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Beyond the balance sheet: How green accounting, innovation, and regulation shape sustainable growth in middle-income economies

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ABSTRACT

Background: This study investigates the influence of green accounting practices on economic growth in middle-income economies, emphasizing the mediating role of technological innovation and the moderating effect of regulatory quality. It seeks to clarify whether environmental accounting frameworks can simultaneously support economic expansion and sustainability across diverse institutional and innovation contexts. **Methods:** Guided by Ecological Modernization Theory, Endogenous Growth Theory, and Institutional Theory, the study uses balanced panel data from 24 middle-income countries spanning 2010–2023. Fixed-effects regressions assess direct effects—Baron and Kenny in 1986—mediation framework examines technological innovation's role, and moderated regression models evaluate regulatory quality's conditioning influence. **Findings:** Green accounting significantly enhances aggregate GDP growth but may constrain short-term per capita welfare, reflecting transitional distributional trade-offs. While green accounting promotes technological innovation, this channel does not mediate its effect on economic growth. Strong regulatory quality, particularly rule-of-law enforcement, amplifies the positive impact of green accounting on economic performance. **Conclusion:** Policymakers should integrate green accounting into broader governance and innovation strategies. Aligning environmental disclosure with fiscal incentives, R&D investment, and transparent regulatory systems can foster inclusive and sustainable growth trajectories. Findings may have limited generalizability across all middle-income economies due to institutional heterogeneity and data constraints. Future studies could expand country coverage and examine sector-specific effects. **Novelty/Originality of this article:** The study offers an integrated empirical framework demonstrating how institutional quality and innovation capacity jointly shape the developmental returns of green accounting, providing actionable insights for sustainable growth in emerging economies.

KEYWORDS: green accounting; institutional quality; middle-income economies; regulatory quality; sustainable growth; technological innovation.

1. Introduction

Mounting climate risks, accelerating resource depletion, and widespread ecological degradation have intensified global calls to rethink how economic progress is conceptualized and measured. Conventional growth indicators, most notably Gross Domestic Product (GDP), systematically fail to account for the depletion of natural capital, pollution externalities, and the erosion of ecosystem services that accompany industrial

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expansion (Stiglitz et al., 2019). As a result, GDP-based assessments often overstate welfare improvements while masking long-term ecological and developmental vulnerabilities. In response, sustainability-oriented measurement frameworks have gained prominence within global development discourse, particularly under the United Nations Sustainable Development Goals (SDGs), including SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation and Infrastructure), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action). These SDGs emphasize the critical need for policies that integrate economic growth with environmental stewardship and technological advancement.

Within this context, green accounting, also referred to as environmental or sustainability accounting, has emerged as a vital instrument for embedding environmental costs and benefits into economic decision-making (Pramesti & Novita, 2024). By systematically internalizing externalities such as carbon emissions, resource depletion, and environmental degradation, green accounting enhances the information base upon which governments and firms allocate resources, evaluate performance, and design development policies. Far from framing environmental protection as a constraint on growth, green accounting positions sustainability as a core driver of long-term economic performance, intergenerational equity, and policy alignment with international development targets. This reframing is especially consequential for middle-income economies (MIEs). Positioned between low-income vulnerability and high-income institutional maturity, MIEs pursue industrial upgrading, infrastructure expansion, and global competitiveness while facing mounting environmental pressures. These economies contribute a growing share of global emissions and resource consumption but often operate under fiscal constraints, fragmented governance, and uneven technological capacity (World Bank, 2024). For MIEs, green accounting represents not only a reporting tool but also a strategic development mechanism capable of reconciling growth imperatives with ecological sustainability and SDG-aligned policy objectives.

Despite its promise, the operationalization of green accounting remains uneven across developing contexts. Empirical evidence is largely concentrated in high-income and OECD countries, where mature institutions, robust innovation systems, and effective regulatory enforcement facilitate environmental accounting's practical impact (Alatrash et al., 2025). Many MIEs, by contrast, face limited regulatory quality, low R&D investment, and nascent innovation ecosystems, which constrain the transformative potential of green accounting reforms (Adeleye et al., 2020). Without targeted policy integration, green accounting initiatives risk remaining largely symbolic, limiting their contribution to sustainable growth and SDG attainment. Understanding this divergence requires moving beyond a direct, linear relationship between green accounting and economic growth. Instead, the growth implications of environmental accounting are conditional upon the mechanisms through which environmental information is translated into productive economic activity and the institutional context within which these processes unfold. Accordingly, this study conceptualizes sustainable growth as the outcome of an interconnected system in which green accounting influences economic performance both directly and indirectly through technological innovation, while the strength of this relationship is conditioned by regulatory quality, as illustrated in the study's conceptual framework (Figure 1).

From an ecological modernization perspective, environmental protection and economic development are not inherently antagonistic but can be mutually reinforcing when supported by innovation-oriented institutions and policy reforms. Green accounting functions within this logic as a reflexive governance tool: by quantifying environmental externalities and revealing resource inefficiencies, it reshapes investment and production decisions toward eco-efficient and low-carbon pathways. This theoretical logic underpins the direct pathway between green accounting and economic growth depicted in Figure 1, whereby internalizing environmental costs enhances allocative efficiency and promotes sustainable modernization. However, ecological modernization alone does not fully explain how environmental information translates into sustained productivity gains. Endogenous Growth Theory provides the critical transmission mechanism by emphasizing that

technological innovation, knowledge accumulation, and productivity improvements are internally generated through policy incentives and institutional arrangements (Romer, 1990). Within this framework, green accounting is expected to stimulate technological innovation by exposing environmental inefficiencies and compliance costs, thereby incentivizing firms and governments to invest in cleaner technologies, renewable energy systems, and circular production models. As reflected in Figure 1, technological innovation therefore operates as a mediating channel through which green accounting influences long-term economic growth.

