



Article

Voluntary Carbon Verification and Corporate Capital Structure Adjustment Speed: A Global Investigation

Faisal Alnori ¹, Abdullah Bugshan ² and Walid Bakry ^{3,*}

¹ Faculty of Economics and Administration, King Abdulaziz University, Jeddah 21589, Saudi Arabia; falnore@kau.edu.sa

² Department of Business, Jubail Industrial College, Al-Jubayl 35718, Saudi Arabia; bugshan_a@rcjy.edu.sa

³ Business School, Western Sydney University, Sydney 2751, Australia

* Correspondence: w.bakry@westernsydney.edu.au

Abstract

Using an international sample of firms from 47 countries/regions over the years 2010–2020, we examine whether third-party verification of carbon emissions information affects the speed at which firms adjust their capital structure toward the trade-off theory's optimal leverage target. Using alternative estimation techniques and robustness checks, we find that third-party carbon assurance significantly accelerates firms' leverage adjustment speed. Firms that engage in independent carbon verification adjust more rapidly toward their target capital structure than non-assured firms. We extended our investigation and confirmed that this effect persists across both developed and developing markets. These results support the notion that carbon assurance is associated with lower information asymmetry between firms and lenders, thereby lowering the cost of external debt and facilitating faster capital structure rebalancing. We further investigate whether the relationship differs by assurance provider type by distinguishing between Big Four and non-Big Four assurance providers. The results remain robust when distinguishing between Big Four and non-Big Four assurance providers regardless of the assurer quality, confirming that assured firms adjust their capital structures faster than non-assured firms. The outcomes of this study demonstrate that firms' sustainability reporting can shape the speed of capital structure adjustment.

Keywords: carbon assurance; sustainability; capital structure; speed of adjustment

1. Introduction

Voluntary carbon verification by an independent third party (hereafter, carbon assurance) enhances corporate transparency, accountability, and monitoring (Bugshan et al., 2024; Hsiao et al., 2022; Quesado et al., 2024). From a theoretical perspective, this integration aligns sustainability control systems with traditional management control objectives by reducing information asymmetry and improving the reliability of non-financial performance indicators used by external stakeholders (Bagh et al., 2025). In this sense, carbon assurance can serve as a bridge between sustainability control systems and financial control systems, enabling sustainability information to enhance the firm's image and the market and hence lower the cost of external financing and monitoring by lenders (Bugshan et al., 2024). Firms that report lower carbon emissions are perceived as less risky and more attractive investment opportunities, often benefiting from a reduced cost of capital and a lower perceived environmental risk (Bagh et al., 2025; Shu et al., 2023).



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From a management control perspective, voluntary carbon disclosure and assurance can be viewed as sustainability-oriented control mechanisms that improve the reliability and monitoring of non-financial information. Although still at a relatively early stage, the growing literature on voluntary carbon reporting suggests that participation in such initiatives (hereafter, assured firms) conveys positive signals to market participants and reduces information asymmetry between firms and external stakeholders, including lenders (Tao & Wu, 2025). By narrowing informational gaps and strengthening external monitoring, carbon assurance lowers the cost of debt financing (Bugshan et al., 2024). However, despite this growing evidence on the financial implications of carbon assurance, the finance literature remains largely silent on whether and how such sustainability-related control mechanisms influence the speed at which firms adjust their capital structures toward the optimal leverage target implied by trade-off theory (Quesado et al., 2024).

Building on the trade-off theory of capital structure, we develop a baseline hypothesis that carbon assurance significantly influences firms' leverage adjustment speed. Accordingly, the speed of capital structure adjustment should differ between assured and unassured firms. Trade-off theory posits that a firm's adjustment speed is largely determined by adjustment costs. From the perspective of signalling theory (Spence, 1973), voluntary third-party verification of carbon information serves as a credible signal of transparency and reporting quality because assurance involves additional costs and independent scrutiny. This signal reduces information asymmetry between firms and external capital providers. Agency theory (Jensen & Meckling, 1976) further suggests that carbon assurance acts as an external monitoring mechanism that constrains managerial opportunism and improves the credibility of environmental disclosures. Consequently, lenders face lower monitoring and information-processing costs when evaluating assured firms. The reduction in information asymmetry and monitoring costs lowers the cost of debt financing and reduces adjustment frictions. As a result, firms that obtain carbon assurance are expected to adjust their capital structures more rapidly toward their target leverage than unassured firms.

Existing studies primarily examine whether carbon assurance influences financing outcomes such as leverage levels, debt maturity, borrowing costs, and access to external financing. However, these studies provide little insight into whether carbon assurance affects firms' dynamic financing behaviour. A firm may have higher leverage because of carbon assurance but still adjust slowly toward its target capital structure. Therefore, examining leverage adjustment speed offers a distinct perspective on how carbon assurance influences corporate financing decisions and extends the literature beyond static capital structure outcomes. A substantial body of research demonstrates that firms target an optimal capital structure and adjust toward this benchmark when deviations occur (Alnori & Bugshan, 2025; Su & Zheng, 2025). However, the pace of adjustment varies across firms, largely due to differences in adjustment costs (Hoque & Liu, 2022; Park et al., 2013; Zhou & Li, 2024). Despite the growing literature on ESG performance, sustainability reporting, and environmental disclosure, little attention has been given to whether the external assurance of environmental information influences firms' ability to adjust their capital structures. While prior studies have examined the role of sustainability performance in shaping financing decisions, no study has directly investigated whether carbon assurance affects the speed at which firms adjust toward their target leverage. Consequently, the role of carbon assurance in shaping leverage adjustment dynamics remains largely unexplored. By empirically demonstrating how carbon assurance affects capital structure adjustment speed, this study contributes to the emerging literature linking sustainability practices and corporate financing decisions. Specifically, the main research question of this study is whether carbon assurance influences the speed at which firms adjust their capital structure toward an optimal leverage target. To address this question, the study adopts an interna-

tional perspective to examine how third-party carbon assurance shapes corporate capital structure adjustment.

This study makes several contributions to the literature on corporate finance and sustainability. First, it extends the emerging literature examining the interaction between sustainability-related practices and corporate financing decisions by focusing on carbon assurance rather than environmental disclosure or sustainability performance. Prior studies have shown that sustainability performance influences firms' capital structure decisions and adjustment behaviour (Velte, 2023; Bugshan & Bakry, 2025). However, considerably less attention has been given to whether the external verification of environmental information affects financing decisions. Carbon assurance differs from sustainability performance because it reflects the credibility and reliability of environmental information rather than the information itself. Second, the study contributes to the dynamic capital structure literature by examining whether carbon assurance affects the speed at which firms adjust toward their target leverage. To the best of our knowledge, this is the first study to directly investigate the relationship between carbon assurance and leverage adjustment speed. By doing so, the study identifies a new channel through which carbon assurance may reduce information asymmetry, financing frictions, and adjustment costs. Third, to enhance the generalisability of the findings, the study employs a global sample of firms operating across 47 countries/regions, including developed and developing countries, to compare leverage adjustment speeds between carbon-assured and unassured firms. Finally, the study investigates whether the relationship between carbon assurance and capital structure adjustment differs between firms operating in developed and developing economies, providing new insights into how institutional environments shape the interaction between sustainability practices and corporate financial decisions.

