

2.7. The Effect of Digital Banking on Green Banking

Digital banking may be seen as a variant of GB, and regulatory bodies like the Financial Services Authority (OJK) are anticipated to provide efficient incentive frameworks to motivate banks to embrace GB methodologies, including the integration of digital technology. [20] discovered that digital transformation in banks significantly enhances green credit practices in Chinese financial institutions. Based on this evidence, the following hypothesis is proposed:
H2: Digital banking has a positive effect on green banking.

2.8. The Effect of Digital Banking on Efficiency Performance

Digital transformation enhances corporate efficiency and positively impacts financial performance. The growth of digital transactions, the COVID-19 pandemic, and changes in consumption patterns have compelled banks to accelerate digitalization [21]. Digital services reduce operational costs and increase industry revenue. [13] found that digital banking significantly impacts operational cost efficiency in Bahraini banks. Therefore, the Hypothesis proposed is:
H3: Digital banking has a positive effect on efficiency performance.

2.9. The Effect of Green Banking on Sustainable Business

Disclosure of GB practices aims to enhance corporate legitimacy by addressing environmental concerns [22]. GB policies help banks minimize negative business impacts by assessing the environmental risks of financed activities [23]. GB is vital as a source for sustainable bank and environmental development. Hence, the hypothesis proposed is:
H4: Green banking has a positive effect on sustainable business.

2.10. The Effect of Efficiency Performance on Sustainable Business

Efficiency reduces operational costs, increases profits, and creates positive investor perceptions, which can improve firm value and sustainable business [24]. BOPO (Operational Costs to Operating Income ratio) influences firm value and bank sustainability in Indonesia. A lower BOPO indicates higher efficiency, which boosts profitability and supports sustainable business. Therefore, the hypothesis Proposed is:
H5: Higher BOPO (lower efficiency) reduces sustainable business; equivalently, greater efficiency (lower BOPO) is associated with higher sustainable business.

2.11. Green Banking Mediates the Effect of Digital Banking on Sustainable Business

GB integrates environmental management with banking operations to create a sustainable industry [25]. Digital transformation has shifted banking from conventional to fully digital operations to support sustainable business. [26] highlight that GB is an important source of sustainable development benefiting banks and the environment as a whole. Therefore, the hypothesis is:
H6: Green banking mediates the effect of digital banking on sustainable business.

2.12. Efficiency Performance Mediates the Effect of Digital Banking on Sustainable Business

Digital banking poses challenges and opportunities for Indonesian banks by potentially reducing operational costs and improving efficiency [27]. Efficiency reflects how well a bank controls its operational costs and increases operating income. Greater efficiency positively impacts sustainable business. [28] showed that efficiency mediates the effect of digital banking on sustainable business. Thus, the hypothesis is:
H7: Efficiency mediates the effect of digital banking on sustainable business.

2.13. Foreign Ownership Moderates the Effect of Digital Banking on Sustainable Business

Foreign-owned companies often prioritize enhancing business performance by superior management systems, innovation, technology, and knowledge, hence benefiting the organization. Foreign ownership is more likely to be involved in innovation and to bring the latest technologies into company operations [29]. Foreign shareholders often have better access to international funding and possess up-to-date technological knowledge and resources that enhance corporate performance. Foreign investors in Indonesian companies generally expect the company to undergo transformation and adopt current technologies to grow their investments. This aligns with previous studies indicating that foreign ownership favorably affects business performance. Based on these theories and prior studies, the hypothesis is:

H8: Foreign ownership moderates the effect of digital banking on sustainable business.

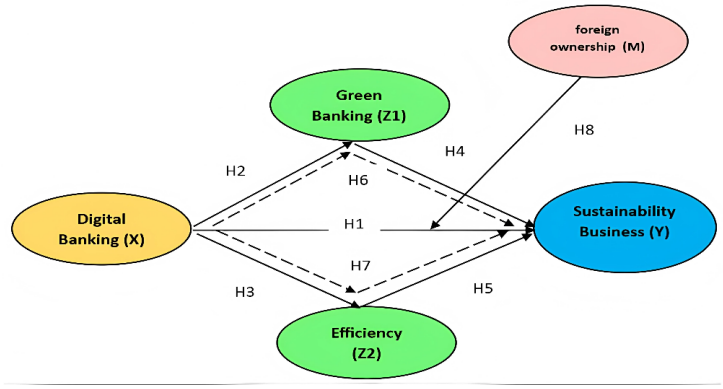

Figure 1. Conceptual Framework

Figure 1 presents the conceptual framework of this study, outlining the hypothesized relationships among digital banking, GB, efficiency, foreign ownership, and sustainable business performance. Digital banking is positioned as the primary explanatory variable that directly influences sustainable business and indirectly affects it through GB and efficiency as mediating mechanisms. Foreign ownership is incorporated as a moderating variable that may alter the strength of the relationship between digital banking and sustainable business. This framework provides a structured theoretical foundation for examining the direct, mediating, and moderating effects proposed in the study.