Yet innovation does not automatically translate into growth outcomes across all institutional contexts. Institutional Theory highlights that the effectiveness of environmental policies and accounting systems depends fundamentally on the quality of governance, regulatory enforcement, and institutional credibility (Field, 1990). In environments characterized by high regulatory quality, marked by transparency, policy consistency, and effective enforcement, environmental accounting information is more likely to influence firm behavior, guide innovation diffusion, and generate measurable productivity gains. Conversely, in weak institutional settings, green accounting reforms may be decoupled from actual practice, limiting their growth-enhancing potential. Accordingly, regulatory quality moderates the innovation–growth relationship, strengthening or weakening the final growth outcomes associated with technological innovation, as explicitly shown in Figure 1. This study develops three interrelated hypotheses linking green accounting practices, technological innovation, regulatory quality, and economic growth in middle-income economies (MIEs). Each hypothesis is theoretically grounded in the Ecological Modernization Theory (EMT), Endogenous Growth Theory (EGT), and Institutional Theory (IT), while addressing critical gaps identified in the empirical literature. Together, they position green accounting not only as a financial or environmental instrument but as a policy-relevant catalyst for sustainable transformation aligned with the United Nations Sustainable Development Goals (SDGs), notably SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation and Infrastructure), SDG 12 (Responsible Consumption and Production), and SDG 16 (Strong Institutions).

Building on Ecological Modernization Theory (EMT), this hypothesis posits that environmental protection and economic progress are not mutually exclusive but can be synergistic when ecological considerations are institutionalized within production and policy systems (Mol et al., 2020). Green accounting operationalizes this integration by translating environmental externalities into quantifiable financial data, enabling policymakers and firms to internalize the costs of resource depletion, carbon emissions, and ecological degradation. This process enhances transparency, promotes efficient resource allocation, and stimulates investments in sustainable infrastructure. Empirical research supports this theoretical assertion. Studies such as Ferreira et al. (2023) & Danlami et al. (2019) show that economies with robust environmental accounting systems experience stronger and more sustainable growth trajectories. At the firm level, Maama & Appiah (2019) and Wiredu et al. (2023) find that organizations incorporating environmental costs into their accounting frameworks achieve superior long-term performance and ecological efficiency. These outcomes illustrate how green accounting can translate sustainability principles into economic productivity gains, especially within emerging and middle-income contexts where green transition policies are expanding.

From a policy standpoint, this relationship underscores the role of green accounting as a data-driven governance tool that enhances fiscal accountability, informs environmental taxation, and supports national green growth strategies. Accordingly, this study tests the following hypothesis: H_1: Green accounting practices have a significant positive effect on Sustainable economic growth in middle-income economies. Anchored in Endogenous Growth Theory (EGT), the second hypothesis conceptualizes technological innovation as the principal transmission mechanism through which green accounting influences long-term economic growth. According to Romer (1990) and Aghion & Howitt (2009), innovation-driven knowledge accumulation is the foundation of sustained economic expansion. Within this framework, green accounting stimulates innovation by revealing the environmental

inefficiencies of existing production systems and incentivizing the development of cleaner technologies and eco-efficient processes. Empirical findings support this mediating pathway. Wang (2023) and Li & Hu (2021) demonstrated that environmental regulation enhances economic growth indirectly through technological innovation. Similarly, Hsu et al. (2021) found that innovation mediates the impact of environmental reporting and green financial systems on green economic growth. At the microeconomic level, Sumayyah et al. (2025) showed that firms adopting green accounting practices experience increased innovation intensity, leading to higher productivity and sustainability performance. These findings collectively indicate that green accounting fosters innovation ecosystems, aligning with SDG 9's emphasis on sustainable industrialization and technological upgrading.

In the context of middle-income economies, where innovation systems remain underdeveloped, the integration of environmental accounting data into national policy frameworks can stimulate green research and technology diffusion. Thus, this study posits that technological innovation serves as the mediating channel linking environmental accounting to macroeconomic progress: H_2: Technological innovation mediates the relationship between green accounting practices and sustainable economic growth. Drawing from Institutional Theory (IT), the third hypothesis asserts that the strength and credibility of regulatory quality determine the extent to which green accounting practices translate into tangible economic outcomes. Institutional theorists (Field, 1990; Scott, 2017) argue that effective governance structures reduce uncertainty, ensure compliance, and enhance legitimacy, conditions essential for sustainability-oriented policy success. High-quality regulatory systems enforce disclosure standards, promote accountability, and enable environmental data to be effectively utilized in decision-making.

