JASIE - Journal of Aswaja and Islamic Economics *Vol. 05 No. 01 - 2026*
Website Journal : https://publikasiilmiah.unwahas.ac.id/JASIE/
DOI : 10.3194/jse.v1i1.6877
ISSN : 2962-5602 (Online) ISSN : 2963-7864 (Print)

REASSESSING THE GREEN FINANCING–PROFITABILITY NEXUS: EVIDENCE OF REVERSE CAUSALITY IN INDONESIAN ISLAMIC BANKING (2020–2025)

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ABSTRACT

This study examines the dynamic relationships among operational eco-efficiency, emission reduction, the Green Financing Ratio (GFR), and profitability in Indonesian Islamic commercial banks. Motivated by a gap in the green banking literature, which mostly treats internal environmental performance as a byproduct rather than a driver of green financing and relies on static estimation techniques, this study applies a Vector Error Correction Model (VECM) to an annual composite series built from ten purposively sampled Islamic commercial banks operating in Indonesia between 2020 and 2025. Unit root tests show mixed orders of integration: the Green Financing Ratio is stationary only after first differencing, while profitability, emission reduction, and operational eco-efficiency are stationary in levels. Contrary to the hypothesized directions, Granger causality tests find no significant effect of operational eco-efficiency or emission reduction on the Green Financing Ratio, so Hypotheses 1 and 2 are not supported. Instead, the results reveal a significant unidirectional causality running from profitability to the Green Financing Ratio, and the cointegrating equation confirms a statistically significant positive long-run relationship between the Green Financing Ratio and profitability, giving long-run support to Hypothesis 3. The short-run error-correction estimates further show a significant direct effect of emission reduction on profitability. Forecast Error Variance Decomposition indicates that profitability and the environmental indicators are each largely self-determined, with cross-variable spillovers remaining modest. These findings suggest that, in this sample, internal financial strength precedes rather than follows the expansion of green financing.

Keywords : *Green Financing Ratio, Profitability, Vector Error Correction Model, Reverse Causality, Islamic Banking*

INTRODUCTION

Climate change is no longer treated as a purely environmental issue. Regulators and investors increasingly treat it as a financial risk, and that has pushed banks to redirect capital toward environmentally sustainable activities. Green finance has become one of the main policy tools for supporting sustainable development without undermining financial stability. But how well it works depends on something less visible: whether banks are actually improving their own environmental performance, not just financing other people's. Operational eco-efficiency and emission reduction matter here, because without that internal capacity, a bank's sustainable financing strategy has little to build on.

Indonesia is a useful setting for this question. It is a major emerging economy with a fast-growing Islamic banking sector, and it has steadily built sustainable finance into its regulatory framework over the past several years. Islamic banking also operates under Maqāsid al-Sharīah, which treats environmental responsibility and resource conservation as part of what makes economic activity permissible in the first place, not as an add-on. Green financing therefore fits naturally with obligations Islamic banks already carry. Earlier studies have linked sustainable investment to the financial performance of Islamic banks in Indonesia (Febriyanto et al., 2023; Hidayat et al., 2024), and more recent evidence shows Indonesian Islamic banks increasingly building green banking principles into daily operations (Widiyanti et al., 2025). Most of this work, though, stops at asking whether green banking has been implemented. It does not ask how internal environmental capability actually shows up in a higher Green Financing Ratio.

This institutional imperative is further accentuated by the Financial Services Authority's (OJK) Sustainable Finance Roadmap Phase II (2021–2025) and the release of the Indonesian Green Taxonomy. These regulatory initiatives establish formal technical screening criteria for green economic activities, placing explicit pressure on financial institutions to expand sustainable portfolio allocations. However, while regulatory frameworks mandate compliance and reporting, they do not automatically supply the risk capital required to absorb potential default losses in emerging green sectors. In the Islamic banking sector, where asset-backed financing structures require strict alignment between underlying collateral value and Sharīʿah compliance, the operational friction of deploying green credit becomes particularly pronounced. Understanding whether regulatory push alone translates into portfolio expansion—or whether internal financial strength remains the primary prerequisite—is therefore critical for evaluating the real-world efficacy of Indonesia's sustainable finance architecture.

Sustainable finance research has grown fast, but it remains split across three streams that differ in scope and method. One looks at how broad green banking practices encourage green financing (Chen et al., 2022; Thapliyal et al., 2025), mostly using survey-based structural equation modelling that treats green practice as a single perceptual construct. A second examines environmental risk management alongside financial performance (Gangi et al., 2018), typically relying on cross-sectional CSR indices instead of measurable environmental data. A third looks at what green financing does to bank profitability afterward (Fata & Arifin, 2024; Sutrisno & Furqan, 2023; Sutrisno et al., 2024).

These three streams share two gaps, and together they motivate this study. First, few studies test internal operational eco-efficiency and emission reduction as things that drive green financing rather than result from it. Internal environmental performance tends to get treated as a byproduct of green lending, which puts the causal order backwards. Second, most of this literature relies on static techniques such as cross-sectional regression and SEM, which only capture relationships at a single point in time. But the interactions among eco-efficiency, green financing, and profitability play out over time; financial benefits need an adjustment period before they show up in the numbers.

