

Construct Validation and Empirical Analysis of Carbon Accrual Manipulations in High-Emission Firms

Authors

Abiodun Okunola, Favour Olaoye, Olowolabi Rhema

Date: October 8, 2026

Abstract

Corporate carbon disclosures increasingly inform capital allocation and regulatory decisions, yet the construct validity of measures used to detect manipulation in these disclosures remains largely unexamined. This study addresses this gap by developing and validating a Carbon Accrual Manipulation (CAM) construct for high-emission firms, drawing on the conceptual foundation established in recent greenwashing measurement research (Okeke, 2026; Okeke & Rahim, 2026). Using a sample of 847 firm-year observations from carbon-intensive industries across 2018–2024, I apply confirmatory factor analysis and structural equation modeling to validate the CAM construct, then compare its predictive performance against established accrual-based earnings management models. The validated CAM framework demonstrates strong psychometric properties ($CFI = 0.94$, $RMSEA = 0.06$) and achieves 89.4% classification accuracy in identifying firms with material carbon disclosure discrepancies, substantially outperforming traditional discretionary accrual models (76.2%). The analysis reveals that carbon intensity, regulatory scrutiny, and short-term incentive structures constitute the primary predictors of CAM, with political cost pressures emerging as the dominant mechanism. These findings provide researchers and regulators with a construct-valid instrument for detecting carbon-related disclosure manipulation and extend political cost theory to the domain of non-financial reporting.

Keywords: carbon accrual manipulation, construct validation, greenwashing measurement, high-emission firms, political cost theory

1. Introduction

1.1 Background

The intersection of corporate environmental disclosure and financial reporting quality has emerged as a critical area of inquiry as climate-related risks become material to firm valuation (Timbate & Kim, 2026). Firms in carbon-intensive industries face mounting pressure from regulators, investors, and the public to demonstrate credible decarbonization progress, yet the incentive structures governing managerial behavior may encourage symbolic rather than substantive environmental action. Prior research has documented that high-emission firms engage in earnings management to manage political costs and deflect regulatory scrutiny (Timbate & Kim, 2026), but the parallel question of whether these firms manipulate carbon-related disclosures through analogous mechanisms remains underexplored.

Recent advances in greenwashing measurement have begun to address the conceptual and methodological challenges inherent in detecting corporate environmental misrepresentation (Okeke, 2026; Okeke & Rahim, 2026). These frameworks provide a foundation for understanding how firms may distort sustainability narratives, but they have not been specifically adapted to the accounting-based mechanisms through which carbon disclosure manipulation may occur. The construct of carbon accrual manipulation—defined here as the systematic misalignment between reported carbon performance and underlying emissions trajectories—represents a theoretically distinct phenomenon that requires dedicated validation.

1.2 Problem Statement

Despite growing evidence that carbon-intensive firms exhibit inferior financial reporting quality relative to other sectors (Timbate & Kim, 2026), no validated measurement framework exists for detecting manipulation specifically targeting carbon-related disclosures. Existing approaches to earnings management, such as the Modified Jones Model, were designed to capture discretionary accounting choices affecting financial statements, not environmental disclosures. While these models have been applied to carbon-intensive contexts, they fail to account for the unique institutional pressures and reporting incentives that shape carbon disclosure behavior. The absence of a construct-validated instrument for carbon accrual manipulation means that researchers cannot reliably distinguish between firms making genuine decarbonization progress and those engaging in symbolic compliance. This measurement gap undermines both academic inquiry and regulatory oversight.

1.3 Objectives of the Study

General objective: To develop and validate a construct for measuring carbon accrual manipulation in high-emission firms and to empirically assess its predictive validity against established models.

Specific objectives:

1. To identify the key predictors and observable indicators of carbon accrual manipulation through confirmatory factor analysis.
2. To validate the psychometric properties of the CAM construct using multiple fit indices and reliability estimates.
3. To compare the predictive performance of the validated CAM framework against traditional discretionary accrual models in identifying firms with material disclosure discrepancies.

1.4 Research Questions

1. What combination of financial, operational, and governance variables most accurately predicts carbon accrual manipulation in high-emission firms?
2. Does the validated CAM construct demonstrate superior classification accuracy compared to established earnings management models?
3. What are the dominant mechanisms through which institutional pressures induce carbon accrual manipulation?

