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Carbon Intensity, Financial Sustainability, and Financial Performance: The Moderating Role of Financial Slack

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Abstract: The transition toward a lower-carbon economy increases the financial relevance of corporate emissions, yet prior evidence on the financial consequences of carbon activity remains mixed. This study examines the association of Carbon Intensity with Financial Sustainability and Financial Performance and tests whether Financial Slack moderates these relationships among non-financial firms listed in ASEAN-5 and China. Using purposive sampling and LSEG Workspace (Refinitiv) data for 2020–2025, the final sample comprises 136 firms and 803 firm-year observations. Financial Sustainability is proxied by the Altman Z-Score, Financial Performance by Return on Assets and Return on Equity, and Financial Slack by the ratio of current assets to current liabilities. Panel regressions in Stata 18 employ model-specific estimators, year fixed effects, firm-clustered standard errors, and pre-specified directional one-tailed tests; two-tailed p-values are also reported for transparency. Carbon Intensity is negatively associated with all three financial outcomes, with weaker evidence for ROA, whereas Financial Slack does not provide evidence of a buffering role. Relative to the closest prior study, this study adds Financial Sustainability to ROA and ROE, uses a combined Scope 1–Scope 2 intensity measure standardized by revenue, and tests the framework in a multi-country ASEAN-5 and China setting.

Keywords: Carbon Intensity, Financial Slack, Financial Sustainability, Financial Performance, Panel Data.

INTRODUCTION

Corporate decision making increasingly occurs under simultaneous pressure from economic uncertainty, the transition toward a lower-carbon economy, tightening carbon-related policies, and stronger stakeholder scrutiny of emission-generating activities. These pressures mean that firms are expected not only to maintain short-term profitability but also to preserve financial resilience over time. The principal mechanism examined in this study is a financial-pressure channel: higher operational emission intensity can be associated with higher energy and compliance costs, transition investment requirements, financing frictions, and reputational

pressure. When these pressures outweigh the operating benefits associated with carbon-intensive activity, both profitability and financial resilience are expected to be weaker. Capital-market evidence is consistent with this concern: higher carbon emissions have been associated with a carbon risk premium (Bolton & Kacperczyk, 2021), while mandatory carbon disclosure can reduce emissions without necessarily impairing operating performance (Downar et al., 2021).

The financial consequences of carbon activity, however, remain empirically unsettled. Carbon-intensive operations can generate output and revenue, so high emissions do not automatically imply weak contemporaneous performance. Vaicondam et al. (2025), for example, report a positive relationship between greenhouse gas emissions and financial performance among Malaysian firms, while Mendieta-Callirgos et al. (2026) find positive associations between Scope 1 emissions and both ROA and ROE for listed Latin American companies. Xu et al. (2025) further show that carbon information disclosure can improve financial performance through lower debt costs and stronger institutional-investor interest in heavily polluting Chinese industries. These findings contrast with the argument that carbon-intensive activity increases costs and financial pressure.

Evidence supporting the adverse channel is also substantial. Ganda and Milondzo (2018) document negative financial consequences of carbon emissions for South African firms. Kabir et al. (2021) find that carbon emissions increase corporate default risk, while Ding et al. (2023) report that greater carbon emissions aggravate financial distress risk in China. Perera et al. (2023) similarly show that higher carbon-emissions intensity is associated with greater idiosyncratic volatility. A meta-analysis by Busch et al. (2022) concludes that the carbon-financial performance relationship is complex, but relative emission measures such as intensity are more likely than absolute emissions to reveal statistically meaningful associations. This motivates the use of Carbon Intensity rather than total emissions alone.

Carbon Intensity in this study captures Scope 1 and Scope 2 greenhouse gas emissions relative to revenue. This ratio makes firms with different scales more comparable because emissions are evaluated against the economic activity used to generate revenue. The focus on operating emissions is especially relevant in a multi-country sample in which firms vary substantially in size and industry. Regional studies reinforce the need for additional evidence: Elago et al. (2025) find only limited profitability effects of GHG-emission intensity among ASEAN listed companies, and Munir and Pratama (2025) show that improved emission performance and environmental disclosure do not automatically translate into higher firm value in Southeast Asia. Cross-country heterogeneity is also emphasized by van Emous et al. (2021) and Hernandez-Vega (2025), who show that the carbon-financial relationship differs with country characteristics, economic development, and sectoral conditions.

This study evaluates two financial dimensions simultaneously. Financial Performance is represented by Return on Assets (ROA) and Return on Equity (ROE), capturing the efficiency of assets and shareholder capital in generating earnings. Financial Sustainability is represented by the Altman Z-Score, which summarizes several accounting ratios to indicate the strength of a firm's financial position and its exposure to financial distress (Altman, 1968). Examining these outcomes together broadens the analysis beyond profitability because a firm can remain profitable in the short run while still becoming financially vulnerable in the longer run.