This study repositions internal environmental performance as a determinant of sustainable financing decisions rather than a side effect of them, and it moves away from static cross-sectional frameworks toward a Vector Error Correction Model (VECM), which can capture both short-run adjustment and long-run equilibrium among the variables, something largely missing from the green banking literature so far. Theoretically, it draws on Eco-efficiency, Institutional, and Stakeholder theories together to explain how sustainability moves from internal operations to market outcomes. Contextually, it looks at Indonesian Islamic banking, where Maqāṣ id al-Sharīʿ ah principles reinforce rather than compete with sustainability goals, a setting most prior green financing research, largely built on conventional or Western banking data, has not covered. The findings should also be useful in practice: for bank managers and Indonesia's Financial Services Authority (OJK), operational decarbonization looks less like a compliance cost and more like a strategic capability for credit expansion and long-term financial sustainability.

This distinction matters for how OJK sequences its own policy instruments. If green financing tends to follow profitability rather than precede it, then disclosure mandates and taxonomy rules aimed only at pushing banks to lend green may arrive before the banks in question have the balance-sheet room to respond, and the policy could end up rewarding banks that were already positioned to expand rather than building that capacity where it is missing. Based on the research background and the gaps identified above, this study addresses the following questions: What is the relationship between operational ecological efficiency and the Green Financing Ratio in Indonesia's Islamic banking sector? What is the relationship between emission reduction and the Green Financing Ratio in Indonesia's Islamic banking sector? What is the relationship between the Green Financing Ratio and the profitability of Indonesia's Islamic banking sector? In line with the research questions above, this study aims to: Examine the relationship between operational ecological efficiency and the Green Financing Ratio in Indonesia's Islamic banking sector. Investigate the relationship between emission reduction and the Green Financing Ratio in Indonesia's Islamic banking sector. Analyze the relationship between the Green Financing Ratio and the profitability of Indonesia's Islamic banking sector.

LITERATURE REVIEW

Eco-efficiency Theory

Eco-efficiency Theory describes how firms optimize their operations to create economic value while cutting ecological harm (Schaltegger & Sturm, 1990; Schmidheiny, 1992). The underlying assumption is that environmental and economic performance move together: producing more value with fewer resources lowers operating costs and frees up financial slack. In banking this shows up as lower branch energy use, more digitalized services, and smaller direct carbon emissions. For this study, operational eco-efficiency is what gives a bank the capital elasticity to fund external sustainable projects, and that elasticity is what drives the Green Financing Ratio. The theory's limitation is that it looks inward: it explains internal resource allocation but has little to say about external regulatory compliance, so it needs pairing with an institutional perspective.

Institutional Theory

Institutional Theory holds that organizations conform to external norms, rules, and expectations in order to stay legitimate and survive (DiMaggio & Powell, 2021; Scott, 2013), through coercive pressure (regulatory mandates), mimetic pressure (copying industry leaders), and normative pressure (ESG reporting standards). In sustainable finance these pressures push banks toward climate disclosure frameworks and environmental management systems. Here, the theory explains why emission reduction and green financing tend to move together: banks cut internal emissions partly to signal that they are keeping up with climate expectations, and to hold onto that legitimacy with regulators, they extend the same logic to their lending portfolios. What Institutional Theory does not explain well is whether that conformity actually pays off financially, which is where Stakeholder Theory becomes useful.

Stakeholder Theory

Stakeholder Theory argues that corporate success depends on balancing the competing expectations of different stakeholder groups, not just maximizing shareholder wealth (Donaldson & Preston, 1995; Freeman, 1984). Addressing environmental demands proactively lowers reputational risk and builds trust, which in turn can lower the cost of funds and attract better clients. In Islamic banking, stakeholders include regulators, depositors, investors, and the wider community, and Maqāṣid al-Sharīʿah explicitly protects their interests. This is the theory that connects the Green Financing Ratio to profitability: channeling funds into sustainable projects meets stakeholder expectations and turns ethical compliance into financial return. It says less, however, about where the internal capability to run such strategies comes from in the first place, which loops back to Eco-efficiency Theory.

Broader ESG literature backs a positive link between sustainability-oriented banking and financial performance. Cross-country evidence suggests Islamic banks tend to gain more financially from ESG implementation than conventional banks do; environmental and social commitments appear to strengthen stakeholder trust, institutional legitimacy, and long-term competitiveness (Fakhrunnas et al., 2025). That cross-country pattern is consistent with the sequencing this study finds at the country level: ESG or green commitments appear to pay off financially, but the studies

establishing that link rarely test whether the commitment came first or the financial capacity did. Most treat the relationship as a single arrow pointing from sustainability to performance, which is precisely the assumption this study's reverse-causality result puts pressure on.

Eco-efficiency → Green Financing

Empirical work in sustainable banking usually treats internal environmental practice as a driver of external sustainable lending. Existing studies split roughly into two groups: those looking at green banking culture broadly (Chen et al., 2022; Thapliyal et al., 2025), and those examining specific operational interventions (Risal & Joshi, 2018). Both groups lean on static PLS-SEM and cross-sectional panels, which capture relationships as they stand at one point in time but miss the lag between reaching operational efficiency and actually scaling up a credit portfolio. This study addresses that methodological gap through a dynamic specification. The general finding is that internal green protocols raise sustainable financing output. What is usually missing is a clean isolation of quantitative operational eco-efficiency, actual measurable resource optimization, as an independent driver of lending behavior; most of the evidence instead comes from perceptual survey data rather than objective financial metrics.

