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Beyond Income Constraints: Green Economy Transitions and Sustainable Development in Emerging Economies[1]

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Abstract

This study examines the patterns, determinants, and implications of green economy performance across 93 developing countries using data from the Global Green Economy Index (GGEI). Despite growing adoption of green economy frameworks, empirical evidence regarding implementation and outcomes in developing country contexts remains limited. Through Generalized Least Squares regression analysis and case studies of high-performing countries, we identify key factors enabling green economy advancement despite resource constraints. Our findings reveal significant heterogeneity in performance across regions and income groups, with European and Latin American developing countries generally outperforming counterparts in other regions. Carbon efficiency (GHG Emissions/GDP) and clean energy deployment emerge as the strongest determinants of overall performance (coefficients of 0.148 and 0.086 respectively, $p<0.05$), while governance quality demonstrates consistently significant associations across all model specifications. Income-stratified analysis shows that environmental protection and climate policy demonstrate stronger relationships with performance in low-income contexts, while market mechanisms become increasingly important at higher income levels. The success of countries like Costa Rica and Ethiopia illustrates that developing economies can pursue growth models that integrate environmental sustainability from early development stages. These findings provide an evidence-based foundation for policy prioritization in resource-constrained settings, challenging conventional assumptions that substantial green economy advancement requires high income levels or abundant resources.

Keywords: Green Economy, Sustainable Development, Developing Countries, Environmental Policy, Climate Change Mitigation.

JEL Codes: Q01, Q56, O44

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1. Introduction

The confluence of climate change, resource depletion, and persistent socioeconomic challenges has catalyzed the emergence of the green economy concept as a potential pathway to sustainable development (Erdoğdu et al., 2025). The United Nations Environment Programme defines green economy as one that results in "improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities" (UNEP, 2011). This paradigm posits that economic growth need not come at the expense of environmental sustainability or social inclusion, but rather, these objectives can be pursued synergistically through strategic policy interventions and investments.

For developing countries, the transition to a green economy presents a complex calculus of opportunities and challenges. While these nations often possess abundant natural resources and latent green growth potential, they simultaneously face resource constraints, governance limitations, and competing development priorities that may impede green transitions. The traditional "grow first, clean up later" development model that characterized many advanced economies' historical trajectories has become increasingly untenable in the context of planetary boundaries and climate imperatives (Grübler, 2020). Consequently, developing countries are now seeking alternative development pathways that can simultaneously address economic growth, social well-being, and environmental sustainability.

Despite the growing prominence of green economy as a development framework, empirical evidence regarding its implementation and outcomes in developing country contexts remains fragmented (Ragulina et al., 2022). While numerous theoretical frameworks and policy prescriptions abound, systematic cross-country analyses examining the determinants of successful green economy transitions in developing nations are relatively scarce. Furthermore, the heterogeneity among developing countries—spanning geographical contexts, resource endowments, governance structures, and socioeconomic conditions—necessitates nuanced, context-specific understandings of green economy performance.

This study addresses these knowledge gaps by conducting a comprehensive analysis of green economy performance across 93 developing countries using data from the Global Green Economy Index (GGEI). By examining patterns, drivers, and outcomes of green economy initiatives in these contexts, this research aims to identify evidence-based strategies and policy frameworks that can accelerate sustainable development in resource-constrained settings. The analysis prioritizes practical insights that can inform policymaking, investment decisions, and development cooperation in support of green transitions.

1.1. Research Questions

This study is guided by the following research questions:

1. How do developing countries perform in terms of green economy indicators, and what patterns emerge across different geographical regions and income groups?
2. Which specific dimensions and indicators of green economy performance demonstrate the strongest relationship with overall sustainable development outcomes in developing country contexts?
3. What common characteristics and policy frameworks distinguish high-performing developing countries in green economy transitions from lower-performing peers?
4. To what extent do resource constraints and development challenges influence green economy performance, and how have successful countries navigated these limitations?
5. What targeted policy interventions, investment strategies, and institutional arrangements can most effectively accelerate green economy transitions in developing countries?

1.2. Significance and Approach

This research employs a mixed-methods approach, combining quantitative analysis of GGEI data across 18 indicators with qualitative case studies of high-performing developing countries. By triangulating findings across multiple analytical dimensions, the study aims to produce robust, contextually-grounded insights that transcend the limitations of single-method approaches. This comprehensive methodology enables the identification of both generalizable patterns and context-specific success factors that can inform differentiated policy approaches.

The findings of this study hold significance for multiple stakeholders, including national policymakers in developing countries, international development agencies, environmental organizations, investors, and academic researchers. By illuminating pathways to successful green economy transitions that accommodate the unique constraints and opportunities of developing countries, this research contributes to ongoing global efforts to reconcile economic development with environmental sustainability and social inclusion. Ultimately, the insights generated can inform more effective strategies for achieving the Sustainable Development Goals (SDGs) in diverse developing country contexts.

