“Carbon costing integration, environmental disclosure, and carbon intensity: Evidence from Jordanian listed firms”

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ARTICLE INFO	Bassam Maali, Ayman Bader, Amer Morshed and Laith T. Khrais (2026). Carbon costing integration, environmental disclosure, and carbon intensity: Evidence from Jordanian listed firms. *Environmental Economics*, *17*(2), 176-190. doi:10.21511/ee.17(2).2026.13
DOI	http://dx.doi.org/10.21511/ee.17(2).2026.13
RELEASED ON	Friday, 22 May 2026
RECEIVED ON	Sunday, 08 February 2026
ACCEPTED ON	Tuesday, 21 April 2026

JOURNAL	"Environmental Economics"
ISSN PRINT	1998-6041
ISSN ONLINE	1998-605X
PUBLISHER	LLC “Consulting Publishing Company “Business Perspectives”
FOUNDER	LLC “Consulting Publishing Company “Business Perspectives”

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
67	0	6

BUSINESS PERSPECTIVES

LLC "CPC "Business Perspectives"
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Sumy, 40022, Ukraine
www.businessperspectives.org

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CARBON COSTING INTEGRATION, ENVIRONMENTAL DISCLOSURE, AND CARBON INTENSITY: EVIDENCE FROM JORDANIAN LISTED FIRMS

Type of the article: Research Article

Received on: 8th of February, 2026
Accepted on: 21st of April, 2026
Published on: 22nd of May, 2026

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Abstract

Environmental reporting is expanding, yet many firms achieve limited environmental improvement when carbon effects are not translated into decision-relevant cost information for budgeting, pricing, and investment appraisal. This study examines whether integrating carbon costing into activity-based costing is associated with higher carbon and environmental disclosure quality and lower carbon intensity among listed firms in Jordan. The analysis uses disclosures for 12 firms over 2018–2024 and estimates two-way fixed-effects panel models with firm-clustered standard errors to test whether within-firm changes in costing integration are followed by changes in disclosure quality and emissions intensity after controlling for firm-specific unobserved heterogeneity and common year effects. The results show no statistically significant association between costing integration and disclosure quality ($\beta = 0.013$, $p > 0.10$) and no significant association with carbon intensity ($\beta = 0.238$, $p > 0.10$). The interaction analysis further indicates that the integration–disclosure relationship is not stronger in environmentally sensitive industries ($\beta = -0.350$, $p > 0.10$). By contrast, firm size is positively related to disclosure quality, suggesting that visibility, organizational capacity, and reporting resources matter more than costing integration in this context. These findings indicate weak implementation depth rather than clear environmental gains. Overall, carbon-costing integration has not yet become sufficiently embedded in routine managerial practice to produce measurable improvements in disclosure quality or emissions performance in Jordanian listed firms.

Keywords carbon, costing, disclosure, intensity, accounting, Jordan

JEL Classification Q56, M41, C23

Conflict of interest statement:
Author(s) reported no conflict of interest

INTRODUCTION

Environmental sustainability has become a material economic issue because climate exposure increasingly affects operating costs, financing conditions, and long-run firm value. At the firm level, however, an important implementation problem remains unresolved: external expectations for carbon disclosure are rising faster than internal systems for measuring and managing carbon-related costs. In many firms, carbon is discussed in narrative reporting but is not translated into decision-relevant cost information that can guide budgeting, pricing, process control, and investment appraisal (Tang, 2025). When carbon information remains outside routine managerial accounting, environmental initiatives become harder to prioritize, evaluate, and scale, and public commitments may coexist with limited operational change. This problem is especially relevant in Jordan and similar emerging-market contexts, where environmental, social, and governance reporting is expanding but the depth, standardization, and verification of environmental measurement remain uneven (Delacote et al., 2024). As a

http://dx.doi.org/10.21511/ee.17(2).2026.13

result, disclosure quality may vary with firm size, governance capacity, and stakeholder pressure rather than with the actual strength of internal environmental management. This creates a broader economic concern because capital markets increasingly respond to climate-related information, and carbon-risk signals can shape firm valuation, investor confidence, and resource allocation (Liu & Wu, 2023). Firms, therefore, face a structural tension: they are expected to provide credible and decision-useful environmental disclosure, yet they may lack the internal cost architecture needed to generate reliable metrics and connect them to operating decisions (Bader et al., 2025).

From an environmental economics perspective, this gap matters because inefficient internal measurement can weaken both environmental performance and the quality of information available to markets. When carbon impacts are not identified, traced, and incorporated into routine managerial decisions, firms are less able to detect emission-intensive activities, assess low-carbon investments, and align operational choices with environmental objectives. Integrating carbon effects into managerial cost systems is therefore not only an accounting issue but also an economic one, as it influences how firms allocate resources, evaluate environmental trade-offs, and convert sustainability pressures into measurable performance outcomes. In this sense, stronger internal carbon-cost measurement may help narrow the gap between environmental disclosure and actual environmental improvement.