A second unresolved issue concerns the role of Financial Slack. Resource-Based View (RBV) argues that heterogeneous internal resources can shape how firms respond to external pressures (Barney, 1991). Financial Slack represents discretionary financial capacity that can be used for working capital, strategic investment, debt service, or low-carbon adjustment. In this study, the current ratio is interpreted specifically as short-term liquidity slack—the capacity of current assets to cover current obligations while preserving near-term financial flexibility. This operationalization is distinct from cash slack, unused debt capacity, or broader excess-

resource measures. Ashraf et al. (2020) find that financial slack supports carbon performance in developing-country cement firms, while Alfiana et al. (2025) and Jaunanda and Putri (2025) demonstrate that financial slack is relevant to carbon-disclosure behavior in Indonesia and Malaysia. In the broader ESG context, Abdillah and Gunawan (2023) and Inayati et al. (2025) explicitly test financial slack as a moderating condition linking sustainability-related practices to firm performance. However, Heubeck and Ahrens (2025) show that the benefits of slack resources are not unlimited, suggesting that having additional resources does not guarantee that they will be allocated to sustainability responses.

Table A. Closest Prior Studies Involving Financial Slack

Study / Setting	Sustainability or Carbon Measure	Financial Outcome	Role of Financial Slack	Key Finding
Ashraf et al. (2020) – developing-country cement firms	Carbon performance	Carbon performance	Explanatory/moderating resource	Financial slack supports carbon performance; moderation depends on the external carbon context.
Abdillah & Gunawan (2023) – Indonesia	ESG	ROA / firm performance	Moderator	Financial slack strengthens the ESG–performance relationship.
Inayati et al. (2025) – Indonesia	ESG	ROA	Moderator	High financial slack does not necessarily strengthen the ESG–ROA relationship.
Mendieta-Callirgos et al. (2026) – Latin America	Scope 1, 2, and 3 emissions	ROA, ROE, Tobin's Q	Moderator	Financial slack moderates selected emissions–performance relationships.

Source: Summarized from the cited studies.

Stakeholder Theory provides a complementary explanation because firms respond to the claims of investors, creditors, regulators, customers, and society rather than to shareholders alone (Freeman, 1984). Carbon-intensive firms may face higher expectations concerning compliance, transition preparedness, disclosure quality, and environmental risk. If those pressures increase costs or restrict financing, Carbon Intensity may reduce both profitability and financial resilience. Financial Slack could theoretically buffer these effects by allowing firms to absorb additional costs and fund operational or technological adjustments. Mendieta-Callirgos et al. (2026) provide the closest empirical precedent by showing that financial slack moderates some relationships between Scope 1 and Scope 3 emissions and financial performance in Latin America.

The research gap therefore has four elements. First, prior findings remain divided between positive, negative, and limited carbon-financial associations. Second, previous studies use heterogeneous carbon measures, whereas this study focuses on the combined intensity of Scope 1 and Scope 2 emissions relative to revenue. Third, studies often examine profitability, firm value, default risk, or financial distress separately; the present design places Financial Sustainability and accounting-based Financial Performance side by side. Fourth, the closest moderation evidence either examines financial slack in broader ESG settings or tests scope-specific emissions and financial performance outside the ASEAN-5 and China setting. The present study extends that evidence by jointly examining Altman Z-Score, ROA, and ROE while treating Financial Slack as a boundary condition in a multi-country Asian sample.

Accordingly, this study examines whether Carbon Intensity is associated with Financial Sustainability and Financial Performance and whether Financial Slack changes the strength of

those relationships. The directional alternatives are specified a priori and form the basis for the one-tailed hypothesis tests used in the empirical analysis.

Stakeholder Theory implies that high carbon intensity can increase transition, compliance, financing, and reputational pressures. When these pressures weaken the overall financial position, a lower Altman Z-Score is expected.

H1: Carbon Intensity is negatively associated with Financial Sustainability (Altman Z-Score).

ROA captures the efficiency with which assets generate earnings. Carbon-related operating and transition costs can reduce this efficiency when they are not offset by equivalent operating benefits.

H2: Carbon Intensity is negatively associated with Return on Assets (ROA).

ROE reflects earnings generated for shareholders. Carbon-related costs, financing pressure, and adjustment expenditures can reduce returns available to equity holders.

H3: Carbon Intensity is negatively associated with Return on Equity (ROE).

Under RBV, short-term liquidity slack can provide resources to absorb carbon-related costs and finance operational adjustments. Therefore, greater Financial Slack is expected to make the negative Carbon Intensity–Z-Score association less severe.

H4: Financial Slack weakens the negative association between Carbon Intensity and Financial Sustainability.

The same buffering mechanism can provide firms with liquidity to fund efficiency improvements or absorb compliance and transition costs, reducing the adverse association between Carbon Intensity and ROA.

H5: Financial Slack weakens the negative association between Carbon Intensity and ROA.

Financial flexibility can also protect shareholder returns by helping firms finance carbon-related adjustments without placing the full burden on current earnings or equity resources.

H6: Financial Slack weakens the negative association between Carbon Intensity and ROE.

METHODS

Sample and Data

The study uses a quantitative explanatory design and secondary panel data from LSEG Workspace (Refinitiv). The population consists of non-financial firms listed in Indonesia, Malaysia, Singapore, Thailand, the Philippines, and China. Financial firms are excluded because their asset, liability, capital, and operating structures differ materially from non-financial firms, making the financial ratios less comparable. Purposive sampling requires availability of Carbon Intensity, the components of the Altman Z-Score, ROA, ROE, Financial Slack, Firm Size, Leverage, Revenue Growth, and GDP Growth for the observations used in the regressions. The observation period covers 2020–2025, and the final analysis uses 136 firms and 803 firm-year observations.