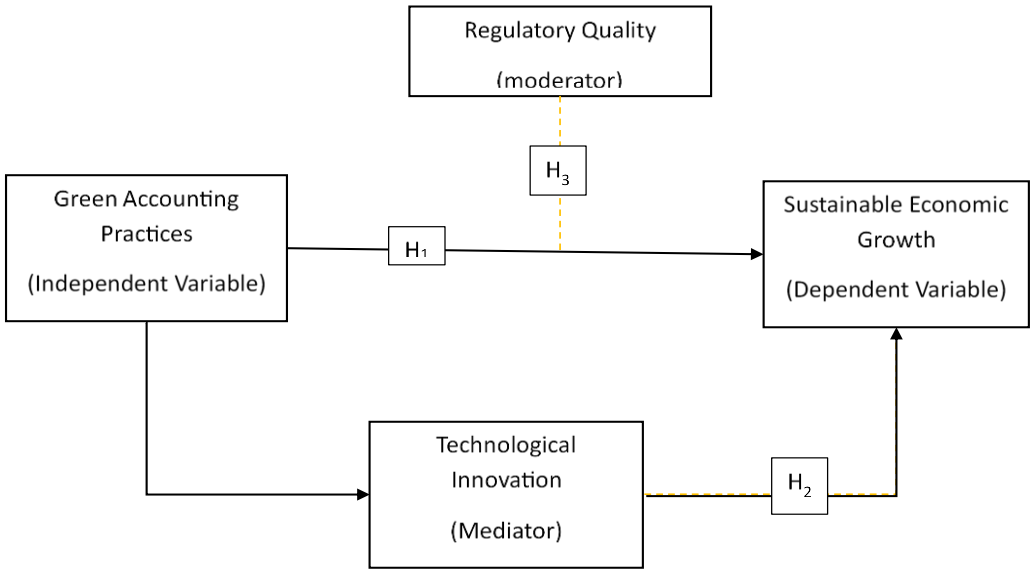

Fig. 1. Conceptual framework of the study: developed by the researcher, based on Ecological Modernization Theory, Endogenous Growth Theory, and Institutional Theory (Developed by the Researcher, 2025; Field, 1990; Romer, 1990)

Empirical studies corroborate this theoretical logic. Teklie et al. (2024), Kamah et al. (2021), & Chen & Hu (2022) found that economies with stronger regulatory institutions experience amplified economic returns from environmental and green innovation policies. Conversely, weak regulatory frameworks often reduce environmental accounting to symbolic compliance, with limited developmental impact. In this sense, regulatory quality acts as a strategic moderator that determines whether green accounting functions as a substantive policy instrument or a procedural formality. For middle-income economies, strengthening regulatory capacity is thus not merely an administrative task but a developmental imperative for realizing SDG 16 (peace, justice, and strong institutions) and for ensuring that sustainability accounting translates into inclusive and resilient growth.

Accordingly, this study proposes the following moderating hypothesis: H_3: Regulatory quality positively moderates the relationship between green accounting practices and sustainable economic growth, such that the effect is stronger in countries with higher regulatory quality. Taken together, these perspectives inform a conceptual framework (Figure 1) in which green accounting influences economic growth through three interconnected pathways. First, green accounting exerts a direct effect on economic growth by internalizing environmental externalities and improving resource allocation efficiency. Second, green accounting indirectly affects growth by stimulating technological innovation, which enhances productivity and supports sustainable industrial transformation. Third, the strength of the innovation–growth relationship is contingent upon regulatory quality, with stronger institutions amplifying the economic benefits of innovation.

Despite growing interest in sustainability-oriented accounting, three critical gaps persist in the literature. First, empirical findings on the relationship between green accounting and economic growth remain inconclusive, partly due to limited attention to mediating and moderating mechanisms (Wiredu et al., 2023; Ganda, 2019). Second, the role of technological innovation as a transmission channel remains underexplored in middle-income and emerging economies, where innovation capabilities are unevenly distributed (Zhou et al., 2021). Third, institutional factors such as regulatory quality are frequently treated as background conditions rather than active determinants shaping how environmental accounting translates into economic performance (Obobisa et al., 2023).

Addressing these gaps is particularly important for middle-income economies, whose transitional institutional structures and evolving innovation systems provide a unique empirical setting for examining the conditional pathways through which sustainability measurement influences development outcomes. Accordingly, this study investigates how green accounting fosters sustainable economic growth in middle-income economies by explicitly modeling technological innovation as a mediating mechanism and regulatory quality as a moderating factor within the conceptual framework presented in Figure 1. Specifically, the study examines: the direct effect of green accounting on economic growth; the mediating role of technological innovation in this relationship; and the moderating influence of regulatory quality on the innovation–growth linkage.

By embedding theoretical logic and conceptual structure directly into the introduction and explicitly anchoring it in the proposed framework, this study advances sustainability accounting research in four important ways. First, it integrates ecological modernization, endogenous growth, and institutional perspectives into a unified conceptual model. Second, it provides multi-country empirical evidence from middle-income economies, addressing a significant geographical and developmental gap in the literature. Third, it develops a conditional explanation of when and how green accounting enhances rather than constrains economic growth. Ultimately, it provides policy-relevant insights for governments and development partners seeking to leverage green accounting, innovation, and regulatory reform to promote sustainable industrialization, environmental protection, and inclusive prosperity.

2. Methods

2.1 Research design

This study adopts a quantitative longitudinal panel design to empirically assess the dynamic relationship between green accounting practices (GAP) and economic growth (EG) in 24 middle-income economies (MIEs) over the period 2010–2023. The analytical model integrates the mediating role of technological innovation (TI) and the moderating effect of regulatory quality (RQ) to explore how innovation systems and institutional governance jointly condition the sustainability–growth nexus.

The choice of a panel approach reflects the study's objective to capture both cross-country heterogeneity and temporal evolution in green accounting adoption and economic performance. This design enables robust estimation of causal relationships while

accounting for unobserved heterogeneity and potential endogeneity (Baltagi, 2021). The quantitative strategy is well-suited for hypothesis testing using objective, verifiable indicators drawn from reputable international databases, thereby enhancing data transparency and replicability, a core requirement for sustainable policy evaluation and SDG monitoring.

This approach aligns with prior sustainability and environmental economics studies (e.g., Elhassan et al., 2025; Fazal & Azam, 2023) that have employed panel econometric techniques to examine institutional, innovation, and governance determinants of green growth. By combining cross-sectional and temporal variation, the design produces more generalizable and policy-relevant findings that reflect the developmental diversity of middle-income economies. All analyses were conducted using STATA version 18, which supports advanced estimation procedures for mediation and moderation within a panel framework.