1. LITERATURE REVIEW AND HYPOTHESES

Environmental economics has long emphasized that environmental degradation persists when firms lack either sufficient incentives or sufficiently precise internal information to identify, price, and manage environmental externalities in routine decisions (Wu et al., 2025b). In parallel, strategy and accounting research shows that environmental capabilities can generate both environmental and economic benefits when they are embedded in operational and investment choices rather than treated as symbolic commitments (Bao et al., 2025; Bindeeba et al., 2025; Giang et al., 2025). This framing is important because it positions managerial accounting not as a purely technical subsystem, but as a governance mechanism through which environmental priorities can be translated into operational routines, monitored over time, and linked to measurable outcomes.

This logic is developed further in the environmental management accounting literature, which argues that environmental outcomes improve when environmental impacts are converted into decision-relevant cost signals that shape planning, control, and process improvement (Aureli et al., 2025; Martínez-Falcó et al., 2025). Studies in this stream indicate that aligning environmental information with internal control systems can strengthen managerial attention to pollution prevention, energy efficiency, and compliance, especially when environmental measures are incorporated into budgeting and performance evaluation (Gao et al., 2025; Wu et al., 2025b). At the same time, this literature also shows that the mere presence of environmental metrics is not enough. Environmental management accounting becomes most effective when it functions as a broader package of controls that combines operational indicators, financial cost information, responsibility assignment, and organizational learning routines rather than as an isolated reporting exercise (Barani et al., 2025; Johnstone, 2025). Accordingly, the likely effect of environmental accounting depends not simply on whether firms report environmental issues, but on whether the information is connected to accountable actors and recurring managerial decisions.

Carbon accounting research sharpens this distinction by separating external emissions reporting from internal carbon management accounting designed to support decision-making (Rahman et al., 2025; Suraj et al., 2025; Tang, 2025). A central theme in this literature is that firms may disclose climate-related information without fully embedding carbon considerations into costing, investment appraisal, and product or process decisions, thereby limiting real environmental improvement (Hu et al., 2025a; Millar et al., 2025). Evidence on internal carbon pricing reinforces this point, showing that firms are more likely to adopt internal carbon prices when regulatory and market pressures are stronger, and that such pricing can influence capital allocation by making carbon trade-offs financially visible (Godase et al., 2025; Sun et al., 2025). However, the same literature also highlights persistent implementation problems, especially when emissions data are incomplete, and systems for tracing carbon-related costs to operational drivers remain weak (Hu et al., 2025b; Xia et al., 2025). This matters because carbon initiatives can remain largely symbolic if firms cannot generate reliable, auditable, and decision-useful carbon cost information.

Within this broader discussion, activity-based costing (ABC) provides a plausible architecture for embedding environmental and carbon considerations into managerial decisions because it traces costs through activities and drivers rather than allocating overhead broadly (Ortiz-Cea et al., 2025; Schwaiger et al., 2025). The potential relevance of ABC is especially strong where carbon and environmental burdens are hidden within indirect costs. Yet the ABC literature is also clear that its effectiveness is conditional on organizational fit, process complexity, and the firm's ability to maintain reliable driver data over time (Nour & Arbussà, 2025; Yousef & Sponem, 2025). This conditionality is critical in the environmental context because environmental and carbon costs are frequently treated as indirect or hidden overheads (Yousef & Sponem, 2025). When such costs remain pooled and untraced, managers may underestimate the true resource and emissions burden of specific products, customers, or processes, which can sustain cross-subsidization and weaken incentives for abatement (Xu et al., 2025). ABC is, therefore, theoretically attractive for carbon integration, but its practical value depends on data quality, traceability routines, and managerial accountability (Shaban & Omoush, 2025).

The environmental costing literature extends this argument by showing how ABC can be adapted to capture environmental resource use and carbon impacts more directly. Case-based and applied studies find that activity-based approaches can allocate energy, waste, and treatment costs more accurately, identify high-impact activities, and reveal abatement opportunities that remain obscured under traditional costing systems (Shash & AbuAlnaja, 2023; Yildiz et al., 2024). Related work combines ABC with life-cycle and footprint approaches to connect operational drivers with broader environmental effects, thereby supporting investment appraisal and process redesign (Alaoui & Schwaiger, 2024; Zaghwan et al., 2024). Across this literature, the recurring conclusion is that environmental ABC improves decision usefulness by making environmental costs traceable to controllable activities, reducing cross-subsidization across products and processes, and strengthening accountability for resource- and emissions-intensive routines. Nonetheless, the current evidence base is still dominated by case settings and applied designs. Although these studies are valuable for illustrating mechanisms, they are less conclusive about whether such effects hold systematically across firms and over time. For this reason, reviews characterize green ABC and related hybrid approaches as promising but still under-tested in archival firm-year settings, particularly outside advanced economies where reporting infrastructure and data systems may be weaker (Ahmed et al., 2023; Morshed, 2025b).

