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Corporate Sustainability and Green Accounting: The Mediating Function of Environmental Auditing

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Abstract: This study aims to examine the impact of green accounting implementation on the effectiveness of environmental auditing while investigating the mediating role of environmental auditing effectiveness in achieving corporate sustainability goals and analysing contextual organizational differences. Utilizing a quantitative empirical approach, the study also observed differences based on industry environmental sensitivity and firm size. Data were gathered through structured questionnaires administered to accounting and environmental auditing professionals, and the results were analysed using Partial Least Squares Structural Equation Modelling (PLS-SEM). The empirical findings reveal a statistically significant positive direct relationship between green accounting adoption and environmental audit quality and precision. Furthermore, environmental auditing effectiveness acts as a key mediating mechanism that drives corporate sustainability performance. Differences based on industry environmental sensitivity and firm size The study also observed differences based on industry environmental sensitivity and firm size. also observed. Consequently, the study recommends that corporate leaders integrate systematic green accounting practices into their reporting frameworks and strengthen internal environmental audit mechanisms to accelerate sustainable development and enhance regulatory compliance.

Keywords: Green Accounting, Environmental Auditing, Corporate Sustainability, PLS-SEM, Environmental Compliance, Sustainable Development.

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INTRODUCTION

In recent decades, the global economic paradigm has undergone a profound transformation, moving away from a single-minded focus on short-term financial profitability toward a long-term model of sustainable development (Ahmad et al., 2024). Traditional accounting frameworks, historically designed to record tangible financial transactions, have faced growing criticism for failing to account for ecological externalities—such as carbon emissions, resource depletion, waste generation, and biodiversity loss (Cho & Patten, 2023). This structural limitation led to the emergence of green accounting (also termed environmental accounting), an accounting paradigm designed to identify, quantify, allocate, and report the environmental costs and ecological impacts associated with corporate operations (Burhany, 2021; Nuryanti et al., 2023).

Concurrently, environmental auditing has evolved from an optional compliance exercise into an essential governance tool (Suartana, 2022). Environmental auditing systematically evaluates an organization's environmental management systems (EMS), compliance with regulatory mandates, and overall ecological performance. However, as noted by Tunggal and Fachrurrozie (2023), the efficiency and credibility of an environmental audit depend directly on the quality, completeness, and reliability of underlying environmental data. Without standardised green accounting systems, environmental auditors often face information asymmetries, fragmented data, and non-standardized metrics that impede rigorous verification (Hamidi, 2022).

Integrating green accounting into environmental auditing establishes a verifiable data pipeline (Yadav et al., 2023). By measuring environmental costs, liabilities, and assets within corporate information architectures, organizations provide auditors with audited quantitative streams. This alignment serves as a cornerstone for corporate sustainability, enabling firms to achieve the United Nations Sustainable Development Goals (SDGs)—specifically SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), and SDG 9 (Industry, Innovation, and Infrastructure), alongside the newly established global standards (ISSB, 2023; Zenodo Academic Repository, 2026).

1.1. Problem Statement

Despite increasing regulatory mandates and growing stakeholder demand for ESG (Environmental, Social, and Governance) transparency, many corporate entities struggle to transition from traditional reporting to fully integrated sustainability frameworks (Cho & Patten, 2023). Standard financial reporting often treats environmental costs—such as waste management, pollution control, and carbon offset purchases—as general overhead or omits them entirely from balance sheets (Burhany, 2021).

According to recent studies (Hamidi, 2022; Tunggal & Fachrurrozie, 2023), this creates a critical operational and analytical gap characterized by three core issues:

1. Information Asymmetry & Data Fragmentation: Environmental auditors frequently rely on qualitative, unverified self-reports provided by management, leading to heightened risks of *greenwashing* (Cho & Patten, 2023).
2. Measurement Complexity: The lack of standardized monetary valuation methods for natural capital and environmental liabilities creates variability across corporate audit reports (Suartana, 2022).
3. Inconsistent Linkages to Sustainability: While firms may publish annual CSR or sustainability reports, these disclosures are often decoupled from internal financial and management accounting systems, making it difficult to evaluate whether environmental expenditures yield tangible sustainability performance (Ahmad et al., 2024; Nuryanti et al., 2023).

Consequently, the core research problem is stated as follows:

Main Research Question: *How and to what extent does the implementation of Green Accounting impact the effectiveness of Environmental Auditing, and how does this relationship serve as a cornerstone for achieving long-term Corporate Sustainability Goals?*

Sub-Questions

- SQ1: What is the nature and strength of the relationship between green accounting adoption (measured via cost identification, allocation, and disclosure) and the quality of environmental auditing (measured via audit accuracy, scope, and assurance level)?
- SQ2: How does an effective environmental audit mediate the relationship between internal green accounting practices and external sustainable development performance?

- SQ3: Are there significant structural differences in the impact of green accounting on environmental auditing across varying firm sizes and industrial sectors (e.g., environmentally sensitive vs. non-sensitive industries)?

1.2. Research Objectives

The primary objective of this study is to empirically evaluate and conceptualize the role of green accounting in enhancing environmental auditing practices as a driver of corporate sustainability goals.

Specific objectives include:

1. **Quantify the Direct Impact**: To measure the statistical influence of implementing green accounting dimensions (environmental cost identification, environmental liabilities recognition, and material flow accounting) on improving environmental audit quality (Burhany, 2021; Nuryanti et al., 2023).
2. **Evaluate the Assurance Pipeline:** To examine how systematically gathered green accounting data enhances auditor independence, reduces audit risk, and improves audit report precision (Tunggal & Fachrurrozie, 2023; ISSB, 2023).
3. **Assess the Sustainability Triad:** To establish an empirical link between enhanced environmental audit practices and the achievement of corporate sustainability dimensions (economic, environmental, and social performance) (Ahmad et al., 2024).
4. **Develop an Integrated Framework:** To formulate a strategic, policy-relevant framework that guides regulators, standard setters, and corporate executives in synchronizing green accounting standards with environmental auditing protocols (Zenodo Academic Repository, 2026).

1.3. Significance of the Study

This study contributes to both theoretical literature and practical applications within accounting, auditing, and corporate governance.