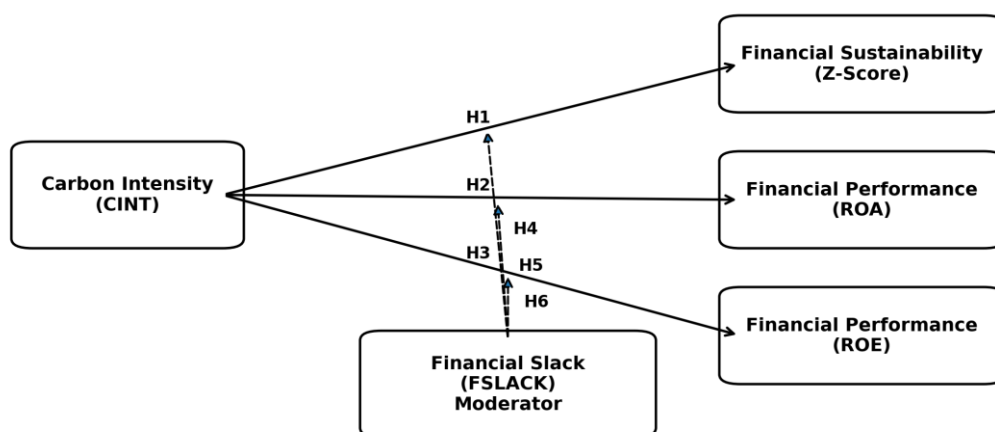
Variable Measurement

Carbon Intensity (CINT) is obtained from LSEG Workspace (Refinitiv) using the provider's GHG Emissions Direct, Scope 1 to Revenue USD in million and GHG Emissions Indirect, Scope 2 to Revenue USD in million fields. CINT is the sum of these two intensity

components; both are already standardized by LSEG relative to revenue in USD million, which supports comparability across countries without a researcher-performed currency conversion. The study uses the LSEG-provided values as supplied and does not re-estimate emissions; observations require the relevant fields to be available. Because original CINT is strongly right-skewed (skewness = 4.6464), the regression uses $\ln CINT = \ln(1 + CINT)$, which compresses the upper tail and provides a consistent transformation that remains defined if zero values occur; the transformed variable has skewness = -0.0367. Financial Sustainability is measured by the Altman Z-Score: $1.2(\text{Working Capital}/\text{Total Assets}) + 1.4(\text{Retained Earnings}/\text{Total Assets}) + 3.3(\text{EBIT}/\text{Total Assets}) + 0.6(\text{Market Value of Equity}/\text{Total Liabilities}) + 1.0(\text{Sales}/\text{Total Assets})$. Financial Performance is measured separately by $\text{ROA} = \text{Net Income After Tax}/\text{Total Assets}$ and $\text{ROE} = \text{Net Income After Tax}/\text{Total Equity}$. Financial Slack (FSLACK) equals $\text{Total Current Assets}/\text{Total Current Liabilities}$ and is interpreted as short-term liquidity slack. Firm Size, Leverage, Revenue Growth, and country-year GDP Growth are included as controls.

Empirical Models

The three direct models use $Y_{it} \in \{ZSCORE_{it}, ROA_{it}, ROE_{it}\}$: $Y_{it} = \alpha + \beta_1 \ln CINT_{it} + \beta_2 SIZE_{it} + \beta_3 LEV_{it} + \beta_4 REVGROWTH_{it} + \beta_5 GDPGROWTH_{ct} + Year_t + u_i + \varepsilon_{it}$. The three moderation models use the same outcomes and controls and add centered Financial Slack and the interaction term: $Y_{it} = \alpha + \beta_1 \ln CINT_{c,it} + \beta_2 FSLACK_{c,it} + \beta_3 (\ln CINT_{c,it} \times FSLACK_{c,it}) + \beta_4 SIZE_{it} + \beta_5 LEV_{it} + \beta_6 REVGROWTH_{it} + \beta_7 GDPGROWTH_{ct} + Year_t + u_i + \varepsilon_{it}$. All reported regressions use the same 803 firm-year observations. Firm effects are handled according to the estimator selected for each model, while year fixed effects capture common annual shocks. The conceptual relationships are summarized in Figure 1.



Source: Developed for this study, 2026.

Figure 1. Conceptual Framework

Analysis Procedure

The analysis is conducted in Stata 18. Descriptive statistics and Pearson correlations are followed by multicollinearity and panel-model specification tests. The pooled-versus-panel tests, Hausman tests, and Lagrange Multiplier tests are used to guide the choice among Common Effect, Fixed Effect, and Random Effect specifications. Because the standard Hausman variance-difference matrix produces warnings in some specifications, correlated-random-effects (Mundlak) checks are additionally reported as a robustness assessment of the estimator choice. Heteroskedasticity and serial correlation are accommodated using standard

errors clustered at the firm level. The F/Wald statistics are interpreted as tests of joint significance of the included regressors rather than as generic tests of model validity. Because all six hypotheses specify the expected coefficient direction in advance, hypothesis decisions use one-tailed p-values at the 1%, 5%, and 10% significance levels; corresponding two-tailed p-values are also reported for transparency.

