

CARBON DISCLOSURE AND THE COST OF DEBT: EVIDENCE FROM VIETNAM AS AN EMERGING MARKET

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ABSTRACT

This study examines the relationship between carbon disclosure and firms' cost of debt in an emerging market context, with a focus on the role of institutional conditions and econometric methodology. Using panel data from Vietnamese listed firms over the period 2017–2024, the analysis employs multiple estimation techniques, including pooled ordinary least squares, fixed effects, and fixed effects with Driscoll–Kraay standard errors, which are robust to cross-sectional dependence. The results indicate that the relationship between carbon disclosure and borrowing costs is sensitive to estimation methods. While the FGLS robustness check suggests a negative association, this relationship is not statistically significant when cross-sectional dependence is properly addressed. The preferred specification therefore provides no robust empirical evidence that carbon disclosure is systematically associated with the cost of debt in the examined market. These findings suggest that carbon disclosure is not yet consistently reflected in debt pricing within this context. This may be explained by institutional characteristics of emerging markets, where disclosure practices are often compliance-driven and may lack credibility and decision usefulness. The study contributes to the literature by providing evidence from an emerging market and by highlighting the methodological sensitivity of carbon disclosure and cost of debt relationships. The results underscore the importance of using robust econometric techniques when examining the financial implications of carbon disclosure.

Keywords: Carbon disclosure, cost of debt, ESG, cross-sectional dependence, Driscoll–Kraay, emerging markets.

1. INTRODUCTION

In recent years, environmental, social, and governance (ESG) issues have attracted increasing attention from both academic researchers and financial market participants. Among these, carbon disclosure has emerged as an important component of corporate transparency, reflecting firms' environmental responsibility and exposure to climate-related risks. Prior studies suggest that enhanced disclosure can reduce information asymmetry between firms and external stakeholders, thereby improving access to external financing and potentially lowering the cost of capital [1-4].

Despite growing interest in ESG, particularly carbon disclosure, the existing literature on the relationship between carbon-related disclosure and the cost of debt remains fragmented and inconclusive. Prior studies can be broadly categorized into three strands. First, several studies document a negative relationship, suggesting that carbon disclosure, climate change disclosure, or stronger carbon performance may reduce information asymmetry, improve creditors' risk assessment, and lower borrowing costs. Recent evidence from emerging and Asia-Pacific markets shows that carbon emission disclosure and corporate carbon performance

can be associated with lower cost of debt [5-7]. Second, other studies report weak, insignificant, or dimension-specific effects, indicating that carbon-related or ESG information does not always translate into lower financing costs. For example, Malaysian evidence shows an insignificant relationship between voluntary carbon emission disclosure quality and weighted-average cost of capital, while Indonesian ESG evidence suggests that governance may matter more for debt costs than environmental or social scores [8, 9]. Third, an emerging strand emphasizes that the ESG–finance relationship is highly contingent on institutional context and econometric specification [10-12].

These limitations raise concerns about whether previously documented relationships reflect true economic effects or are driven by contextual and methodological factors [10-15]. Therefore, it remains unclear whether carbon disclosure is actually priced in debt markets, particularly in emerging economies under more rigorous econometric treatment. This gap is particularly relevant because recent studies in emerging markets provide mixed evidence. While carbon emission disclosure and climate change disclosure have been found to reduce the cost of debt in Indonesia and Egypt, respectively, evidence from Malaysia indicates that carbon disclosure quality does not significantly affect WACC, and ESG evidence from Indonesia suggests that creditors may respond more strongly to governance than to environmental or social dimensions [5, 7-9]. Although prior studies show that carbon-related information can affect the cost of capital, bank loans, and corporate valuation, evidence on the debt-pricing role of carbon disclosure in emerging markets remains limited and inconclusive [1, 4, 16-19].

Motivated by these gaps, this study examines whether carbon disclosure affects firms' cost of debt in Vietnam over the period 2017–2024. In addition, it evaluates whether the observed relationship is sensitive to both institutional conditions and estimation methods. To achieve this, the analysis applies multiple panel data techniques, including pooled OLS, fixed effects (FE), and FE with Driscoll–Kraay standard errors, which are robust to heteroskedasticity, serial correlation, and cross-sectional dependence [12, 14].

The findings indicate that while the FGLS robustness check suggests that carbon disclosure may reduce borrowing costs, this effect disappears once cross-sectional dependence is properly addressed. The preferred specification suggests that carbon disclosure does not have a statistically significant impact on the cost of debt, implying that it is not yet consistently reflected in debt pricing within the examined market.

This study contributes to the literature in two important ways. First, it provides evidence from an emerging market context by extending the Vietnam-based carbon disclosure literature from cost of capital and firm value to the cost of debt [18, 19]. Second, it highlights the methodological sensitivity of carbon disclosure and debt-pricing relationships by demonstrating that empirical results may be driven by estimation choices, particularly when cross-sectional dependence is ignored [11, 12, 14, 15].

2. THEORETICAL BACKGROUND

2.1 Theoretical background

The relationship between carbon disclosure and the cost of debt can be explained through signaling theory, stakeholder theory, and institutional theory [20-23]. From the perspective of signaling theory, firms disclose information to reduce information asymmetry between insiders and external stakeholders [24, 25]. High-quality firms are more likely to disclose carbon-related information as a signal of superior environmental performance, climate-risk awareness, and risk management capability [1, 16]. Such disclosure can reduce uncertainty regarding future cash flows, environmental liabilities, transition risks, and regulatory exposure, thereby lowering perceived credit risk and the cost of debt [4, 16, 17].