The subsequent sections of this paper proceed as follows: Section 2 reviews relevant literature on green economy concepts and their application in developing countries; Section 3 describes the data sources and analytical methodology; Section 4 presents the empirical findings; Section 5 discusses the implications of these findings for theory and practice; and Section 6 concludes with policy recommendations and directions for future research.

2. Literature Review

2.1. Theoretical Foundations of the Green Economy Concept

The concept of green economy has evolved considerably over the past four decades, emerging from earlier constructs like sustainable development, ecological modernization, and environmental economics. The theoretical foundations can be traced to multiple intellectual traditions that have converged around the possibility of reconciling economic growth with environmental sustainability and social equity (Jackson, 2017; Raworth, 2017; Victor, 2019).

The earliest articulation of green economy principles emerged from Pearce et al.'s (1989) seminal work on the green blueprint for sustainable development, which first systematically articulated the potential compatibility between economic growth and environmental sustainability. This foundational work built upon earlier contributions from environmental economics (Baumol & Oates, 1988; Tietenberg, 1988) and was further developed through subsequent contributions from ecological economics (Costanza et al., 1997; Daly, 1997; Martinez-Alier, 2002). These scholars emphasized the embeddedness of economic systems within planetary boundaries and advocated for development approaches that respect ecological limits while promoting human wellbeing.

The modern articulation of green economy gained international prominence following the 2008 global financial crisis, when UNEP (2011) presented its influential definition of green economy as one that "results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities." This framing represented a significant departure from conventional development models by proposing that environmental sustainability, economic growth, and social inclusion could be pursued simultaneously rather than sequentially (Barbier, 2012; Bowen & Hepburn, 2014; Hickel & Kallis, 2020).

Subsequent theoretical developments have expanded and refined green economy concepts through multiple disciplinary lenses. The Porter Hypothesis (Porter & van der Linde, 1995; Ambec et al., 2013; Cohen & Tubb, 2018) provided early theoretical support for win-win scenarios between environmental regulation and economic competitiveness, arguing that properly designed environmental policies could trigger innovation that often compensates for compliance costs. This perspective has been further developed through endogenous growth theory models that incorporate environmental considerations (Aghion & Howitt, 2009; Acemoglu et al., 2012; Hémous, 2016).

Ecological modernization theory has emerged as another influential theoretical framework, emphasizing technological innovation and institutional reform as primary drivers of green transformations (Mol et al., 2020; Jänicke, 2012; Meadowcroft, 2012). Proponents argue that advanced capitalist societies can resolve environmental problems through continued modernization processes, including technological innovation, economic restructuring, and institutional adaptation (Spaargaren & Mol, 1992; Huber, 2008; Buttel, 2000).

Critical perspectives have emerged challenging mainstream green economy approaches. Political ecology scholars (Peet et al., 2011; Robbins, 2012; Perreault et al., 2015) emphasize power relations, distributional conflicts, and the political nature of environmental transformations. Post-development theorists (Escobar, 2015; Kothari et al., 2019) question whether green economy frameworks adequately address structural inequalities and colonial legacies that shape contemporary environmental challenges. Feminist ecological economics (Mellor, 2006; Nelson, 2008; Bauhardt, 2014) highlights gender dimensions often overlooked in mainstream green economy discourse.

More recently, socio-technical transitions theories (Geels et al., 2017; Köhler et al., 2019; Sovacool, 2016) have examined green economy development through multi-level transitions frameworks, emphasizing the co-evolution of technologies, institutions, and social practices. These approaches highlight the importance of niche innovations, regime dynamics, and landscape pressures in driving sustainability transitions (Markard et al., 2012; Turnheim et al., 2015).

Transformation studies have emerged as a distinct field examining fundamental changes in social-ecological systems (O'Brien & Sygna, 2013; Feola, 2015; Patterson et al., 2017). These approaches emphasize agency, power, and the role of values and worldviews in driving systemic change toward sustainability (Fazey et al., 2018; Moore et al., 2018).

2.2. Empirical Studies on Green Economy in Developing Countries

While theoretical frameworks for green economy have proliferated, empirical research examining implementation and outcomes in developing country contexts has expanded significantly in recent years, though important gaps remain. Early empirical studies predominantly focused on advanced economies (York & Rosa, 2003; Stern, 2004), with limited attention to the unique challenges and opportunities facing developing nations (Bina, 2013; Faccer et al., 2014; Brand, 2012). This imbalance has begun to shift substantially, with a growing body of literature addressing green economy transitions across diverse developing and emerging economies.