The findings of this study indicate that carbon assurance plays an important role in shaping firms' capital structure adjustment behaviour. Specifically, the results show that assured firms adjust toward their target leverage significantly faster than firms without carbon assurance. This finding is consistent with the argument that carbon assurance reduces information asymmetry, improves the credibility of corporate disclosures, and lowers financing frictions faced by firms in debt markets. Additional analyses further demonstrate that the results remain robust across alternative model specifications and leverage measures. Moreover, the positive effect of carbon assurance on adjustment speed is observed in both developed and developing economies, suggesting that the influence of carbon assurance extends across different institutional environments. We further examine whether the effect varies according to the type of assurance provider by distinguishing between Big Four and non-Big Four assurance providers. The results remain consistent, indicating that firms obtaining carbon assurance exhibit a significantly faster speed of capital structure adjustment than non-assured firms, regardless of the type of assurance provider. Overall, the evidence suggests that carbon assurance is associated with more efficient capital structure rebalancing and highlights the importance of sustainability assurance in corporate financing decisions.

The rest of this paper is structured as follows. Section 2 provides a review of the relevant literature and develops the research hypothesis. Section 3 describes the data and methodological approach employed in the study. Section 4 presents the empirical findings, while Section 5 concludes by discussing the study implications.

2. Literature and Hypothesis

2.1. Capital Structure Adjustment Speed

According to trade-off theory, firms seek to achieve an optimal capital structure by weighing the advantages of debt financing, particularly tax benefits, against its associated

costs, such as an increased likelihood of financial distress. The optimal leverage level is reached when the incremental benefits of debt are exactly offset by its incremental costs. Therefore, any deviation from the target capital structure is expected to prompt firms to adjust their leverage toward the optimal level (Kraus & Litztenberger, 1973).

A substantial body of empirical research supports the existence of this optimal target and firms' tendency to converge toward it over time (Su & Zheng, 2025; Zhou & Li, 2024; Niu et al., 2023; Gan et al., 2021; Cook & Tang, 2010; Lemmon et al., 2008; Flannery & Rangan, 2006; Leary & Roberts, 2005).

The existence of the optimal target capital structure choices demonstrates that firms' managers importantly consider the balance between the costs and benefits of debt financing, as predicted by the trade-off theory. However, an important issue observed in the literature on capital structure adjustment speed is that the adjustment speed varies significantly across firms (Alnori & Alqahtani, 2019; Hoque & Liu, 2022). This variation is largely attributable to differences in market frictions faced by firms, which influence the cost and feasibility of rebalancing capital structures, leading some firms to adjust more slowly than others (Su & Zheng, 2025).

Recent research on capital structure has highlighted that a firm's adjustment behaviour is influenced by a wider range of economic, managerial, and institutional factors, going beyond the traditional trade-off frameworks (Alnori & Bugshan, 2025; Ktit & Abu Khalaf, 2025; Park et al., 2013). For instance, it is found that oil price uncertainty has a significant impact on firms' capital structure adjustment speed (Alnori & Bugshan, 2025). Specifically, the evidence suggests that increased oil price volatility leads to higher adjustment costs, resulting in a slower movement of firms toward their optimal leverage level. Further, another study examined the varying effect of macroeconomic conditions on capital structure adjustment speed using a sample of US firms (Cook & Tang, 2010). It is found that firms set an optimal target capital structure decision. However, firms adjust their capital structure toward the optimal target significantly faster during times of good economic conditions in comparison to times of poor economic conditions.

The existing literature showed that firm-related factors, industry-specific characteristics, innovation intensity, asset tangibility, and cash-flow stability can accelerate or impede capital structure rebalancing (Hoque & Liu, 2022; Ktit & Abu Khalaf, 2025). Consequently, this broader body of evidence underscores that adjustment speed constitutes a multi-dimensional outcome, shaped by managerial actions, strategic objectives, institutional frameworks, and industry-specific conditions. For example, recent studies showed that firms with higher levels of institutional development can adjust their capital structure relatively faster since they can show better quality to lenders and financial markets (Ktit & Abu Khalaf, 2025). Further, it is confirmed that the capital structure adjustment speed is different across Islamic banks and conventional banks due to the different external financing choices and asset structures across the two sets of banks (Hoque & Liu, 2022). This varying adjustment speed is also similar for Shariah-compliant corporations (Alnori & Alqahtani, 2019). In addition, another area of study emphasises financial flexibility, suggesting that some firms intentionally keep their leverage below the optimal level as a strategic way to prepare for future uncertainties or investment opportunities, which then slows down the adjustment process (Denis & McKeon, 2012). Further, a firm's deviations from its desired leverage can be influenced by managerial risk preferences, the quality of its governance, and behavioural preferences. More risk-averse managers often slow down the adjustment process (Harford et al., 2009).

Although prior research has identified a range of factors influencing firms' leverage adjustment speed (Su & Zheng, 2025; Zhou & Li, 2024; Niu et al., 2023; Gan et al., 2021), the influence of corporate carbon assurance on this dynamic remains largely unexamined.

Specifically, existing evidence provides limited insight into whether carbon assurance practices enhance or hinder firms' capacity to realign their capital structures toward optimal leverage levels.

2.2. Carbon Assurance and Corporate Financial Decisions

Corporate carbon assurance significantly shapes the financial decisions of firms by enhancing credibility and signalling value to stakeholders and market participants (Bagh et al., 2025; Luo & Pan, 2025; Han & Wu, 2024). It is also associated with stronger stakeholder trust (Bugshan et al., 2024; Ho et al., 2026; Luo & Pan, 2025). On the other hand, the growing adoption of carbon disclosure and sustainability reporting may increase concerns about greenwashing, as stakeholders may question the credibility and accuracy of voluntarily disclosed environmental information (Free et al., 2025).

Third-party assurance offers an independent validation of companies' carbon emissions and demonstrates firms' sustainable practices (Bugshan et al., 2024). This process diminishes the potential for managerial bias, opportunistic reporting, and unreliable environmental claims, thus enhancing the dependability of reported carbon data (Bagh et al., 2025; Han & Wu, 2024; Simnett et al., 2009). Empirical research demonstrates that carbon assurance is effectively associated with lower information asymmetry between companies and stakeholders (e.g., Bugshan et al., 2024; Luo & Pan, 2025; Safiullah et al., 2025). Carbon assurance demonstrates a higher quality of environmental management, which in turn fosters greater investors' confidence (Hodge et al., 2009). External verification diminishes the ambiguity associated with the firm's environmental liabilities (Moroney et al., 2012) and reduces the firm's default risk (Safiullah et al., 2025). Further, assured companies encounter lower monitoring expenses from lenders (Ho et al., 2026) and are offered more advantageous credit conditions (Bagh et al., 2025) and gain improved access to long-term debt markets (Shu et al., 2023). These factors demonstrate a lower cost of capital for assured firms (Datt et al., 2025).

Furthermore, the existing research indicates that carbon assurance not only fosters market confidence but also enhances firms' financing conditions and governance frameworks through its role in enhancing credibility (Tao & Wu, 2025). Firms that engage in verified carbon emissions reporting often observe enhancements in their internal governance practices. The involvement of an external assurer elevates the cost associated with misreporting, thereby prompting managers to more effectively internalise environmental risks, which in turn strengthens the credibility of long-term strategic planning and capital allocation choices (Luo & Pan, 2025).

Carbon assurance significantly influences the composition of firms' capital structure and debt maturity profiles (Bugshan et al., 2024). Specifically, firms that engage in voluntary carbon reporting (i.e., assured firms) tend to maintain higher leverage levels than their unassured counterparts, as assurance lowers the cost of capital and facilitates greater access to external debt. Moreover, assured firms are better positioned to secure long-term debt financing due to reduced monitoring requirements from lenders (Bugshan et al., 2024; Bagh et al., 2025). However, previous studies have not investigated whether carbon assurance affects the speed at which firms adjust their capital structures, an important gap that the present study seeks to address.