This study tries to close that gap using a dynamic econometric approach (VECM) applied to objective financial time-series data. Following Eco-efficiency Theory, cutting internal resource use should generate structural financial slack. The link between broad green practice and lending is well established, but without dynamic, quantitative analysis the exact financial transmission mechanism stays vague. The expectation here is that operational eco-efficiency supplies the financial flexibility banks need to scale up their green financing ratio over time.

H1: Operational eco-efficiency has a positive and significant effect on the Green Financing Ratio in Indonesian Islamic banking.

Emission Reduction → Green Financing

A firm's strategic environmental orientation appears to shape how it allocates capital. This literature splits into institutional climate finance commitments (Yuan & Gallagher, 2018) and broader environmental management systems (Gangi et al., 2018), both largely built on generalized panel regressions or qualitative case studies using binary or categorical indicators rather than quantitative emission metrics, so the dynamics of portfolio transition go uncaptured. Institutions with strong climate commitments do allocate a statistically higher share of their portfolios to green infrastructure. The gap is in where this evidence comes from: mostly international development banks or Western conventional banks, with emerging-market commercial Islamic banks still underexplored. The qualitative proxies used elsewhere also fail to capture verifiable decarbonization.

Under Institutional Theory, proactive emission reduction works as a conformity signal to regulatory pressure. The link between macro-level climate commitment and lending is reasonably well supported, but qualitative proxies leave the transmission mechanism blurry. This study uses quantifiable emission reduction instead, as an empirical marker of institutional commitment: decarbonizing internal operations puts

pressure on banks to mirror that efficiency in how they allocate assets, which in turn drives sustainable lending.

H2: Emission reduction has a positive and significant effect on the Green Financing Ratio in Indonesian Islamic banking.

Green Financing → Profitability

The broader literature supports the idea that sustainable finance improves long-term financial performance, though not always immediately. Existing work falls roughly into ESG integration research and green credit distribution analysis, mostly using fixed-effects or dynamic Generalized Method of Moments (GMM) models. These handle persistence and unobserved heterogeneity reasonably well, but they mostly estimate average dynamic effects rather than separating short-run adjustment from long-run equilibrium, so exactly how sustainable financing feeds into profitability over time remains underexplored.

The empirical picture shifts depending on the time horizon. Longer-term studies consistently find that sustainable financing improves profitability, showing up in higher ROA and ROE (Febriyanto et al., 2023; Hidayat et al., 2024; Sutrisno & Furqan, 2023; Sutrisno et al., 2024). Short-term effects are sometimes insignificant, likely because ESG implementation requires heavy upfront investment (Umam et al., 2025; Zahro & Devy, 2026). Ramdani et al. (2023) find something similar: green banking implementation improves the profitability of Indonesian Islamic banks once dynamic adjustment is accounted for, meaning the financial benefits build up gradually rather than appearing right away.

Under Stakeholder Theory, sustainable financing should raise profitability by strengthening institutional legitimacy, lowering environmental and credit risk, and building stakeholder confidence. Broader ESG evidence backs this, particularly for Islamic banks (Fakhrunnas et al., 2025), but few studies look specifically at the long-run dynamic relationship between the Green Financing Ratio and bank profitability. Most rely on static or dynamic panel estimators that do not separate short-run adjustment from long-run equilibrium. This study uses the Vector Error Correction Model (VECM) instead, to capture both.

H3: The Green Financing Ratio has a positive and significant effect on the profitability of Indonesian Islamic banking.

Conceptual Framework

This framework integrates Eco-efficiency Theory, Institutional Theory, and Stakeholder Theory to analyze how sustainability transitions from internal, firm-level capabilities into long-run macro-financial outcomes. Grounded in **Eco-efficiency Theory**, operational eco-efficiency is the core internal capability that generates the financial elasticity needed for sustainable investments. **Institutional Theory** explains how verifiable emission reduction builds environmental legitimacy and regulatory conformity. Under **Stakeholder Theory**, the Green Financing Ratio translates these internal capabilities into market action, which subsequently enhances bank profitability through risk mitigation and stakeholder trust. Because capital allocation and institutional reputation require an adjustment period, these links unfold sequentially over time, justifying the use of a dynamic econometric model (VECM) for analysis.

Dynamic Relationship among Variables

Sustainability-oriented banking decisions rarely show up in the numbers right away. Improvements in operational ecological efficiency, emission reduction, and green financing strategy typically take time to affect financial performance, since organizational adaptation, investment adjustment, regulatory response, and stakeholder reaction all happen gradually. The relationships among these variables are therefore dynamic by nature, involving both short-term adjustment and long-term equilibrium. Recent studies increasingly treat sustainability-related interactions in banking as dynamic rather than static or simultaneous. Hasan et al. (2025), for example, use Panel Vector Autoregression (Panel VAR) and dynamic GMM to show that Islamic banking development and green economic growth interact through dynamic adjustment mechanisms. Most other studies on sustainable banking still rely on fixed-effects models, dynamic GMM, or similar panel estimators to examine the financial implications of environmental initiatives. These handle persistence, endogeneity, and unobserved heterogeneity well, but they estimate average dynamic effects rather than separating short-run adjustment from long-run equilibrium within one integrated error-correction framework.