A similar tracing logic appears in adjacent environmental management accounting tools. Material flow cost accounting (MFCA), for example, links physical flows with monetary values to identify inefficiencies such as waste and scrap that conventional accounting systems often obscure, frequently revealing resource-efficiency opportunities with both environmental and economic benefits (Kokubu et al., 2023; Wang et al., 2023). Although MFCA differs from ABC in method, both approaches rest on the same principle: environmental outcomes improve when internal systems reveal where environmental burdens arise within operations, why they arise, and how they can be expressed in forms that managers can use to allocate attention and resources.

Environmental disclosure research provides a second major stream that is relevant to the present study because it offers a publicly observable way to assess environmental outcomes while also exposing an important debate. On the one hand, disclosure quantity and quality vary systematically with governance characteristics and stakeholder pressure, and disclosure is not always a reliable proxy for actual environmental performance because legitimacy incentives and impression man-

http://dx.doi.org/10.21511/ee.17(2).2026.13

agement may shape reporting behavior (Abdalla et al., 2024; Morshed, 2025a). On the other hand, disclosure is economically meaningful because markets react to carbon-related information and may penalize higher emissions exposure or insufficient transparency, meaning that disclosure can influence economic outcomes even when it does not perfectly reflect operational reality (Liu & Wu, 2023; Xu et al., 2024). These positions can be reconciled by treating disclosure quality as partly dependent on underlying internal measurement capacity. Disclosure may be strategically motivated, but it is more likely to become credible and consistently informative when it is supported by structured internal data and traceable routines (Nieto & Papathanassiou, 2024; Wang, 2023). Methodologically, this is why the disclosure literature favors structured content indices and reliability safeguards, including clear coding rules and inter-coder checks, to ensure that disclosure-based measures capture decision usefulness rather than subjective impressions (Nyakuwanika & Panicker, 2025; Ongsakul et al., 2025).

Taken together, these literatures suggest two connected channels through which carbon-cost integration may influence environmental outcomes. First, more granular carbon and environmental costing can improve operational decisions and thereby affect carbon intensity by redirecting managerial attention and resources toward high-impact activities and by strengthening accountability for energy and emissions drivers (Ongsakul et al., 2025; Yıldırım et al., 2025). Second, firms that embed carbon and environmental costs in ABC-like routines may be better positioned to produce higher-quality and more decision-useful disclosures because they possess structured internal data, clearer measurement boundaries, and documented routines for traceability (Yıldırım et al., 2025). This second channel is also consistent with voluntary disclosure arguments, which suggest that credible disclosure becomes easier to produce and verify when internal information systems reduce verification costs and clarify what is being measured (Amel-Zadeh & Tang, 2025; Ho et al., 2025). In this context, carbon-ABC integration can be understood as the extent to which carbon, energy, and environmental cost pools are traced to activities and drivers and embedded in routine costing and control processes rather than treated as non-operational overhead (Ortiz-Cea et al., 2025; Schwaiger et al., 2025). By contrast, carbon and environmental disclosure quality (CEDQ) reflects the decision usefulness of disclosed environmental and carbon information rather than the simple volume of narrative reporting. In comparison, carbon intensity reflects emissions relative to economic output and may respond more slowly because it depends on operational change, technology, and investment, not only on reporting or measurement upgrades (Nyakuwanika & Panicker, 2025; Ongsakul et al., 2025; Rahman et al., 2025; Tang, 2025).

Evidence from emerging markets, including Jordan, further highlights the relevance of this internal-systems perspective. Research on Jordanian listed firms reports relatively low but evolving levels of CSR, sustainability, and ESG-related disclosure, with variation explained by firm size, profitability, leverage, industry, and governance-related attributes (Delacote et al., 2024). Broader sustainability reporting studies similarly show that institutional pressures and stakeholder scrutiny can increase disclosure while leaving important gaps in measurement depth and quantitative emissions data across many firm-years (Adisorn et al., 2023; Goswami et al., 2022). However, most evidence in the Jordanian setting focuses on the determinants of disclosure and the market or financial consequences of reporting, while giving much less attention to whether firms adopt internal costing routines such as ABC-based tracing of carbon, energy, and environmental cost pools that could plausibly strengthen both disclosure credibility and operational decarbonization. This omission is important because internal traceability is a precondition for converting environmental priorities into controllable managerial decisions rather than post hoc narratives (Shaban & Barakat, 2023).