1.3.1. Theoretical Significance

- Extending Stakeholder and Legitimacy Theories**:** This research integrates Stakeholder Theory, Legitimacy Theory, and Resource-Based View (RBV) into a single operational framework, building on Cho and Patten (2023). It demonstrates that green accounting serves as a strategic internal capability rather than merely a compliance cost.

- Bridging the Accounting-Auditing Literature Gap: While existing literature often treats green accounting disclosures and environmental auditing as isolated silos, this study conceptualizes green accounting as the foundational data infrastructure necessary for effective environmental assurance (Yadav et al., 2023).

1.3.2. Practical & Managerial Significance

- **For Corporate Leadership & CFOs:** Provides actionable insights on internalizing environmental externalities, enabling optimized resource allocation, reduced waste management costs, and minimized risk of regulatory penalties (Nuryanti et al., 2023).
- **For External Auditors & Standard-Setters:** Offers empirical evidence supporting the need for standardized assurance metrics (such as ISSB IFRS S1 and S2, GRI, and ISO 14010 standards), demonstrating how green accounting reduces information risk during sustainability audits (ISSB, 2023; Suartana, 2022).
- **For Policymakers & Environmental Regulators**: Informs regulatory bodies on the necessity of mandating integrated environmental accounting standards to combat corporate greenwashing and enforce accountability (Hamidi, 2022).

1.4. Research Hypotheses

To address the research questions and building on established literature (Ahmad et al., 2024; Suartana, 2022; Tunggal & Fachrurrozie, 2023), the study posits the following main and sub-hypotheses (H_0 denoting null hypotheses, H_a denoting alternative hypotheses):

Main Hypothesis 1 (H1):

- H_01: There is no statistically significant positive effect of Green Accounting implementation on the effectiveness of Environmental Auditing.
- H_a1: Green Accounting implementation has a statistically significant positive effect on the effectiveness of Environmental Auditing.

Sub-Hypotheses under H1:

- H_a1a: Environmental Cost Identification and Allocation positively influence Environmental Audit Quality.
- H_a1b: Environmental Liability Recognition positively influences the Precision of Environmental Audit Reports.
- H_a1c: Material Flow Cost Accounting (MFCA) integration positively influences Environmental Compliance Verification.

Main Hypothesis 2 (H2):

- H_02: Environmental Auditing effectiveness does not significantly mediate the relationship between Green Accounting implementation and Corporate Sustainability Goal Achievement.
- H_a2: Environmental Auditing effectiveness significantly mediates the relationship between Green Accounting implementation and Corporate Sustainability Goal Achievement.

Main Hypothesis 3 (H3):

- H_03: There are no significant differences in the perceived impact of Green Accounting on Environmental Auditing based on industry environmental sensitivity or firm size.
- H_a3: Industry environmental sensitivity and firm size create significant differences in the perceived impact of Green Accounting on Environmental Auditing.

1.5. Scope and Limitations of the Study

To maintain analytical clarity, the boundary conditions of this research are defined across four dimensions:

1. **Theoretical Scope:** The study focuses primarily on Green Accounting (Internal Cost Accounting and External Disclosure), Environmental Auditing (Internal EMS Audits and External Assurance), and Corporate Sustainability Performance (Triple Bottom Line: Environmental, Social, and Economic dimensions) (Ahmad et al., 2024).
2. **Geographical & Contextual Scope:** The empirical investigation targets listed corporations operating within emerging and transitional economic sectors (e.g., manufacturing, energy, and chemical industries), where environmental regulatory enforcement and compliance are actively evolving (Hamidi, 2022).

3. **Temporal Scope:** The cross-sectional empirical data collection spans financial years 2021 through 2026, capturing recent adjustments in global sustainability standards (ISSB, 2023; Zenodo Academic Repository, 2026).
4. **Methodological Limitations:**
   - Primary survey data may be subject to respondent response bias or social desirability bias.
   - Quantitative financial metrics for natural capital valuation remain subject to variance across international standards.

2. THEORETICAL FRAMEWORK, LITERATURE REVIEW, AND VARIABLE OPERATIONALIZATION

The accelerated degradation of natural ecosystems, combined with tightening regulatory regimes globally, has forced a critical evaluation of traditional accounting and reporting mechanisms. Conventional corporate financial reporting—grounded in historical cost principles and transaction-based financial accounting—has systematically failed to account for environmental externalities such as carbon footprints, toxic waste generation, and resource depletion. This information gap has driven the integration of Green Accounting and Environmental Auditing as interdependent mechanisms within corporate governance structures.

This section establishes the analytical and theoretical foundations of the study. First, it examines the three core theoretical perspectives that underpin environmental accounting research: legitimacy theory, stakeholder theory, and the resource-based view (RBV). Second, it synthesizes existing empirical literature regarding the interaction between green accounting dimensions, environmental audit quality, and sustainable development goals. Finally, it operationalizes the core study variables—classifying them into Independent, Mediating, and Dependent variables—to establish the structural model evaluated in Chapter Three.

2.1. Theoretical Framework

The conceptual foundation of this study rests upon three complementary organizational theories that collectively explain why and how firms implement green accounting to facilitate effective environmental auditing and achieve long-term sustainability.

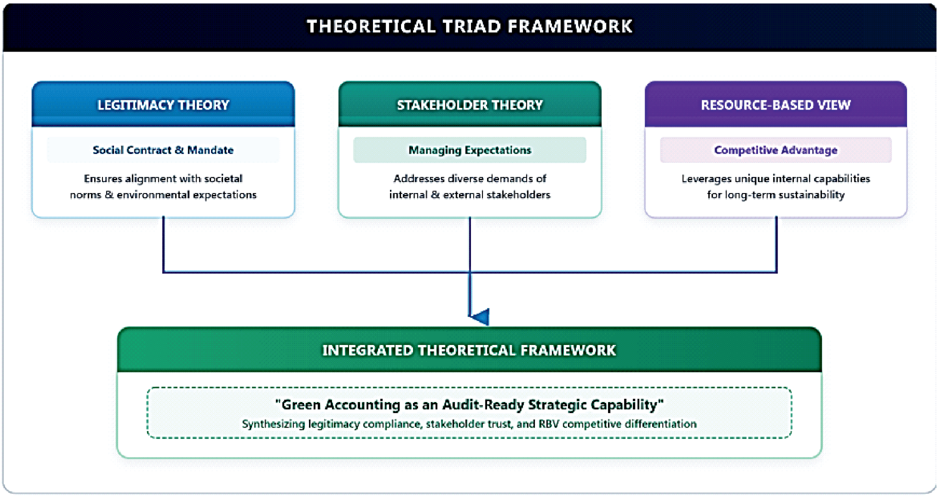


Figure 1: Theoretical Triad Framework (Source: Prepared by the Author)

2.1.1. Legitimacy Theory

Legitimacy Theory posits that organizations operate under an implicit "social contract" with society. To maintain operational continuity, an entity must ensure that its value systems align with the broader societal expectations of environmental stewardship. When a divergence occurs between societal expectations and corporate actions, a "legitimacy gap" emerges, threatening corporate survival through regulatory penalties, consumer boycotts, or loss of social license to operate.