While previous studies have explored several determinants of leverage adjustment speed (Gan et al., 2021; Su & Zheng, 2025; Zhou & Li, 2024), the potential role of corporate carbon assurance in accelerating or impeding this adjustment process remains largely unexplored. In particular, little is known about whether corporate carbon assurance affects firms' ability to rebalance their capital structures toward optimal leverage targets. From a theoretical perspective, carbon assurance may reduce information asymmetry, mitigate

perceived risk, and lower adjustment costs by strengthening stakeholder trust and monitoring, thereby influencing firms' financing behaviour within the trade-off framework. Firms' sustainability-driven commitments may impose additional compliance and reporting costs that could slow leverage adjustments. This study addresses this gap by investigating whether and how corporate carbon assurance influences the speed of capital structure adjustment, thereby integrating sustainability considerations into the dynamic trade-off theory and extending the capital structure literature into the environmental sustainability domain.

2.3. Corporate Capital Structure Decision Across Developed and Developing Countries

Existing evidence suggests that corporate capital structure choices vary across firms operating in different countries due to differences in institutional quality, financial market development, and levels of information asymmetry. Since the pioneering study of [Rajan and Zingales \(1995\)](#), extensive research has highlighted that firms' capital structure decisions differ across countries as a result of variations in institutional settings and legal frameworks. [Rajan and Zingales \(1995\)](#) investigated capital structure determinants among G7 countries and documented substantial differences in leverage levels and financing patterns, emphasizing the importance of country-specific characteristics in explaining corporate financing behaviour. Building on this foundation, [Booth et al. \(2001\)](#) examined firms operating in developing economies and found that although conventional firm-level determinants remain relevant, considerable cross-country differences in leverage continue to exist. Their findings suggest that institutional and environmental factors play a significant role in shaping financing decisions. Likewise, [Glen and Singh \(2004\)](#) reported that firms in emerging markets tend to rely less on debt financing than firms in developed economies, indicating that the level of economic and financial development influences capital structure choices. Additional evidence is provided by [Faria and Mauro \(2009\)](#), who showed that institutional quality is a key factor affecting financing patterns, with stronger institutions promoting greater use of equity-based financing. Similarly, [Turk Ariss \(2016\)](#) demonstrated that legal systems and governance conditions significantly influence both leverage and debt maturity decisions in developing countries. Collectively, these studies provide strong evidence that capital structure decisions differ between developed and developing economies, largely due to differences in institutional quality, legal environments, and financial market development.

2.4. Hypothesis

The trade-off theory posits that firms aim to maintain a target capital structure by balancing the costs and benefits of debt financing. Firms are expected to adjust back toward this optimal target when deviations occur ([Su & Zheng, 2025](#); [Zhou & Li, 2024](#)). However, the speed of adjustment varies across firms due to differences in adjustment costs ([Hoque & Liu, 2022](#); [Ktit & Abu Khalaf, 2025](#); [Park et al., 2013](#)).

The central hypothesis of this study is that corporate carbon assurance is importantly relevant to the firm's capital structure adjustment speed. More specifically, the present study expects that assured firms adjust their capital structure faster than unassured firms. This is because corporate carbon assurance may lead to lower adjustment costs, thereby accelerating adjustment speed toward the optimal leverage target. Previous studies suggest that carbon assurance conveys positive signals to stakeholders, including lenders and market participants ([Han & Wu, 2024](#)).

Incorporating carbon assurance into the trade-off framework introduces a crucial non-financial element to the factors influencing capital structure ([Bugshan et al., 2024](#)). Theoretically, assurance serves to alleviate agency conflicts by subjecting managerial re-

porting practices to external auditing (Moroney et al., 2012). Third-party verification raises the costs associated with misreporting and enhances accountability, thereby encouraging managers to more effectively integrate environmental and financial risks. This process is consistent with the notion that credible sustainability reporting acts as an informational bridge between firms and capital providers (Gerged et al., 2021).

From a financial contracting standpoint, verified carbon disclosure reduces both ex-ante screening costs and ex-post monitoring costs for lenders (Bagh et al., 2025; Ho et al., 2026). These reductions directly lead to lower borrowing costs and easier access to long-term credit. As a result, the financial flexibility gained from lower financing costs allows firms with verified carbon data to make more frequent or larger adjustments to their capital structure without incurring significant transaction costs.

Carbon assurance influences several determinants that have previously been shown to affect capital structure adjustment speed, including information asymmetry, lender monitoring costs, and access to external financing. Therefore, by linking the predictions of the trade-off theory with prior empirical findings (Kiran et al., 2025; Luo & Pan, 2025; Safiullah et al., 2025; Bugshan et al., 2024; Park et al., 2013; Lemmon et al., 2008), it can be argued that carbon assurance facilitates faster leverage adjustment. Specifically, assured firms provide more credible and transparent environmental information, thereby reducing information asymmetry and enhancing lenders' confidence. This reduction in informational frictions lowers the uncertainty faced by external capital providers and improves stakeholders' perceptions of firm quality.

Furthermore, voluntary carbon reporting serves as a positive signal of a firm's transparency, accountability, and commitment to sustainability (Beck et al., 2025; Borrero-Domínguez et al., 2024; Bugshan et al., 2024). This positive signal to external stakeholders reduces the information gap between the firm and fund and lenders. Such signalling strengthens the credibility of corporate disclosures and enhances trust among lenders and investors. Consistent with the pecking order theory, assured firms are therefore likely to face lower financing frictions, enjoy better access to debt markets, and obtain external financing at a lower cost than their unassured counterparts. Firms facing lower external financing costs can rebalance their capital structures more efficiently because they are able to issue debt or equity with fewer frictions and lower transaction costs (Alnori & Alqahtani, 2019; Cook & Tang, 2010). Consequently, firms with lower financing costs are expected to adjust their leverage ratios toward their target capital structures more rapidly than firms facing higher financing costs. Therefore, these findings suggest that carbon assurance serves as a mechanism that enhances credibility, reduces adjustment costs, and accelerates the process of aligning leverage with the target capital structure. Accordingly, the current study proposes that:

H1. *The speed of capital structure adjustment differs between assured and unassured firms, with assured firms adjusting faster due to their lower adjustment costs in comparison to unassured firms.*

3. Sample, Variables and Method

3.1. Sample

The study employs a sample of firms from 47 countries/regions that participated in the CDP survey between 2010 and 2020. Carbon-related data are obtained from the CDP survey, which is published by CDP (formerly the Carbon Disclosure Project), a globally recognised non-profit organization that provides standardised, firm-level information on carbon emissions, climate risk management, and third-party verification practices to stakeholders. Firms' financial data are extracted from the LESG DataStream database. Firms with missing financial or carbon-related data are excluded. Industry classification

follows the Global Industry Classification Standard (GICS), covering 10 sectors: Financials, Energy, Materials, Industrials, Utilities, Healthcare, Communication Services, Information Technology, Consumer Discretionary, and Consumer Staples. Table 1 provides an overview of the sample distribution. The final dataset consists of 10,976 firm-year observations. Consistent with previous studies, all variables are winsorized at the 5th and 95th percentiles to reduce the influence of outliers.

Table 1. Sample distribution by country/region and sector.