1.5 Significance of the Study

This research matters for several constituencies. For **practitioners and auditors**, the validated CAM framework provides a replicable tool for assessing carbon disclosure credibility and identifying areas warranting enhanced scrutiny. For **policymakers and regulators**, the findings illuminate the institutional conditions that facilitate or constrain carbon disclosure manipulation, informing the design of disclosure mandates and enforcement mechanisms. For **academic literature**, the study extends political cost theory into the domain of non-financial reporting and establishes a construct-validated measurement instrument that future research can employ. For **future researchers**, the CAM framework offers a methodological foundation for investigating carbon-related managerial behavior across different institutional contexts and time periods.

1.6 Scope and Limitations

This study focuses on publicly traded firms in carbon-intensive industries (energy, utilities, materials, and industrials) across North American and European markets during 2018–2024. The analysis relies on publicly available carbon disclosure data and financial statement information. Key limitations include the reliance on vendor-estimated emissions data for certain observations, the assumption that historical relationships between predictors and manipulation remain stable, and the exclusion of private firms for which carbon disclosure data are unavailable. The construct

validation approach, while rigorous, cannot definitively establish causality between institutional pressures and manipulation behavior.

2. Literature Review

2.1 Conceptual Review

Carbon Accrual Manipulation (CAM). This construct refers to the systematic divergence between a firm's reported carbon performance indicators and the emissions trajectory that would be expected given its operational characteristics, investment patterns, and sector-level benchmarks. Unlike earnings management, which affects financial statement line items, CAM operates through the selection, measurement, and presentation of carbon-related metrics.

Political Cost. Following positive accounting theory, political cost refers to the adverse consequences—regulatory intervention, public scrutiny, legislative action—that firms face when their activities attract unfavorable attention. Carbon-intensive firms face elevated political costs due to their environmental externalities (Timbate & Kim, 2026).

Construct Validity. The degree to which a measurement instrument captures the theoretical construct it purports to measure, established through convergent, discriminant, and nomological validity evidence (Okeke & Rahim, 2026).

2.2 Theoretical Framework

This study integrates three theoretical perspectives. **Political Cost Theory** predicts that firms facing heightened regulatory scrutiny will manage disclosures—both financial and environmental—to reduce perceived risk and deflect intervention (Timbate & Kim, 2026). For carbon-intensive firms, this implies incentives to understate emissions or overstate reduction progress.

Agency Theory provides the mechanism through which managerial incentives translate into disclosure manipulation. When compensation structures emphasize short-term performance targets, managers face pressure to achieve those targets through whatever reporting discretion is available, including carbon-related disclosures.

Legitimacy Theory explains the broader institutional context. Firms seek to maintain alignment between their observed behavior and societal expectations; when substantive decarbonization is costly or slow, symbolic disclosure manipulation offers a lower-cost alternative for maintaining legitimacy.

2.3 Empirical Review

Timbate and Kim (2026) analyzed US firms from 2006 to 2024 and found that carbon-intensive industries exhibit higher earnings management than other sectors, with the discretionary accrual

gap narrowing over time while real earnings management persists. Their study establishes the baseline relationship between carbon intensity and financial reporting quality but does not address carbon-specific disclosure manipulation.

Okeke (2026) developed a greenwashing measurement framework validating constructs for corporate environmental misrepresentation, demonstrating that multi-dimensional indicators achieve superior construct validity compared to single-metric approaches. Okeke and Rahim (2026) extended this work through a triangulated greenwashing index, showing that combining qualitative and quantitative indicators enhances precision in identifying misrepresentation. These studies provide methodological foundations but focus on environmental disclosure broadly rather than carbon accrual mechanisms specifically.

Research on carbon offset markets has documented systematic over-crediting and additionality failures (Stanley, 2024), suggesting that the incentives for carbon-related misrepresentation extend beyond direct emissions reporting. However, the accounting-based mechanisms through which firms may manipulate carbon disclosures have not been subjected to rigorous construct validation.

2.4 Research Gap

No construct-validated instrument exists for measuring carbon accrual manipulation that specifically incorporates the institutional, operational, and governance predictors theorized to drive this behavior. Existing earnings management models capture financial reporting discretion but lack the specificity required to detect carbon-focused manipulation. This study fills that gap by developing and validating the CAM construct through confirmatory factor analysis and assessing its predictive superiority over established models.

3. Methodology

3.1 Research Design

This study employs a quantitative, construct validation design combining confirmatory factor analysis (CFA) with predictive modeling. The design proceeds in three phases: (1) construct specification and indicator development based on theoretical review, (2) CFA to validate the measurement model, and (3) comparative predictive performance assessment against baseline models. This design is appropriate because construct validation requires both theoretical grounding and empirical testing of psychometric properties.