3. RESEARCH METHODOLOGY

3.1. Method of Data Collection

This study employs a quantitative research design and relies exclusively on secondary data obtained from Indonesian commercial banks' annual reports and audited financial statements. The data collection process is conducted through documentation and literature review techniques, which involve systematically gathering, classifying, recording, and analyzing published financial and non-financial information [30]. Annual reports are used as the primary data source because they contain comprehensive disclosures on banks' financial performance, corporate governance, sustainability initiatives, digital banking development, and operational efficiency. Using secondary data allows this study to ensure objectivity, consistency, and comparability across banks and across time, while also minimizing researcher bias. In addition, the documentation method enables the researcher to trace trends and patterns in banking practices related to digitalization and sustainability over the observation period.

The population of this study consists of all commercial banks classified under the Core Capital Bank Groups (KBMI) 3 and 4 that are listed on the Indonesia Stock Exchange during the 2018-2024 period, totaling 13 banks. A non-probability sampling approach is applied, as not every element of the population has an equal probability of being selected. However, given the relatively small and clearly defined population, this study adopts a saturated (census) sampling technique, in which all members of the population are included as the research sample. This approach is appropriate because KBMI 3 and 4 banks represent institutions with strong capital structures, systemic importance, and active involvement in digital transformation and sustainability-oriented practices. By including the entire population, the study ensures a comprehensive and representative

analysis of the relationships among digital banking, GB, efficiency, foreign ownership, and sustainable business performance in the Indonesian banking sector.

Table 1. Research Sample

No	Bank Code
1.	BBRI
2.	BMRI
3.	BBCA
4.	BBNI
5.	PNBN
6.	BDMN
7.	BNGA
8.	BTPN
9.	BNLI
10.	NISP
11.	BNII
12.	BBTN
13.	MEGA

Table 1 summarizes the research sample, which comprises 13 Indonesian commercial banks classified under the Core Capital Bank Group (KBMI) 3 and 4 and listed on the Indonesia Stock Exchange during the 2018-2024 period. The application of a saturated sampling technique ensures that the entire population is included, enabling a comprehensive analysis of banks with substantial capital strength and systemic relevance. These institutions represent banks that have actively implemented digital banking initiatives and sustainability-oriented practices, making them suitable for examining the relationships among digital banking, GB, efficiency, and sustainable business performance. Figure 1 illustrates the conceptual framework of the study by outlining the hypothesized relationships among the variables tested within this sample, thereby reinforcing the role of KBMI 3 and 4 banks as the empirical basis for hypothesis testing.

3.2. Data Analysis Method

This quantitative research tests the assumption using descriptive statistical analysis and multiple linear regression analysis of secondary data. The analysis used Eviews 12 statistical software.

3.3. Result and Discussion

The outcomes of the descriptive statistical analysis are presented in Table 2 below:

Table 2. Statistical Descriptive

Statistic	Y_BB	X_DB_SQRT	Z1_GB	Z2_EFFICIENCY	M_KSA
Mean	44.83670	94.71923	76.63538	78.14165	44.83670
Median	45.50000	95.12000	81.25000	80.10000	45.50000
Maximum	62.05000	100.0000	100.0000	98.12000	62.05000
Minimum	25.89000	75.59000	18.75000	46.50000	25.89000
Std. Dev.	9.078301	4.926988	19.56585	10.52518	9.078301
Skewness	-0.158829	-1.204759	-1.131535	-0.790110	-0.158829
Kurtosis	2.060080	5.172042	3.850520	3.330474	2.060080

Source: Processed Data 2025

Based on Table 2, the dataset consists of 91 observations from 13 KBMI 3 and 4 banks over the 2018-2024 period, with no missing data. The average sustainable business score is 44.83%, indicating moderate performance, while digital banking adoption is very high (94.71%) and supported by strong GB practices (76.63%). The average efficiency score of 78.14% suggests relatively low efficiency, and foreign ownership averages 44.83%, reflecting substantial but non-majority foreign investor participation.