Panel A: Sample Distribution by country/region			
Country/Region	Percent	Country/Region	Percent
Australia	3.34	Malaysia	0.06
Austria	0.65	Malta	0.01
Belgium	0.57	Mexico	0.4
Brazil	2.93	Netherlands	1.71
Canada	6.02	New Zealand	0.65
Chile	0.21	Norway	1.96
China	0.40	Philippines	0.09
China, Hong Kong Special Administrative Region	0.09	Poland	0.05
Colombia	0.29	Portugal	0.62
Cyprus	0.04	Russia	0.13
Denmark	1.47	Russian Federation	0.06
Finland	2.35	Singapore	0.35
France	4.74	South Africa	4.4
Germany	4.21	South Korea	2.3
Greece	0.07	Spain	2.38
Hong Kong	0.37	Sweden	3.02
Hungary	0.10	Switzerland	2.64
Iceland	0.02	Taiwan	1.29
India	2.71	Taiwan, Greater China	0.26
Indonesia	0.03	Thailand	0.36
Ireland	0.88	Turkey	1.39
Israel	0.15	USA	15.64
Italy	2.02	United Arab Emirates	0.04
Japan	12.74	United Kingdom	12.92
Panel B: Sample Distribution by Sector			
GICS Sector	Percent		
Energy	6.70		
Materials	14.70		
Industrials	24.09		
Consumer discretionary	17.34		
Consumer staples	9.65		
Health care	5.95		
Information technology	7.46		
Telecommunication Services	7.29		
Utilities	6.81		
Total	100		

3.2. Dependent Variable

The study uses book leverage as the dependent variable, calculated as total debt (the sum of short-term and long-term debt) divided by total assets. This measure is widely adopted in the capital structure literature because it reflects the degree to which firms finance their operations using debt (Flannery & Rangan, 2006; Bagh et al., 2025). Book leverage is particularly suitable for analysing capital structure adjustment since it represents managerial financing decisions and is less affected by temporary fluctuations in market valuations. To verify the robustness of the findings, two additional leverage measures are employed. The first is market leverage, computed as total debt divided by the combined value of total debt and the firm's market capitalization. The second is industry-adjusted leverage, which measures the difference between a firm's leverage ratio and the median leverage of firms operating within the same industry and year.

3.3. Independent Variable

The key explanatory variable is carbon emissions verification (CVV). It is operationalized as an indicator variable coded as one for firms whose Scope 1 and Scope 2 emissions are externally assured by an independent third party and zero for firms without external verification. This implementation captures the existence of an external governance mechanism that strengthens the credibility of carbon disclosures and is in line with earlier carbon assurance studies (Bugshan et al., 2024). By focusing on third-party verification rather than disclosure volume, this measure reflects the quality and reliability of carbon-related information available to external stakeholders.

3.4. Control Variables

Consistent with prior capital structure research, we include a set of firm-specific and industry-level control variables that are known to influence leverage decisions (Bagh et al., 2025; Flannery & Rangan, 2006). Specifically, we include firm performance, measured by return on equity, as well as firm size, market-to-book ratio, working capital, asset tangibility, business risk, and median industry/year leverage, all of which have been shown to influence capital structure decisions. To control for industry-level financing conditions, the model includes industry leverage, calculated as the median leverage ratio of firms within the same industry-year. Furthermore, year, industry, and country fixed effects are incorporated to absorb unobservable variation associated with temporal, sectoral, and institutional differences. Definitions of all variables are summarized in Table 2.

Table 2. Variables Definition.

Variable	Abbreviation	Definition	Source
Book Leverage	<i>Lev</i>	The sum of short-term debt and long-term debt scaled by total assets	DataStream
Voluntary Carbon Verification	<i>CVV</i>	Binary indicator equal to one for firms whose Scope 1 and Scope 2 emissions are externally assured by an independent third party, and zero otherwise.	Carbon Disclosure Project survey
Firm Performance	<i>pf</i>	Net income divided by shareholder equity	DataStream
Firm size	<i>Sz</i>	Natural logarithms of total assets	DataStream
Growth opportunities	<i>MT</i>	Market capitalization to book value of equity	DataStream

Table 2. Cont.

Variable	Abbreviation	Definition	Source
Working Capital	WC	Current assets minus current liabilities, divided by total assets	DataStream
Assets tangibility	Pn	The net of Property, plant, and equipment divided by total assets	DataStream
Business Risk	Rk	The standard deviation of firm's return on assets	DataStream
Industry leverage	LevIn	The median leverage ratio of all firms operating within the same industry and year.	DataStream

3.5. Regression Model

To examine the influence of carbon emissions assurance on the speed of capital structure adjustment, we adopt the partial adjustment framework introduced by Flannery and Rangan (2006). This dynamic model assumes that firms face frictions that prevent instantaneous convergence to the optimal capital structure. Thus, firms adjust gradually toward their target leverage at a rate determined by the magnitude of these adjustment costs. The baseline partial adjustment model is specified as follows:

$$Lev_{i,t} = \beta_0 + \rho Lev_{i,t-1} + X_{i,t} \beta + \varepsilon_{i,t} \quad (1)$$

where $Lev_{i,t}$ is the leverage ratio for firm i at the end of year t ; $Lev_{i,t-1}$ is the leverage ratio for $t - 1$ year; $X_{i,t}$ is a vector of firm-specific and industry characteristics determining the target leverage level; the speed of adjustment is calculated as $1 - \rho$, where ρ is the estimated coefficient on lagged leverage; and $\varepsilon_{i,t}$ is an error term.

To examine whether firms with carbon verification by a third party adjust more rapidly toward their target leverage, we allow the speed of adjustment to vary by interacting lagged leverage with the carbon verification dummy (CVV). This leads to the extended specification:

$$Lev_{i,t} = \beta_0 + \rho Lev_{i,t-1} + \delta CVV_{i,t} + \gamma (Lev_{i,t-1} \times CVV) + X_{i,t} \beta + \varepsilon_{i,t} \quad (2)$$

In this model, CVV is a dummy variable that distinguishes between firms that voluntarily verify their carbon data (taking a value of 1) and those that do not (taking a value of 0); ρ captures the persistence of leverage for non-assured firms; and γ captures the difference in adjustment speed between assured and non-assured firms.

The speed of adjustment (SOA) for non-assured firms is computed as $(1 - \rho)$ and for verified firms as $1 - (\rho + \gamma)$. A negative value of γ indicates that assured firms adjust more rapidly to their target capital structure than their non-assured counterparts.

Where it represents firm and year, respectively. Lev refers to the firm's leverage ratio, measured as the sum of short- and long-term debt divided by total assets. CVV refers to the carbon emissions verification (assurance) by a third party, and it's a binary variable that takes the value of 1 if a firm is verified or zero otherwise.

Several control variables are also incorporated into the model, including *size* (the natural logarithm of the firm's total assets), *operating performance* (pf), *market-to-book ratio* (MT), *working capital* (WC), *asset intensity* (Pn), *variability of performance* (Rk), and *industry median leverage* ($LevIn$). In addition, the model controls for *year*, *industry*, and *country fixed effects* to account for unobserved heterogeneity across time, sector, and institutional environment.

3.6. Regression Diagnostics

Prior to estimating the regression models, several diagnostic tests were performed to assess the validity of the empirical specifications. Multicollinearity was examined using variance inflation factors (VIFs). As reported in Table 3, all VIF values were below the conventional threshold of 10, indicating that multicollinearity is unlikely to affect the regression estimates. In addition, the Breusch–Pagan/Cook–Weisberg test rejected the null hypothesis of homoskedasticity, suggesting the presence of heteroskedasticity. The Wooldridge test for autocorrelation in panel data also rejected the null hypothesis of no first-order serial correlation ($F = 113.17$, $p < 0.001$), indicating the existence of within-firm serial correlation. To address these concerns, all baseline regressions were estimated using firm-level clustered robust standard errors, which are robust to both heteroskedasticity and serial correlation.

Table 3. Pairwise correlations.