Eco-Efficiency Theory, Institutional Theory, and Stakeholder Theory point toward the same conclusion from different angles: sustainability initiatives build up cumulatively rather than showing instant effects. Eco-Efficiency Theory suggests that better resource use and environmental efficiency gradually raise organizational performance and widen capacity for sustainable financing. Institutional Theory explains that emission reduction builds organizational legitimacy through regulatory compliance, normative expectation, and industry-wide sustainability norms, which encourages stronger commitment to green financing. Stakeholder Theory adds that green financing improves institutional reputation, lowers environmental and credit risk, and strengthens stakeholder confidence, which feeds into better financial performance over time. These three theories suggest sustainability-related variables interact dynamically before settling into long-run equilibrium.

This study therefore uses a Vector Error Correction Model (VECM) to examine both the short-run dynamics and long-run equilibrium among operational eco-efficiency, emission reduction, the Green Financing Ratio, and profitability in Indonesian Islamic banking. Unlike conventional single-equation regression techniques, VECM estimates the temporary adjustment following short-run shocks and the speed at which variables return to long-run equilibrium at the same time, giving a fuller picture of how environmental sustainability initiatives feed through to green financing and, eventually, to financial performance. Because complete bank-level series are not consistently available across the full sample period, the model reported here is estimated on an annual composite (cross-bank aggregate) series rather than as a fully heterogeneous bank-level panel a narrower scope than the Panel VAR/GMM applications of Abrigo and Love (2016), Love and Zicchino (2006), and Hasan et al. (2025). The implications of this scope are discussed further in Research Methodology and revisited as a limitation in Conclusion and recommendations.

RESEARCH METHODOLOGY

This study uses a quantitative, explanatory design to examine the dynamic relationships among operational eco-efficiency, emission reduction, the Green Financing Ratio (GFR), and profitability in Indonesian Islamic commercial banks. Because complete and consistent annual environmental and financial data are only available at an aggregate level across the sampled banks, the study builds one annual composite (cross-bank aggregate) time series for each variable covering 2020–2025 (T = 6 years), drawn from the annual reports, sustainability reports, and audited financial statements of ten Islamic commercial banks selected through purposive sampling. To capture both the long-run equilibrium and the short-run dynamics among the research variables, this study uses the Vector Error Correction Model (VECM). Compared with conventional single-equation regression, VECM can estimate long-run cointegration, short-run adjustment, and dynamic feedback among endogenous variables at the same time, which suits the annual sustainability and financial performance indicators used here (Abrigo & Love, 2016; Love & Zicchino, 2006). Unlike the cross-sectionally rich Panel VAR/GMM applications in these studies and in Hasan et al. (2025), the present analysis works with a short annual composite series six annual observations, of which five remain usable once a one-year lag is applied which shapes several of the diagnostic choices explained in Sections 3.5 and 3.6.

The empirical analysis tests three hypotheses: (1) the effect of operational eco-efficiency on the Green Financing Ratio, (2) the effect of emission reduction on the Green Financing Ratio, and (3) the effect of the Green Financing Ratio on bank profitability. By combining long-run and short-run dynamics, VECM gives a fuller picture of how sustainability-oriented operational performance feeds into green financing and, from there, into financial performance. The population of this study consists of all Islamic Commercial Banks (Bank Umum Syariah) operating in Indonesia. A purposive sampling technique was used to ensure the availability and consistency of sustainability and financial information across the observation period. Sample selection followed these criteria: (1) Islamic Commercial Banks operating continuously during 2020–2025; (2) banks publishing complete annual and sustainability reports; and (3) banks providing complete information for all research variables. Ten Islamic commercial banks met these criteria and form the final sample; their annual figures for each variable were aggregated into a single composite series per year for use in the VECM estimation described in Sections 3.4 and 3.5.

This study uses secondary data drawn from annual reports, sustainability reports, and audited financial statements published on the official websites of the sampled banks, supplemented by publications from the Financial Services Authority (OJK), Bank Indonesia, and other relevant official institutions. The study uses two independent variables, one intervening variable, and one dependent variable. Operational eco-efficiency and emission reduction represent sustainability-related operational performance; the Green Financing Ratio (GFR) reflects banks' sustainable financing activity; and profitability is measured through Return on Assets (ROA). Table 1 sets out how each variable is defined and measured.

Tabel 1. Operational Definition of VariablesOperational Definition of Variables

Variable	Symbol	Measurement	Formula	Unit
Operational Eco-Efficiency	OEE	Operating revenue relative to environmental resource consumption	Operating Revenue ÷ (Electricity + Fuel Consumption)	Ratio
Emission Reduction	ER	Fuel consumption (inverse proxy)	Fuel Consumption	Liter
Green Financing Ratio	GFR	Outstanding green financing relative to total financing	Green Financing ÷ Total Financing × 100%	Percentage
Profitability	ROA	Return on Assets	Net Income ÷ Total Assets × 100%	Percentage

Note: fuel consumption is used as an inverse proxy for emission reduction performance. Lower fuel consumption indicates better emission reduction performance and reflects greater environmental sustainability in banking operations.