RESULTS AND DISCUSSION

Sample and Descriptive Statistics

Before conducting the regression analysis, the data were screened to ensure that the observations used in the study had complete and consistent information for all variables included in the research model. The initial sample consisted of 139 non-financial firms, resulting in 834 firm-year observations. During the screening process, 31 firm-year observations from three firms were excluded because the required information was not sufficiently available to construct the variables used in the analysis. After the screening process, the final sample consisted of 136 firms with 803 firm-year observations.

The exclusion of these observations was based on data availability and consistency rather than on the statistical results of the regression analysis. In other words, observations were not removed because they produced significant, insignificant, positive, or negative results. This approach was applied consistently to ensure that the sample selection did not depend on the expected research findings.

The remaining observations were retained for the analysis without removing observations solely because of their large or small values. This approach allows the analysis to reflect the actual characteristics of the firms in the sample while avoiding the risk of selectively excluding observations that may influence the research results. As an additional consideration, the sensitivity of the findings to the observation-screening procedure can be examined by comparing the main results with those obtained from the full available sample and, where appropriate, a winsorized specification.

Table 1. Final Sample Composition

Category	Firms	Percentage
Panel A. Country composition		
China	32	23.53%
Thailand	31	22.79%
Malaysia	27	19.85%
Singapore	21	15.44%
Indonesia	13	9.56%
Philippines	12	8.82%
Total	136	100.00%
Panel B. GICS sector composition		
Industrials	25	18.38%
Real Estate	19	13.97%
Consumer Staples	19	13.97%
Energy	14	10.29%
Materials	14	10.29%
Utilities	12	8.82%
Communication Services	11	8.09%
Consumer Discretionary	10	7.35%
Information Technology	6	4.41%
Health Care	6	4.41%
Total	136	100.00%
Panel C. GICS industry composition		
Real Estate Management & Development	15	11.03%

Category	Firms	Percentage
Oil, Gas & Consumable Fuels	11	8.09%
Industrial Conglomerates	7	5.15%
Wireless Telecommunication Services	7	5.15%
Metals & Mining	7	5.15%
Food Products	7	5.15%
Independent Power and Renewable Electricity Producers	5	3.68%
Transportation Infrastructure	5	3.68%
Chemicals	5	3.68%
Passenger Airlines	4	2.94%
Electronic Equipment, Instruments & Components	4	2.94%
Beverages	4	2.94%
Other 33 GICS industries	55	40.44%
Total	136	100.00%

Source: Research data and GICS classifications from LSEG Workspace (Refinitiv), 2026.

Table 2 shows substantial variation across firms. The mean Z-Score is 2.8977, while mean ROA and ROE are 0.0370 and 0.1391, respectively. Original CINT has a mean of 628.9734 and a maximum of 11,643.56, confirming a strongly right-skewed distribution. The transformed lnCINT used in the regressions has a mean of 5.0388, a standard deviation of 1.7900, a minimum of 0.0704, and a maximum of 9.3626. Mean Financial Slack is 2.4988, indicating that current assets are, on average, about 2.5 times current liabilities in the observed firm-years.

Table 2. Descriptive Statistics

Variable	N	Mean	Std. Dev.	Min	Max
ZSCORE	803	2.8977	2.3448	-1.0640	21.2306
ROA	803	0.0370	0.0649	-0.1679	0.7995
ROE	803	0.1391	0.2243	-1.2821	2.3070
CINT	803	628.9734	1,331.6150	0.0730	11,643.5600
FSLACK	803	2.4988	3.3012	0.0007	43.0184
SIZE	803	22.6457	1.3755	19.3529	26.7373
LEV	803	0.2795	0.4769	0.0000	4.4438
REVGROWTH	803	0.0939	0.3261	-0.7912	3.2843
GDP	803	3.4300	3.6960	-9.5183	9.0317

Source: Data processed with Stata 18, 2026.

Pearson correlations provide preliminary evidence on the regression direction. Original CINT is negatively and significantly correlated with Z-Score and ROE and negatively but not significantly correlated with ROA. Correlations among explanatory variables remain well below 0.80, and the mean variance inflation factor is 1.05 with a maximum of 1.10, indicating no material multicollinearity. Diagnostic tests indicate heteroskedasticity in the three direct models and serial correlation in the Z-Score and ROA models, while serial correlation is not detected for ROE. These features primarily affect statistical inference rather than automatically invalidating the panel estimators, so the reported models use standard errors clustered at the firm level. Residual non-normality is reported as a distributional feature and interpreted cautiously rather than treated as a generic failure of the panel estimators.

Panel Specification and Model-Level Significance

Panel specification tests select Random Effects for the direct Z-Score model and Fixed Effects for the direct ROA and ROE models; all three moderation models use Fixed Effects.