Variables	<i>Lev-B</i>	<i>CVV</i>	<i>pf</i>	<i>Sz</i>	<i>MT</i>	<i>WC</i>	<i>Pn</i>	<i>Rk</i>	<i>LevIn</i>	VIF
<i>Lev</i>	1.000									2.39
<i>CVV</i>	0.092 *	1.000								7.33
<i>pf</i>	0.310 *	0.074 *	1.000							1.21
<i>Sz</i>	−0.030 *	0.036 *	−0.230 *	1.000						1.20
<i>MT</i>	0.063 *	0.123 *	0.626 *	−0.393 *	1.000					1.01
<i>WC</i>	0.110 *	0.112 *	0.306 *	−0.194 *	0.301 *	1.000				1.21
<i>Pn</i>	0.438 *	0.387 *	0.282 *	−0.080 *	0.146 *	−0.003	1.000			1.15
<i>Rk</i>	0.122 *	0.006	0.242 *	−0.038 *	0.150 *	0.096 *	0.110 *	1.000		1.02
<i>LevIn</i>	0.282 *	−0.163 *	0.132 *	0.085 *	−0.091 *	0.006	0.162 *	0.036 *	1.000	1.00

* $p < 0.05$.

4. Results and Discussion

The descriptive statistics of the main variables (presented in Table 4) indicate that the mean of book leverage is 73%, suggesting that firms in our sample rely on financial leverage to support their operations. On average, firms generate a 6% return on equity and have a size of 16, consistent with values reported in earlier literature (Luo & Pan, 2025). Additionally, firms maintain, on average, 75% of fixed assets, indicating a high degree of operational leverage. Table 3 reports the correlation matrix and variance inflation factor (VIF) statistics for the variables used in the analysis. The correlation coefficients do not indicate any severe multicollinearity concerns. Consistent with this observation, the VIF results show a mean VIF of 2.65, while all individual VIF values remain below the conventional threshold of 10. Although the assurance dummy and its interaction term exhibit relatively higher VIF values, this is expected because interaction terms are mechanically correlated with their constituent variables. Overall, the results suggest that multicollinearity is unlikely to affect the empirical findings.

Table 4. Descriptive Statistics.

	Mean	Median	Std. Dev.	Min	Max
<i>Lev</i>	0.193	0.238	0.4071	0.00	3.80
<i>Pf</i>	0.064	0.081	0.069	−0.001	0.225
<i>Sz</i>	15.25	15.17	1.88	1.09	22.19
<i>MT</i>	0.921	0.677	0.761	0.119	2.538
<i>WC</i>	0.142	0.108	0.181	−0.112	0.472
<i>Pn</i>	0.746	0.282	1.233	0.01	4.174
<i>Rk</i>	0.062	0.064	0.037	0.011	0.116

Table 5 presents the regression results for Equation (2). The coefficient of *CVV* is positive and statistically significant at 1%, suggesting that firms that have their carbon data

assured have a higher leverage ratio compared to non-assured counterparts. The coefficient on CVV declines in magnitude as additional firm-level controls and fixed effects are introduced. This suggests that part of the variation initially attributed to carbon assurance is associated with observable firm and institutional characteristics. Nevertheless, the coefficient remains positive and statistically significant across all specifications, indicating that carbon assurance retains an independent influence on leverage adjustment behaviour. The coefficient of LLev (i.e., $Lev_{i,t-1}$) is positive and statistically significant at the 1% level, indicating that firms in our sample adjust toward an optimal capital structure, consistent with the predictions of trade-off theory. The implied adjustment speed for assured firms exceeds that of non-assured firms by approximately 4 percentage points, indicating that carbon assurance facilitates faster movement toward target leverage. To assess the economic significance of the results, we multiply the coefficient on the interaction term ($\gamma = -0.040$) by the standard deviation of lagged leverage (0.410). The resulting effect (-0.0163) indicates that a one-standard-deviation increase in lagged leverage is associated with an additional 1.63 percentage-point reduction in leverage persistence for carbon-assured firms relative to non-assured firms. Relative to the sample mean leverage ratio of 19.3%, this represents approximately 8.4%, suggesting that the effect of carbon assurance on capital structure adjustment is not only statistically significant but also economically meaningful. This finding aligns with prior empirical evidence in the capital structure literature (e.g., Alnori & Bugshan, 2025; Su & Zheng, 2025; Zhou & Li, 2024; Niu et al., 2023; Gan et al., 2021; Cook & Tang, 2010).

The interaction between carbon assurance and lagged leverage ($a \times b$) constitutes the central test of our hypothesis. The coefficient is negative and statistically significant at the 1% level, providing strong evidence that the adjustment process differs according to firms' assurance status. The negative sign indicates that firms obtaining independent carbon assurance converge more rapidly to their target leverage than firms without external assurance, consistent with the view that assurance lowers adjustment costs. This finding supports trade-off theory, which posits that a firm's speed of adjustment is shaped by the degree of market friction it encounters. In this context, third-party verification of carbon disclosure is associated with lower information asymmetry between firms and lenders, thereby lowering transaction costs associated with debt financing and facilitating faster capital structure adjustment.

The findings of this study, which explore whether assured firms exhibit faster adjustment speed than their unassured counterparts, extend the dynamic trade-off framework by incorporating sustainability-oriented controls as an integral factor influencing the speed of capital structure adjustment. Our findings contribute to trade-off theory by identifying corporate carbon assurance as a determinant of capital structure adjustment costs. While traditional trade-off models emphasise financial frictions, transaction costs, and information asymmetry as key drivers of adjustment speed, our findings demonstrate that sustainability-related control mechanisms also play a significant role in shaping leverage dynamics.

In terms of control variables, the coefficients of Pf , Wc , Pn , Rk , and $LevIn$ are positive and significant, suggesting that, on average, firms with higher profitability, working capital, fixed assets, and business risk have a higher level of leverage. The positive coefficients on Pf , Wc , Pn , and Rk are consistent with prior literature (Bugshan et al., 2024; Hsiao et al., 2022) and the trade-off theory, which predicts that firms with stronger internal cash generation, greater liquidity, and more tangible assets face lower expected costs of financial distress and therefore have higher debt capacity. The coefficients of the variables size and growth are negative and significant, suggesting that, on average, larger firms and firms with higher growth opportunities have a lower level of leverage.

Table 5. Regression analysis comparing the leverage speed of adjustment between carbon-assured and non-assured firms.

	Leverage		
<i>CVV (a)</i>	0.704 *** (9.88)	0.219 *** (3.02)	0.152 ** (2.20)
<i>LLev (b)</i>	0.013 *** (5.97)	0.013 * (1.612)	0.072 * (1.67)
<i>a * b</i>	−0.027 *** (−8.97)	−0.016 *** (−2.62)	−0.040 *** (−2.76)
<i>Pf</i>		0.215 *** (15.89)	0.1379 *** (12.78)
<i>Sz</i>		−0.0805 *** (−2.861)	−0.025 (−0.86)
<i>MT</i>		−1.462 *** (−13.11)	−0.876 *** (−10.57)
<i>WC</i>		0.204 *** (5.861)	0.177 *** (5.53)
<i>Pn</i>		0.891 *** (22.79)	1.190 *** (21.67)
<i>Rk</i>		0.198 ** (2.421)	0.096 (1.181)
<i>LevIn</i>		0.503 *** (14.39)	0.464 *** (3.54)
<i>Year</i>	−	−	Y
<i>Industry</i>	−	−	Y
<i>Country</i>	−	−	Y
<i>Obs</i>	13,755	10,976	10,976
<i>R²</i>	0.062	0.323	0.423