Stakeholder theory suggests that firms engaging in responsible environmental practices are more likely to gain the trust of key stakeholders, including creditors [3, 13, 21]. Carbon disclosure can signal a firm's commitment to sustainability, potentially enhancing reputation, reducing stakeholder pressure, and improving access to external financing [2, 3, 17].

However, the effectiveness of carbon disclosure depends on its credibility, comparability, and informational content. Institutional theory emphasizes that disclosure practices are shaped by regulatory pressure, enforcement quality, and broader institutional environments [10, 22, 23]. In emerging markets, disclosure is often driven by compliance rather than voluntary transparency, which may reduce its credibility. As a result, such disclosure may be perceived as symbolic rather than substantive and may fail to provide decision-useful information to lenders, limiting its impact on borrowing costs [10, 13, 19]. Overall, while carbon disclosure may reduce information asymmetry and enhance stakeholder trust, its effect on the cost of debt is conditional on institutional context, disclosure credibility, verification mechanisms, and the extent to which creditors incorporate climate-related information into credit risk assessment [16, 17, 26-28].

2.2 Empirical research

Empirical evidence on the relationship between ESG/carbon disclosure and the cost of debt can be organized into three main streams.

First, several studies suggest that ESG, CSR, environmental disclosure, and carbon-related information can reduce firms' financing costs. This stream argues that greater disclosure enhances transparency, reduces information asymmetry, and allows capital providers, including creditors, to better assess firms' risk profiles [2, 3, 24, 25]. El Ghouli et al. show that firms with stronger CSR performance face a lower cost of capital, while Cheng, Ioannou and Serafeim demonstrate that CSR engagement improves firms' access to finance [2, 3]. More directly related to debt markets, Jung, Herbohn and Clarkson find that carbon risk is associated with the cost of debt financing, and Goss and Roberts show that CSR performance is reflected in the pricing of bank loans [16, 17]. Chava further shows that environmental concerns are relevant to both equity and debt capital costs [4]. Recent evidence also provides more direct support for the carbon-debt pricing channel. Nasih et al. find that carbon emission disclosure is associated with lower cost of debt in Indonesia, while Al Rabab'a, Rashid and Shams show that firms with stronger corporate carbon performance have lower cost of debt across Asia-Pacific countries [5, 6]. Almutairi further reports that climate change disclosure decreases the cost of debt, with political connections and ESG disclosure moderating this relationship [7]. These studies imply that carbon disclosure may reduce the cost of debt by signaling better environmental risk management, lower transition risk, and lower default risk.

Second, another stream reports weak, insignificant, dimension-specific, or context-dependent effects. This literature suggests that ESG or environmental disclosure does not always translate into financial benefits, especially when the disclosed information lacks credibility, comparability, verification, or substantive content [10, 13, 29]. Clarkson et al. show that the financial consequences of environmental strategies are not always straightforward, while Gillan, Koch and Starks emphasize that ESG-related outcomes vary across firms, markets, and research designs [13, 29]. Evidence from Malaysia also shows that voluntary carbon emission disclosure quality does not have a significant relationship with weighted-average cost of capital, suggesting that low disclosure quality may limit the financial relevance of carbon reporting [8]. Similarly, recent Indonesian evidence indicates that although overall ESG scores are associated with lower debt costs, only the governance component has a statistically significant negative relationship with debt costs, while environmental and social scores do not show meaningful standalone effects [9]. In emerging markets, CSR or carbon-related disclosure may also be symbolic rather than substantive, reducing its usefulness for creditors and investors [10, 19]. These findings indicate that the relationship between carbon disclosure and the cost of debt should not be assumed to be

uniformly negative, because creditors may discount ESG or carbon-related information if it is not credible, verified, or useful for credit risk assessment.

Third, a growing stream emphasizes the role of institutional context and econometric methodology. From an institutional perspective, ESG and carbon disclosure may be more informative in markets where reporting standards, enforcement mechanisms, assurance practices, and stakeholder pressure are stronger [10, 27, 28]. In emerging markets, however, disclosure may be compliance-driven or symbolic rather than substantive [10]. Recent Vietnam-based studies show that carbon-related information is becoming relevant to capital-market outcomes, including WACC and firm value, but the evidence remains context-specific and does not directly resolve whether carbon disclosure is priced in debt markets [18, 19]. From a methodological perspective, prior research warns that conventional panel estimators may produce misleading inference when cross-sectional dependence is ignored. Petersen shows that standard-error choices are critical in finance panel data, while Hoechle demonstrates that Driscoll–Kraay standard errors are robust to cross-sectional dependence [11, 12, 14, 15].

Taken together, these three streams show that the relationship between carbon disclosure and the cost of debt remains unresolved. Although several studies suggest that ESG, CSR, carbon disclosure, climate change disclosure, and stronger carbon performance can lower financing costs or cost of debt, other studies report weak, insignificant, dimension-specific, or context-dependent effects [4-9, 16, 17]. These mixed findings suggest that the financial relevance of carbon disclosure depends on disclosure credibility, verification, institutional conditions, ESG dimensions, creditor sophistication, and estimation methods. Therefore, this study addresses these gaps by examining Vietnamese listed firms and testing whether the carbon disclosure–cost of debt relationship remains significant after accounting for cross-sectional dependence.