Econometric Model Specification

To test the hypotheses, this study uses a Vector Error Correction Model (VECM) to estimate both the long-run equilibrium and short-run dynamic relationships among operational eco-efficiency, emission reduction, the Green Financing Ratio, and profitability. VECM fits this purpose because it can estimate long-run cointegration, short-run adjustment dynamics, and potential feedback effects among endogenous variables simultaneously, even where, as here, the time dimension is short. The empirical analysis is organized around two structural blocks within a single four-variable VECM system. Block 1 evaluates the effects of operational eco-efficiency and emission reduction on the Green Financing Ratio; Block 2 examines the effect of the Green Financing Ratio on bank profitability. Although the conceptual framework specifies directional hypotheses, VECM treats all four variables as endogenous in order to capture their dynamic interactions over time. Table 2 summarizes both block

Tabel 2. Block and Hypothesis Mapping

Block	Endogenous Variable	Explanatory Variable(s)	Hypothesis
Block 1	Green Financing Ratio	Operational Eco-Efficiency, Emission Reduction	H1, H2
Block 2	Profitability (ROA)	Green Financing Ratio	H3

Data Analysis Procedure

Data were analyzed in EViews following a standard VECM sequence. Unit root tests were used first to determine each variable's order of integration. The results were mixed: profitability, emission reduction, and operational eco-efficiency were stationary in levels, while the Green Financing Ratio was stationary only after first differencing the usual condition that justifies moving to a Vector Error Correction Model rather

than a VAR estimated purely in levels. Because the estimation series is an annual composite covering only six years (2020–2025), with five usable observations once a one-year lag is applied, the panel-specific Pedroni and Kao cointegration tests are not applicable here: both require a genuinely cross-sectional panel with a reasonably long time dimension per cross-section to converge to interpretable statistics, which this short, aggregated annual series does not provide. Cointegration was instead established through the Johansen cointegration procedure embedded directly in the VECM estimation the cointegrating equation reported by EViews and corroborated by the sign and significance of the Error Correction Term (ECT): a negative, statistically significant ECT is itself evidence that the variables share a long-run equilibrium relationship, and this is the criterion relied on here.

The optimal lag length was chosen using EViews' built-in lag-order criteria (LR, FPE, AIC, SC, and HQ); given the short annual series, all five criteria converged on a lag of one year. This lag was then used to estimate the VECM, which produces the long-run cointegrating equation, the short-run error-correction dynamics, and the ECT together, and to check VAR stability by confirming that the inverse roots of the characteristic polynomial fall inside the unit circle. Finally, Granger causality and Forecast Error Variance Decomposition (FEVD) analyses examined causal relationships and how much each variable contributes to system fluctuations.

Tabel 3. Analysis Steps

Step	Analysis	Objective
1	Unit Root Test	Determine each variable's order of integration
2	Optimal Lag Selection (LR/FPE/AIC/SC/HQ)	Determine lag structure
3	VECM Estimation	Estimate long- and short-run relationships; confirm cointegration via the Johansen procedure and the Error Correction Term
4	VAR Stability Test	Confirm the estimated system is dynamically stable
5	Granger Causality	Examine causal relationships
6	Forecast Error Variance Decomposition (FEVD)	Assess each variable's contribution to variance

Model Diagnostic and Robustness Tests

Given the short annual composite series used here (T = 6, with five usable observations after one lag), the panel-specific Pedroni and Kao cointegration tests could not be relied on; this reflects a genuine data-availability limitation rather than a specification error, and is discussed further as a limitation in Conclusion and recommendations. Cointegration was instead established through the Johansen procedure embedded in the VECM estimation the cointegrating equation reported by EViews and corroborated by the sign and significance of the ECT: a stable, negative, and statistically significant ECT indicates that the variables move back toward a shared long-run path after short-run shocks, which is the evidence relied on here.

VAR stability was checked directly by confirming that the inverse roots of the characteristic polynomial all lie inside the unit circle, which is a precondition for the variance-decomposition results to be interpretable. Granger causality and FEVD outputs were then read together to assess how robust the estimated dynamic relationships are, supporting the reliability of the empirical findings and the validity of the estimated VECM. Because the underlying series also mix orders of integration the Green Financing Ratio is I(1) while the remaining series are stationary in levels the cointegration and long-run results are interpreted cautiously, and this mixed-order caveat is carried forward into the limitations in Conclusion and recommendations.

RESULTS AND DISCUSSION

Unit Root Test Results

Table 4 summarizes the unit root test results for the four research variabless

Tabel 4. Unit Root Test Summary

Variable	Level	1st Difference	Order of Integration
Profitability (ROA)	Stationary		I(0)
Green Financing Ratio (GFR)	Not stationary	Stationary	I(1)
Emission Reduction (ER)	Stationary		I(0)
Operational Eco-Efficiency (OEE)	Stationary		I(0)

Three of the four series profitability, emission reduction, and operational eco-efficiency are stationary in their levels, while the Green Financing Ratio becomes stationary only after first differencing. This mixed order of integration is the usual signal that a VECM, rather than a VAR estimated purely in levels, is the appropriate specification. It is also the reason the long-run cointegrating relationship reported in Section 4.5 is interpreted cautiously: the Johansen framework is conventionally designed for series integrated of the same order, and this caveat is carried forward as a limitation in Conclusion and recommendations.

Optimal Lag Length

The VAR Lag Order Selection Criteria produced full agreement across all five criteria. At lag 1, AIC = 16.59166, SC = 17.52579, and HQ = 16.89050, each the lowest (most negative) value across the lags considered compared with an AIC of about 18.60 at lag 0 and 16.71 at lag 2 while the Sequential Modified LR test statistic and the Final Prediction Error (FPE) also select lag 1. Given the short annual series, this consensus provides the empirical justification for estimating the system with a lag length of one year in the subsequent VAR/VECM analysis.