2.2 Data sources and sample

The study relies exclusively on secondary, publicly accessible data sourced from two reputable World Bank databases: The World Development Indicators (WDI) for macroeconomic and innovation-related variables. The Worldwide Governance Indicators (WGI) for governance and regulatory quality measures. The 2010–2023 period was selected to ensure data completeness, capture post-global financial crisis recovery, and reflect the acceleration of sustainability accounting and green innovation initiatives globally. This time horizon also corresponds to the implementation era of the UN Sustainable Development Goals (SDGs), making the findings directly relevant for assessing progress toward SDGs 8, 9, 12, and 16.

The study population includes all economies classified by the World Bank (2024) as middle-income, comprising both lower-middle-income and upper-middle-income countries. These economies are at the intersection of industrial expansion, environmental vulnerability, and institutional reform, conditions that make them ideal for analyzing how green accounting can reconcile growth and sustainability objectives. A purposive sampling technique was applied to select 24 countries with consistent data across all study variables during the reference period. The sample spans multiple regions, Africa, Asia, Europe, and Latin America, allowing for cross-regional comparability and external validity. Representative countries include Argentina, China, India, Malaysia, Morocco, and Kenya, among others.

2.3 Green accounting practices (GAP) and economic growth (EG)

Green accounting, the independent variable, measures the extent to which countries integrate environmental costs into their national income accounts. Consistent with prior work (Guanfeng et al., 2024), it is proxied by: Adjusted Net Savings (ANS) excluding particulate emission damage (% of GNI), capturing sustainability-adjusted capital formation; and Carbon intensity of GDP (kg CO_2e per 2021 US$ of GDP), reflecting carbon efficiency in production. Higher ANS and lower carbon intensity jointly indicate stronger green accounting performance. Economic growth, the dependent variable, represents the macroeconomic outcome of interest. It is measured through: GDP growth rate (% annual), and GDP per capita (constant 2015 US$). These dual measures capture both the pace and inclusiveness of economic expansion, enabling policy inference on sustainable growth quality.

2.4 Technological innovation (TI), regulatory quality (RQ), and control variables (CVs)

Technological innovation serves as the mediating variable, reflecting each country's capacity for knowledge creation and diffusion. Following Elhassan et al. (2025), innovation intensity is measured by: Patent applications by residents, and Patent applications by non-

residents. Together, these indicators capture domestic innovation capability and cross-border knowledge spillovers, both of which are central to SDG 9 (Industry, Innovation, and Infrastructure).

Regulatory quality functions as the moderating variable, denoting the institutional capacity of governments to formulate and implement policies that promote efficiency, transparency, and environmental responsibility. Derived from the WGI, it is operationalized through: Regulatory quality index, and Rule of law index (Fazal & Azam, 2023). High regulatory quality enhances environmental compliance and governance accountability, consistent with SDG 16 (Strong Institutions). To mitigate omitted variable bias, three macroeconomic controls are included: Foreign Direct Investment (FDI) inflows (% of GDP), Energy consumption (EC) (kg of oil equivalent per capita), and Population growth (POP) (% annual). These variables are standard determinants of economic growth and environmental impact (World Bank, 2024) and are controlled to isolate the unique effects of green accounting and governance.

2.5 Variable operationalization and data quality assurance

All study variables were operationalized using validated, widely accepted proxies from prior sustainability, innovation, and economic growth research to ensure consistency, comparability, and transparency. The independent variable (Green Accounting Practices, GAP) was measured using Adjusted Net Savings (ANS) excluding particulate emission damage and carbon intensity of GDP, capturing sustainability-adjusted capital formation and carbon efficiency, respectively. The dependent variable (Economic Growth, EG) was captured through GDP growth rate and GDP per capita, reflecting both the pace and inclusiveness of growth. Technological Innovation (TI), the mediating variable, was proxied by resident and non-resident patent applications, indicating domestic and cross-border innovation capacity. Regulatory Quality (RQ), the moderating variable, was measured using the Regulatory Quality Index and Rule of Law Index from the WGI. Control variables, FDI inflows, energy consumption, and population growth, were selected based on their established influence on growth and environmental outcomes.

To ensure data quality and reliability, all variables were sourced from publicly accessible, reputable databases (World Bank WDI and WGI). Each dataset was cross-checked for completeness, consistency, and temporal coverage over the 2010–2023 period. Outliers and missing values were carefully inspected, and only countries with complete, consistent data across all variables were included in the analysis. This approach ensures that the study's results are transparent, reproducible, and policy-relevant, supporting robust inferences about the links between green accounting, innovation, governance, and sustainable growth.

2.6 Model specification and estimation technique

Three hierarchical econometric models were specified to test the direct, mediating, and moderating hypotheses. Model 1 is direct effect of green accounting on economic growth. This baseline model estimates the direct relationship between green accounting practices and economic growth.

Model 1:

$$EGit = \beta 0 + \beta 1 GAPit + \beta 2 FDIit + \mu i + \varepsilon it \quad \text{(Eq. 1)}$$

Both Fixed Effects (FE) and Random Effects (RE) estimations were conducted, with the Hausman test determining the preferred specification. Then, model 2 is mediating role of technological innovation. The mediation procedure follows Baron & Kenny (1986) within a panel context in below. A statistically significant reduction in the GAP coefficient between Step 1 and Step 2, with TI remaining significant, indicates mediation.

Step 1:

$$TIit = \beta0 + \beta1GAit + \beta2POPit + \beta3ECit + \mu i + \varepsilon it \quad \text{(Eq. 2)}$$

Step 2:

$$EGit = \beta0 + \beta1GAPit + \beta2TIit + \beta3POPit + \beta3ECit + \mu i + \varepsilon it. \quad \text{(Eq. 3)}$$

Model 3 is moderating role of regulatory quality. The interaction term tests whether regulatory quality amplifies or dampens the growth effects of green accounting. Robust standard errors were applied to correct for heteroskedasticity and serial correlation.