2.3 Hypothesis Development

Under signaling theory, firms voluntarily disclose information to reduce information asymmetry between insiders and external capital providers [20, 24, 25]. Carbon disclosure can signal superior environmental risk management, carbon-risk awareness, and lower exposure to future regulatory, transition, or liability risks [1, 16, 27]. By improving transparency regarding environmental performance and climate-related risk, disclosure may reduce uncertainty about future cash flows, downside risk, transition risk, and potential environmental liabilities. In credit markets, lower perceived risk should translate into tighter loan pricing and a lower cost of debt. Consistent with this mechanism, prior empirical studies document that CSR, environmental risk, carbon emission disclosure, climate change disclosure, and corporate carbon performance can affect access to finance, bank loan pricing, and the cost of debt financing [3, 5-7, 16, 17].

H1: Carbon disclosure is negatively associated with firms' cost of debt.

While signaling theory predicts a negative effect, institutional theory implies that the effectiveness of disclosure depends on the credibility of the institutional environment, the quality of enforcement, and the extent of external verification [10, 22, 23]. In emerging markets, disclosure is often compliance-driven rather than voluntarily informative, and enforcement and assurance mechanisms may be weaker. As a result, carbon disclosure may be perceived as symbolic rather than substantive, reducing its informational value to creditors [10, 13, 19]. When credibility is low, lenders are less likely to incorporate disclosed ESG or carbon-related information into credit risk assessment, weakening or eliminating the pricing effect [16, 17, 26].

H2: In an emerging market setting, the negative relationship between carbon disclosure and the cost of debt is weakened or becomes statistically insignificant when disclosure credibility and institutional enforcement are limited.

Observed carbon disclosure and cost of debt relationships can be sensitive to econometric specification, particularly in panel settings with heteroskedasticity, serial correlation, and cross-sectional dependence arising from common shocks, macroeconomic conditions, and industry-wide dynamics [11, 15]. If such dependence is ignored, standard errors may be biased downward, leading to overstated statistical significance and potentially misleading inference [11, 12, 14]. Methods robust to heteroskedasticity, serial correlation, and cross-sectional dependence, such as Driscoll–Kraay standard errors, provide more reliable inference in panel data settings [12, 14]. Therefore, an apparent negative relationship identified under estimators that do not adequately address cross-sectional dependence may disappear once appropriate corrections are applied.

H3: The apparent negative relationship between carbon disclosure and the cost of debt becomes statistically insignificant when cross-sectional dependence is properly addressed.

3. METHODOLOGY

3.1 Data and Sample

This study employs a panel dataset consisting of 320 firm-year observations. The sample includes publicly listed firms over the study period, with data collected from financial statements and publicly available disclosures.

Financial variables are obtained from firms' annual reports, while carbon disclosure (CED) is constructed based on firms' environmental reporting. The final sample is restricted to firms with complete data for all variables used in the analysis, ensuring a balanced panel structure.

3.2 Variable Definitions

The dependent variable in this study is the cost of debt (COD), measured as the ratio of interest expenses to total debt. This measure captures the effective borrowing cost faced by firms and is widely used in the corporate finance and disclosure literature as a proxy for debt financing costs [16, 17, 30, 31].

The key independent variable, carbon disclosure (CED), is measured as a binary indicator that takes the value of 1 if a firm discloses carbon-related information and 0 otherwise. This approach is consistent with prior studies that focus on the presence of environmental or carbon-related disclosure as an initial signal of transparency [1, 19, 29]. In the context of an emerging market such as Vietnam, where standardized ESG reporting frameworks are still developing and disclosure practices remain heterogeneous, a binary measure provides a practical and consistent way to capture firms' participation in carbon reporting [10, 18, 19].

However, this measure does not capture the quality, depth, comparability, or credibility of the disclosed information. Prior literature suggests that the effectiveness of carbon disclosure depends not only on whether firms disclose information, but also on the extent to which such disclosure is detailed, comparable, verified, and decision-useful [13, 27, 28]. As a result, the binary measure may introduce measurement limitations by treating all disclosures as equally informative, regardless of their substantive content.

This limitation is particularly relevant in emerging markets, where disclosure may be driven by regulatory compliance or symbolic considerations rather than genuine transparency [10, 19]. Consequently, the lack of a significant relationship between carbon disclosure and

the cost of debt observed in this study may partly reflect the inability of the binary measure to distinguish between high-quality and low-quality disclosure.

Future research may address this limitation by constructing a composite disclosure index that captures multiple dimensions of carbon reporting, such as emission metrics, reduction targets, climate-related risk management, third-party verification, and alignment with international frameworks such as IFRS S2 and TCFD [1, 27, 28]. Such an approach would allow for a more nuanced assessment of how disclosure quality influences creditors' risk perception and financing costs.