3.2 Study Area / Population

The target population comprises publicly traded firms in carbon-intensive industries classified under Global Industry Classification Standard sectors: Energy, Utilities, Materials, and Industrials. These sectors account for approximately 70% of global industrial carbon emissions and face the most direct regulatory and stakeholder pressure regarding carbon performance.

3.3 Sample Size and Sampling Technique

The sample consists of 847 firm-year observations from 218 unique firms across North American and European markets, covering fiscal years 2018–2024. Stratified sampling ensured proportional representation across sectors and regions. The sample size exceeds the minimum threshold for CFA (typically 5–10 observations per estimated parameter) and provides adequate statistical power for structural modeling.

3.4 Data Collection Methods

Data were extracted from three sources: (1) carbon disclosure data from CDP (formerly Carbon Disclosure Project) and vendor-estimated Scope 1 and Scope 2 emissions, (2) financial statement data from Compustat and Worldscope, and (3) governance and compensation data from BoardEx and ExecuComp. The observation window spans 2018–2024 to capture the post-Paris Agreement institutional environment and subsequent regulatory developments.

3.5 Research Instruments

Analyses were conducted in R (version 4.3.1) using the lavaan package for structural equation modeling and the caret package for predictive modeling. Missing data were handled through multiple imputation using the mice package. All continuous variables were winsorized at the 1st and 99th percentiles to mitigate outlier influence. Following Okeke and Rahim (2026), I employed a triangulation approach to indicator development, incorporating both financial and non-financial signals of carbon-related discretion.

3.6 Validity and Reliability

Content validity was established through theoretical derivation of indicators from political cost, agency, and legitimacy theories, with each indicator mapping to a specified mechanism. **Construct validity** was assessed through CFA fit indices (CFI, TLI, RMSEA, SRMR), convergent validity through average variance extracted (AVE), and discriminant validity through comparison of AVE square roots with inter-construct correlations. **Predictive validity** was evaluated through out-of-sample classification accuracy using 10-fold cross-validation. **Inter-rater reliability** for the qualitative coding of carbon disclosure narratives was assessed using Cohen's kappa, yielding $\kappa = 0.82$.

3.7 Data Analysis Techniques

The measurement model was estimated using maximum likelihood CFA. Model fit was evaluated using conventional thresholds: $CFI \geq 0.90$, $RMSEA \leq 0.08$, $SRMR \leq 0.08$. Predictive performance was assessed by comparing the CAM-based classification model against the Modified Jones Model for discretionary accruals (Dechow et al., 1995) and the Dechow-Dichev (2002) accrual quality model. Classification accuracy, sensitivity, specificity, and area under the ROC curve (AUC) served as performance metrics. Feature importance was derived from random forest variable importance measures and standardized path coefficients.

3.8 Ethical Considerations

This study relies exclusively on de-identified, publicly available data from commercial databases and voluntary corporate disclosures. No protected health information or personally identifiable information was accessed. The research protocol was reviewed and determined to be exempt from institutional review board oversight under 45 CFR 46.104(d)(4) as secondary analysis of public data.

4. Results

4.1 Data Presentation

Table 1. Descriptive Statistics by Sector

Indicator	Energy (n=312)	Utilities (n=198)	Materials (n=187)	Industrials (n=150)
Carbon intensity (mean, SD)	2.84 (1.12)	3.21 (1.34)	1.96 (0.87)	1.42 (0.64)
Discretionary accruals (mean, SD)	0.043 (0.038)	0.038 (0.031)	0.029 (0.027)	0.021 (0.019)
Political cost proxy (mean, SD)	4.67 (1.23)	4.92 (1.41)	3.18 (1.07)	2.54 (0.92)
Short-term incentives (mean, SD)	0.31 (0.14)	0.28 (0.12)	0.19 (0.09)	0.14 (0.07)
CAM score (mean, SD)	0.72 (0.21)	0.68 (0.19)	0.51 (0.16)	0.38 (0.12)

Table 1 reveals systematic variation across sectors, with Energy and Utilities exhibiting the highest carbon intensity and CAM scores. This pattern aligns with political cost theory, as these sectors face the greatest regulatory scrutiny.

4.2 Analysis of Results

Construct validation. The CFA model exhibited adequate fit: $\chi^2(142) = 387.6$, $p < .001$; CFI = 0.94; TLI = 0.93; RMSEA = 0.06 (90% CI [0.05, 0.07]); SRMR = 0.05. All factor loadings exceeded 0.60 (range: 0.63–0.89), and composite reliability for the CAM construct was 0.87. AVE was 0.58, exceeding the 0.50 threshold and supporting convergent validity.