Overall, prior research indicates that internal environmental costing and management-control integration can support real environmental improvement, that ABC-style tracing offers a concrete mechanism for operationalizing carbon and environmental costs, and that disclosure-based outcomes are economically meaningful but depend on the credibility and structure of internal information systems. Yet archival firm-year evidence remains limited, particularly in Jordan and similar markets, on whether integrating carbon costing into ABC routines is systematically associated with better environmental disclosure quality and lower carbon intensity (Ahmed et al., 2023; Morshed, 2025b).

Accordingly, the purpose of this study is to examine whether integrating carbon costing into activity-based costing is associated with improved environmental outcomes for Jordanian listed firms, measured through carbon and environmental disclosure quality and carbon intensity, using publicly available online firm disclosures in an unbalanced firm-year panel.

Study hypotheses are as follows:

H1: *Carbon-ABC integration is positively related to carbon and environmental disclosure quality.*

H2: *Carbon-ABC integration is negatively related to carbon intensity.*

H3: *Carbon-ABC integration is more strongly related to carbon and environmental disclosure quality in environmentally sensitive industries.*

2. METHODS

The study adopts a quantitative, archival (secondary-data) research design to examine whether integrating carbon-costing into activity-based costing (Carbon-ABC) is associated with environmental disclosure quality and carbon-intensity outcomes for Jordanian listed firms. The empirical setting is Jordan, and the unit of analysis is the firm-year. Firm-level information is collected exclusively from publicly available online disclosures, including annual reports, audited financial statements and notes, governance reports, and, where available, sustainability/ESG reports released by firms and via the Amman Stock Exchange disclosure system. The sample is an unbalanced panel because disclosure availability differs across firms and years. The study period spans 2018–2024, selected to maximize consistent access to digitally archived reports and to capture the recent increase in sustainability and climate-related reporting in the Jordanian market; the endpoint (2024) reflects the most recent year for which reports are broadly available across the sample.

The empirical strategy relies on a two-way fixed-effects specification (firm and year effects) with firm-clustered standard errors, using a panel of 12 Amman Stock Exchange-listed firms observed over 2018–2024. The final estimation sample is determined by the availability of required control variables, notably Sales_Growth, which reduces the usable firm-year observations for regression analysis relative to the full panel. Specifically, Sales_Growth is available from 2019 onward, yielding an estimation window of 2019–2024 and 72 firm-year observations. Table 1 summarizes the sample structure, observation counts, and the named firm composition.

The study operationalizes carbon and environmental disclosure quality (CEDQ) and carbon-ABC integration (CABCI) as composite indices constructed from observable disclosure and costing components coded at the firm-year level. Table 2 provides descriptive statistics for these measures in two ways. Panel A reports the share of firm-years (%) exhibiting each underlying component for CEDQ, such as emissions data, targets, governance/risk, and external assurance, and for carbon-ABC, including ABC implementation, carbon-cost identification, and allocation via cost drivers. Panel B reports yearly means of the main indices and the carbon-intensity measure in the forms used for descriptive reporting (lnCI and CI × 10^5), enabling a transparent view of how the constructs evolve over time within the 2018–2024 panel (Oreqat, 2021).

Two outcome measures are employed to reflect environmental economics performance using publicly observable information. The primary outcome is a disclosure-based measure, carbon and environmental disclosure quality (CEDQ), constructed as a content index that captures the presence and decision-usefulness of environmental and carbon-related reporting (Khan et

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Table 1. Sample structure and composition (including named firms)

Panel A. Sample structure	
Item	**Value**
Firms	12
Period (full panel)	2018–2024
Firm-year observations (full panel)	84
Estimation period (Sales_Growth available)	2019–2024
Firm-year observations (regressions)	72

Panel B. Sample firms (names, tickers, and sectors)				
Firm_ID	**Company**	**Ticker**	**Sector**	**Env-sensitive**
1	Jordan Phosphate Mines Company	JOPH	Mining & Extraction	Yes
2	Arab Potash Company	APOT	Mining & Extraction	Yes
3	Jordan Cement Factories Company	JOCM	Manufacturing	Yes
4	United Iron & Steel Manufacturing Company	MANS	Manufacturing	Yes
5	Jordan Telecom Company	JTEL	Telecommunications	No
6	Arab Bank	ARBK	Banking	No
7	Capital Bank of Jordan	CAPL	Banking	No
8	Jordan National Shipping Lines	SHIP	Transportation	Yes
9	Jordan Electric Power Company	JOEP	Utilities	Yes
10	Jordanian Duty Free Shops	JDFS	Services	No
11	National Cable & Wire Manufacturing Company	WIRE	Manufacturing	Yes
12	National Chlorine Industries Company	NATC	Manufacturing	Yes

Table 2. Disclosure and carbon-ABC component prevalence (Panel A) and year trends (Panel B)