The Hausman statistics are $\chi^2(9) = 16.26$ ($p = 0.0617$) for H1, $\chi^2(9) = 52.36$ ($p < 0.001$) for H2, $\chi^2(9) = 18.04$ ($p = 0.0347$) for H3, $\chi^2(11) = 21.68$ ($p = 0.0270$) for H4, $\chi^2(11) = 75.83$ ($p < 0.001$) for H5, and $\chi^2(11) = 21.30$ ($p = 0.0304$) for H6. The H1 Random-Effects choice is also supported by the Breusch-Pagan LM test ($\text{chibar}2 = 1297.56$, $p < 0.001$). For the Fixed-Effects moderation models, the firm-effects tests reject pooled OLS: H4 $F(135,655) = 25.12$, H5 $F(135,655) = 5.85$, and H6 $F(135,655) = 7.90$ (all $p < 0.001$). Table 3 reports the final firm-clustered model-level statistics. These F/Wald tests indicate joint significance of the included regressors; they are not interpreted as generic tests of model validity.

Table 3. Panel Specification and Model-Level Significance

Model / Outcome	Estimator	Within R ²	Overall R ²	Robust F/Wald statistic (p)
1 – ZSCORE	Random Effect	0.0693	0.0912	Wald $\chi^2(10) = 43.91$ ($p < 0.001$)
2 – ROA	Fixed Effect	0.0992	0.1062	$F(10,135) = 2.36$ ($p = 0.0134$)
3 – ROE	Fixed Effect	0.0792	0.0082	$F(10,135) = 2.34$ ($p = 0.0140$)
4 – ZSCORE moderation	Fixed Effect	0.0963	0.1365	$F(12,135) = 4.97$ ($p < 0.001$)
5 – ROA moderation	Fixed Effect	0.1173	0.1214	$F(12,135) = 2.69$ ($p = 0.0028$)
6 – ROE moderation	Fixed Effect	0.0860	0.0082	$F(12,135) = 2.98$ ($p = 0.0010$)

Source: Data processed with Stata 18, 2026.

As a robustness check, correlated-random-effects (Mundlak) specifications add firm means of the time-varying regressors. The joint mean tests are $\chi^2(5) = 8.13$ ($p = 0.1491$) for H1, $\chi^2(5) = 25.42$ ($p = 0.0001$) for H2, $\chi^2(5) = 9.29$ ($p = 0.0980$) for H3, $\chi^2(7) = 44.86$ ($p < 0.001$) for H4, $\chi^2(7) = 34.80$ ($p < 0.001$) for H5, and $\chi^2(7) = 12.39$ ($p = 0.0884$) for H6. The checks strongly support the FE treatment in H2, H4, and H5 and are consistent with the RE treatment in H1; H3 and H6 are less decisive under Mundlak, so their FE selection is retained on the basis of the Hausman and firm-effects tests. Importantly, the moderation coefficients remain essentially unchanged under the correlated-random-effects specification.

Hypothesis Testing

Table 4 reports both the pre-specified directional one-tailed p-values and conventional two-tailed p-values. H1 is supported: $\ln\text{CINT}$ has a coefficient of -0.1624429 for Z-Score (p one-tail = 0.0095 ; p two-tail = 0.019), indicating a negative association significant at the 1% directional level. H2 is supported only at the 10% directional level: the ROA coefficient is -0.0109504 (p one-tail = 0.0615 ; p two-tail = 0.123), so the evidence is weaker than for H1 and H3. H3 is supported at the 5% directional level because the ROE coefficient is -0.0308611 (p one-tail = 0.0290 ; p two-tail = 0.058). Thus, the estimated association is negative across all three outcomes, but its statistical strength differs across measures.

The moderation hypotheses are not supported. For H4, the $\ln\text{CINT} \times \text{FSLACK}$ coefficient is positive as predicted (0.0199078) but statistically insignificant (p one-tail = 0.2925 ; p two-tail = 0.585). For H5, the interaction coefficient is negative (-0.0025715), opposite to the hypothesized positive buffering direction, and is not significant in the firm-clustered model (p two-tail = 0.189 ; directional one-tailed p for the hypothesized positive sign = 0.9055). H6 is also negative (-0.0044549) and not significant (p two-tail = 0.243 ; directional one-tailed p = 0.8785). Financial Slack therefore does not significantly weaken the negative Carbon Intensity association in any of the three outcomes.

Table 4. Hypothesis Testing Results

H	Relationship	Expected Sign	Coefficient	p (1-tail / 2-tail)	Decision
H1	$\ln\text{CINT} \rightarrow \text{ZSCORE}$	–	-0.1624429	$0.0095 / 0.019$	Supported
H2	$\ln\text{CINT} \rightarrow \text{ROA}$	–	-0.0109504	$0.0615 / 0.123$	Supported at 10%
H3	$\ln\text{CINT} \rightarrow \text{ROE}$	–	-0.0308611	$0.0290 / 0.058$	Supported
H4	$\ln\text{CINT} \times \text{FSLACK} \rightarrow \text{ZSCORE}$	+	0.0199078	$0.2925 / 0.585$	Not supported

H	Relationship	Expected Sign	Coefficient	p (1-tail / 2-tail)	Decision
H5	lnCINT×FSLACK → ROA	+	-0.0025715	0.9055 / 0.189	Not supported: opposite sign
H6	lnCINT×FSLACK → ROE	+	-0.0044549	0.8785 / 0.243	Not supported: opposite sign

Source: Data processed with Stata 18, 2026. Decisions use the pre-specified directional one-tailed tests; two-tailed p-values are reported for transparency.