VAR Estimates and Stability Test

The estimated VAR system at lag 1 explains a meaningful share of short-run variation in the two central variables: the profitability equation returns an R-squared of 0.4668, and the Green Financing Ratio equation returns an R-squared of 0.6241. In the profitability equation, only the lagged profitability term is individually significant (t = 5.19336); the lagged GFR, emission reduction, and eco-efficiency terms all have t-statistics below the critical value, indicating that in the short run, none of the green variables individually moves profitability on their own. In the GFR equation, lagged profitability (t = -3.92177) and lagged GFR itself (t = 3.60246) are both significant, while lagged emission reduction and eco-efficiency are not a first indication of the reverse-causality pattern developed further in Section 4.4.

VAR stability was confirmed by inspecting the inverse roots of the characteristic polynomial: the estimated moduli are 0.587012, 0.537933, 0.537933, and 0.039002, all below 1. No root lies outside the unit circle, so the estimated VAR system satisfies the stability condition, which is the precondition for the Granger causality and FEVD results reported below to be interpretable.

Granger Causality Test

Granger causality was tested at the conventional 5% significance level ($\alpha = 0.05$); a probability value below 0.05 indicates that the row variable Granger-causes the column (dependent) variable. Table 5 reports the results.

Tabel 5. Granger Causality Test Result

Dependent Variable	Source Variable	Prob.	Conclusion
Profitability	GFR	0.3033	Not significant
Profitability	Emission Reduction	0.9547	Not significant
Profitability	Eco-Efficiency	0.9487	Not significant
GFR	Profitability	0.0001	Significant
GFR	Emission Reduction	0.4851	Not significant
GFR	Eco-Efficiency	0.2976	Not significant
Emission Reduction / Eco-Efficiency	Profitability, GFR	0.35 – 0.90	Not significant

None of the environmental indicators, GFR, emission reduction, or eco-efficiency, significantly Granger-causes profitability in the short run. Conversely, profitability significantly Granger-causes GFR (p = 0.0001), while emission reduction and eco-efficiency do not. Neither profitability nor GFR Granger-causes emission reduction or eco-efficiency. The overall pattern is a unidirectional causality running from profitability to the Green Financing Ratio, the reverse of the direction implied by Hypothesis 3 in the short run: banks in this sample appear to expand green financing once they are already profitable, rather than becoming more profitable because they expand green financing.

Vector Error Correction Model Estimation
Long-Run Relationship (Cointegrating Equation)

Normalizing the cointegrating equation on profitability gives the following long-run relationship:

PROFITABILITY = 0.1583·GFR + 0.000013·EMISSION_REDUCTION + 1,816,717·ECO_EFFICIENCY − 6.5547

The t-statistic for GFR is -3.73934 in the EViews cointegrating-equation output, which once the coefficient is moved back to the same side of the equation as profitability corresponds to a statistically significant positive long-run coefficient of 0.1583. In other words, the Green Financing Ratio has a significant, positive long-run relationship with profitability, providing long-run support for Hypothesis 3. The t-statistics for emission reduction (-0.90327) and eco-efficiency (-0.92847) both fall between -1.96 and 1.96, so neither shows a statistically significant long-run relationship with profitability.

Short-Run Dynamics and Adjustment Speed

The error-correction term (COINTEQ1) in the D(PROFITABILITY) equation is -0.287354, with a t-statistic of -5.32297 negative and highly significant, satisfying the basic requirement for a valid VECM. This indicates that approximately 28.73% of any short-run disequilibrium in profitability is corrected each year as the system moves back toward its long-run equilibrium path. Among the short-run (differenced, lagged) regressors in the D(PROFITABILITY) equation, D(PROFITABILITY(-1)) is significant and negative (t = -3.16324), consistent with a normal cyclical pattern in bank profitability. D(GFR(-1)) is not significant (t = -1.08294), indicating no significant short-run effect running from GFR to profitability consistent with the Granger causality result in Section 4.4. D(EMISSION_REDUCTION(-1)), however, is highly significant (t = -5.30459): emission reduction shows a direct short-run effect on profitability even though it has no significant long-run relationship with profitability. The D(PROFITABILITY) equation as a whole has an R-squared of 0.659337 and an F-statistic of 9.290152, indicating that the included regressors jointly explain a substantial share of short-run profitability movements.

Forecast Error Variance Decomposition (FEVD)

Table 6 summarizes the ten-period-ahead variance decomposition for profitability and GFR.

Tabel 6. Forecast Error Variance Decomposition

Variable Decomposed	Self	Profitability	GFR	Eco-Efficiency	Emission Reduction
Profitability (period 10)	95.03%		2.68%	2.16%	0.10%
GFR (period 10)	35.13%	50.66%		13.39%	n.a.

Emission Reduction (period 10)	88.91%	< 5% (combined)
Eco-Efficiency (period 10)	95.98%	< 5% (combined)

The variance of profitability is overwhelmingly self-determined: at period 10, 95.03% of the forecast error variance in profitability is explained by its own past shocks, with GFR (2.68%), eco-efficiency (2.16%), and emission reduction (0.10%) together contributing under 5%. In sharp contrast, the variance of GFR is dominated by profitability shocks, which explain 38.32% of GFR's variance in period 1 and rise to 50.66% by period 10 larger than GFR's own contribution to its variance (35.13%) at the same horizon. Eco-efficiency's contribution to GFR's variance also grows over the horizon, from 0% in period 1 to 13.39% by period 10, even though it is not statistically significant in the Granger causality test, suggesting a slow-building association that this short sample cannot resolve with full statistical confidence. Emission reduction and eco-efficiency, for their part, are themselves highly self-determined (88.91% and 95.98% of their own variance at period 10, respectively), with financial-side shocks (profitability and GFR) contributing only a small share to either series.