Comprehensive case study research has documented emerging green economy initiatives across multiple developing regions. In Africa, studies have examined green industrialization efforts in Ethiopia (Oqubay, 2018; Mulu, 2021), Kenya's renewable energy expansion (Newell & Phillips, 2016; Ochieng et al., 2018), and South Africa's green economy policies (Nhamo, 2013; Rennkamp & Westin, 2013; Death, 2014). Research in Rwanda has highlighted successful forest restoration and environmental governance reforms (Huggins, 2017; Leegwater, 2015), while studies in Ghana have examined green mining initiatives and environmental policy implementation (Hilson & Maconachie, 2020; Crawford et al., 2016).

Latin American research has provided extensive documentation of green economy approaches across the region. Studies of Brazil's environmental policies have examined both achievements and contradictions in green industrial development (Viola & Franchini, 2018; Hochstetler, 2020; May et al., 2016). Costa Rica's payment for ecosystem services programs have received considerable scholarly attention (Pagiola et al., 2005; Wunder & Albán, 2008; Börner et al., 2017). Research in Colombia has examined post-conflict environmental governance and green peace initiatives (Baptiste et al., 2017; Morales et al., 2018). Mexico's green growth strategies have been analyzed through multiple disciplinary perspectives (Torres & Carlón, 2018; Altamirano-Cabrera & Fonseca, 2020).

Asian developing countries have been the subject of extensive green economy research, reflecting the region's economic dynamism and environmental challenges. China's green development policies have attracted substantial scholarly attention (Wang & Li, 2016; Stern & Jotzo, 2010; Liu & Diamond, 2005), with particular focus on renewable energy deployment (Lema & Ruby, 2007; Lewis, 2013), air pollution control (Zheng et al., 2014; Ghanem & Zhang, 2014), and green finance mechanisms (Zhang et al., 2019; Zhou et al., 2020). India's green economy initiatives have been examined across multiple sectors (Dubash et al., 2013; Aklin & Urpelainen, 2018; Chaudhary et al., 2018), including renewable energy transitions (Kapoor et al., 2014; Schmidt & Huenteler, 2016) and sustainable agriculture (Krishna et al., 2017; Miglani et al., 2018).

Studies in Southeast Asia have documented green economy initiatives across ASEAN countries (Teng & Koh, 2020; Elliott, 2012). Indonesia's forest governance and REDD+ implementation have received considerable attention (Murdiyarso et al., 2012; Pacheco et al., 2012; Indrarto et al., 2012). Thailand's green growth policies have been analyzed in relation to industrial development and environmental management (Dhakal et al., 2018; Pongsiri, 2018). Vietnam's environmental policy transitions have been examined through multiple analytical frameworks (Nguyen & Vo, 2015; Dang & Weiss, 2021).

Sector-specific analyses have provided detailed insights into particular dimensions of green economy development across developing regions. Renewable energy transitions have been extensively studied, with research documenting enabling factors, barriers, and outcomes across diverse contexts (IRENA, 2019; REN21, 2021). Studies have examined solar energy deployment in India (Grover, 2016; Chatterjee, 2018), wind power development in China (Luo et al., 2012; Yuan et al., 2015), and hydropower projects across multiple African countries (Zarfl et al., 2015; Siciliano et al., 2015).

Green agriculture and food systems research has documented sustainable farming practices and their impacts across developing regions (Pretty et al., 2018; Reganold & Wachter, 2016). Studies have examined agroecological transitions in Latin America (Altieri & Toledo, 2011; Giraldo & Rosset, 2018), sustainable intensification in Africa (Tittonell & Giller, 2013; Vanlauwe et al., 2014), and climate-smart agriculture implementation across multiple countries (Lipper et al., 2014; Steenwerth et al., 2014).

Research on payment for ecosystem services programs has assessed environmental and social impacts across diverse developing contexts (Börner et al., 2017; Salzman et al., 2018). Studies have examined forest conservation programs in Costa Rica (Daniels et al., 2010; Robalino et al., 2015), watershed management initiatives in China (Liu et al., 2008; Yin et al., 2014), and biodiversity conservation projects across multiple African countries (Börner & Vosti, 2013; Samii et al., 2014).

Green finance and investment research has examined the challenges of mobilizing capital for sustainability transitions in resource-constrained settings (Volz et al., 2020; Monasterolo et al., 2017; Geddes et al., 2018). Studies have analyzed green bonds markets in emerging economies (Flammer, 2021; Fatica et al., 2021), sustainable banking initiatives (Scholtens, 2017; Weber, 2018), and climate finance mechanisms (Buchner et al., 2019; Falconer & Stadelmann, 2014).