Following the existing literature, several firm-level control variables are included to account for factors that may influence the cost of debt [4, 16, 17]. Firm size (SIZE) is measured as the natural logarithm of total assets. Larger firms are generally expected to have lower borrowing costs due to greater diversification, better access to capital markets, and lower perceived default risk. Leverage (LEV) is defined as total debt divided by total assets, capturing the firm's financial risk; higher leverage is typically associated with higher borrowing costs due to increased default risk. Profitability (ROA), measured as return on assets, reflects firms' operating performance; more profitable firms are expected to face lower financing costs as they are perceived to be less risky. Asset tangibility (TANG) is measured as the ratio of fixed assets to total assets and represents the availability of collateral, which may reduce borrowing costs by mitigating lenders' risk exposure. Liquidity (LIQ), measured as the current ratio, captures firms' short-term solvency; firms with higher liquidity are generally expected to have lower borrowing costs.

To control for unobserved macroeconomic shocks and time-specific effects that may influence all firms, year fixed effects are included in all regression models [11, 12].

3.3 Model Specification

To examine the relationship between carbon disclosure and the cost of debt, the following baseline regression model is estimated:

$$\text{COD}_{it} = \beta_0 + \beta_1 \text{CED}_{it} + \beta_2 \text{SIZE}_{it} + \beta_3 \text{LEV}_{it} + \beta_4 \text{ROA}_{it} + \beta_5 \text{TANG}_{it} + \beta_6 \text{LIQ}_{it} + \gamma_t + \varepsilon_{it}$$

where i denotes firms, t denotes year, and γ_t represents year fixed effects.

3.4 Estimation Strategy

To examine the relationship between carbon disclosure and the cost of debt, this study employs panel data estimation techniques with increasing levels of econometric rigor [32, 33].

The analysis begins with pooled ordinary least squares (OLS) and fixed effects (FE) models as baseline specifications. The pooled OLS model provides a benchmark estimate but does not control for unobserved heterogeneity across firms. To address this limitation, the fixed effects model is employed to control for time-invariant firm-specific characteristics that may affect borrowing costs [32, 33]. The Hausman specification test is conducted to determine the appropriate panel estimator, and the results indicate that the fixed effects model is preferred over the random effects model [33, 34].

However, standard panel estimators rely on assumptions that are often violated in corporate finance data. Specifically, firms may be subject to common shocks, industry-wide dynamics, and macroeconomic conditions, leading to cross-sectional dependence across panel units. In addition, panel data may exhibit heteroskedasticity and serial correlation, which can invalidate conventional inference if not properly addressed [11, 12, 15].

Prior research highlights that improper treatment of standard errors in panel data settings may result in biased statistical inference [11]. In particular, ignoring cross-sectional dependence can lead to underestimated standard errors and overstated statistical significance [12, 14, 15]. These issues are especially relevant in emerging market contexts, where firms are

more likely to be affected by common institutional, regulatory, and macroeconomic factors [10, 15].

To address these econometric concerns, this study adopts the fixed effects model with Driscoll–Kraay standard errors as the preferred estimation approach. This method provides standard errors that are robust to heteroskedasticity, serial correlation, and cross-sectional dependence, making it well-suited for panel data with cross-sectional correlation [12, 14].

For comparison purposes, additional estimation techniques are also employed, including fixed effects with cluster-robust standard errors and feasible generalized least squares (FGLS). Cluster-robust standard errors address within-firm correlation and heteroskedasticity, while FGLS accounts for specific forms of heteroskedasticity and autocorrelation under stronger assumptions about the error structure [11, 33]. However, these approaches may not fully address cross-sectional dependence when common shocks affect firms simultaneously [12, 15]. As a result, their estimates are interpreted with caution and primarily used as robustness checks rather than as the basis for main conclusions.

This estimation strategy allows the study to distinguish between apparent relationships and those that are robust to econometric concerns. In particular, by explicitly accounting for cross-sectional dependence, the analysis reduces the risk of biased inference and provides more reliable evidence on whether carbon disclosure is systematically associated with the cost of debt [11, 12, 14].

3.5 Robustness Checks

To ensure that the baseline results are robust and not driven by model specification or estimation choices, several additional estimation techniques and alternative model specifications are employed [11, 32, 33].

First, the fixed effects model with cluster-robust standard errors, clustered at the firm level, is estimated to account for within-firm serial correlation and heteroskedasticity [11, 33]. While this approach provides more reliable inference than conventional fixed effects, it does not fully address cross-sectional dependence [12, 15]. Therefore, it serves as a complementary specification rather than a substitute for the preferred Driscoll–Kraay estimator [12, 14].

Second, the random effects model is estimated as an alternative panel specification. Although the Hausman test indicates that the fixed effects model is more appropriate, reporting random effects estimates provides additional insights under different assumptions regarding unobserved heterogeneity [32–34]. This comparison helps assess whether the main findings are sensitive to model selection.

Third, a lagged-disclosure specification is introduced by incorporating a one-period lag of carbon disclosure. This approach allows for the possibility that creditors may respond to disclosure with a delay, rather than immediately. The lagged model helps capture potential temporal effects and provides additional evidence on whether carbon disclosure has a persistent or delayed impact on the cost of debt [16, 17, 33].

Finally, feasible generalized least squares is employed as an additional robustness check. FGLS accounts for heteroskedasticity and autocorrelation in the error structure and is widely used in panel data analysis [32, 33]. However, it relies on specific assumptions about the variance–covariance matrix and does not adequately correct for cross-sectional dependence. As a result, FGLS may produce downward-biased standard errors and overstated statistical significance when cross-sectional correlation is present [11, 12, 15]. Therefore, its results are interpreted with caution and are primarily used for comparison with the preferred Driscoll–Kraay estimates [12, 14].