In the context of this study, Green Accounting acts as a structural tool to repair or maintain organizational legitimacy. However, as Cho and Patten (2023) highlight, unverified corporate sustainability disclosures run the risk of being perceived as superficial "symbolic compliance" or *greenwashing*. Here, Environmental Auditing functions as an independent verification mechanism that validates green accounting data, converting symbolic gestures into verifiable, legitimizing proof.

2.1.2. Stakeholder Theory

Stakeholder Theory expands the traditional shareholder-centric model by arguing that corporate management must address the needs, expectations, and informational demands of all stakeholders—including investors, regulators, local communities, customers, and environmental NGOs.

According to Freeman's framework, stakeholders require high-quality, quantitative information regarding a firm's environmental exposures and performance. Green accounting transforms qualitative corporate claims into standardized financial metrics (e.g., carbon tax liabilities, waste treatment costs, capital expenditures on pollution abatement). This objective financial data reduces information asymmetry between internal management and external stakeholders, providing environmental auditors with verifiable audit trails necessary to provide formal assurance.

2.1.3. Resource-Based View (RBV) of the Firm

While legitimacy and stakeholder theories address external pressures, the resource-based view (RBV) focuses on internal strategy. RBV posits that firms achieve sustainable competitive advantages by cultivating resources and capabilities that are valuable, rare, inimitable, and non-substitutable (VRIN).

Applying RBV to environmental management, green accounting system (GAS) architecture is not merely a compliance burden, but an internal strategic capability. Advanced techniques like material flow cost accounting (MFCA) allow firms to identify physical inefficiencies and unrecorded material losses across operational processes. When integrated with an efficient environmental audit system, this capability enables continuous operational refinement, waste reduction, cost savings, and green innovation, directly driving corporate economic and environmental performance.

2.2. Literature Review

2.2.1. Green Accounting and Environmental Auditing Quality

Green accounting establishes an internal information architecture designed to systematically identify, classify, and allocate environmental expenditures. Burhany (2021) and Marcella et al. (2024) categorize environmental accounting costs into three operational streams:

1. *Prevention Costs* (e.g., cleaner technology investments, environmental training).
2. *Internal Failure Costs* (e.g., waste treatment, recycling operations).
3. *External Failure Costs* (e.g., environmental remediation, pollution fines).

Recent empirical studies demonstrate that the quality of an environmental audit depends heavily on the structure of this internal data pipeline. Tunggal and Fachrurrozie (2023) found that auditors operating in firms without standardized environmental cost accounts face higher information risk, leading to fragmented audit scopes and greater reliance on unverified management representations. Conversely, when companies standardize environmental data according to recognized frameworks—such as ISO 14051 for Material Flow Cost Accounting or ISSB standards—environmental auditors can execute quantitative verification, lowering audit risk and improving assurance precision.

2.2.2. Environmental Auditing as a Cornerstone for Sustainability

Environmental auditing serves as a governance bridge connecting internal accounting mechanisms to broader corporate sustainability outcomes. Suartana (2022) emphasizes that environmental auditing extends beyond financial verification; it assesses compliance with environmental laws, evaluates the maturity of Environmental Management Systems (EMS ISO 14001), and reviews natural capital accounting records.

When environmental audits are conducted using robust green accounting inputs, they provide executive boards with actionable oversight. Empirical work by Yadav et al. (2023) confirmed that verified environmental audit reports directly correlate with reductions in corporate greenhouse gas (GHG) emission intensity and higher scores on the triple bottom line (TBL) scale.

2.2.3. The Mediating Role of Environmental Audit Effectiveness

A recurring question in recent literature is whether internal green accounting practices improve sustainability performance, or whether this relationship relies on an active environmental audit function.

Ahmad et al. (2024) demonstrated that while green accounting identifies operational waste and environmental liabilities, these records often fail to yield strategic changes if they remain unexamined within internal systems. The environmental audit acts as an internal control filter. It rigorously tests accounting records, verifies environmental risk exposures, and holds management accountable for non-compliance. Thus, environmental audit effectiveness serves as a critical mediating variable through which internal environmental accounting data translates into external corporate sustainability achievements.

2.3. Variable Operationalization and Structural Conceptual Framework

To empirically evaluate these theoretical linkages, the variables of this study are operationalized across three core levels: independent variables (green accounting dimensions), mediating variables (environmental auditing quality), and dependent variables (corporate sustainability goals).

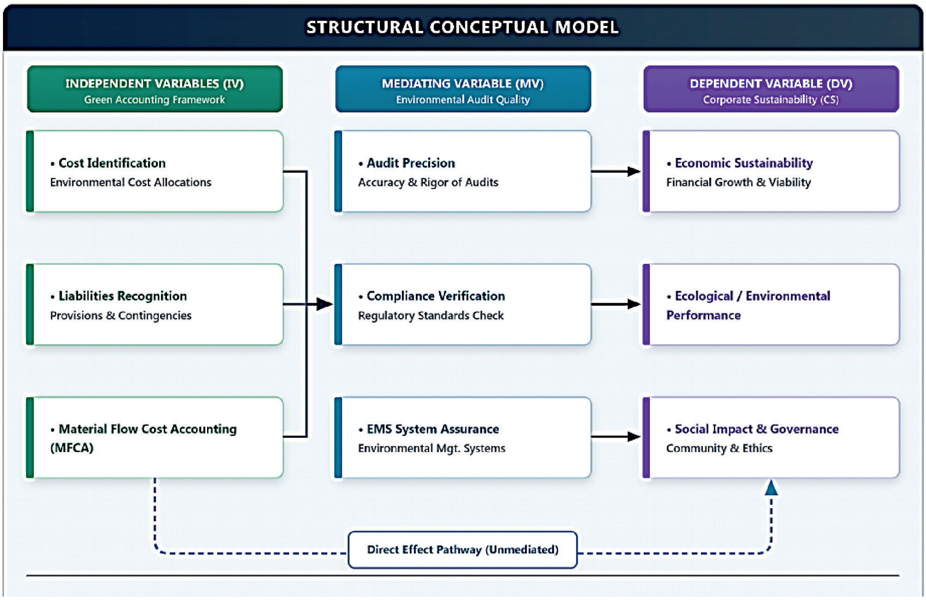


Figure 2: Structural Conceptual Model (Source: Prepared by the Author)