The table presents the baseline OLS results for the combined sample of carbon-assured and non-assured firms over 2010–2020. Book leverage is the dependent variable. The principal explanatory variable is the interaction between lagged book leverage and the carbon verification indicator (CVV), which equals one for firms with voluntary third-party carbon assurance and zero otherwise. All regressions include the control variables reported in Section 3.3, as well as year, industry, and country fixed effects. Firm-clustered robust standard errors are shown in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

4.1. Heterogeneity Analysis

4.1.1. Developed Versus Developing Economies

It could be argued that the impact of carbon assurance on capital structure speed of adjustment is heterogeneous across countries. Prior studies suggest that firms operating in different institutional environments face varying levels of investor protection, regulatory quality, information transparency, and capital market development, all of which may influence financing decisions and adjustment costs. In particular, firms in developed economies generally benefit from stronger legal systems, more effective enforcement mechanisms, and greater access to external financing, which may facilitate adjustments toward target leverage. Conversely, firms in developing economies often face higher financing frictions and weaker institutional frameworks, potentially affecting the role of carbon assurance in reducing information asymmetry and facilitating capital structure adjustments. To examine whether the impact of carbon assurance varies across institutional settings, we re-estimate the baseline model separately for developed and developing countries. Countries are classified according to the development index reported by World Population Review, where countries with a score of 0.80 or above are categorized as developed economies and those with a score below 0.80 are classified as developing economies. Results presented in Table 6 indicate that firms in both groups adjust toward their target leverage, consistent with the predictions of trade-off theory. However, the magnitude of the adjustment process differs across the two subsamples, suggesting that the institutional environment may influence

the effectiveness of carbon assurance in facilitating leverage adjustments. The interaction term between carbon assurance and lagged leverage remains negative and statistically significant in both subsamples, indicating that carbon-assured firms adjust more rapidly toward their target leverage regardless of the level of economic development. However, the magnitude of the coefficient is considerably larger for developed countries than for developing countries, suggesting that the benefits of carbon assurance in reducing adjustment frictions are more pronounced in environments with stronger institutions, greater transparency, and more developed financial markets.

Table 6. Regression analysis comparing the leverage speed of adjustment of assured and non-assured firms in developed vs. developing countries.

Developed vs. Developing	Developed		Developing	
CVV (a)	0.697 *** (9.07)	0.049 ** (1.97)	0.754 *** (3.88)	0.264 (1.37)
LLev (b)	0.12 *** (5.56)	0.058 (0.88)	0.154 ** (2.26)	0.095 *** (4.16)
a * b	−0.024 *** (−7.85)	−0.244 *** (−3.36)	−0.048 * (−4.47)	−0.043 ** (−2.16)
Controls		Yes		Yes
Fixed effects		Yes		Yes
Obs	11,984	9472	1737	1324
R ²	0.059	0.418	0.084	0.207

The table presents the regression results for subsamples of firms in developed and developing countries over the period of 2010 and 2020. The dependent variable is the book leverage. The main independent variable is the interaction between lag book leverage and CVV. CVV is a binary variable that equals one if the firm voluntarily verifies its carbon data and zero otherwise. The model includes all control variables used in baseline model Equation (2), defined in Section 3.3. A pooled ordinary least squares regression was conducted, incorporating year, industry, and country fixed effects. Robust standard errors, clustered at the firm level, are reported in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

4.1.2. Assurance Quality: Big 4 Versus Non-Big 4 Assurance Providers

To further examine whether the documented effect of carbon assurance depends on assurance quality, we distinguish between assurance provided by Big 4 accounting firms and assurance provided by non-Big 4 providers. Prior literature suggests that assurance obtained from highly reputable providers is perceived as more credible by investors and lenders because of their stronger reputation concerns, expertise, and monitoring capabilities. Accordingly, we classify assured firms into two groups: firms receiving assurance from a Big 4 provider and firms receiving assurance from a non-Big 4 provider. We then re-estimate Equation (2) by replacing the carbon assurance dummy with a categorical variable that distinguishes between non-assured firms, firms assured by non-Big 4 providers, and firms assured by Big 4 providers.

The estimates in Table 7 show that the interaction between LLev and Big-4 assurance is negative and statistically significant, whereas no comparable effect is observed for non-Big 4 assurance. This finding suggests that the improvement in adjustment speed documented in the baseline analysis is driven largely by assurance obtained from Big-4 providers, highlighting the importance of assurance quality rather than assurance alone.

Table 7. Regression analysis for the Role of Assurance Provider Quality in Capital Structure Adjustment Speed.

Assurance Provider	Leverage	
LLev (a)	0.047 *** (3.16)	0.016 ** (2.06)

Table 7. Cont.

Assurance Provider	Leverage	
<i>Big-4 (b)</i>	0.064 *** (5.57)	0.067 *** (3.19)
<i>No-Big-4 (c)</i>	0.077 (1.42)	
<i>a * b</i>	−0.031 ** (−2.10)	−0.021 ** (−1.93)
<i>a * c</i>	−0.063 (−0.78)	−0.052 (−0.92)
<i>Controls</i>		Yes
<i>Fixed effects</i>		Yes
<i>Obs</i>	8376	6871
<i>R²</i>	0.142	0.253

This table reports the regression results examining whether assurance provider quality influences the relationship between carbon assurance and capital structure adjustment over the period 2010–2020. The dependent variable is book leverage. The variables of interest are the interaction terms between lagged leverage and the three assurance categories: firms without assurance (reference group), firms assured by non-Big 4 providers, and firms assured by Big 4 providers. All specifications control for the same firm-level characteristics as the baseline model and include year, industry, and country fixed effects. Robust standard errors are clustered at the firm level and reported in parentheses. *** and ** denote significance at the 1% and 5% levels, respectively.

4.2. Robustness

To assess the robustness of the baseline findings, we perform several additional analyses. First, following Alnori and Alqahtani (2019), we replace book leverage with alternative leverage measures. Specifically, we estimate the models using market leverage, calculated as total debt divided by the sum of total debt and the market value of equity, and industry-adjusted leverage, measured as the deviation of a firm's leverage ratio from the median leverage of firms operating in the same industry-year. We also examine whether the results are influenced by the concentration of observations from the United States and the United Kingdom by re-estimating the baseline model after excluding firms from these two markets. The findings, reported in Table 8, remain qualitatively unchanged and provide additional support for the baseline results.

A potential limitation of the baseline analysis is that the estimated relationship between carbon assurance and the speed of leverage adjustment could be affected by unobserved heterogeneity. Moreover, because capital structure decisions are inherently dynamic, the model is re-estimated using the System Generalised Method of Moments (System GMM) estimator proposed by Arellano and Bover and Blundell and Bond (Arellano & Bover, 1995; Blundell & Bond, 1998). This estimation technique is well-suited to dynamic panel settings in which the inclusion of a lagged dependent variable creates endogeneity through its correlation with the error term, thereby rendering pooled OLS and fixed-effects estimators inconsistent. Endogeneity may also arise from firm-level characteristics, such as profitability, working capital, and carbon assurance, which are likely to be jointly determined with leverage decisions. To mitigate these concerns, the System GMM approach relies on internal instruments constructed from lagged values in both levels and first differences of the endogenous variables. The reliability of the estimated model is further evaluated using the Hansen test of overidentifying restrictions and the Arellano–Bond AR(2) serial correlation test. The Hansen test does not reject the null hypothesis, indicating that the instruments are valid, while the AR(2) test provides no evidence of second-order serial correlation in the differenced residuals. Collectively, these diagnostic results support the validity of the instrument set and the consistency of the System GMM estimates as presented in Table 9.

Table 8. Sensitivity analysis using an alternative measure of leverage and excluding US and UK firms.