Predictive performance. The CAM-based classification model achieved 89.4% accuracy in identifying firms with material carbon disclosure discrepancies (defined as a carbon intensity residual exceeding the 90th percentile). The Modified Jones Model achieved 76.2% accuracy, and the Dechow-Dichev model achieved 74.8%. The difference in AUC between CAM (0.91) and Modified Jones (0.79) was statistically significant (DeLong test, $p < .001$).

Feature importance. Random forest variable importance identified carbon intensity (importance = 0.24), political cost proxy (0.21), short-term incentive ratio (0.18), regulatory exposure (0.15), and board environmental committee presence (0.12) as the top five predictors of CAM.

Statistical significance. Multiple regression analysis revealed that carbon intensity ($\beta = 0.34$, $p < .001$), short-term incentives ($\beta = 0.28$, $p < .001$), and political cost ($\beta = 0.22$, $p < .01$) were significantly associated with CAM scores after controlling for firm size, profitability, and leverage.

5. Discussion

5.1 Interpretation

The validation of the CAM construct with strong psychometric properties and 89.4% classification accuracy addresses the first research question by identifying a reliable combination of predictors for detecting carbon accrual manipulation. The dominance of carbon intensity and political cost as predictors supports the theoretical framework: firms with higher emissions face greater political pressure, which in turn creates stronger incentives to manage carbon disclosures.

The superior performance of CAM relative to traditional earnings management models answers the second research question. The 13.2 percentage point accuracy advantage over the Modified Jones Model indicates that carbon-specific measurement captures variance in disclosure manipulation that financial accrual models miss. This finding aligns with Okeke's (2026) conclusion that multi-dimensional, context-specific constructs outperform general-purpose measures in detecting environmental misrepresentation.

The primacy of short-term incentives as a predictor addresses the third research question and extends agency theory to carbon disclosure contexts. When managers face pressure to meet short-term performance targets, carbon-related discretion provides an additional channel through which to manage reported outcomes, complementing financial accrual manipulation.

5.2 Implications

Academic implications. This study extends political cost theory from financial reporting to carbon disclosure, demonstrating that the same institutional pressures that induce earnings management also drive carbon accrual manipulation. The validated CAM construct provides a replicable instrument for future research investigating carbon-related managerial behavior, including cross-national comparisons and longitudinal analyses of regulatory effects.

Practical implications. Auditors and regulators can employ the CAM framework to identify firms warranting enhanced scrutiny of carbon disclosures. The feature importance results suggest specific monitoring priorities: firms with carbon intensity above sector medians, short-term compensation structures, and high regulatory exposure should receive particular attention. The 89.4% classification accuracy provides a quantified benchmark for cost-benefit analysis of enhanced monitoring programs.

5.3 Limitations

1. **Sample generalizability.** The focus on North American and European firms may limit applicability to emerging markets with different institutional frameworks.
2. **Vendor-estimated emissions.** For approximately 22% of observations, Scope 1 emissions data were vendor-estimated rather than directly reported, introducing potential measurement error.
3. **Historical pattern stability.** The assumption that relationships between predictors and CAM remain stable over time may not hold through major regulatory regime shifts.
4. **Construct scope.** The CAM construct captures systematic misalignment in carbon disclosures but does not distinguish between intentional manipulation and unintentional reporting inaccuracy.

5.4 Future Research Directions

1. Extension of the CAM framework to other institutional contexts, including emerging markets and state-owned enterprises.
2. Longitudinal designs examining how regulatory changes (e.g., mandatory climate disclosure rules) affect CAM prevalence and detection.
3. Integration of the CAM construct with qualitative analyses of managerial decision-making processes to distinguish intentional from unintentional misreporting.
4. Development of real-time CAM monitoring systems using machine learning approaches.

6. Conclusion

This study developed and validated a Carbon Accrual Manipulation construct for high-emission firms, achieving 89.4% classification accuracy and demonstrating psychometric properties suitable for research and regulatory applications. The framework substantially outperforms traditional earnings management models in identifying firms with material carbon disclosure discrepancies, providing a replicable instrument that extends political cost theory to non-financial reporting domains. For practitioners, the findings offer a validated tool for assessing carbon disclosure credibility, with carbon intensity, short-term incentives, and political cost emerging as priority monitoring indicators. As carbon disclosure increasingly informs capital allocation and regulatory decisions, the CAM framework provides a foundation for evidence-based oversight of corporate climate claims.

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