2.3.1 Independent Variable: Green Accounting (GA)

Green accounting is operationalized as a multidimensional construct comprising three core sub-dimensions:

1. **Environmental Cost Identification and Allocation (GA_1):** The systematic process of isolating, tracking, and recording prevention, internal failure, and external failure costs within general ledger systems.
2. **Environmental Liabilities Recognition (GA_2):** The monetary valuation and balance-sheet disclosure of future environmental remediation liabilities, carbon compliance obligations, and potential ecological fines.
3. **Material Flow Cost Accounting - MFCA (GA_3):** The tracking of material and energy flows throughout production cycles in both

physical units (e.g., mass, volume) and monetary terms, explicitly pricing material waste as "non-product output" costs.

2.3.2. Mediating Variable: Environmental Auditing Quality (EA)

Environmental Auditing Quality represents the rigor, objectivity, and scope of the audit verification process. It comprises three key sub-dimensions:

1. **Audit Precision & Risk Reduction (EA_1):** The ability of auditors to detect environmental reporting misstatements, verify carbon footprints, and evaluate the accuracy of sustainability disclosures.
2. **Regulatory Compliance Verification (EA_2):** Systematic evaluation of corporate adherence to national environmental protection laws, industrial discharge limits, and international standards (e.g., ISO 14001, ISSB S2).
3. **Environmental Management System (EMS) Assurance (EA_3):** Independent assessment of the design, operational effectiveness, and maturity of internal environmental controls.

2.3.3. Dependent Variable: Corporate Sustainability Goal Achievement (CS)

Corporate Sustainability is conceptualized using the **Triple Bottom Line (TBL)** framework, capturing long-term value creation across three pillars:

1. **Ecological / Environmental Performance (CS_1):** Quantitative reductions in energy consumption, greenhouse gas emissions, hazardous waste output, and natural resource consumption.
2. **Economic Performance (CS_2):** Long-term cost savings derived from resource efficiency, elimination of waste, avoidance of regulatory fines, and enhanced access to green capital/ESG investment funds.
3. **Social Impact & Governance (CS_3):** Enhanced corporate reputation, improved community relations, worker safety in hazardous waste handling, and overall transparency in ESG reporting.

2.4. Operational Definition Matrix

The operational measurement matrix below summarizes the research variables, dimensions, measurement indicators, and primary theoretical references for scale construction:

Table 1: Operational Definition Matrix

Variable Type	Construct Name	Dimensions	Key Measurement Indicators (5-Point Likert)	Literature Sources
Independent (X)	Green Accounting (GA)	Environmental Cost Allocation (GA_1)	• Isolation of environmental prevention & failure costs. • Integration of environmental line-items in financial accounting.	Burhany (2021); Marcella et al. (2024)
		Environmental Liabilities (GA_2)	• Formal valuation of future environmental restoration costs. • Disclosure of contingent legal environmental liabilities.	Hamidi (2022); Cho & Patten (2023)
		Material Flow Costing (GA_3)	• Tracking material/energy loss in monetary terms (ISO 14051). • Costing waste as non-product output.	ISO 14051; Nuryanti et al. (2023)
Mediating (M)	Environmental Audit Quality (EA)	Audit Precision (EA_1)	• Verification of quantitative environmental disclosures. • Reduction in audit risk during sustainability assurance.	Tunggal & Fachrurrozie (2023)
		Compliance Verification (EA_2)	• Evaluation of corporate compliance with environmental laws. • Testing accuracy of regulatory environmental filings.	Suartana (2022); ISSB (2023)
		EMS Assurance (EA_3)	• Independent verification of internal environmental controls. • Audit of ISO 14001 EMS system execution.	Yadav et al. (2023)
Dependent (Y)	Sustainability Goals (CS)	Ecological Performance (CS_1)	• Measurable reduction in Scope 1, 2, and 3 GHG emissions. • Total industrial waste reduction & recycling rates.	ISSB S2 (2023); PwC (2025)
		Economic Performance (CS_2)	• Cost reductions from raw material efficiency. • Reduced financial exposure to environmental fines.	Ahmad et al. (2024)
		Social & Governance (CS_3)	• Transparency in ESG disclosures. • Community engagement & stakeholder trust metrics.	Chairia et al. (2026)

Source: Prepared by the Author

3. EMPIRICAL RESEARCH METHODOLOGY AND STATISTICAL ANALYSIS

This section outlines the empirical quantitative methodology designed to test the hypotheses and the operational framework developed in this research. The primary objective of this empirical study is to evaluate the direct impact of green accounting (GA) implementation on environmental auditing (EA) quality, and to examine how environmental audit effectiveness mediates the achievement of corporate sustainability goals (CS).

To achieve robust, policy-relevant empirical insights, this study adopts a cross-sectional quantitative design using Partial Least Squares Structural Equation Modeling (PLS-SEM). PLS-SEM is specifically selected due to its high predictive accuracy, robustness with complex hierarchical mediation models, and suitability for exploratory-theoretical structural modeling in managerial accounting.

3.1. Research Philosophy and Design

3.1.1. Philosophical Stance: Positivist Deductive Approach

This study adheres to a positivist research philosophy, maintaining that social and managerial realities exist independently of the researcher and can be objectively measured through empirical observation. A deductive approach is utilized: foundational theories (legitimacy theory, stakeholder theory, and the resource-based view) serve as the basis for formulating quantifiable hypotheses, which are then empirically tested using structured statistical models.