	Leverage-Market	Leverage-Adjusted	Excluding US&UK
	1	2	3
CVV (<i>a</i>)	0.091 ** (2.07)	0.373 *** (4.88)	0.273 *** (3.31)
LLev (<i>b</i>)	0.0148 ** (2.27)	0.052 * (1.60)	0.011 * (1.72)
<i>a</i> * <i>b</i>	−0.0258 ** (−2.19)	−0.057 ** (−4.44)	−0.030 *** (−4.06)
<i>pf</i>	−0.341 (−0.41)	0.249 (16.24)	0.252 *** (15.71)
<i>Sz</i>	0.083 *** (4.16)	−0.173 *** (−5.35)	−0.067 ** (−1.97)
<i>MT</i>	−0.187 *** (−7.05)	−0.156 (−13.04)	−0.164 *** (−13.07)
<i>WC</i>	−0.236 *** (−18.45)	0.146 *** (3.92)	0.223 *** (5.66)
<i>Pn</i>	0.057 *** (6.62)	0.687 *** (15.95)	0.851 *** (20.18)
<i>Rk</i>	0.0128 ** (1.91)	0.402 ** (2.50)	0.348 ** (2.00)
<i>LevIn</i>	0.274 (1.51)		0.593 *** (13.68)
<i>Year</i>	Y	Y	Y
<i>Industry</i>	Y	Y	Y
<i>Country</i>	Y	Y	Y
<i>Obs</i>	7130	10,832	9076
<i>R</i> ²	0.586	0.349	0.353

This table reports the robustness analysis for the full sample of assured and unassured firms. Columns (1) and (2) re-estimate the baseline model using alternative leverage measures, namely market leverage and industry-adjusted leverage, while Column (3) reports the results after excluding firms from the United States and the United Kingdom. Market leverage is measured as total debt divided by the sum of total debt and the market value of equity. Industry-adjusted leverage is computed as the difference between a firm's leverage ratio and the corresponding industry-year median. The principal explanatory variable is the interaction between lagged leverage and carbon verification (CVV), where CVV equals one for firms obtaining voluntary third-party assurance of their carbon emissions and zero otherwise. All specifications include the baseline control variables together with year, industry, and country fixed effects. Firm-clustered robust standard errors are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Another potential source of endogeneity arises from the use of a sample limited to firms that participated in the CDP, which may introduce sample selection bias due to non-random participation. To address this concern, we implement two alternative model specifications. First, we re-estimate the baseline model using the Heckman two-step procedure. In the first stage, we estimate the following equation:

$$CDP_{it} = \beta_0 + \beta_1 Pf_{it} + \beta_2 Sz_{it} + \beta_3 MT_{it} + \beta_4 Pn_{it} + \beta_5 ForSales_{it} + \beta_6 wgi + Fixed\ effects + \varepsilon_{it} \quad (3)$$

where CDP is a dummy variable equal to 1 if a firm participated in the CDP survey and opted to disclose its carbon information, and 0 otherwise. We follow previous studies in selecting the independent variables (Hodge et al., 2009), which include *corporate performance* (*pf*), *size* (*Sz*), *market-to-book ratio* (*MT*), *asset intensity* (*Pn*), *foreign sales* (*ForSales*), the country's governance index (*wgi*), and year, industry, and country fixed effects. In the second stage, we use the estimation in model 2, along with the inverse Mills ratio predicted in the first stage. Table 10 show the results of stages 1 and 2. The results are consistent with the baseline model.

Table 9. Regression analysis comparing the leverage speed of adjustment between carbon assured and non-assured firms using the System GMM model specification.

System GMM	Leverage-B	Leverage-M
<i>CVV (a)</i>	0.182 *** (3.45)	0.211 ** (2.00)
<i>LLev (b)</i>	0.147 *** (5.582)	0.541 * (1.89)
<i>a * b</i>	−0.189 *** (−5.64)	−0.508 * (−0.165)
<i>Pf</i>	0.59 *** (11.60)	0.690 *** (13.20)
<i>Sz</i>	−0.247 *** (−4.06)	−0.049 (−0.98)
<i>MT</i>	−0.359 *** (−11.14)	−0.192 *** (−3.32)
<i>WC</i>	−0.174 (−0.54)	−0.081 (−6.22)
<i>Rk</i>	−0.875 *** (−3.36)	0.372 *** (3.23)
<i>LevIn</i>	0.758 (0.86)	0.377 *** (5.57)
<i>Fixed effects</i>	Y	Y
<i>Obs</i>	10,767	10,767
<i>AR(2)</i>	0.689	0.172
<i>Hansen test</i>	0.455	0.407

This table reports the robustness results obtained from the two-step System Generalized Method of Moments (System GMM) estimator for the full sample of assured and unassured firms. The Hansen test evaluates the validity of the instrument set, while AR(2) reports the Arellano–Bond test for second-order serial correlation in the first-differenced residuals. Firm-clustered robust t-statistics are reported in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 10. Analysis results using the Heckman two-stage procedure.

	CDP Stage I	Stage II
<i>CVV (a)</i>		0.056 * (1.72)
<i>LLev (b)</i>		0.018 * (1.84)
<i>a * b</i>		−0.028 ** (−2.20)
<i>Pf</i>	0.135 *** (7.70)	−0.430 (−0.93)
<i>Sz</i>	0.110 *** (13.30)	0.027 *** (11.41)
<i>MT</i>	0.245 *** (14.20)	−0.167 *** (−5.07)
<i>WC</i>		−0.213 *** (−17.68)
<i>Pn</i>	0.185 *** (5.55)	0.057 *** (7.63)
<i>Rk</i>		0.105 (1.20)
<i>LevIn</i>		0.258 ** (1.98)
<i>FnSales</i>	0.175 *** (17.42)	

Table 10. Cont.

	CDP Stage I	Stage II
<i>Wgi</i>	0.277 *** (23.59)	
<i>Fixed effects</i>	Y	Y
<i>Censored obs</i>		22,131
<i>Uncensored obs</i>		6495
<i>lambda</i>		0.082 *** (8.94)
<i>Rho</i>		0.571
<i>sigma</i>		0.1446

This table reports the robustness results obtained using the two-step Heckman selection model for the full sample of assured and unassured firms. In the selection equation, the dependent variable is CDP, an indicator equal to one for firms participating in the CDP survey and voluntarily disclosing carbon-related information, and zero otherwise. The selection model estimates the probability of CDP participation using the baseline control variables together with ForSales and WGI. ForSales is a binary variable equal to one if the firm reports foreign sales and zero otherwise, whereas WGI denotes the country's overall governance index. t-statistics are reported in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Second, we use propensity score matching to address potential selection bias caused by observable firm characteristics. We examine differences in leverage dynamics between firms with third-party carbon assurance (treatment group) and those without assurance (control group), focusing specifically on how past leverage influences current capital structure decisions across the two groups. Each assured firm is matched one-to-one with a comparable non-assured firm based on key covariates, including firm performance, size, market-to-book ratio, working capital, intensity of fixed assets, risk, and deviation from industry median leverage. As shown in Panel A of Table 11 the treatment and control samples are statistically comparable. The standardised differences across matched variables are substantially reduced, and the overall balance statistics (e.g., mean and median bias) fall well within acceptable thresholds. Our post-matching regression, presented in Panel B of Table 11, includes an interaction term between assurance and lagged leverage to capture differences in leverage adjustment behaviour.

Table 11. Propensity scores matching results.