Taken together, these robustness checks provide a comprehensive assessment of the stability of the empirical results across alternative estimation approaches. Consistent findings

across these specifications would strengthen confidence in the main conclusions, while any discrepancies would highlight the importance of appropriate econometric treatment, particularly in the presence of cross-sectional dependence [11, 12, 14, 15].

4. RESULTS AND DISCUSSION

4.1 Empirical Results

Table 1. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
COD	320	0.049	0.025	0	0.117
CED	320	0.203	0.403	0	1
SIZE	320	16.244	1.471	14.024	20.151
LEV	320	0.49	0.173	0.134	0.839
ROA	320	0.073	0.067	-0.016	0.31
TANG	320	0.33	0.23	0.007	0.872
LIQ	320	1.894	1.299	0.326	7.614

Source: Author's calculations based on the study dataset using Stata 17.

Table 1 presents the descriptive statistics of the variables used in the analysis, based on 320 firm-year observations. The average cost of debt (COD) is relatively low, suggesting moderate borrowing costs among the sampled firms. Carbon disclosure (CED) has a mean value of 0.203, indicating that only a small proportion of firms disclose carbon-related information. The relatively high standard deviation reflects the binary nature of the variable and variation in disclosure practices across firms.

The control variables exhibit reasonable variation. Firm size (SIZE) shows moderate dispersion, while leverage (LEV) indicates that firms rely substantially on debt financing. Profitability (ROA) is positive on average, although some firms report negative values. Asset tangibility (TANG) and liquidity (LIQ) display considerable heterogeneity, suggesting differences in asset structure and financial conditions across firms. Overall, the dataset provides sufficient variation to support panel data analysis.

Table 2. Correlation Matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) COD	1.000						
(2) CED	-0.027	1.000					
(3) SIZE	0.176***	0.064	1.000				
(4) LEV	0.122**	-0.160***	0.271***	1.000			
(5) ROA	-0.094*	0.029	-0.260***	-0.569***	1.000		
(6) TANG	0.222***	0.058	-0.028	-0.019	-0.244***	1.000	
(7) LIQ	-0.127**	0.094*	-0.146***	-0.649***	0.493***	-0.268***	1.000

*Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$*

Source: Author's calculations based on the study dataset using Stata 17.

Table 2 reports the correlation matrix. The correlation coefficients are generally low to moderate, suggesting that multicollinearity is unlikely to be a major concern. The highest correlation is observed between leverage (LEV) and liquidity (LIQ), which is negative and

consistent with financial theory. Importantly, carbon disclosure (CED) shows a weak and statistically insignificant correlation with the cost of debt (COD), providing preliminary evidence that carbon disclosure may not directly influence borrowing costs.

Table 3. Diagnostic tests for model validity

Test	Method	Statistic	P-value	Conclusion
Hausman Test	Hausman Specification Test	$\chi^2 = 14.38$	0.0257	Fixed effects model preferred
Multicollinearity	Variance Inflation Factor (VIF)	Mean VIF = 1.58	–	No evidence of multicollinearity
Heteroskedasticity	Modified Wald Test	$\chi^2 = 1093.60$	0.0000	Heteroskedasticity detected
Autocorrelation	Wooldridge Test	F = 25.126	0.0000	First-order autocorrelation detected
Cross-sectional dependence	Pesaran CD Test	CD = 11.509	0.0000	Cross-sectional dependence detected
Endogeneity	Durbin–Wu–Hausman (F-test)	F = 0.782	0.3774	No statistical evidence of endogeneity detected

Source: Author's calculations based on the study dataset using Stata 17.

The diagnostic test results are reported in Table 3. The Hausman test rejects the null hypothesis of random effects (p-value = 0.0257), indicating that the fixed effects model is more appropriate for the analysis.

The results also reveal several violations of standard panel data assumptions. The Modified Wald test strongly rejects the null hypothesis of homoskedasticity ($\chi^2 = 1093.60$, $p < 0.01$), indicating the presence of heteroskedasticity. Similarly, the Wooldridge test rejects the null hypothesis of no first-order autocorrelation ($F = 25.126$, $p < 0.01$), confirming the existence of serial correlation within panels.

In addition, the Pesaran CD test provides strong evidence of cross-sectional dependence ($CD = 11.509$, $p < 0.01$), suggesting that firms are subject to common shocks or unobserved factors that induce correlation across cross-sectional units. This issue is particularly relevant in corporate finance contexts, where firms may be jointly affected by macroeconomic conditions, regulatory changes, and industry-wide dynamics.

Finally, the Durbin–Wu–Hausman test does not reject the null hypothesis of exogeneity for carbon disclosure. However, this result should be interpreted as a diagnostic check rather than definitive evidence that endogeneity is absent.

Taken together, these findings imply that conventional panel estimators such as pooled OLS, standard fixed effects, and random effects may yield biased standard errors and unreliable statistical inference. Therefore, this study adopts the fixed effects model with Driscoll–Kraay standard errors, which is robust to heteroskedasticity, autocorrelation, and cross-sectional dependence.