Model 3:

$$EGit = \beta0 + \beta1GAPit + \beta2RQit + \beta3\,(GAPit \times RQit) + \beta4FDIit + \mu i + \varepsilon it. \quad \text{(Eq. 4)}$$

Diagnostic and robustness tests: comprehensive diagnostic procedures, including variance inflation factor (VIF) tests for multicollinearity, wooldridge tests for serial correlation, and Pesaran CD tests for cross-sectional dependence, were performed to ensure model validity. Sensitivity analyses using alternative growth proxies and lag structures confirmed the robustness of results.

2.7 Data analysis procedure

The data analysis was carried out through a systematic and sequential process comprising five main phases. First, descriptive statistics and correlation analyses were employed to provide an initial understanding of the data. These analyses summarized the general patterns, central tendencies, and dispersion of the variables, while also examining the strength and direction of pairwise relationships among them. Second, panel unit root tests, specifically the Levin–Lin–Chu (LLC) and Im–Pesaran–Shin (IPS) tests, were conducted to assess the stationarity properties of the variables. This step was essential to ensure the validity and reliability of subsequent panel estimations. Third, both fixed effects and random effects models were estimated to examine the relationships among the study variables. The Hausman specification test was then applied to determine the most appropriate estimation technique, with the results confirming the consistency and suitability of the fixed effects model for the analysis. Fourth, mediation and moderation analyses were carried out in a sequential manner using STATA's xtreg and structural equation modeling (sem) modules. These techniques enabled the study to assess both direct and indirect effects, as well as interaction effects among the variables within the panel framework. Finally, all hypotheses were tested at a 5% level of significance. This threshold ensured statistical rigor, enhanced the credibility of the findings, and facilitated meaningful comparison with results from prior empirical studies in the literature.

2.8 Ethical and data transparency considerations

All data employed in this study are publicly accessible and fully reproducible, sourced from the World Bank's verified repositories. No confidential, private, or human-subject data were used. Data processing, coding, and analysis scripts are available upon replication request. This commitment to open data principles aligns with SAMPJ's research integrity policy and advances SDG 17 (Partnerships for the Goals) by promoting shared knowledge and institutional transparency in sustainability research.

3. Results and Discussion

3.1 Direct effect of green accounting practices on economic growth

Table 1 here shows that both proxies for green accounting (GAP1 and GAP2) exert significant and positive effects on economic growth (EG_1), with coefficients of 0.19 and 16.52

respectively. This indicates that countries with stronger environmental reporting and sustainable investment practices experience higher GDP growth. FDI also contributes positively, reinforcing the complementary role of foreign capital in sustainability-led growth.

Table 1. Direct effect of green accounting practices on economic growth

Variable	Coefficient	Std. Error	t-Statistic	P-value
EG1				
GAP1	0.1896	0.0430	4.41	0.000
GAP2	16.5208	4.5128	3.66	0.000
FDI	0.2357	0.0975	2.42	0.016
Constant	-2.1552	1.0755	-2.00	0.046
EG2				
GAP1	-35.3458	8.4576	-4.18	0.000
GAP2	-14420.3200	888.2459	-16.23	0.000
FDI	45.4483	19.1987	2.37	0.018
Constant	8113.2850	211.6848	38.33	0.000

However, when an alternative growth measure (EG_2) is used in Table 1, the coefficients of GAP1 and GAP2 turn negative and remain statistically significant. This suggests that while green accounting supports overall economic expansion, it may slow short-run per-capita growth, possibly due to adjustment costs and reallocation of resources. The consistently positive and significant FDI coefficient underscores the stabilizing influence of investment inflows.

3.2 Mediation analysis: Technological innovation

The mediation analysis (Tables 2) examines whether technological innovation transmits the effects of green accounting on economic growth. Results show that both GAP1 and GAP2 significantly and negatively affect technological innovation (TI_1 and TI_2). Furthermore, the results of Table 2 implying that short-term compliance or reporting costs may crowd out innovation efforts in some middle-income countries.

Table 2. Effect of green accounting on technological innovation

Variable	Coefficient	Std. Error	t-Statistic	P-value
Effect of green accounting on technological innovation				
TI1				
GAP1	-2711.665	845.100	-3.21	0.001
GAP2	-1,443,029	86,407.71	-16.70	0.000
Population	12,691.44	6,210.64	2.04	0.042
Energy Cons.	279.75	20.80	13.45	0.000
Constant	31,317.6	35,614.48	0.88	0.380
TI2				
GAP1	-113.19	57.59	-1.97	0.050
GAP2	-87,141.84	5,888.30	-14.80	0.000
Population	530.12	423.23	1.25	0.211
Energy Cons.	23.55	1.42	16.61	0.000
Constant	912.24	2,426.97	0.38	0.707
Effect of GAP and technological innovation on economic growth				
EG2				
GAP1	0.206	0.044	4.63	0.000
GAP2	25.038	5.787	4.33	0.000
TI1	2.85e-06	3.93e-06	0.72	0.469
TI2	0.000025	0.000058	0.43	0.670
Population	-0.057	0.324	-0.18	0.860
Energy Cons.	-0.00188	0.00138	-1.36	0.175
Constant	-1.536	1.851	-0.83	0.407
EG2				

GAP1	-11.687	5.547	-2.11	0.036
GAP2	-13,226.70	722.74	-18.30	0.000
TI1	-0.000735	0.000491	-1.50	0.135
TI2	-0.001515	0.007201	-0.21	0.833
Population	-26.723	40.47	-0.66	0.509
Energy Cons.	3.631	0.173	21.03	0.000
Constant	3,619.79	231.15	15.66	0.000

When technological innovation variables are introduced into the growth equations (Tables 3), GAP1 and GAP2 remain significant, but TI_1 and TI_2 are insignificant. This indicates the absence of a mediation effect, green accounting influences growth directly rather than indirectly through technological innovation. The finding suggests that innovation systems in middle-income countries may not yet be strong enough to channel the benefits of green accounting into productivity growth.