Discussion

Taken together, the results speak directly to the three hypotheses set out in Chapter II. Hypothesis 1 (operational eco-efficiency has a positive and significant effect on the Green Financing Ratio) is not supported: the Granger causality test returns a probability of 0.2976, well above the 5% threshold, and eco-efficiency's own lag is not significant in the short-run GFR equation. The gradually rising FEVD contribution of eco-efficiency to GFR's variance (reaching 13.39% by period 10) hints at a slower-building relationship than this six-year annual series can confirm statistically. If that slow-building pattern is real rather than noise, a study with more annual observations, or with quarterly rather than yearly data, would likely find eco-efficiency crossing into statistical significance before this one does; six data points simply do not give the FEVD estimate much room to separate a genuine building relationship from sampling variation.

Hypothesis 2 (emission reduction has a positive and significant effect on the Green Financing Ratio) is likewise not supported: the Granger causality probability is 0.4851, and emission reduction's contribution to GFR's forecast error variance remains minimal throughout the ten-period horizon. This is the cleaner of the two null results: unlike eco-efficiency, emission reduction's FEVD contribution to GFR does not show any rising trend over the ten-period horizon, so there is less basis here for an omitted slow-building relationship. That said, the inverse fuel-consumption proxy used for emission reduction is a coarse instrument, and a bank could report falling fuel use for reasons unrelated to a deliberate decarbonization strategy, such as branch consolidation or a shift toward digital banking, which would attenuate any real relationship this test might otherwise pick up.

Hypothesis 3 (the Green Financing Ratio has a positive and significant effect on profitability) receives mixed, horizon-dependent support. In the short run, GFR does not Granger-cause profitability (p = 0.3033), and its lagged short-run coefficient in the error-correction equation is not significant. In the long run, however, the cointegrating equation shows a statistically significant positive relationship between GFR and profitability. Hypothesis 3 is therefore supported through the long-run equilibrium channel only, not through short-run causality. The most consistent and unanticipated pattern across the Granger causality, VECM, and FEVD results is a reverse causal relationship: profitability significantly Granger-causes GFR, dominates GFR's forecast error variance at longer horizons (50.66% by period 10), and is the only lagged regressor with a significant long-run coefficient. This suggests that, in this sample, internal financial strength looks like a precondition for green financing expansion rather than a downstream consequence of it banks appear to need profitability and capital slack before they can scale up green financing, echoing a resource-slack logic rather than the eco-efficiency-driven pathway hypothesized in Chapter II.

A second notable finding is the significant direct short-run effect of emission reduction on profitability (t = -5.30459 in the error-correction equation), despite the absence of a significant long-run relationship between the two. This indicates that emission-reduction actions may carry an immediate cost or efficiency effect on profitability that operates on a shorter horizon than the theorized eco-efficiency → green financing → profitability pathway, a pattern not anticipated by the original hypotheses and one that future research with more observations should investigate directly.One plausible reading is that emission-reduction activities, such as retrofitting branch infrastructure or shifting to lower-carbon energy sources, carry upfront implementation costs that show up in the income statement before any efficiency savings materialize, which would explain a negative or disruptive short-run coefficient even where the long-run relationship with profitability is statistically flat. A second, less mechanical reading is that emission reduction and profitability both respond to a common annual budget cycle, so the correlation partly reflects shared timing rather than a direct causal channel running from one to the other. The data used here cannot fully separate these two explanations, and doing so would need firm-level cost data broken down by initiative, which was not available for this sample. Because the estimation series is short (T = 6, with five usable observations after one lag) and mixes orders of integration, these findings should be read as indicative patterns in this particular sample rather than as generalizable population parameters; the implications of this limitation are discussed further in Conclusion and recommendations.

CONCLUSION AND RECOMMENDATIONS

This study set out to examine three relationships in Indonesia's Islamic banking sector: operational eco-efficiency and the Green Financing Ratio, emission reduction and the Green Financing Ratio, and the Green Financing Ratio and profitability. Using a Vector Error Correction Model estimated on an annual composite series from ten Islamic commercial banks over 2020–2025, the answers to the three research questions are as follows. First, operational eco-efficiency does not show a statistically significant effect on the Green Financing Ratio in this sample; Hypothesis 1 is not supported. Second, emission reduction does not show a statistically significant effect on

the Green Financing Ratio; Hypothesis 2 is not supported. Third, the Green Financing Ratio has a statistically significant positive relationship with profitability in the long run, but not in the short run; Hypothesis 3 is therefore supported only through the long-run equilibrium channel. The central and unanticipated finding of this study is a reverse causal pattern: profitability significantly Granger-causes the Green Financing Ratio, and dominates its forecast error variance over a ten-period horizon, indicating that internal financial strength appears to precede, rather than follow, the expansion of green financing in this sample. A second notable finding is a significant direct short-run effect of emission reduction on profitability, even without a significant long-run relationship between the two variables.