Table 4. Baseline Regression Results

Dependent variable: Cost of Debt (COD)			
Variables	(1) OLS	(2) FE	(3) FE (Driscoll–Kraay)
CED	-0.00228 (-0.66)	0.000132 (0.04)	0.000132 (0.05)
SIZE	0.00300*** (3.05)	-0.00677** (-2.32)	-0.00677** (-2.61)
LEV	0.0191 (1.56)	0.0215 (1.52)	0.0215 (1.47)
ROA	0.0310 (1.16)	0.0898** (4.30)	0.0898** (3.10)
TANG	0.0283*** (4.26)	0.0653*** (8.96)	0.0653*** (20.07)
LIQ	0.000289 (0.19)	0.00158 (1.11)	0.00158 (0.74)
Year Fixed Effects	No	Yes	Yes
Observations	320	320	320

Note: *t*-statistics are reported in parentheses. *, **, *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Column (3) uses Driscoll–Kraay standard errors, robust to heteroskedasticity, autocorrelation, and cross-sectional dependence.

Source: Author's calculations based on the study dataset using Stata 17.

Table 4 reports the baseline regression results using pooled OLS, fixed effects (FE), and fixed effects with Driscoll–Kraay standard errors, which is the preferred specification.

Across all models, the coefficient on carbon disclosure (CED) is statistically insignificant. In the preferred Driscoll–Kraay specification, the coefficient is economically small and indistinguishable from zero, indicating no robust empirical evidence that carbon disclosure is associated with the cost of debt in this sample. These findings do not support H1 and suggest that carbon disclosure is not yet priced by creditors in the examined market.

Among the control variables, firm size (SIZE) is negatively associated with the cost of debt, indicating that larger firms benefit from lower borrowing costs. Profitability (ROA) shows a positive and significant relationship with COD, which may reflect increased borrowing demand or risk-taking behavior among more profitable firms. Asset tangibility (TANG) is positively and strongly associated with borrowing costs, suggesting that firms with higher tangible assets may operate in more capital-intensive environments. In contrast, leverage (LEV) and liquidity (LIQ) are not statistically significant in the preferred specification.

Overall, the results suggest that traditional financial characteristics remain the primary determinants of firms' cost of debt, while carbon disclosure is not yet consistently reflected in debt pricing in the examined market under the preferred estimation approach.

Table 5. Robustness Checks

Dependent variable: Cost of Debt (COD)				
Variables	(1) FGLS	(2) FE (Clustered)	(3) RE	(4) Lagged Model
CED	-0.00493** (-2.04)	0.000132 (0.03)	-0.0055 (-0.43)	—
L.CED	—	—	—	0.00601 (1.25)
SIZE	0.00159 (1.58)	-0.00677 (-1.40)	-0.000626 (-0.33)	-0.0111** (-2.78)
LEV	0.0111 (1.12)	0.0215 (0.99)	0.0182 (1.44)	0.0320* (2.12)
ROA	0.00263 (0.16)	0.0898** (3.11)	0.0831*** (4.04)	0.0627*** (4.33)
TANG	0.0406*** (6.47)	0.0653*** (4.61)	0.0566*** (8.34)	0.0630*** (33.06)
LIQ	0.000944 (0.73)	0.00158 (0.66)	0.000966 (0.71)	0.00257 (1.35)
Year Fixed Effects	No	Yes	Yes	Yes
Observations	320	320	320	280

Note: *t*-statistics are reported in parentheses. *, **, *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

L.CED is the one-period lag of carbon disclosure.

Column (1) reports FGLS estimates.

Column (2) uses standard errors clustered at the firm level.

Column (3) reports Random Effects estimates.

Column (4) includes a one-period lag of carbon disclosure to test delayed disclosure effects.

Source: Author's calculations based on the study dataset using Stata 17.

Table 5 presents the results from alternative estimation techniques to assess the robustness of the baseline findings. The FGLS model in Column (1) indicates a negative and statistically significant relationship between carbon disclosure and the cost of debt. However, this result contrasts with the preferred Driscoll–Kraay estimation. Given that FGLS does not adequately address cross-sectional dependence, the observed significance is likely driven by downward-biased standard errors rather than a true economic effect. Consistent with this interpretation, the fixed effects model with cluster-robust standard errors in Column (2) yields an insignificant coefficient on CED. Similarly, the random effects model in Column (3) does not provide evidence of a significant relationship. The lagged model in Column (4) also shows that the one-period lag of carbon disclosure (*L.CED*) is statistically insignificant, suggesting that there is no delayed effect on borrowing costs.

Overall, these results support H3, indicating that the apparent significance of carbon disclosure disappears once cross-sectional dependence is properly addressed. This finding underscores the importance of using appropriate econometric techniques in panel data analysis.

4.2 Discussion

The empirical findings provide several important insights into the relationship between carbon disclosure and the cost of debt.

First, the results indicate that carbon disclosure does not exhibit a statistically significant association with borrowing costs in the examined market. This finding contrasts with the

predictions of signaling and stakeholder theories, which suggest that greater transparency can reduce information asymmetry, strengthen stakeholder confidence, and improve access to external financing [3, 20, 21, 24, 25]. It is also inconsistent with several recent studies showing that carbon emission disclosure, climate change disclosure, and stronger corporate carbon performance may reduce firms' cost of debt [5-7, 16, 17]. A plausible interpretation is that carbon disclosure, as currently practiced in Vietnam, does not convey sufficiently credible, comparable, or decision-useful information to creditors. In particular, because carbon disclosure is measured as a binary indicator, it captures the existence of reporting rather than the quality, depth, reliability, or verification of the disclosed information. Consequently, creditors may not be able to distinguish firms with substantive environmental commitment from those engaging primarily in symbolic or compliance-oriented disclosure [10, 13, 19].