Table 5. Simple-Slopes / Marginal-Effects Analysis

Outcome	Financial Slack level	Centered FSLACK	dY/dlnCINT	p (2-tail)
Z-Score	Low (P25)	-1.498737	-0.1781045	0.043
Z-Score	Median	-0.959878	-0.1673769	0.050
Z-Score	High (P75)	0.204789	-0.1441910	0.128
ROA	Low (P25)	-1.498737	-0.0069846	0.227
ROA	Median	-0.959878	-0.0083703	0.176
ROA	High (P75)	0.204789	-0.0113653	0.130
ROE	Low (P25)	-1.498737	-0.0236510	0.101
ROE	Median	-0.959878	-0.0260516	0.079
ROE	High (P75)	0.204789	-0.0312400	0.059

Source: Marginal effects from the final firm-clustered moderation models. Low, median, and high Financial Slack correspond to the 25th, 50th, and 75th percentiles.

Carbon Intensity and Financial Sustainability

The negative Carbon Intensity coefficient for the Altman Z-Score indicates that higher operating emissions relative to revenue are associated with lower financial resilience. This result is consistent with Stakeholder Theory because carbon-intensive operations may be associated with greater regulatory exposure, transition costs, financing concerns, and reputational pressure. The finding also aligns with Kabir et al. (2021), who associate carbon emissions with higher default risk, and Ding et al. (2023), who find that emissions aggravate financial distress risk. Perera et al. (2023) adds a capital-market dimension by showing that higher carbon-emissions intensity is associated with greater idiosyncratic volatility. These results should be interpreted as associations rather than causal effects because the observational design does not eliminate simultaneity or other time-varying omitted factors.

The use of a relative intensity measure contributes to this interpretation. Busch et al. (2022) show that relative carbon measures often reveal more consistent financial associations than absolute emissions. An intensity ratio captures how much operating emission is required to generate a unit of revenue, so a higher value may signal a less carbon-efficient economic process. In the present sample, that condition is associated with a lower composite measure of financial health even after controlling for size, leverage, revenue growth, GDP growth, and year effects.

Carbon Intensity and Financial Performance

Carbon Intensity is also negatively associated with ROA and ROE in the directional tests, although the strength of the evidence differs. The ROA result is supported only at the 10% directional level, whereas the ROE association is supported at the 5% directional level. Higher emissions relative to revenue can be associated with weaker earnings efficiency when energy costs, compliance expenditures, transition investment, and operational adjustments outweigh contemporaneous operating benefits. The evidence is consistent with Ganda and Milondzo (2018), who report adverse carbon-performance relationships, and with the broader risk channel identified by Bolton and Kacperczyk (2021).

At the same time, the results differ from several prior studies. Vaicondam et al. (2025) find positive relationships between greenhouse gas emissions and financial performance in

Malaysia, while Mendieta-Callirgos et al. (2026) report positive links between Scope 1 emissions and ROA and ROE in Latin America. Xu et al. (2025) also documents a positive financial channel through carbon information disclosure in heavily polluting Chinese industries. These differences suggest that the financial consequences of emissions are context-dependent rather than universal. Cross-country work by van Emous et al. (2021) and Hernandez-Vega (2025) similarly indicates that institutional development, country characteristics, and sectoral structure can alter the observed carbon-financial relationship.

The ASEAN evidence also remains mixed. Elago et al. (2025) report limited profitability associations of GHG-emission intensity, while Munir and Pratama (2025) show that emission performance can improve environmental disclosure without automatically increasing firm value. In the present sample, the estimated pattern is negative across Z-Score, ROA, and ROE, but the statistical strength differs across outcomes. In particular, the ROA evidence is weaker and is supported only at the 10% directional level, so it should not be interpreted as equally strong as the Z-Score or ROE findings.

The Moderating Role of Financial Slack

Financial Slack does not provide statistically significant evidence of buffering the negative Carbon Intensity association with Z-Score, ROA, or ROE. The simple-slopes results clarify the pattern. For Z-Score, the estimated $\ln\text{CINT}$ slope becomes less negative as Financial Slack rises, but the interaction is not significant, so the attenuation cannot be interpreted as confirmed moderation. For ROA and ROE, the estimated slopes become more negative at higher Financial Slack, which points toward amplification rather than buffering; however, the interaction coefficients are also statistically insignificant. Under RBV, slack resources remain potentially valuable because they increase strategic flexibility (Barney, 1991), but their availability alone does not reveal how the resources are actually allocated.

The result contrasts with Mendieta-Callirgos et al. (2026), who identify moderation in some carbon-emission and financial-performance relationships, and with evidence that slack can support carbon performance or disclosure (Ashraf et al., 2020; Alfiana et al., 2025; Jaunanda & Putri, 2025). However, it is consistent with the broader proposition that slack is not uniformly beneficial. Heubeck and Ahrens (2025) find a nonlinear relationship between slack resources and ESG performance, while Inayati et al. (2025) show that high financial slack does not necessarily strengthen the relationship between ESG and ROA. Fitriana et al. (2024) similarly report that financial performance does not moderate the relationship between carbon-emission disclosure and firm value. These findings collectively caution against treating financial flexibility as an automatic sustainability buffer.