Panel A. Share of firm-years (%)	
Item	**Percent**
Emissions data	42.9
Targets	36.9
Actions	50.0
Energy use	56.0
Renewables	31.0
Governance/risk	32.1
External assurance	7.1
ABC implemented	41.7
Carbon costs identified	29.8
Carbon costs allocated via drivers	28.6

Panel B. Yearly means					
Year	**N**	**Mean_CEDQ**	**Mean_CABCI**	**Mean_lnCI**	**Mean_CI_x1e5**
2018	12	0.274	0.250	–10.436	4.021
2019	12	0.238	0.333	–10.383	4.445
2020	12	0.429	0.361	–10.503	4.263
2021	12	0.333	0.306	–10.309	4.231
2022	12	0.357	0.389	–10.001	5.083
2023	12	0.488	0.417	–10.203	4.206
2024	12	0.440	0.278	–10.287	4.190

al., 2023). CEDQ is coded using a transparent checklist of binary items that cover:

(i) emissions and energy metrics (levels and/or intensities);

(ii) targets and progress;

(iii) operational actions and investments related to efficiency and decarbonization; and

(iv) governance, risk management, and assurance signals.

The index is computed as the firm-year sum of disclosed items and can be scaled to the [0,1] interval for comparability. A secondary, more outcome-focused measure is estimated for the subset of firm-years that provide sufficient quantitative data: carbon intensity (emissions relative to firm scale, such as revenue). When firms disclose emissions directly (Scope 1/2 or total), carbon intensity is calculated as emissions divided by revenue and log-transformed to reduce skewness. When emissions are not disclosed, but electricity consumption is inferable from cost data, electricity use is approximated by dividing electricity expense by the relevant average tariff schedule for that year; Scope 2 emissions are then estimated by multiplying kWh by the applicable grid emission factor. These steps are implemented consistently across all firms, and sensitivity checks are used to evaluate the impact of alternative tariff and emission-factor assumptions (Aras & Van, 2022). Where feasible, an additional monetized environmental economics outcome is computed as a carbon-cost intensity measure by applying a shadow carbon price to estimated emissions and scaling by revenue; robustness is assessed using alternative carbon price scenarios (Ahmad et al., 2024).

The main explanatory variable operationalizes carbon-cost accounting through a Carbon-ABC Integration Index (CABCI), which captures whether the firm internalizes carbon and environmental costs within ABC-style routines rather than treating them solely as undifferentiated period expenses. CABCI is constructed from firm disclosures using observable criteria: evidence of ABC or cost-driver-based allocation practices; identification of carbon, energy, or environmental cost pools, such as energy, waste, emissions-related compliance, or environmental costs; and explicit allocation of such costs to activities, products, processes, or segments using drivers consistent with ABC logic (Liu et al., 2025). A parsimonious specification defines CABCI as the average of three binary indicators – ABC adoption, carbon/environmental cost identification, and ABC-style allocation – producing a continuous index ranging from 0 to 1. To strengthen measurement reliability, the coding protocol specifies keyword triggers and contextual decision rules, a pilot coding is conducted to refine the rubric, and an independent double-coding is performed on a subsample of firm-years; inter-rater agreement is assessed, for example, using Cohen's kappa, with disagreements reconciled through documented rules.

The baseline models include standard firm controls that influence both disclosure behavior and environmental performance: firm size (log total assets), profitability (ROA), leverage, sales growth, and capital intensity. Year fixed effects are included to account for economy-wide shocks, while time-invariant sectoral differences are absorbed by firm fixed effects (Morshed, 2025b). The core econometric specification is a two-way fixed-effects panel model estimated with firm and year fixed effects to mitigate omitted-variable bias stemming from time-invariant firm characteristics and common time shocks:

$$Y_{it} = \alpha + \beta CABCI_{it} + \gamma' X_{it} + \mu_i + \lambda_t + \varepsilon_{it}, \quad (1)$$

where Y_{it} represents either CEDQ (full sample) or carbon intensity (quantitative-disclosure subsample), X_{it} is the vector of controls, μ_i are firm fixed effects, and λ_t are year fixed effects. Inference is based on heteroskedasticity-robust standard errors clustered at the firm level to address within-firm serial correlation. Because disclosure-related outcomes may be persistent, a dynamic robustness specification is also estimated by including a lagged dependent variable and re-evaluating the stability of β. In addition, where the sample design permits, an institutional policy-pressure extension is implemented to test whether post-mandate years are associated with higher CABCI and improved outcomes for firms subject to stronger reporting requirements relative to other listed firms, using an interaction between treatment status and a post-policy indicator (Alsmadi & Alrawashdeh, 2025).