Second, the findings highlight the critical role of institutional context in shaping the effectiveness of carbon disclosure. In emerging markets such as Vietnam, environmental reporting may be driven more by regulatory compliance than by voluntary transparency, thereby reducing its credibility and informational value [10, 13, 19]. From an institutional perspective, disclosure that is weakly standardized, weakly verified, or primarily compliance-oriented is more likely to be perceived as symbolic rather than substantive. This weakens the signaling role of carbon disclosure and limits its usefulness for creditors in assessing credit risk [10, 27, 28].

In addition, the structure of the financial system may further limit the role of carbon disclosure in debt pricing. In bank-based financial systems, creditors often place greater emphasis on traditional financial indicators such as collateral, leverage, profitability, liquidity, and repayment capacity, while non-financial disclosures may be less systematically incorporated into credit risk assessment [16, 17, 26]. This may reduce the likelihood that lenders rely heavily on carbon-related information when pricing debt. Moreover, the absence of standardized reporting frameworks and independent assurance mechanisms limits the comparability and reliability of carbon-related information across firms. Without credible, comparable, and verifiable metrics, creditors face difficulties in incorporating environmental information into lending decisions [26-28].

These findings are broadly consistent with the view that the financial relevance of ESG and carbon-related information varies across institutional contexts and disclosure dimensions. Evidence from Indonesia suggests that carbon emission disclosure may reduce the cost of debt when supported by institutional mechanisms and environmental disclosure programs [5]. Evidence from Asia-Pacific countries also shows that firms with stronger corporate carbon performance tend to face lower cost of debt [6]. However, evidence from Malaysia reports an insignificant relationship between voluntary carbon emission disclosure quality and weighted-average cost of capital, suggesting that weak disclosure quality may limit the financial relevance of carbon reporting [8]. Similarly, recent Indonesian ESG evidence indicates that although overall ESG performance may be associated with debt costs, creditors appear to place greater weight on governance-related information than on environmental or social dimensions [9]. These mixed findings reinforce the argument that carbon disclosure is not automatically priced by creditors; rather, its pricing effect depends on disclosure credibility, institutional quality, verification mechanisms, ESG dimensions, and creditors' ability to incorporate non-financial information into credit risk assessment.

Third, the discrepancy between FGLS and Driscoll-Kraay results underscores the importance of econometric methodology. The significant negative relationship observed under FGLS disappears once cross-sectional dependence is properly addressed, suggesting that the initial result may be driven by biased standard errors rather than a true economic effect. Prior research demonstrates that inappropriate standard-error treatment and failure to account for cross-sectional dependence can lead to overstated statistical significance in panel-data

regressions [11, 12, 14, 15]. This finding highlights the importance of using robust estimation techniques when examining carbon disclosure and cost-of-debt relationships, particularly in settings where firms are simultaneously exposed to common macroeconomic, industry-wide, regulatory, and institutional shocks.

Finally, the results suggest that creditors in the examined market continue to rely primarily on traditional financial indicators when assessing credit risk, while ESG-related and carbon-related information has not yet been systematically incorporated into lending decisions. This does not imply that carbon disclosure is economically irrelevant. Rather, it suggests that the debt-pricing role of carbon disclosure is conditional on disclosure quality, institutional support, verification mechanisms, lender sophistication, and the availability of standardized reporting frameworks. This interpretation is consistent with recent international evidence showing that carbon emission disclosure, climate change disclosure, and corporate carbon performance can reduce borrowing costs in some institutional settings, while weak disclosure quality or limited creditor reliance on ESG information may weaken such effects [5-9]. Taken together, the findings suggest that the economic relevance of carbon disclosure depends not only on firms' reporting behavior but also on institutional quality, disclosure credibility, reporting standards, verification mechanisms, and appropriate econometric treatment.

4.3 Implications

The findings of this study have several important implications for academic research, corporate practice, and public policy.

From an academic perspective, this study contributes to the ESG–finance literature by showing that the relationship between carbon disclosure and the cost of debt is highly sensitive to econometric specification. In particular, the disappearance of statistical significance after correcting for cross-sectional dependence suggests that prior evidence reporting a negative relationship between carbon disclosure and borrowing costs should be interpreted with caution if heteroskedasticity, serial correlation, and cross-sectional dependence are not adequately addressed [11, 12, 14, 15]. This implication is especially relevant for corporate finance research in emerging markets, where firms may be simultaneously affected by macroeconomic shocks, regulatory changes, and industry-wide conditions. The findings also contribute to the growing literature showing that the financial effects of carbon-related information are not uniform across institutional settings. While recent studies document that carbon emission disclosure, climate change disclosure, and stronger carbon performance can reduce the cost of debt in some contexts, other evidence reports insignificant or dimension-specific effects [5-9]. Therefore, future research should pay closer attention to disclosure credibility, institutional conditions, ESG dimensions, and methodological choices when examining the financial consequences of carbon disclosure.