Table 3. Fixed-Effects results

Variable	Coefficient	Std. Error	t-Statistic	P-value
EG1				
GAP1 (environmental taxes, %)	0.188	0.063	2.99	0.003
GAP2 (green expenditure, %GDP)	11.074	9.900	1.12	0.264
IQ1 (gov't effectiveness)	1.198	2.541	0.47	0.637
IQ2 (rule-of-law)	−1.370	2.523	−0.54	0.588
GAR1 (board size)	−0.070	0.126	−0.56	0.579
GAR2 (board independence)	−0.002	0.142	−0.01	0.991
GAR3 (audit quality)	−5.830	9.678	−0.60	0.547
GAR4 (CSR committee)	−1.356	13.100	−0.10	0.918
FDI (net inflow, %GDP)	0.266	0.102	2.61	0.009
Constant	−1.980	1.890	−1.05	0.295
EG2				
GAP1	−45.894	11.623	−3.95	0.000
GAP2	−11,659.63	1,828.54	−6.38	0.000
IQ1	254.286	469.404	0.54	0.588
IQ2	1,465.06	465.978	3.14	0.002
GAR1	40.554	23.299	1.74	0.082
GAR2	−26.396	26.136	−1.01	0.313
GAR3	770.751	1,787.399	0.43	0.667
GAR4	408.120	2,419.586	0.17	0.866
FDI	28.345	18.830	1.51	0.133
Constant	8,438.724	349.102	24.17	0.000

Tables 3 assess the moderating effect of regulatory quality (RQ) on the green accounting–growth nexus. For EG_1, GAP1 shows a positive and significant impact on growth, and FDI remains robustly positive. This indicates that environmental taxes and sustainable expenditures contribute to growth when institutional controls are included. In contrast, for EG_2, both GAP1 and GAP2 are negative and significant, suggesting that high compliance or green spending burdens may temporarily dampen per-capita income growth. Notably, Regulatory Quality (RQ2) exerts a positive and significant moderating effect, confirming that stronger institutional frameworks help convert green accounting efforts into productive economic outcomes. Governance attributes (GAR) are generally weak, though board size (GAR_1) shows a marginal influence. Overall, these results suggest that while green accounting positively affects aggregate growth, its benefits for per-capita income depend critically on institutional quality and governance capacity, a key insight for middle-income economies.

3.3 Green accounting and economic growth: A dual-pathway relationship

This section interprets the study's empirical results through the theoretical lenses of Ecological Modernization Theory (EMT), Endogenous Growth Theory (EGT), and Institutional Theory (IT). It situates the findings within the developmental and institutional realities of middle-income economies, emphasizing their sustainability and policy implications in light of the Sustainable Development Goals (SDGs). The analysis revealed that green accounting exerts a dual effect on economic growth across the sampled middle-income economies. On one hand, the positive association between green accounting indicators and aggregate GDP validates the EMT proposition that economic progress and ecological modernization can be mutually reinforcing when environmental externalities are internalized into decision-making frameworks (Mol et al., 2020). Through enhanced transparency, improved environmental valuation, and more efficient resource allocation, green accounting encourages firms and governments to innovate, attract sustainable investments, and achieve productivity gains. This supports the EMT notion of "win–win modernization," where environmental responsibility aligns with competitiveness. Conceptually, this finding resonates with SDG 8 (Decent Work and Economic Growth), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action).

However, the negative effect on GDP per capita exposes an important caveat. Drawing on EGT, the short-run transition toward greener industries often reallocates capital and labor away from traditional, high-emission sectors, potentially reducing employment and household income. Institutional Theory further clarifies that, in the absence of strong redistributive frameworks, such as retraining programs, social protection, and fiscal recycling of carbon revenues, the early phases of green transition can exacerbate inequality. The result thus highlights a temporal trade-off between macroeconomic expansion and social inclusivity, reinforcing the SDG principle of "leaving no one behind." Empirical evidence from South Africa, Vietnam, and Chile mirrors this duality.

Initial green reforms in these countries reduced consumption and job creation in carbon-intensive sectors before yielding longer-term efficiency and investment gains (Eitrem et al., 2024). In Colombia and Indonesia, environmental accounting enhanced fiscal transparency yet widened income disparities during early implementation phases. These patterns suggest that while EMT's modernization logic holds, its distributive outcomes are conditional on institutional maturity and compensatory policy design. Theoretically, the results extend EMT by showing that modernization may be ecologically progressive but socially uneven in transitional economies. They also refine EGT by illustrating that green-driven restructuring may create transitory welfare costs before long-term benefits materialize. Hence, sustainable development in middle-income contexts requires institutionally mediated sequencing, where green accounting reforms are complemented by redistributive fiscal policies and inclusive social investments to sustain both efficiency and equity outcomes.

3.4 Technological innovation as a missing transmission mechanism

The mediation analysis found that while green accounting significantly enhances environmental transparency and compliance, technological innovation fails to transmit its effects to economic growth. This non-significant mediating role provides a revealing insight into the capability constraints of middle-income economies and refines the propositions of both EGT and EMT. According to Endogenous Growth Theory, innovation and knowledge accumulation are the engines of long-term productivity growth (Romer, 1990). Similarly, Ecological Modernization Theory posits that environmental regulation can stimulate technological innovation that reconciles ecological and economic goals. The current findings, however, indicate a "compliance–innovation disconnect," where green accounting increases awareness and regulatory discipline but does not generate the endogenous technological momentum necessary for sustained growth. This reflects structural and

institutional weaknesses, underdeveloped R&D infrastructure, limited access to green finance, and fragile university–industry linkages.