Model selection and diagnostic testing follow a transparent sequence common in panel-data applications. Panel unit-root tests are applied to continuous variables; where non-stationarity is detected, log transformations and/or first differences are used as appropriate (Abdeen, 2025). Multicollinearity is assessed using correlation matrices and variance inflation factors (Alin, 2010). Residual diagnostics evaluate heteroskedasticity and serial correlation; these diagnostics motivate the use of firm-clustered standard errors in the main regressions (Al-Muntasir, 2022). Finally, the incremental contribution of firm and year fixed

http://dx.doi.org/10.21511/ee.17(2).2026.13

effects is assessed using redundant fixed-effects F-tests (Baltagi, 2024). Robustness checks include alternative constructions of CABCI, alternative scaling of outcomes, winsorization, alternative tariff/emission-factor assumptions for Scope 2 estimation, and alternative shadow carbon prices (Sarstedt et al., 2020).

3. RESULTS

Table 3 indicates mid-level disclosure quality on average (CEDQ ≈ 0.38). Economically, this suggests that many firm-years disclose some relevant information but do not yet provide a consistently decision-useful package. The dispersion implies uneven measurement and reporting discipline across firm-years. Carbon-ABC integration is also partial on average (CABCI ≈ 0.35). This matters because it indicates the main explanatory variable is not "fully adopted vs not adopted," but mostly incremental and uneven integration.

Emissions exposure is economically material when scaled by revenue. A useful benchmark from Table 3 is that carbon intensity corresponds to roughly 44 tCO2e per JOD 1 million of revenue. This is large enough to be relevant for cost control, financing discussions, and investment screening. In short, Table 3 shows

(i) real variation in disclosure maturity and

(ii) non-trivial carbon exposure, so both disclosure-quality outcomes and emissions outcomes are economically meaningful in this market context.

Table 4 shows that sector structure dominates unconditional relationships. The simple association between carbon-ABC integration and disclosure quality is weak. This implies that improving internal costing routines does not automatically show up as higher disclosure quality in the raw data (Mnif et al., 2025). By contrast, environmental

Table 3. Descriptive statistics

Variable	N	Mean	Median	SD	Min	Max
CEDQ	72	0.381	0.429	0.186	0.000	0.857
CABCI	72	0.347	0.333	0.265	0.000	1.000
lnCI	72	–10.281	–9.901	0.905	–13.316	–9.547
Carbon intensity (×10^{-5} tCO_{2e}/JOD)	72	4.403	5.011	2.165	0.165	7.145
Carbon cost intensity (USD/JOD)	72	0.003	0.003	0.001	0.000	0.004
Revenue (bn JOD)	72	1.197	1.296	0.518	0.131	2.335
Ln_Assets	72	21.099	21.401	0.861	19.127	21.889
ROA	72	0.117	0.044	0.192	0.003	0.877
Leverage	72	0.590	0.599	0.074	0.471	0.730
Sales_Growth	72	0.047	0.052	0.054	–0.106	0.227
Capital_Intensity	72	0.289	0.313	0.092	0.116	0.416

Note: Regression sample: 2019–2024, N = 72.

Table 4. Correlation matrix

Variable	CEDQ	CABCI	lnCI	Ln_Assets	ROA	Leverage	Sales_ Growth	Capital_ Intensity	Env_ Sensitive
CEDQ	1.000	0.082	0.170	0.049	0.099	–0.140	–0.136	0.229*	0.228*
CABCI	0.082	1.000	0.197*	0.119	0.066	–0.092	0.118	0.055	0.149
lnCI	0.170	0.197*	1.000	0.191	–0.011	–0.588***	–0.055	0.711***	0.802***
Ln_Assets	0.049	0.119	0.191	1.000	–0.852***	–0.183	0.032	0.165	0.210*
ROA	0.099	0.066	–0.011	–0.852***	1.000	0.029	0.025	0.008	–0.002
Leverage	–0.140	–0.092	–0.588***	–0.183	0.029	1.000	–0.019	–0.632***	–0.756***
Sales_Growth	–0.136	0.118	–0.055	0.032	0.025	–0.019	1.000	–0.052	–0.005
Capital_Intensity	0.229*	0.055	0.711***	0.165	0.008	–0.632***	–0.052	1.000	0.907***
Env_Sensitive	0.228*	0.149	0.802***	0.210*	–0.002	–0.756***	–0.005	0.907***	1.000

Note: Pearson correlation coefficients are reported. *, **, *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

sensitivity moves strongly with the emissions profile and capital intensity. Economically, this indicates that "high exposure" firms differ because of what they produce and how capital-intensive their processes are, not only because of reporting choices. This is why the main tests must rely on within-firm variation rather than cross-sector comparisons (Harasis, 2026).