The rejected moderation hypotheses also refine the stakeholder interpretation. Greater liquidity does not remove stakeholder pressure associated with carbon-intensive activity; firms still face transition, disclosure, regulatory, and financing demands. Financial Slack may matter only when it is actively converted into capabilities or investments that address those pressures. Future work should therefore distinguish the existence of slack from its allocation and should test alternative slack measures, such as cash holdings or unused debt capacity.

Research Finding and Novelty

The central finding is a negative estimated association between Carbon Intensity and three complementary measures of corporate financial condition, with differing statistical strength across outcomes, combined with no statistically supported buffering role for Financial Slack. Relative to the closest Latin American evidence, the present study adds Financial Sustainability (Altman Z-Score) to ROA and ROE, uses a combined Scope 1–Scope 2 intensity measure standardized by revenue, and evaluates the framework in ASEAN-5 and China. The moderation results can be interpreted through RBV as suggesting that the mere availability of

short-term liquidity resources does not guarantee protection from carbon-related financial pressure. This is a theoretical interpretation rather than a directly observed capability, because the dataset does not identify how firms allocate their available slack.

CONCLUSION AND RECOMMENDATIONS

Conclusion

This study examines Carbon Intensity, Financial Sustainability, Financial Performance, and the moderating role of Financial Slack among non-financial firms in ASEAN-5 and China during 2020–2025. The evidence answers the research objectives in two main ways. First, Carbon Intensity is negatively associated with Financial Sustainability and Financial Performance: higher emissions relative to revenue are associated with a lower Altman Z-Score, lower ROA, and lower ROE, although the ROA evidence is supported only at the 10% directional level. Second, Financial Slack does not significantly moderate these relationships in the hypothesized buffering direction. The availability of current assets relative to current liabilities therefore cannot be interpreted as automatic protection against carbon-related financial pressure. Theoretically, the findings are consistent with Stakeholder Theory and provide a boundary-condition interpretation for RBV, while the observational design does not establish causality. Practically, managers should integrate carbon-intensity control into risk, investment, and performance management rather than relying on liquidity buffers alone.

Limitations

Several limitations should qualify the interpretation. The 803 observations from 136 firms form an unbalanced panel because a small number of companies lack complete annual data. Carbon Intensity includes only Scope 1 and Scope 2 emissions relative to revenue and therefore excludes value-chain Scope 3 emissions. Financial Slack is measured by current assets divided by current liabilities, which mainly reflects short-term liquidity flexibility and does not capture other forms of slack such as cash holdings or unused borrowing capacity. The cross-country sample also combines economies, industries, regulatory regimes, and carbon-policy environments that remain heterogeneous even after firm and year effects are considered. In addition, the study is observational and does not use an instrumental-variable, lagged-predictor, or other causal identification strategy; reverse causality and firm-specific time-varying omitted factors therefore cannot be ruled out. Finally, heteroskedasticity and serial correlation are addressed through firm-clustered standard errors, while residual non-normality is treated as a distributional limitation rather than a generic failure of the panel estimators.

Recommendations

Future research should extend the carbon measure to Scope 3 where reliable data are available and may test Scope 1, Scope 2, and Scope 3 separately to identify different financial channels. Alternative Financial Slack proxies, including cash holdings and unused debt capacity, should be examined to determine whether moderation depends on the form of financial flexibility. Country-specific or industry-specific analyses would also clarify whether the Carbon Intensity effect is stronger in carbon-intensive industries or in jurisdictions with stricter transition policies. Further studies can add other financial outcomes such as cash flow, cost of debt, Tobin's Q, and alternative distress measures, and can evaluate estimators or transformations that better address the remaining distributional limitations.

Author Contributions

The author(s) contributed to research conceptualization, theoretical development, data collection, data analysis, interpretation of findings, manuscript preparation, scholarly revision, and final approval of the manuscript.