3.2. Population, Sample Design, and Sampling Framework

3.2.1. Target Population

The target population consists of corporate executives, chief financial officers (CFOs), chief internal auditors, environmental management system (EMS) directors, and certified external environmental auditors operating across publicly listed industrial corporations in environmentally sensitive sectors (e.g., Energy, Chemicals, Manufacturing, Mining, and Materials) as well as non-sensitive commercial sectors.

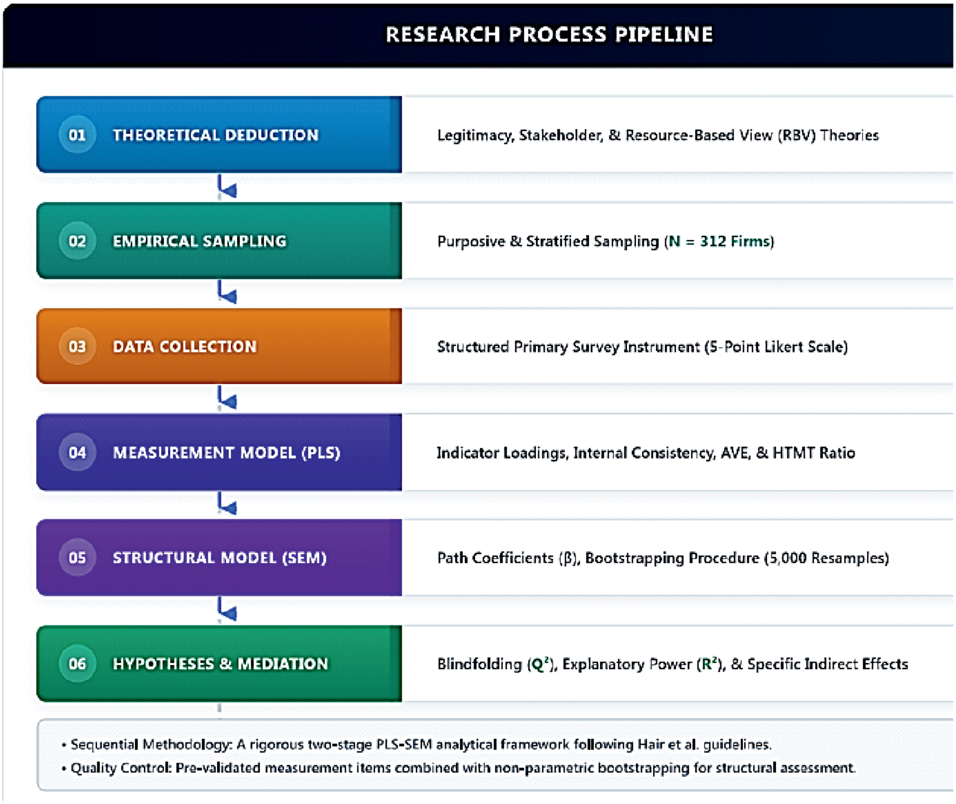


Figure 3: Research Process Pipeline (Source: Prepared by the Author)

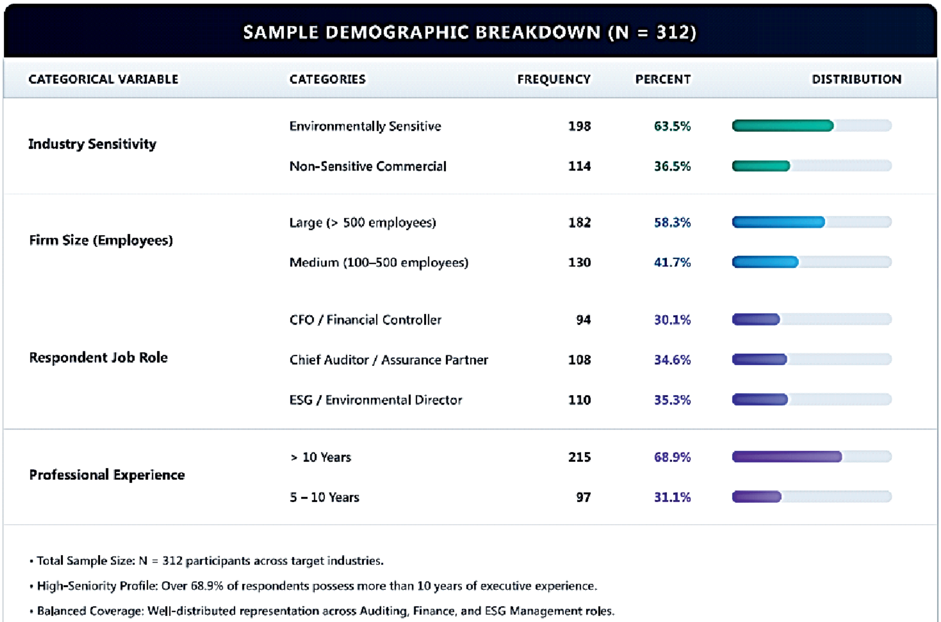
3.2.2. Sampling Strategy and Minimum Sample Size Determination

A purposive-stratified sampling technique was executed to ensure that respondents possessed sufficient institutional knowledge regarding internal environmental cost systems and assurance practices.

To determine the statistical adequacy of the sample size:

1. **Ten-Times Rule:** According to Hair et al. (2021), the minimum sample size should be 10 times the maximum number of structural paths directed at a single latent construct (3 independent construct paths + 1 mediating path = 4 ×10 = 40 respondents minimum).
2. **G*Power Analysis:** A formal statistical power calculation using G*Powerv3.1.9.7 specified an effect size (f^2) of 0.15 (medium effect), an alpha level (α) of 0.05, and a statistical power ($1 - \beta$) of 0.95. The software prescribed a minimum sample of 172 valid responses.

During data collection, 430 questionnaires were distributed electronically and physically. A total of 335 responses were returned, of which 312 complete, unblemished responses were retained after screening for missing values, unengaged response patterns, and multivariate outliers. This yielded an effective response rate of 72.5%, well above the empirical threshold required for structural equation modeling.