Table 5 motivates a conservative identification strategy. The diagnostics indicate dependence within firms over time. That is expected in economic terms. Disclosure routines, technology, and capital structure change slowly. They also create persistence in outcomes. For that reason, the study retains firm and year fixed effects and uses firm-clustered inference. This reduces the risk of overstating precision in a small panel. It aligns with standard panel practice when the objective is within-firm identification under common shocks (Yang et al., 2025).

Table 6 reports the two-way fixed-effects estimates.

H1 (Carbon-ABC → disclosure quality). The CABCI effect on disclosure quality is small and not statistically reliable. Economically, this means that marginal improvements in Carbon-ABC integration do not, by themselves, deliver measurably higher disclosure quality once stable firm traits and common shocks are controlled. A more realistic interpretation is that disclosure quality reflects a broader reporting capability – data governance, reporting controls, verification routines, and managerial commitment – beyond the costing routine alone (Taqa, 2025). The positive association with firm scale is consistent with capacity and visibility effects documented in disclosure settings (Wang, 2023).

H2 (Carbon-ABC → emissions intensity). The CABCI effect on emissions intensity is not robust. Economically, this suggests that changes in internal costing integration are not sufficient to shift physical emissions intensity over the observed window. Emissions outcomes are typically driven by operational technology, energy mix, and investment cycles. Internal accounting can support these decisions, but it may not translate into observable emissions changes unless it triggers investment or process change. This is consistent with evidence that external monitoring and capital-market pressure can be important alongside internal systems (Cohen et al., 2023).

H3 (stronger effect in environmentally sensitive firms). The interaction does not support a stronger CABCI–CEDQ relationship in environmentally sensitive firms. Economically, this implies that higher-exposure sectors do not convert incremental costing integration into higher-quality disclosure more effectively than other firms. One consistent reading is that high-exposure firms face stronger legitimacy and risk-management pressures that can weaken the mapping from internal routines to disclosure quality (Liu et al., 2023). In such settings, disclosure may reflect risk narratives and compliance positioning as much as internal costing integration.

Taken together, the findings indicate that – under a stringent within-firm identification strategy – carbon-ABC integration does not exhibit a robust association with either disclosure quality

Table 5. Panel diagnostics and specification checks

Diagnostic	Statistic	Inference
Panel unit-root (Fisher-ADF): CEDQ	255.7	p < 0.001 (stationary)
Panel unit-root (Fisher-ADF): CABCI	97.2	p < 0.001 (stationary)
Panel unit-root (Fisher-ADF): lnCI	200.9	p < 0.001 (stationary)
Multicollinearity (max VIF among regressors)	4.684	Below 5 (acceptable)
Heteroskedasticity (Breusch–Pagan p): Model 1 (CEDQ)	0.099	Marginal evidence
Heteroskedasticity (Breusch–Pagan p): Model 2 (lnCI)	0.053	Marginal evidence
Serial correlation (residual lag(1) p): Model 1 (CEDQ)	0.007	Evidence present
Serial correlation (residual lag(1) p): Model 2 (lnCI)	0.030	Evidence present
Redundant firm FE F-test p: Model 1 (CEDQ)	0.692	Not rejected
Redundant year FE F-test p: Model 1 (CEDQ)	0.067	Borderline (10% level)
Redundant firm FE F-test p: Model 2 (lnCI)	0.059	Borderline (10% level)
Redundant year FE F-test p: Model 2 (lnCI)	0.552	Not rejected

http://dx.doi.org/10.21511/ee.17(2).2026.13

Table 6. Two-way fixed-effects regressions

Variable	CEDQ (FE)	lnCI (FE)	CEDQ + interaction (FE)
CABCI	0.013	0.238	0.201*
	(0.104)	(0.296)	(0.122)
CABCI_Env			–0.350
			(0.255)
Ln_Assets	1.037*	1.389	1.230**
	(0.554)	(1.610)	(0.622)
ROA	–0.079	0.912	–0.133
	(0.454)	(1.918)	(0.461)
Leverage	0.168	–0.098	0.213
	(0.397)	(1.953)	(0.434)
Sales_Growth	–0.416	–1.181	–0.527
	(0.385)	(0.808)	(0.320)
Capital_Intensity	0.737	–3.057	0.751
	(0.796)	(3.044)	(0.729)
const	–22.133*	–38.420	–26.200**
	(12.301)	(29.836)	(12.816)
Observations	72	72	72
R-squared	0.407	0.716	0.449
Adj. R-squared	0.141	0.588	0.184
Firm fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
SE clustering	Firm	Firm	Firm

Note: Standard errors clustered by firm are reported in parentheses. *, **, *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

(*H1*) or emissions intensity (*H2*), and the hypothesized amplification in environmentally sensitive industries (*H3*) is not supported. The descriptive evidence (Tables 2–3) nonetheless highlights economically meaningful emissions exposure (≈ 44 tCO2e per JOD 1 million of revenue) and very limited use of external assurance (7.1%), which may help explain why incremental integration signals are not consistently reflected in higher-quality disclosures in the fixed-effects setting (Alshehadeh et al., 2025).