REFERENCES

- Abdillah, P., & Gunawan, S. R. A. (2023). Does financial slack moderate effect of environmental, social, and governance (ESG) on firm performance? *Economics and Digital Business Review*, 4(2), 379–390. <https://doi.org/10.37531/ecotal.v4i2.627>
- Alfiana, S., Muchlis, M., & Jannah, R. (2025). Pengaruh profitabilitas, ukuran perusahaan, financial slack terhadap carbon emission disclosure dengan tekanan eksternal sebagai variabel moderasi. *Indonesian Journal of Taxation and Accounting*, 3(1), 40–55. <https://doi.org/10.66053/ijota.v3i1.167>
- Altman, E. I. (1968). Financial ratios, discriminant analysis and the prediction of corporate bankruptcy. *The Journal of Finance*, 23(4), 589–609. <https://doi.org/10.2307/2978933>
- Ashraf, N., Comyns, B., Tariq, S., & Chaudhry, H. R. (2020). Carbon performance of firms in developing countries: The role of financial slack, carbon prices and dense network. *Journal of Cleaner Production*, 253, 119846. <https://doi.org/10.1016/j.jclepro.2019.119846>
- Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of Management*, 17(1), 99–120. <https://doi.org/10.1177/014920639101700108>
- Bolton, P., & Kacperczyk, M. (2021). Do investors care about carbon risk? *Journal of Financial Economics*, 142(2), 517–549. <https://doi.org/10.1016/j.jfineco.2021.05.008>
- Busch, T., Bassen, A., Lewandowski, S., & Sump, F. (2022). Corporate carbon and financial performance revisited. *Organization & Environment*, 35(1), 154–171. <https://doi.org/10.1177/1086026620935638>
- Ding, X., Li, J., Song, T., Ding, C., & Tan, W. (2023). Does carbon emission of firms aggravate the risk of financial distress? Evidence from China. *Finance Research Letters*, 56, 104034. <https://doi.org/10.1016/j.frl.2023.104034>
- Downar, B., Ernstberger, J., Reichelstein, S., Schwenen, S., & Zaklan, A. (2021). The impact of carbon disclosure mandates on emissions and financial operating performance. *Review of Accounting Studies*, 26, 1137–1175. <https://doi.org/10.1007/s11142-021-09611-x>
- Elago, A. S., Capangpangan, A. T., Sabino, M. J., Gacho, S., Marcelo, J., & Catamco, E. (2025). Influence of GHG emissions intensity and ESG scores on the financial performance of publicly listed companies in the ASEAN region. *Critical Issue of Sustainable Future*, 2(1), 1–19. <https://doi.org/10.61511/crsusf.v2i1.1816>
- van Emous, R., Krušinskas, R., & Westerman, W. (2021). Carbon emissions reduction and corporate financial performance: The influence of country-level characteristics. *Energies*, 14(19), 6029. <https://doi.org/10.3390/en14196029>
- Fitriana, A., Maharani, D. A., Amelia, S. R., & Pangestika, L. W. (2024). Pengungkapan emisi karbon untuk meningkatkan nilai perusahaan: Apakah kinerja keuangan mampu memoderasi? *Akurasi: Jurnal Studi Akuntansi dan Keuangan*, 7(2), 407–420. <https://doi.org/10.29303/akurasi.v7i2.587>
- Freeman, R. E. (1984). *Strategic management: A stakeholder approach*. Pitman.
- Ganda, F., & Milondzo, K. S. (2018). The impact of carbon emissions on corporate financial performance: Evidence from the South African firms. *Sustainability*, 10(7), 2398. <https://doi.org/10.3390/su10072398>
- Hernandez-Vega, M. (2025). Corporate GHG emissions and financial performance: A cross-country panel analysis of sectoral heterogeneity in advanced and emerging economies. *Journal of Risk and Financial Management*, 18(10), 583. <https://doi.org/10.3390/jrfm18100583>
- Heubeck, T., & Ahrens, A. (2025). Governing the responsible investment of slack resources in environmental, social, and governance (ESG) performance: How beneficial are CSR

- committees? *Journal of Business Ethics*, 198(2), 365–385.
<https://doi.org/10.1007/s10551-024-05798-6>
- Inayati, N. I., Rahmawati, I. Y., Pandansari, T., Hapsari, I., & Ramadhani, A. N. (2025). Environmental, social and governance (ESG) and corporate financial performance: Moderating effects of financial slack. *MAKSIMUM: Media Akuntansi Universitas Muhammadiyah Semarang*, 15(1), 110–120.
<https://doi.org/10.26714/mki.15.1.2025.110-120>
- Jaunanda, M., & Putri, C. N. (2025). Financial slack and environmental performance on carbon disclosure in Indonesia and Malaysia mining companies. *EKUITAS (Jurnal Ekonomi dan Keuangan)*, 9(1), 125–138. <https://doi.org/10.24034/j25485024.y2025.v9.i1.6938>
- Kabir, M. N., Rahman, S., Rahman, M. A., & Anwar, M. (2021). Carbon emissions and default risk: International evidence from firm-level data. *Economic Modelling*, 103, 105617.
<https://doi.org/10.1016/j.econmod.2021.105617>
- Mendieta-Callirgos, A. I., Pérez-López, M. C., Muñoz-Pérez, I., & López-Pérez, G. (2026). How do carbon emissions affect the performance of listed Latin American firms? The moderating effect of financial slack. *Business Strategy and the Environment*.
<https://doi.org/10.1002/bse.70758>
- Munir, A. R., & Pratama, A. (2025). Emission performance, environmental disclosure, and firm value: Evidence from Southeast Asia. *Risks*, 13(12), 235.
<https://doi.org/10.3390/risks13120235>
- Perera, K., Kuruppuarachchi, D., Kumarasinghe, S., & Suleman, M. T. (2023). The impact of carbon disclosure and carbon emissions intensity on firms' idiosyncratic volatility. *Energy Economics*, 128, 107053. <https://doi.org/10.1016/j.eneco.2023.107053>
- Sekaran, U., & Bougie, R. (2016). *Research methods for business: A skill-building approach* (7th ed.). John Wiley & Sons.
- Vaicondam, Y., Mustafa, A. M. A. A., Roslan, S. N. M., Ming, K. L. Y., & Ramayah, M. (2025). GHG and carbon emission intensity: Examining their impact on financial performance. *International Journal of Energy Economics and Policy*, 15(1), 190–196.
<https://doi.org/10.32479/ijeep.17474>
- Xu, A., Su, Y., Wang, Y., & Liao, J. (2025). Carbon information disclosure and corporate financial performance: Empirical evidence based on heavily polluting industries in China. *PLOS ONE*, 20(1), e0313638. <https://doi.org/10.1371/journal.pone.0313638>