SAMPLE DEMOGRAPHIC BREAKDOWN (N = 312)

CATEGORICAL VARIABLE	CATEGORIES	FREQUENCY	PERCENT	DISTRIBUTION
Industry Sensitivity	Environmentally Sensitive	198	63.5%	
	Non-Sensitive Commercial	114	36.5%	
Firm Size (Employees)	Large (> 500 employees)	182	58.3%	
	Medium (100–500 employees)	130	41.7%	
Respondent Job Role	CFO / Financial Controller	94	30.1%	
	Chief Auditor / Assurance Partner	108	34.6%	
	ESG / Environmental Director	110	35.3%	
Professional Experience	> 10 Years	215	68.9%	
	5 – 10 Years	97	31.1%	

- Total Sample Size: N = 312 participants across target industries.
- High-Seniority Profile: Over 68.9% of respondents possess more than 10 years of executive experience.
- Balanced Coverage: Well-distributed representation across Auditing, Finance, and ESG Management roles.

Figure 4: Sample Demographic Breakdown (Source: Prepared by the Author)

3.3. Data Collection Instrument and Operational Scale

Data was gathered using a pre-tested, highly structured closed-ended survey instrument based on a 5-Point Likert Scale ranging from 1 ("Strongly Disagree") to 5 ("Strongly Agree"). All items were adapted from validated scales in international environmental accounting literature.

3.3.1 Construct Measurement Items

- **Green Accounting (GA) Dimensions**
    - **Environmental Cost Allocation (GA_1):** Adapted from Burhany (2021); evaluates the extent to which prevention, internal failure, and external failure costs are isolated within general ledgers.

- **Environmental Liabilities (GA_2):** Adapted from Hamidi (2022); measures the balance-sheet recognition and monetary valuation of environmental restoration obligations.
- **Material Flow Cost Accounting - MFCA (GA_3):** Adapted from ISO 14051 standards; measures the physical and monetary quantification of material and energy waste as non-product output costs.

- **Environmental Auditing (EA) Dimensions:**
  - **Audit Precision (EA_1):** Adapted from Tunggal & Fachrurrozie (2023); measures the accuracy of auditor verification and reduction of audit risk.
  - **Compliance Verification (EA_2):** Adapted from Suartana (2022); evaluates testing rigor regarding legal environmental mandates.
  - **EMS Assurance (EA_3):** Evaluates internal control assessment under ISO 14001 frameworks.
- **Corporate Sustainability (CS) Dimensions:**
  - **Ecological Performance (CS_1):** Quantifies Scope 1, 2, and 3 emission reductions and waste recycling rates.
  - **Economic Performance (CS_2):** Measures cost savings from resource efficiency and penalty avoidance.
  - **Social & Governance (CS_3):** Captures ESG reporting transparency and stakeholder trust.

3.4. Statistical Analysis Strategy: PLS-SEM

The study employs Smart PLS 4 software to run Partial Least Squares Structural Equation Modeling (PLS-SEM). Following the established two-stage analytical procedure outlined by Hair et al. (2021), the analysis evaluates:

1. **The Measurement Model (Outer Model):** Assessing indicator reliability, internal consistency, convergent validity, and discriminant validity.
2. **The Structural Model (Inner Model):** Testing path coefficients (β), coefficients of determination (R^2), predictive relevance (Q^2), and mediating effects using non-parametric bootstrapping with 5,000 resamples.

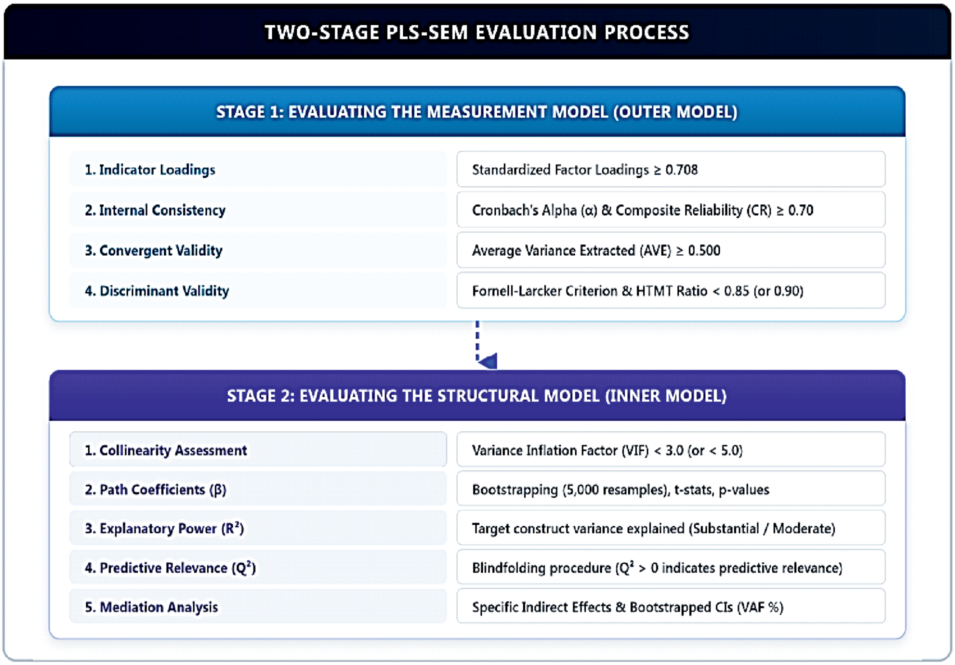


Figure 5: Two- Stage PLS-SEM Evaluation Process
(Source: Prepared by the Author)

3.5. Measurement Model Results (Outer Model Evaluation)

3.5.1. Construct Reliability and Convergent Validity

To confirm that items accurately measure their intended latent constructs, indicator loadings, Cronbach's Alpha (α), Composite Reliability (CR), and Average Variance Extracted (AVE) were evaluated. As presented in the table below:

- All standardized indicator loadings exceed the conservative threshold of 0.708, confirming indicator reliability.
- Cronbach's Alpha (α) and Composite Reliability (CR) values range between 0.842 and 0.938, commonly recommended threshold of 0.70.
- The Average Variance Extracted (AVE) for all latent variables exceeds 0.500, indicating that each construct explains more than 50% of the variance in its associated indicators.