3.4. Panel Data Regression Model Selection Test

Based on the findings of the Chow test, Hausman test, and Lagrange Multiplier test, the optimal panel data regression model for this study is the random effects model. The results of model selection are displayed in the subsequent Table 3:

Table 3. Panel Data Regression Model Selection Results

Test	Hypothesis	Result
Chow Test	Common Effect Model vs Fixed Effect Model	Fixed Effect Model
Hausman Test	Random Effect Model vs Fixed Effect Model	Random Effect Model
Lagrange Multiplier Test	Common Effect Model vs Random Effect Model	Random Effect Model

Source: Processed Data 2025

Based on Table 3, the Chow test results indicate that the fixed effects model is more appropriate than the common effects model, suggesting the presence of individual heterogeneity across banks. The Hausman test further confirms that the random effects model is preferable to the fixed effects model, indicating that individual effects are not correlated with the explanatory variables [31]. In addition, the Lagrange Multiplier test shows that the random effects model is superior to the common effects model. Taken together, these results consistently support the selection of the random effects model as the most appropriate panel data regression model for this study.

3.5. F-Test

To evaluate the combined effect of each independent variable in the regression model on the dependent variable, the F-test was used. The research model's F-test statistic is presented as follows in Table 4, 5, and 6:

Table 4. F-Test (1)

Weighted Statistics			
Mean dependent var	6.190330	R-squared	0.651143
S.D. dependent var	4.421136	Adjusted R-squared	0.634918
Sum squared resid	613.7014	S.E. of regression	2.671341
Durbin-Watson stat	1.285433	F-statistic	40.12991
Prob(F-statistic)			**0.000000**

Source: Processed Data 2025

Table 5. F-Test (2)

Weighted Statistics			
Mean dependent var	12.85428	R-squared	0.725554
S.D. dependent var	12.90356	Adjusted R-squared	0.722471
Sum squared resid	4112.618	S.E. of regression	6.797735
Durbin-Watson stat	0.889184	F-statistic	235.2899
Prob(F-statistic)			**0.000000**

Source: Processed Data 2025

Table 6. F-Test (3): Weighted Statistics

Statistic	Value	Statistic	Value
Mean dependent var	16.80804	R-squared	0.104631
S.D. dependent var	5.756937	Adjusted R-squared	0.094571
Sum squared resid	2670.715	S.E. of regression	5.477959
Durbin–Watson stat	1.375713	F-statistic	10.40035
		Prob (F-statistic)	**0.001763**

Source: Processed Data 2025

According to the F-test results presented in Tables 4, 5, and 6, all models show probability values below the 0.05 significance level. This indicates that the independent variables jointly have a statistically significant effect on the dependent variable in each estimated model [32]. These findings confirm that the proposed regression models are appropriate and that the explanatory variables, when considered simultaneously, provide meaningful explanatory power in explaining variations in the dependent variable [19].

3.6. Coefficient of Determination (R^2)

The effect of independent factors on the dependent variable is assessed by the coefficient of determination (R^2). If the independent factors have a significant impact on the dependent variable, it can be determined by computing the (R^2) value. If a research model's (R^2) score is greater than zero, it is considered to be effective [33]. Below in Table 7 is the research model's coefficient of determination:

Table 7. Results of Coefficient of Determination R^2 (1): Weighted Statistics

Statistic	Value	Statistic	Value
Mean dependent var	6.190330	R-squared	**0.651143**
S.D. dependent var	4.421136	Adjusted R-squared	0.634918
Sum squared resid	613.7014	S.E. of regression	2.671341
Durbin–Watson stat	1.285433	F-statistic	40.12991
		Prob (F-statistic)	**0.000000**

Source: Processed Data 2025

The coefficient of correlation for the sustainable business parameter in Table 8 is 0.6511. This indicates that 65.11% of the variance in sustainable business performance across KBMI 3 and 4 commercial banks is influenced by digital banking, GB, and efficiency. The remaining 34.89% is influenced by elements not elucidated or incorporated in this study model [34].