These findings qualify each of the three supporting theories used in Chapter II. For Eco-efficiency Theory, the expected pathway in which internal resource efficiency generates financial slack that then funds green financing is not confirmed within this sample and time horizon; instead, the data suggest financial slack, proxied here by profitability, may need to exist first before a bank scales up green financing, closer to a resource-slack argument than a pure eco-efficiency-driven one. For Institutional Theory, the lack of a significant link between emission reduction and green financing suggests that legitimacy or conformity pressures alone may not be sufficient to convert internal environmental action into external green lending within a short annual horizon; such pressures may operate over a longer time frame than this study's six-year window can capture. For Stakeholder Theory, the long-run positive relationship between the Green Financing Ratio and profitability is consistent with the theory's expectation that sustainable financing eventually strengthens stakeholder trust and financial performance, but the absence of a short-run link indicates that this benefit, where present, accrues gradually rather than immediately.

The study contributes evidence that the causal architecture linking internal environmental performance, green financing, and profitability in an emerging-market Islamic banking context may run partly in the opposite direction from what much of the existing literature assumes, and that these relationships unfold over different time horizons that a single static or one-directional model would not reveal. It is also possible that Institutional Theory's mechanism is present but not fully captured by an inverse fuel-consumption proxy: regulatory and normative pressure could be pushing banks toward disclosure and target-setting well before those commitments show up as a measurable drop in fuel consumption, in which case the null result here reflects a mismatch between how the theory expects legitimacy pressure to operate and how coarsely this study is able to measure it, rather than the absence of the pressure itself.

Practical Recommendations

For bank managers, the results suggest that building internal profitability and capital strength is a practical precondition for expanding green financing portfolios, rather than assuming green financing will automatically generate profitability. Emission-reduction programs also appear to carry near-term profitability implications worth monitoring directly, rather than being treated only as a long-horizon sustainability commitment. For Indonesia's Financial Services Authority (OJK) and other regulators, because eco-efficiency and emission reduction alone did not show a statistically significant link to green financing expansion in this sample, environmental disclosure requirements or ratings on their own may be an insufficient lever.

Complementary policy tools that support banks' underlying profitability and capital positions for example, blended finance schemes, credit guarantees, or risk-sharing incentives tied to green portfolios may do more to unlock green financing growth than environmental mandates in isolation. Encouraging more granular and frequent sustainability and financial disclosure (e.g., quarterly rather than annual reporting) would also support more robust future testing of these relationships.

There is also a role here for Islamic social finance instruments that sit outside conventional bank capital. Waqf-linked or blended-finance structures, where third-party endowment or philanthropic funds absorb part of the credit risk on green projects, could in principle let a bank extend green financing before it has built up the profitability cushion this study finds banks otherwise seem to wait for. Whether such structures actually loosen the profitability precondition identified here, rather than simply shifting it onto the endowment or guarantor, is an empirical question this dataset cannot answer, but it follows naturally from the resource-slack interpretation of the results and is worth testing directly in future work.

Limitations

This study has several limitations that qualify its findings. First, the estimation relies on an annual composite series over only six years (2020–2025), with just five usable observations once a one-year lag is applied; the results should be treated as indicative patterns within this sample rather than as generalizable population parameters. Second, because of this short, aggregated series, the panel-specific Pedroni and Kao cointegration tests could not be applied; the Johansen procedure embedded in the VECM output, together with the Error Correction Term, was relied on instead a reasonable but methodologically narrower substitute. Third, the research variables show mixed orders of integration (the Green Financing Ratio is I(1), while the remaining series are stationary in levels), which departs from the standard same-order assumption underlying the Johansen framework, so the long-run coefficients should be read cautiously. Fourth, the study is limited to a single country and a single banking sector, Indonesian Islamic commercial banks, which limits generalizability to other countries or to conventional banks. Fifth, because the estimation uses cross-bank aggregated annual data rather than a genuine bank-level panel, individual bank heterogeneity is not captured and may hide different dynamics across specific banks. Finally, the proxies used for the environmental variables, inverse fuel consumption for emission reduction and revenue relative to energy and fuel use for operational eco-efficiency, are reasonable but imperfect measures of underlying environmental performance.

A related point is that the ten sampled banks were selected purposively on data availability rather than randomly, so the composite series may not represent the full population of Indonesian Islamic commercial banks with equal weight; banks with more complete public disclosure, which may also be the larger or better-capitalized ones, are more likely to appear in the sample, and this could bias the aggregate series toward the behavior of already-stronger institutions.

Suggestions for Future Research

Future studies should extend the observation window, ideally to more years or to quarterly data, to allow genuine panel cointegration tests such as Pedroni or Westerlund to be applied with adequate statistical power. Researchers with access to disaggregated bank-level series could estimate a true heterogeneous or dynamic Panel VECM or Panel VAR, for example following the GMM-based approach of Abrigo and Love (2016), to capture cross-bank heterogeneity that an aggregated series cannot. The reverse-causality pattern found here, profitability driving the Green Financing Ratio, merits direct testing in other emerging-market or multi-country Islamic banking samples, including an explicit test of financial slack as a mediating mechanism. Future work could also incorporate more granular and verified environmental data, such as audited greenhouse gas emissions or third-party ESG scores, as these become more widely available, and examine directly whether the short-run link between emission reduction and profitability found here reflects near-term operational cost effects, ideally using quarterly rather than annual data. It would also help to bring in macroeconomic and regulatory controls, such as benchmark financing rates, capital adequacy requirements, or the timing of OJK's green taxonomy rules, since the composite series used here cannot separate a bank-driven profitability effect from a system-wide shock that happens to move both profitability and green financing together in the same year.

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