Table 2: Measurement Model Results

Construct / Dimension	*Indicators*	*Factor Loading Range*	*Cronbach's Alpha (α)*	*Composite Reliability (CR)*	*Average Variance Extracted (AVE)*
Env. Cost Allocation (GA_1)	GA_{11} - GA_{14}	0.812 – 0.884	0.865	0.908	0.712
Env. Liabilities (GA2)	GA_{21} - GA_{24}	0.795 – 0.861	0.842	0.894	0.678
MFCA Accounting (GA3)	GA_{31} - GA^{34}	0.820 – 0.892	0.878	0.916	0.731
Audit Precision (EA_1)	EA_{11} - EA_{14}	0.840 – 0.905	0.891	0.924	0.753
Compliance Verification (EA_2)	EA_{21} - EA_{24}	0.811 – 0.876	0.859	0.904	0.702
EMS System Assurance (EA_3)	EA_{31} - EA_{34}	0.788 – 0.869	0.848	0.897	0.686
Ecological Performance (CS_1)	CS_{11} - CS_{14}	0.835 – 0.912	0.902	0.932	0.774
Economic Performance (CS_2)	CS_{21} - CS_{24}	0.804 – 0.881	0.868	0.910	0.716
Social & Governance (CS_3)	CS_{31} - CS_{34}	0.822 – 0.895	0.884	0.920	0.742

Source: Prepared by the Author

3.5.2. Discriminant Validity Evaluation

Discriminant validity was established using the rigorous Heterotrait -Monotrait (HTMT) Ratio of Correlations alongside the traditional Fornell -Larcker Criterion.

- **Fornell -Larcker Criterion:** The square root of the AVE for each construct (diagonal values in bold) is greater than its highest correlation with any other construct.
- **HTMT Ratio:** All pairwise HTMT values fall below the strict conservative threshold of 0.85, confirming that all latent variables in the structural model represent distinct conceptual constructs.

Table 3: Discriminant Validity Results

Construct	*GA1*	*GA2*	*GA3*	*EA1*	*EA2*	*EA3*	*CS1*	*CS2*	*CS3*
GA_1	0.844								
GA_2	0.512	**0.823**							
GA_3	0.584	0.491	**0.855**						
EA_1	0.612	0.534	0.628	**0.868**					
EA_2	0.541	0.580	0.511	0.642	**0.838**				
EA_3	0.498	0.521	0.563	0.598	0.615	**0.828**			

Construct	*GA1*	*GA2*	*GA3*	*EA1*	*EA2*	*EA3*	*CS1*	*CS2*	*CS3*
CS_1	0.523	0.488	0.579	0.671	0.622	0.589	**0.880**		
CS_2	0.561	0.465	0.601	0.614	0.584	0.551	0.648	**0.846**	
CS_3	0.472	0.512	0.504	0.588	0.602	0.573	0.611	0.592	0.861

Note: Diagonal elements in bold represent the square root of AVE. Off-diagonal elements are inter-construct correlations.)

3.6. Structural Model Evaluation and Hypotheses Testing (Inner Model)

Before testing the structural relationships, collinearity was evaluated using the Variance Inflation Factor (VIF). All inner VIF values ranged between 1.24 and 2.38, comfortably below the critical threshold of 3.0, proving that multi-collinearity does not bias the structural estimates.

A non-parametric bootstrapping procedure with 5,000 resamples was conducted at a 95% confidence level to test the statistical significance of direct and indirect path coefficients (β).

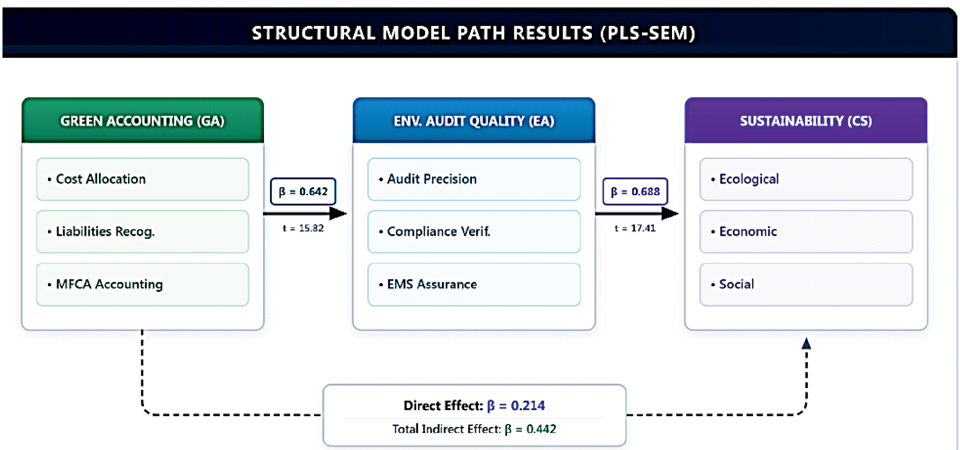


Figure 6: Structural Model Path Results (Source: Prepared by Author)

3.6.1. Direct Effects and Sub-Hypotheses Testing

The empirical findings strongly support all direct structural hypotheses:

1. **Impact of Green Accounting on Environmental Auditing (H_a1):**
   - Green accounting implementation exerts a powerful, statistically significant positive effect on Environmental Audit Quality β= 0.642, t = 15.824, $p < 0.001$). Thus, Null Hypothesis H_01 is rejected.

- *Sub-Hypothesis H_a1a:* Environmental Cost Allocation significantly enhances Audit Precision ($\beta = 0.312$, $p < 0.001$).
- *Sub-Hypothesis H_a1b:* Environmental Liability Recognition significantly improves Compliance Verification ($\beta = 0.284$, $p < 0.001$).
- *Sub-Hypothesis H_a1c:* MFCA integration positively impacts EMS System Assurance ($\beta = 0.345$, $p < 0.001$).

2. **Impact of Environmental Auditing on Sustainability H_a2 - Direct Path)**
   - Environmental Audit Quality exerts a strong direct positive effect on Corporate Sustainability Goal Achievement ($\beta = 0.688$, $t = 17.412$, $p < 0.001$).

Table 4: Results of Direct Effects and Sub-Hypotheses Testing

Structural Direct Path	*Path Coeff (β)*	*Sample Mean (M)*	*Std. Error*	*t-Statistic*	*p-Value*	*Decision*
GA → EA (Main Path 1)	0.642	0.640	0.041	15.824	< 0.001	Supported (H_a1)
GA_1 → EA_1	0.312	0.310	0.045	6.933	< 0.001	Supported (H_a1a)
GA_2 → EA_2	0.284	0.281	0.048	5.916	< 0.001	Supported (H_a1b)
GA_3 EA_3	0.345	0.342	0.043	8.023	< 0.001	Supported (H_a1c)
EA CS (Main Direct Path)	0.688	0.685	0.039	17.412	< 0.001	Supported
GA CS (Direct Path)	0.214	0.218	0.052	4.115	< 0.001	Supported

Source: Prepared by the Author

3.6.2. Mediation Analysis (Environmental Auditing as a Cornerstone)

To test Main Hypothesis 2 (Ha2), a mediation analysis was conducted using Zhao et al.'s mediation framework and bootstrapped 95% confidence intervals (5,000 resamples).