Table 8. Results of Coefficient of Determination R^2 (Weighted Statistics)

Statistic	Value	Statistic	Value
Mean dependent var	12.85428	R-squared	0.725554
S.D. dependent var	12.90356	Adjusted R-squared	0.722471
Sum squared resid	4112.618	S.E. of regression	6.797735
Durbin-Watson stat	0.889184	F-statistic	235.289
		Prob(F-statistic)	0.000000

Source: Processed Data 2025

The coefficient of determination for the GB variable is 0.7255. This signifies that 72.55% of the diversity in GB practices of KBMI 3 and 4 commercial banks is attributable to digital banking, whilst the remaining 27.45% is impacted by other factors not elucidated or incorporated in this study model in Table 9.

Table 9. Results of Coefficient of Determination R^2 (Weighted Statistics)

Statistic	Value	Statistic	Value
Mean dependent var	16.80804	R-squared	0.404631
S.D. dependent var	5.756937	Adjusted R-squared	0.394571
Sum squared resid	2670.715	S.E. of regression	5.477959
Durbin-Watson stat	1.375713	F-statistic	10.40035
		Prob(F-statistic)	0.001763

Source: Processed Data 2025

The coefficient of determination for the efficiency variable is 0.4046. This signifies that 40.46% of the variance in the efficiency of KBMI 3 and 4 commercial banks is attributable to digital banking, whilst the remaining 59.54% is impacted by other factors not elucidated or incorporated in this study model.

3.7. Hypothesis Test

The Individual Parameter Significance Test (t-test) is used to ascertain if each independent variable exerts a significant partial influence on the dependent variable [35]. The findings of the t-test, derived from the regression analysis employing the random effects model, are as follows in Table 10:

Table 10. Direct Effect Test (t-Statistic 1)

Variable	Coefficient	Std. Error	t-Statistic	Prob.	Result
C	-11.52049	10.64604	-1.082138	0.2822	not significant
DB → SB	0.265451	0.128924	2.058966	0.0425	significant
GB → SB	0.187848	0.043387	4.329627	0.0000	significant
EF → SB	-0.177717	0.053442	3.315445	0.0013	significant

Source: Processed Data 2025

The results of the t-test lead to the following conclusions:

- The t-test result for the digital banking variable on sustainable business indicates a probability value at a significance level of $\alpha = 5\%$ of 0.0425, which is less than 0.05, accompanied by a regression coefficient of 0.265451. It can be concluded that DB exerts a positive and significant influence on sustainable business practices. Consequently, the hypothesis in this study (H1) is accepted.
- The t-test result for the GB variable on sustainable business indicates a probability value at a significance level of $\alpha = 5\%$ of 0.0000, which is less than 0.05, accompanied by a regression coefficient of 0.187848. It can be concluded that GB exerts a positive and significant influence on sustainable business practices. Consequently, the hypothesis in this study (H4) is accepted.
- The t-test result for the efficiency variable on sustainable business indicates a probability value at a significance level of $\alpha = 5\%$ of 0.0013, which is less than 0.05, accompanied by a regression coefficient of -0.177717. It can be concluded that EF exerts a negative and significant impact on sustainable business. Consequently, the hypothesis in this study (H5) is accepted.

Table 11. Direct Effect Test (t-Statistic 2)

Variable	Coefficient	Std. Error	t-Statistic	Prob.	Result
C	-146.4744	15.23673	-9.613247	0.0000	significant
DB → GB	2.355486	0.154410	15.25473	0.0000	significant

Source: Processed Data 2025

Table 11 presents the results of the direct effect test examining the influence of digital banking (DB) on GB. The estimation results indicate that the probability (p-value) is 0.0000 at a significance level of $\alpha = 5\%$, which is well below the threshold of 0.05. This confirms that the relationship between digital banking and GB is statistically significant [36]. In addition, the regression coefficient of 2.355486 demonstrates a positive direction, implying that improvements in digital banking adoption substantially enhance GB practices. This finding suggests that digital banking initiatives such as paperless transactions, digital documentation, and online service delivery play a crucial role in strengthening banks' environmental commitment [37]. Therefore, the results provide strong empirical support for the acceptance of hypothesis H2, confirming that digital banking significantly and positively affects GB.