In addition, the findings underscore the need for more refined measurement of carbon disclosure. The use of a binary proxy may obscure important variation in disclosure quality, depth, comparability, and verification. A firm that merely mentions carbon-related issues should not be treated as equivalent to a firm that provides detailed emissions data, reduction targets, governance mechanisms, transition-risk assessment, and third-party assurance. Future studies should therefore develop multidimensional carbon disclosure indices that capture the substantive content and decision-usefulness of disclosure, rather than relying only on the presence or absence of reporting [13, 19, 27, 28]. Such an approach would allow researchers to distinguish between symbolic and substantive disclosure and to better assess whether creditors respond to high-quality carbon information.

From a managerial perspective, the results indicate that firms should not expect immediate financial benefits, such as lower borrowing costs, from merely disclosing carbon-

related information. When disclosure is perceived as compliance-driven, generic, or weakly verified, it is unlikely to influence creditors' credit risk assessments. Therefore, firms need to move beyond symbolic disclosure and provide substantive, credible, and decision-useful carbon information. This includes detailed emissions metrics, reduction targets, climate-risk governance, transition-risk management, and independent verification [26-28]. Enhancing the credibility and transparency of carbon disclosure may improve its effectiveness as a signaling mechanism and increase its relevance for lenders' financial decision-making. In the absence of such improvements, ESG reporting may remain a formal compliance exercise rather than a value-creating activity.

From a policy perspective, the findings highlight the critical role of institutional development in determining the economic relevance of carbon disclosure. Although regulatory frameworks increasingly require firms to disclose environmental information, such disclosure may have limited financial impact if it lacks standardization, comparability, verification, and enforcement. Policymakers should therefore strengthen carbon disclosure standards and ESG reporting frameworks by promoting alignment with internationally recognized frameworks such as IFRS S2 and the TCFD recommendations [27, 28]. In addition, regulators should encourage independent assurance mechanisms to improve disclosure credibility and reduce the risk that carbon reporting becomes symbolic or compliance-oriented [10, 19].

Finally, financial regulators and banking supervisors should encourage the integration of ESG and climate-related financial risks into banking regulation, supervisory review, internal risk management systems, and credit risk assessment guidelines [26]. This is particularly important in emerging markets, where creditors may continue to rely primarily on traditional financial indicators such as collateral, leverage, profitability, and repayment capacity. By improving the credibility of corporate carbon disclosure and encouraging financial institutions to incorporate climate-related information into lending decisions, policymakers may help strengthen the link between carbon transparency and debt pricing. Taken together, these implications suggest that the effectiveness of carbon disclosure depends not only on firms' reporting behavior, but also on disclosure quality, verification mechanisms, institutional enforcement, lender sophistication, and appropriate econometric treatment.

5. CONCLUSION

This study examines the relationship between carbon disclosure and firms' cost of debt in an emerging market context, with a particular focus on the role of institutional conditions and econometric methodology. Using panel data from Vietnamese listed firms over the period 2017–2024, the analysis applies multiple estimation techniques, including pooled OLS, fixed effects, FGLS, and fixed effects with Driscoll–Kraay standard errors, which are robust to cross-sectional dependence.

The results show that the relationship between carbon disclosure and borrowing costs is highly sensitive to estimation methods. While the FGLS estimator suggests a significant negative association between carbon disclosure and the cost of debt, this relationship disappears when cross-sectional dependence is properly addressed using Driscoll–Kraay standard errors. The preferred specification therefore indicates that carbon disclosure does not have a statistically significant impact on the cost of debt in the examined market.

These findings do not imply that carbon disclosure is economically irrelevant. Rather, they suggest that the debt-pricing role of carbon disclosure is conditional on disclosure credibility, reporting quality, institutional enforcement, verification mechanisms, and creditors' ability to incorporate non-financial information into credit risk assessment. This interpretation is consistent with recent evidence showing that carbon emission disclosure, climate change disclosure, and stronger corporate carbon performance can reduce the cost of

debt in some institutional settings, while other studies report weak, insignificant, or dimension-specific effects [5-9].

This study contributes to the literature in two important ways. First, it provides evidence from Vietnam as an emerging market, where carbon disclosure practices and ESG reporting infrastructure are still developing. The findings suggest that carbon disclosure may not be consistently reflected in debt pricing when disclosure is compliance-oriented, weakly standardized, or insufficiently verified. Second, the study highlights the methodological sensitivity of carbon disclosure and cost-of-debt relationships by showing that empirical conclusions may change once cross-sectional dependence is properly addressed. This finding reinforces the importance of using robust econometric methods in corporate finance panel-data research [11, 12, 14, 15].

Several limitations should be acknowledged. First, the analysis focuses on a single emerging market, which may limit the generalizability of the findings to other institutional contexts. Second, carbon disclosure is measured using a binary proxy, which captures the presence of disclosure but does not reflect its quality, depth, comparability, credibility, or verification. Third, the study focuses on firm-level financial and disclosure data and does not directly observe how banks or creditors internally process carbon-related information in lending decisions.

Future research may extend this study in several directions. First, future studies should develop multidimensional carbon disclosure indices that capture emissions metrics, reduction targets, climate-risk governance, transition-risk management, and third-party assurance [27, 28]. Second, cross-country studies could examine whether the debt-pricing effect of carbon disclosure differs across institutional environments, regulatory regimes, and levels of ESG reporting maturity. Third, future research may investigate whether improvements in carbon reporting standards, independent verification, and banking supervision strengthen the incorporation of ESG and climate-related risks into credit risk assessment and loan pricing [26].

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