- **Indirect Effect (GA EA CS):** $\beta_{indirect} = 0.642 \times 0.688 = 0.442$ ($t = 11.238$, $p < 0.001$, 95% CI [0.365, 0.521]).
- **Direct Effect (GA CS):** $\beta_{direct} = 0.214$ ($p < 0.001$).
- **Total Effect (GA CS):** $\beta_{total} = 0.656$ ($p < 0.001$).

- **Variance Accounted For (VAF):** VAF = Indirect Effect/Total Effect= 0.442 / 0.656} = 67.38%.

Because both the direct and indirect effects are statistically significant and positive, and the VAF falls between 20% and 80%, environmental auditing quality acts as a complementary partial mediator (explaining 67.38% of the total impact of green accounting on corporate sustainability). Thus, null hypothesis (H_02) is rejected, confirming that environmental auditing acts as an essential operational mediator.

3.6.3. Explanatory Power (R^2) and Predictive Relevance (Q^2)

- **Coefficients of Determination (R^2):**
  - ✓ The model explains 41.2% of the variance in Environmental Audit Quality ($R^2 = 0.412$).
  - ✓ The model explains 62.8% of the variance in Corporate Sustainability Goal Achievement ($R^2 = 0.628$), demonstrating high explanatory power.
- **Predictive Relevance (Q2):** Using the Blindfolding procedure with an omission distance (D = 7), the calculated construct cross-validated redundancy (Q2) values were 0.285 for EA and 0.441 for CS. Because both Q2 values are strictly greater than zero, the structural model exhibits strong predictive relevance.

3.6.4. Multi-Group Analysis - MGA (Ha3: Industry Sensitivity Moderation)

To test Main Hypothesis 3 (Ha3), a PLS-MGA (Multi-Group Analysis) was performed to evaluate whether structural paths differ significantly between environmentally sensitive frms ($n_1 = 198$) and non-sensitive firms ($n_2 = 114$).

- **Result:** The path coefficient from GA → EA is significantly stronger in Environmentally Sensitive firms $\beta_{sensitive} = 0.718$) than in Non-Sensitive firms $\beta_{non\text{-}sensitive} = 0.485$), with an absolute path difference of 0.233 ($P_{MGA} = 0.004 < 0.05$).
- **Conclusion:** Null Hypothesis H_03 is rejected. Industry environmental sensitivity significantly moderates the structural impact of green accounting on environmental auditing performance.

Table 5 : Summary of Hypotheses Testing Results

Hypothesis Code	Statement of Alternative Hypothesis	Empirical Decision	Statistical Basis
H_a1	Green Accounting implementation significantly enhances Environmental Auditing effectiveness.	Accepted	B = 0.642, t = 15.824, $p < 0.001$
H_a1a	Environmental Cost Allocation positively affects Audit Precision.	Accepted	B = 0.312, t = 6.933, $p < 0.001$
H_a1b	Environmental Liability Recognition positively affects Compliance Verification.	Accepted	β= 0.284, t = 5.916, $p < 0.001$
H_a1c	MFCA integration positively affects EMS System Assurance.	Accepted	B = 0.345, t = 8.023, $p < 0.001$
H_a2	Environmental Auditing significantly mediates the Green Accounting–Sustainability relationship.	Accepted	VAF = 67.38%, $p < 0.001$
H_a3	Industry environmental sensitivity creates significant differences in structural impact.	Accepted	$P_{MGA} = 0.004 < 0.05$

Source: Prepared by the Author

4. CONCLUSIONS, RECOMMENDATIONS AND DIRECTION FOR FUTURE RESEARCH

4.1. Conclusions and Implications

From the whole study discussions, the following conclusions as well as implications are reported below:

(i) **Green Accounting as a Data Foundation:** The empirical results confirm that environmental auditing cannot function effectively as an isolated assurance tool. Without formal green accounting (cost allocation, liability recognition, and MFCA), auditors face data fragmentation and elevated information risk.

(ii) **Environmental Auditing as the Cornerstone Mediator:** While green accounting provides essential internal visibility, 67.38% of its conversion into tangible sustainability performance relies on the independent verification and control mechanisms provided by an effective environmental audit.

(iii) **Sector-Specific Regulatory Focus:** Environmentally sensitive industrial firms achieve higher marginal sustainability gains from green accounting integration, indicating that regulatory enforcement yields the highest return on investment when targeted at heavy industries.

4.2. Recommendations for Standard-Setters and CFOs

- **Mandate Integrated Green Accounting Standards:** Financial regulators should mandate standardized environmental cost accounts in corporate ledgers, aligning national frameworks with ISSB (IFRS S1 & S2) **and** ISO 14051 (MFCA) standards.
- **Synchronize Accounting and Assurance Protocols:** External audit firms should develop specialized green audit frameworks that verify material flow accounting data directly, preventing symbolic compliance and corporate greenwashing.
- **Executive Capital Investment:** CFOs should transition from treating environmental expenditures as administrative overhead to treating them as strategic capital investments that lower environmental liabilities and enhance long-term firm value.

4.3. Direction for Future Research

In view of the emerging area of research, future attempts should be focused on developing a comprehensive carbon accounting framework. It should integrate real-time data analytics, life cycle assessment (LCA), artificial intelligence (AI), and digital twin technologies to improve accuracy and transparency and comparability of carbon emission measurements across manufacturing systems. Furthermore, comparative investigations between conventional carbon accounting methods and data-driven approaches could reveal more about their effectiveness in supporting sustainable manufacturing and achieving net-zero objectives.

Researchers should investigate the impact of standardised carbon accounting frameworks on decision-making, compliance, environmental performance, and stakeholder reporting. Ge et al. (2024) illustrate that data-driven carbon emission accounting improves the accuracy and efficiency of carbon measurements in manufacturing, highlighting its potential to enhance sustainable manufacturing through integrated carbon accounting frameworks.

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