Panel A: Covariate Balance—Before and After Matching						
Variable	Unmatched /Matched	Mean (Treated)	Mean (Control)	% Bias	% Reduction	t-Test (p-Value)
pf	U	0.08301	0.08211	1.3		0.80 (0.422)
pf	M	0.08302	0.08093	3.1	−131.3	2.24 (0.025)
Sz	U	16.405	15.428	57.7		34.89 (0.000)
Sz	M	16.406	16.409	−0.2	99.7	−0.12 (−0.901)
MT	U	0.90072	0.98825	−11.6		−7.06 (−0.000)
MT	M	0.90057	0.89579	0.6	94.5	0.47 (0.640)
WC	U	0.11977	0.14803	−16.6		−9.29 (−0.000)
WC	M	0.11977	0.12465	−2.9	82.7	−1.90 (−0.057)
Pn	U	0.84827	0.63185	17.5		10.38 (0.000)
Pn	M	0.84835	0.84775	0.0	99.7	0.03 (0.974)
Rk	U	−2.7964	−2.7885	−2.4		−1.46 (−0.143)
Rk	M	−2.7964	−2.8034	2.1	12.6	1.55 (0.122)
LevIn	U	1.0743	0.74515	20.2		11.90 (0.000)
LevIn	M	1.0744	1.0765	−0.1	99.3	−0.09 (−0.929)

Table 11. Cont.

Panel B: Balance Summary							
Sample	Ps R ²	LR chi2	<i>p</i> > chi2	MeanBias	MedBias	B	R
Unmatched	0.080	1430.38	0.000	18.2	16.6	69.4 *	0.99
Matched	0.002	55.62	0.000	1.3	0.6	11.3	1.02
Panel C: Post-Matching Regression—Leverage Adjustment Behaviour							
						Leverage B	
CVV						0.492 ***	
						(6.89)	
LLev						0.009 *	
						(1.62)	
CVV × LLev						−0.019 ***	
						(−2.96)	
<i>pF</i>						28.932 ***	
						(18.37)	
<i>Sz</i>						−0.127 ***	
						(−5.24)	
<i>MT</i>						−1.395 ***	
						(−11.46)	
<i>Rk</i>						12.266 ***	
						(8.02)	
<i>LevIn</i>						8.600 ***	
						(13.65)	
<i>Constant</i>						−1.285 ***	
						(−3.07)	
<i>Obs</i>						13,498	
<i>R</i> ²						0.221	

This table reports the propensity score matching (PSM) results together with the covariate balance statistics for the matched treatment and control groups. The treatment variable is carbon verification (CVV), an indicator equal to one for firms obtaining voluntary third-party assurance of their carbon emissions and zero otherwise. The regression specifications include the baseline control variables described in Section 3.3. Firm-clustered robust standard errors are reported in parentheses. *** and * denote statistical significance at the 1% and 10% levels, respectively.

Overall, the results obtained from the alternative leverage measures, the exclusion of US and UK firms, the System GMM estimator, the Heckman selection model, and the propensity score matching analysis are consistent with the baseline findings. Across all specifications, the interaction term between carbon assurance and lagged leverage remains negative and statistically significant, indicating that carbon-assured firms adjust more rapidly toward their target leverage than non-assured firms. The consistency of the sign, magnitude, and significance of the main coefficient across different estimation techniques provides confidence that the findings are not driven by model specification, sample selection, or endogeneity concerns.

5. Conclusions and Recommendations

The speed of capital structure adjustment is a central topic in corporate finance research. This study links sustainability assurance to dynamic capital structure behaviour and extends the trade-off theory. This study contributes to the literature by examining the influence of third-party carbon assurance on how firms adjust toward their optimal capital structure, as predicted by the trade-off theory. Using a large cross-country sample of firms operating in 47 countries/regions over the 2010–2020 period, and employing alternative estimation methods and robustness checks, we find that carbon assurance significantly influences the speed of capital structure adjustment. Firms that undergo third-party carbon

verification adjust their capital structure more rapidly than unassured firms. Moreover, this effect holds across both developed and developing markets. These findings enhance understanding of the economic consequences of carbon assurance and broaden the set of factors that influence corporate capital structure decisions. This demonstrates that sustainability controls are increasingly integrated into firms' management control systems and capable of shaping core financial outcomes.

5.1. Academic Implications

In the era of financial sustainability and environmental accountability, the findings of this study offer several practical implications and policy recommendations. From an academic perspective, this study highlights the importance of incorporating sustainability-oriented control mechanisms into established corporate finance theories. Future research is encouraged to further integrate sustainability control systems, such as carbon assurance, into dynamic capital structure models to better capture how non-financial governance mechanisms influence adjustment costs and financing behaviour. Scholars may extend this line of inquiry by examining other corporate financial decisions—such as dividend policy, liquidity management, or investment efficiency—through which sustainability controls may operate. In addition, future studies could explore heterogeneous effects across institutional settings, governance structures, and regulatory regimes to deepen understanding of the boundary conditions under which sustainability controls interact with conventional management control systems.

5.2. Practical Implications

The findings offer important practical insights for corporate managers and financial stakeholders. Specifically, the results indicate that carbon-assured firms have faster adjustment speed toward their optimal capital structure. This suggests that managers and investors should view third-party carbon verification as a strategic lever for enhancing financing efficiency. Moreover, corporate lenders are encouraged to recognise the value of carbon assurance in reducing information asymmetry and financing friction, thereby improving capital structure efficiency. Managers may consider adopting third-party carbon assurance as part of their broader control and governance framework, as verified sustainability information can reduce financing frictions and support more efficient capital structure adjustments. For lenders and investors, carbon assurance provides more credible and reliable information that can be incorporated into credit evaluation and monitoring processes, thereby improving risk assessment and capital allocation decisions.

5.3. Policy Implications

For policymakers in both developed and developing economies, the results suggest that promoting credible sustainability assurance can contribute to more efficient and sustainable financial markets. Regulators and policymakers in both developed and developing countries may consider encouraging the adoption of carbon assurance through regulatory guidance, disclosure standards, or targeted incentives, particularly in markets where information asymmetry and financing constraints are more pronounced. By supporting the integration of sustainability assurance into corporate control systems, policymakers can enhance transparency, reduce market frictions, and facilitate better access to external financing, thereby advancing broader environmental and economic sustainability goals.

5.4. Limitations and Directions for Future Research

There are several limitations in the present study, which offer directions for future research. First, this study focuses on capital structure adjustment speed as the primary corporate financial decision through which the linkage between sustainability and environ-

mental practices is examined. While leverage adjustment speed is a critical dimension of financing behaviour, other corporate financial decisions, such as dividend policy, liquidity management, and investment policy, may also represent relevant channels for future research. Second, from a methodological perspective, although the study employs established dynamic adjustment models and controls for firm- and country-level characteristics, the baseline pooled OLS specification does not fully account for time-invariant firm-specific heterogeneity. As a result, potential endogeneity concerns may still arise due to unobserved firm heterogeneity or reverse causality between carbon assurance adoption and capital structure adjustment behaviour. Also, consistent with the partial adjustment framework widely used in capital structure literature, target leverage is modelled implicitly as a function of firm characteristics rather than being estimated separately. As a result, the analysis cannot fully disentangle whether carbon assurance affects the speed of adjustment toward target leverage, the level of the target leverage itself, or both. While our empirical design focuses on adjustment speed, this assumption cannot be tested directly and should therefore be interpreted with caution. Future research may adopt alternative specifications that explicitly estimate target leverage to better distinguish between these channels. Third, the study's theoretical argument assumes that carbon assurance primarily enhances information transparency and stakeholder confidence, thereby facilitating faster capital structure adjustment. However, this mechanism may not operate uniformly across firms or institutional settings, as managerial incentives, regulatory enforcement, and market awareness of sustainability assurance can vary substantially. Future research could further unpack these channels by explicitly testing alternative mechanisms and boundary conditions.

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