Empirical evidence supports this interpretation. Studies in Ghana and the Philippines reveal that while environmental reporting frameworks have improved data quality and accountability, they have not substantially increased domestic patent activity or clean-technology adoption (Maama & Appiah, 2019; Hsu et al., 2021). Similarly, Nigeria's donor-driven green accounting initiatives have generated reporting compliance rather than innovation diffusion. These cases underscore that green accounting reforms are policy-induced but not capability-driven, a limitation that restricts the transformative potential of environmental accountability. Theoretically, this result extends EGT by showing that innovation functions not as an automatic outcome of environmental reform but as a conditional process dependent on institutionalized learning systems. It also refines EMT by demonstrating that modernization through environmental governance requires a technological absorptive capacity, which remains underdeveloped in many emerging contexts.

From a policy standpoint, these findings highlight the need to couple environmental accounting reforms with innovation-enabling instruments, such as green R&D funding, intellectual-property protection, technology-transfer platforms, and public–private incubators. Strengthening these linkages would advance SDG 9 (Industry, Innovation and Infrastructure) and SDG 17 (Partnerships for the Goals). In sum, the absence of mediation redefines the green accounting–innovation–growth relationship as institutionally contingent rather than automatic. Environmental transparency creates the necessary foundation for sustainable growth, but only innovation ecosystems, anchored in governance quality and policy coherence, can transform that foundation into long-term developmental outcomes.

3.5 Regulatory quality as an institutional amplifier

The moderation results demonstrate that regulatory quality significantly conditions the strength and direction of the green accounting–growth relationship. In countries with low rule-of-law and weak enforcement systems, green accounting is associated with negative per-capita growth effects, reflecting high compliance costs and limited investor confidence. However, in contexts where regulatory quality improves, the interaction between green accounting and economic growth becomes positive and statistically significant. This finding reaffirms Institutional Theory's premise that the effectiveness of policy instruments depends on the quality of institutional governance (Field, 1990; Scott, 2017). Regulatory quality operates as an institutional amplifier, transforming green accounting from a symbolic or compliance-based activity into a developmental mechanism that fosters innovation, transparency, and capital deepening. In weak institutional environments, environmental reforms often elevate transaction costs and create rent-seeking opportunities. Conversely, in Chile, Malaysia, and Costa Rica, strong regulatory systems ensure predictable policy enforcement, enabling firms to internalize environmental costs without compromising competitiveness. These findings align with the empirical evidence of Teklie et al. (2023) & Kamah et al. (2021), who found that governance quality magnifies the effectiveness of environmental policy instruments in driving sustainable growth.

Theoretically, this result bridges EMT and EGT within the institutional framework. Regulatory quality operationalizes EMT's "modernization function" by stabilizing policy environments and signalling credible commitment to sustainability, while simultaneously enabling EGT's "innovation multiplier" by fostering confidence and reducing uncertainty around green investment. The study, therefore, extends Institutional Theory by introducing the concept of institutional absorptive capacity, the ability of governance systems to convert compliance-based reporting into innovation-driven growth outcomes. From a sustainability policy perspective, this finding has profound implications for SDG 16 (Peace, Justice and Strong Institutions). Strengthening the rule of law, regulatory coherence, and anti-corruption mechanisms is not merely administrative housekeeping but a strategic pathway

to ensure that environmental accounting reforms translate into inclusive, innovation-led development.

Collectively, the results portray a multi-layered dynamic: green accounting stimulates macroeconomic growth but introduces distributive trade-offs; technological innovation remains an unrealized channel of transformation; and regulatory quality serves as the institutional fulcrum determining whether environmental accountability fosters or constrains development. For policy, governments should integrate green accounting within comprehensive sustainability strategies that simultaneously enhance innovation capacity, strengthen institutional quality, and cushion social transitions. This implies aligning fiscal, industrial, and environmental policies to create a coherent ecosystem that drives both efficiency and equity.

For practice, corporate managers and public agencies must move beyond compliance-oriented reporting to leverage green accounting as a strategic tool for eco-innovation, stakeholder engagement, and performance optimization. Integrating financial and environmental disclosures through frameworks like IFRS S2 or the GRI Standards can improve comparability, transparency, and investor confidence. From a sustainable-development standpoint, progress toward SDGs 8, 9, 12, 13, and 16 depends on coordinated institutional action. Green accounting will only achieve its transformative potential when embedded within innovation ecosystems, governed by credible institutions, and accompanied by inclusive redistributive mechanisms that ensure environmental reform leads to both economic resilience and social justice.

3.6 Concluding synthesis and systemic implications

The empirical evidence presented in 3.3.1 to 3.3.3 collectively underscores a complex and institutionally contingent pathway through which green accounting shapes economic development in middle-income economies. First, green accounting clearly stimulates macroeconomic growth by enhancing transparency, improving resource allocation, and incentivizing environmentally responsible investment, confirming the "win–win" premise of Ecological Modernization Theory. At the same time, the observed negative effects on GDP per capita highlight the transitional trade-offs inherent in greening the economy, particularly where labor and capital shift away from carbon-intensive sectors. This duality emphasizes that achieving sustainable growth requires policies that simultaneously pursue efficiency and social inclusivity, consistent with the SDG principle of leaving no one behind. Second, the analysis reveals that technological innovation remains an underutilized channel, reflecting capability constraints, limited R&D infrastructure, and weak linkages between universities, industry, and government. Green accounting alone enhances compliance and awareness, but its potential to drive endogenous innovation, and thereby long-term productivity growth—is unrealized in the absence of institutionalized learning systems and innovation-enabling policies. This finding highlights the need for deliberate innovation ecosystem development, including investment in green R&D, technology-transfer platforms, and public–private incubators, to translate environmental accountability into sustained economic and technological progress.