4. DISCUSSION

The fixed-effects results reported in Table 6 indicate that carbon-ABC integration (CABCI) does not yet produce measurable improvements in either carbon and environmental disclosure quality (CEDQ) or carbon intensity once unobserved firm heterogeneity and common year shocks are taken into account. Although the coefficient on CABCI is positive in the disclosure model, the magnitude is small and statistically insignificant, indicating that within-firm increases in carbon-ABC integration were not consistently followed by better disclosure during the study period. A similar pattern appears for carbon intensity, where no reliable improvement is observed. This suggests that incremental changes in costing practice may be insufficient to alter near-term emissions performance when production technology, energy mix, and capital constraints remain the dominant drivers of adjustment (Liu & Wu, 2023; Wang, 2023).

A key explanation is likely implementation depth. Carbon management accounting is expected to influence environmental outcomes only when carbon information is converted into decision-relevant cost signals and embedded in routine managerial processes such as budgeting, pricing, process redesign, investment appraisal, and performance evaluation, rather than being adopted mainly for documentation or reporting purposes (Tang, 2025; Suraj et al., 2025). This interpretation is consistent with prior work on activity-based approaches, which shows that ABC-type systems generate environmental benefits when they reallocate managerial attention toward high-impact activities and support operational change, not when they remain primarily classificatory or symbolic tools (Ortiz-Cea et al., 2025; Schwaiger et al., 2025). The present findings, therefore, suggest that, in this setting, carbon-ABC may still be operating at an early or selective stage of adoption that improves the visibility of carbon-related costs without yet changing decisions at a scale sufficient to affect observable disclosure quality or emissions intensity.

The findings also point to a possible decoupling between internal practice and external disclosure. Environmental and climate disclosure are shaped not only by internal measurement quality, but also by stakeholder pressure, legitimacy incentives, and market scrutiny, all of which can stimulate reporting even when internal systems remain only partially developed (Cohen et al., 2023; Liu et al., 2023). This helps explain why firm size is positively associated with CEDQ: larger firms tend to face greater public visibility and usually possess stronger reporting capacity, broader governance infrastructure, and more resources for data collection and internal review. In this context, assurance quality becomes especially important because it can strengthen the connection between internal measurement routines and credible external reporting by improving verifiability and reducing skepticism toward disclosure claims (Ho et al., 2025).

The non-significant moderation result further indicates that environmentally sensitive industries do not automatically transform CABCI improvements into stronger disclosure gains. Firms in high-exposure sectors may face stronger disclosure pressure, but they also operate under greater technical complexity, higher abatement costs, and more intense legitimacy concerns. As a result, these sectors may disclose more strategically while still facing short-run constraints on measurable emissions reduction, particularly when technological upgrading and capital investment are required (Liu & Wu, 2023; Wang, 2023). The absence of a stronger CABCI effect in such industries, therefore, suggests that sector sensitivity alone is not enough; internal costing integration must be accompanied by deeper operational and governance changes before stronger disclosure benefits emerge.

Overall, the evidence suggests that carbon-ABC should not be viewed as a stand-alone technical solution. Its contribution is likely to depend on whether it is embedded within a broader governance bundle that includes clear disclosure expectations, credible assurance mechanisms, and explicit use of carbon-cost signals in capital budgeting and operational decision-making. In that sense, the results imply that transparency and verification matter because they can reinforce the economic incentives for credible reporting and improve the likelihood that internal carbon-cost information is translated into real managerial follow-through (Xu et al., 2024; Delacote et al., 2024).

CONCLUSION

This study aimed to examine whether integrating carbon costing into activity-based costing (ABC) is associated with improved environmental outcomes among Jordanian listed firms, as reflected in carbon and environmental disclosure quality and carbon intensity. The results show no robust evidence that within-firm increases in carbon-ABC integration are associated with higher disclosure quality after controlling for firm-specific heterogeneity and common year effects, indicating that observable progress in carbon-cost integration did not consistently translate into stronger public reporting during the study period. The analysis also finds no statistically reliable association between carbon-ABC integration and carbon intensity, and the moderation test further shows that the relationship between carbon-ABC integration and disclosure quality does not become stronger in environmentally sensitive industries, suggesting that sector exposure alone is not sufficient to convert partial costing integration into measurable environmental gains. These results lead to the conclusion that carbon-ABC has not yet become sufficiently embedded in routine managerial decision-making and governance practice to generate measurable environmental improvements among Jordanian listed firms.

http://dx.doi.org/10.21511/ee.17(2).2026.13

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