Table 12. Direct Effect Test (t-Statistic 3)

Variable	Coefficient	Std. Error	t-Statistic	Prob	Result
C	115.9015	12.04129	9.625341	0.0000	
DB → EFF	-0.398651	0.123945	-3.216350	0.0018	Significant

Source: Processed Data 2025

Table 12 reports the results of the direct effect test analyzing the impact of digital banking (DB) on efficiency (EFF). The findings show a probability value of 0.0018 at a significance level of $\alpha = 5\%$, which is lower

than 0.05, indicating that the effect is statistically significant. The regression coefficient is 0.398651, reflecting a negative relationship between digital banking and the efficiency variable measured by BOPO [38]. Since a lower BOPO value indicates higher efficiency, this negative coefficient implies that digital banking improves efficiency by reducing operational costs relative to operating income. These results indicate that increased digital banking adoption contributes to cost optimization and process automation within banks. Consequently, hypothesis H3 is accepted, confirming that digital banking has a significant effect on efficiency performance [39].

Table 13. Indirect Effect Test Results (Mediation)

Variable	**Z Sobel**	**Z Table (Z = 1.96)**	**Result**
DB (X) $\rightarrow$ GB (Z1) $\rightarrow$ SB (Y)	4.165085	$4.165085 > 1.96$	Mediate
DB (X) $\rightarrow$ EFF (Z2) $\rightarrow$ SB (Y)	-1.152886	$-1.152886 < 1.96$	Not Mediate

Source: Processed Data 2025

Table 13 presents the results of the indirect effect (mediation) test using the Sobel test. At a significance level of α = 5%, the findings show that GB mediates the relationship between DB and SB, as indicated by a Sobel Z value of 4.165085, which exceeds the critical value of 1.96. This result confirms that GB serves as a significant mediating variable, leading to the acceptance of hypothesis H6. In contrast, EF does not mediate the relationship between digital banking and sustainable business, as the Sobel Z value of -1.152886 is below 1.96. Therefore, hypothesis H7 is rejected.

- The indirect effect test of DB on SB through GB yielded a Sobel Z value of $4.165085 > 1.96$ (greater), indicating that GB mediates the influence of DB on SB. Therefore, the hypothesis in this study (H6) is accepted.
- The indirect effect test of DB on SB through efficiency resulted in a Sobel Z value of $-1.152886 < 1.96$ (smaller), indicating that EF does not mediate the influence of DB on SB. Therefore, the hypothesis in this study (H7) is rejected.

Table 14. Moderation Test

Variable	**Prob.**	**Result**
DB (X) $\rightarrow$ KSA (M) $\rightarrow$ SB (Y)	$0.0652 > 0.05$	Not moderating

Source: Processed Data 2025

Table 14 shows the results of the moderation test show that the relationship between foreign ownership and digital banking generated a p-value of 0.0652, which is higher than the 0.05 cutoff. This suggests that the impact of digital banking on environmentally friendly business practices is unaffected by foreign ownership. Digital banking's impact on a bank's sustainability performance is unaffected by foreign ownership, neither increasing nor decreasing it [40]. Consequently, the hypothesis in this study (H8) is rejected.

3.8. Discussion

The findings confirm that digital banking plays a strategic role in enhancing sustainable business performance in Indonesian commercial banks. Digitalization improves operational efficiency, reduces paper usage and energy consumption, and expands access to inclusive financial services, thereby supporting the economic, environmental, and social dimensions of sustainability. Consistent with prior studies [41], banks that actively implement digital banking are better positioned to integrate sustainability principles into their business models. In addition, digital banking significantly promotes GB practices by enabling paperless transactions, reducing carbon footprints, and facilitating environmentally responsible financing, thus strengthening banks' environmental commitment and long-term reputation [42].

The results also show that digital banking improves operational efficiency by lowering transaction costs, automating processes, and increasing service speed. However, efficiency exhibits a negative relationship with sustainable business performance when it is overly focused on short-term cost reduction [43]. This finding supports the argument that efficiency gains do not automatically translate into sustainability outcomes if they are not aligned with social and environmental objectives. Excessive efficiency orientation may reduce

investments in human capital, social responsibility, or environmental initiatives, thereby weakening long-term sustainability. Thus, efficiency must be strategically directed toward supporting the triple bottom line rather than purely financial performance [44].