Third, regulatory quality emerges as a critical institutional fulcrum. Strong governance, enforcement of the rule of law, and regulatory coherence amplify the developmental impact of green accounting, converting compliance-based reforms into mechanisms that support innovation, investment, and inclusive growth. Weak institutions, by contrast, limit the effectiveness of environmental reforms and may exacerbate transitional costs, underscoring that sustainable development is fundamentally institution-dependent. Taken together, these findings indicate that green accounting's transformative potential is neither automatic nor linear. For middle-income economies, inclusive and sustainable growth requires an integrated approach in which environmental reforms are embedded within strong institutions, capable innovation systems, and redistributive social policies. Only through this systemic alignment can green accounting drive long-term economic resilience, social equity,

and progress toward SDGs 8, 9, 12, 13, and 16, ensuring that environmental responsibility and economic development advance in tandem.

3.7 Discussios

The study contributes to sustainability accounting scholarship by integrating Ecological Modernization Theory (EMT), EGT, and Institutional Theory into a cohesive analytical framework. It advances Institutional Theory by conceptualizing regulatory quality as an institutional absorptive capacity, capable of converting environmental accountability mechanisms into innovation-driven and sustainable growth outcomes. The findings further refine EMT by demonstrating that transitions toward sustainable production systems are effective only when supported by coherent policy frameworks and institutional readiness. The lack of a mediating effect for technological innovation challenges EGT's assumption that innovation automatically drives productivity, emphasizing that the innovation–growth nexus is governance-dependent and requires systemic policy support to achieve meaningful outcomes. From a policy perspective, the findings suggest that green accounting should be embedded as a core component of national development and environmental governance strategies rather than treated as a standalone compliance exercise. Governments should strengthen regulatory frameworks through transparent, enforceable environmental legislation, effective rule-of-law enforcement, and anti-corruption mechanisms to ensure that accounting reforms translate into tangible ecological and economic outcomes. Investment in research, development, and innovation infrastructure is equally critical, and can be stimulated through targeted fiscal incentives for green technologies, dedicated funding for sustainability-oriented research, and public–private partnerships that link academia, industry, and government agencies.

Policymakers are further encouraged to develop environmental fiscal instruments—including carbon taxes, emissions trading schemes, and green subsidies—that align economic incentives with sustainability objectives while safeguarding social welfare. Enhancing the transparency and reliability of environmental accounting systems will also support evidence-based policymaking, strengthen monitoring of SDG progress, and improve national reporting under international climate agreements, such as the Paris Agreement. At the corporate level, firms in middle-income economies should integrate green accounting into strategic management and performance evaluation systems. Sustainability reporting should be aligned with international frameworks, such as the Global Reporting Initiative (GRI) and IFRS S2, to ensure comparability, credibility, and investor confidence. Boards and managers should actively collaborate with regulators and policymakers to co-create robust environmental accountability standards, embedding green accounting within broader innovation ecosystems so that environmental transparency can translate into both enhanced economic performance and societal legitimacy.

The observed divergence between aggregate GDP growth and per capita income highlights that gains from green accounting are not inherently inclusive. To ensure that sustainable development benefits are equitable, governments should implement redistributive measures, including the allocation of carbon tax revenues to vulnerable populations, targeted green employment initiatives, and social protection programs for communities disproportionately affected by environmental reforms. Embedding social equity into green fiscal and accounting policies not only advances SDG 10 (Reduced Inequalities) but also strengthens the legitimacy and durability of sustainability transitions in middle-income contexts. While this study provides robust macro-level insights through panel data analysis, it is limited in capturing sectoral heterogeneity and firm-level dynamics. Future research should explore micro-level effects of green accounting on productivity, innovation, and profitability using disaggregated datasets or multi-level modeling. Employing advanced econometric techniques such as System GMM or Panel VAR could improve causal inference. Comparative regional studies could elucidate how governance traditions, cultural norms, and environmental policies shape the effectiveness of green

accounting across contexts. Researchers are encouraged to consider additional mediating or moderating variables, such as financial inclusion, digital innovation, and policy implementation quality, to deepen understanding of the mechanisms linking environmental accounting to inclusive growth. Finally, mixed-methods approaches, including interviews with policymakers, regulators, and corporate actors, can provide richer insights into the behavioral and institutional processes underpinning green accounting reforms.

4. Conclusions

This study investigated the relationship between green accounting practices and economic growth across twenty-four middle-income economies, with particular attention to the mediating role of technological innovation and the moderating influence of regulatory quality. The empirical evidence demonstrates that green accounting significantly enhances aggregate GDP growth, confirming its potential as a tool for ecological modernization and macroeconomic efficiency. However, the analysis also reveals a negative impact on GDP per capita, highlighting a structural trade-off between overall economic expansion and the equitable distribution of welfare. This dual outcome indicates that while environmental accounting frameworks can improve productivity and resource allocation at the national level, the benefits are not automatically inclusive, underscoring the importance of integrating social equity considerations into sustainability strategies. Contrary to the expectations of Endogenous Growth Theory (EGT), technological innovation does not mediate the relationship between green accounting and economic growth. This finding suggests that integrating environmental information into national accounting systems alone does not automatically translate into innovation-led productivity gains in middle-income economies. Rather, innovation outcomes are constrained by institutional capacity, limited R&D infrastructure, weak university-industry linkages, and restricted access to green finance. In contrast, regulatory quality emerged as a critical moderator, confirming that economies with stronger governance frameworks derive more pronounced developmental benefits from green accounting adoption. These results collectively indicate that green accounting's transformative potential is highly institution-dependent, aligning with Sustainable Development Goals (SDGs) 8, 9, 12, and 16.

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