Furthermore, GB is proven to mediate the relationship between digital banking and sustainable business, indicating that digital transformation contributes more effectively to sustainability when it is embedded within environmentally responsible banking frameworks [45]. GB channels the benefits of digitalization toward ESG-oriented outcomes, ensuring that technological innovation supports long-term ecological and social goals. In contrast, efficiency does not mediate this relationship, suggesting that efficiency gains from digital banking are not yet systematically allocated to sustainability initiatives [46]. Additionally, foreign ownership does not moderate the digital banking sustainability relationship, implying that foreign shareholders neither strengthen nor weaken the sustainability impact of digitalization. This may reflect limited foreign investor involvement in sustainability strategies or a greater focus on financial returns rather than ESG-driven digital transformation.

4. MANAGERIAL IMPLICATIONS

The findings of this study suggest that bank management should position digital banking not merely as a tool for improving operational efficiency or service convenience, but as a strategic driver of long-term sustainability. Managers are encouraged to align digital transformation initiatives with sustainability objectives by embedding environmental and social considerations into digital banking strategies. This includes prioritizing paperless operations, energy-efficient digital infrastructure, and digital platforms that support financial inclusion. By doing so, banks can ensure that digital innovation contributes directly to sustainable business performance rather than focusing solely on short-term cost reduction.

The results also highlight the critical role of GB as a mechanism that channels the benefits of digital banking toward sustainable outcomes. Bank executives should therefore strengthen the integration between digital banking and GB policies, such as by using digital systems to enhance environmental risk assessments, monitor green financing portfolios, and improve transparency in sustainability reporting. Investing in GB initiatives supported by digital technologies can enhance corporate reputation, improve stakeholder trust, and support long-term value creation.

Furthermore, the negative association between efficiency and sustainable business performance indicates that managers must adopt a more balanced view of efficiency. Operational efficiency should be pursued in a way that supports, rather than undermines, social and environmental goals. Cost-saving measures should not come at the expense of human capital development, social responsibility, or environmental investments. In addition, the insignificant moderating role of foreign ownership implies that sustainability-oriented digital transformation must be driven primarily by internal management commitment rather than reliance on foreign shareholders. Therefore, bank leaders should proactively design governance and performance evaluation systems that reward sustainability-oriented digital innovation.

5. CONCLUSION

This study examines the impact of digital banking on the sustainable business performance of Indonesian commercial banks, focusing on institutions classified under KBMI 3 and 4. The findings reveal that digital banking has a positive and significant effect on sustainability, as it enhances operational efficiency, reduces environmental impacts through paperless transactions, and expands financial inclusion. Digital banking also positively influences GB and operational efficiency. Furthermore, GB is proven to have a direct positive effect on sustainable business and serves as a key mediating mechanism through which digital banking translates into sustainability outcomes. In contrast, operational efficiency measured by BOPO exhibits a negative relationship with sustainable business when it is overly oriented toward short-term cost reduction.

The results further indicate that efficiency does not mediate the relationship between digital banking and sustainable business, suggesting that efficiency gains from digitalization are not automatically directed toward sustainability initiatives. Additionally, foreign ownership does not moderate the digital banking sustainability relationship, implying that sustainability-oriented digital transformation is largely driven by internal managerial strategies rather than ownership structure. These findings contribute to the literature by integrating digital banking, GB, and efficiency within a sustainability framework and by clarifying the boundary conditions under which digital transformation supports sustainable business performance.

From a managerial and policy perspective, the study highlights the importance of aligning digital

banking strategies with GB initiatives to maximize sustainability benefits. Bank managers should ensure that efficiency improvements are balanced with investments in environmental and social programs rather than focusing solely on cost minimization. For regulators, the findings emphasize the need to encourage policies that integrate digitalization and sustainability while strengthening ESG-oriented governance. Future research is encouraged to extend this analysis to smaller banks (KBMI 1 and 2), incorporate qualitative or longitudinal approaches, and explore additional moderating or mediating factors such as corporate governance quality, digital maturity, or green innovation to deepen understanding of sustainable digital transformation in the banking sector.

6. DECLARATIONS

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6.2. Author Contributions

Conceptualization: IS; Methodology: LC; Software: YM; Validation: HA and YF; Formal Analysis: IS and LC; Investigation: YM; Resources: YF; Data Curation: YM; Writing Original Draft Preparation: IS and LC; Writing Review and Editing: IS and YM; Visualization: HA; All authors, IS, HA, LC, YF, and YM, have read and agreed to the published version of the manuscript.

6.3. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

6.4. Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

6.5. Declaration of Conflicting Interest

The authors declare that they have no conflicts of interest, known competing financial interests, or personal relationships that could have influenced the work reported in this paper.

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