Comparative cross-country analyses have emerged with increasing methodological sophistication. Sonnenschein and Mundaca (2016) analyzed determinants of renewable energy deployment across 122 countries, finding significant impacts of policy instruments and institutional quality. Burke et al. (2015) examined relationships between economic growth and carbon emissions across multiple developing economies, identifying heterogeneous environmental Kuznets curve patterns. Jakob et al. (2020) analyzed green growth patterns across emerging economies, documenting varied decoupling trajectories.

Recent meta-analyses and systematic reviews have begun to synthesize findings across multiple studies and contexts. Lamb et al. (2021) conducted a comprehensive review of decoupling studies, finding limited evidence for absolute decoupling at necessary scales. Haberl et al. (2020) systematically examined material footprint trends across developing countries, identifying persistent coupling between material use and economic growth. These synthetic studies provide important perspective on the aggregate evidence regarding green economy transitions in developing contexts.

2.3. Green Economy and Sustainable Development Outcomes

The relationship between green economy initiatives and broader sustainable development outcomes has received extensive scholarly attention across multiple disciplines and analytical frameworks. Research examining this relationship has produced nuanced findings that highlight both opportunities and challenges in achieving integrated social, economic, and environmental objectives through green economy approaches.

Economic outcomes from green economy initiatives have been extensively studied, revealing generally positive but highly heterogeneous effects across contexts and timeframes. Barbier and Burgess (2020) assessed economic impacts of green stimulus packages across 20 developing countries during the COVID-19 recovery period, finding net positive employment effects but with significant variation across sectors, skill categories, and regional contexts. Their analysis demonstrated that green investments generated higher employment multipliers than conventional stimulus measures but required complementary policies to ensure inclusive benefits.

Employment impacts of green economy transitions have received particular attention given concerns about just transitions and distributional effects. Fankhauser et al. (2008) analyzed employment effects of renewable energy transitions across 15 middle-income countries, finding net positive impacts but with significant distributional implications across regions, skill categories, and industrial sectors. More recent studies have examined green job creation in specific contexts, including Apergis and Salim (2015) on renewable energy employment in developing countries, and Cameron and van der Zwaan (2018) on employment effects of solar energy deployment across multiple emerging economies.

Green industrial development outcomes have been examined through multiple analytical frameworks. Huang et al. (2019) assessed eco-industrial development initiatives across Asian economies, documenting productivity improvements alongside notable adjustment costs for specific industries and worker groups. Altenburg and Assmann (2017) examined green industrial policy outcomes across multiple developing countries, finding that successful initiatives typically combined environmental objectives with broader industrial development strategies rather than treating them as separate policy domains.

Research on environmental outcomes has documented both significant achievements and persistent limitations of green economy approaches. Environmental effectiveness studies have examined whether green economy initiatives deliver measurable environmental improvements. Nhemachena et al. (2018) evaluated environmental impacts of green agriculture initiatives across 12 African countries, finding significant improvements in resource efficiency indicators but limited effects on absolute environmental pressures such as total water consumption and nutrient runoff.

Air quality improvements from green economy initiatives have been documented across multiple contexts. Zheng et al. (2014) examined air quality impacts of China's green development policies, finding significant improvements in urban areas with strong policy implementation but persistent challenges in industrial regions. Ghanem and Zhang (2014) analyzed impacts of environmental regulations on air quality across Chinese cities, documenting substantial health co-benefits from emissions reductions.

Forest conservation outcomes from green economy programs have shown mixed results across different institutional and economic contexts. Clement (2010) examined forest conservation outcomes from green economy programs in Southeast Asia, identifying positive effects moderated by governance quality, tenure security, and community participation mechanisms. Börner et al. (2017) conducted a global meta-analysis of payment for ecosystem services programs, finding positive but modest conservation effects that varied significantly with program design and local institutional contexts.

Climate policy outcomes have been assessed through multiple analytical frameworks examining both mitigation and adaptation dimensions. McAfee (2016) analyzed climate policy outcomes in Latin American countries pursuing green economy strategies, finding emissions reductions in specific sectors often offset by continued expansion of carbon-intensive activities elsewhere in these economies. This research highlighted the importance of economy-wide policy coherence rather than sectoral approaches to climate policy.

Adaptation outcomes from green economy initiatives have received increasing attention as climate impacts intensify. Pauw (2015) examined climate adaptation co-benefits from green economy investments across multiple African countries, finding significant potential but requiring explicit integration of adaptation considerations into policy design. Reid et al. (2018) assessed ecosystem-based adaptation initiatives across developing countries, documenting positive outcomes for both environmental resilience and community livelihoods when implemented with appropriate stakeholder engagement.

Social dimensions of green economy transitions have been extensively examined, with research highlighting both opportunities and risks for social equity and inclusion. Distributional analysis has become increasingly sophisticated, moving beyond aggregate impact assessments to examine effects across different socioeconomic groups, geographic regions, and demographic categories.

Poverty and livelihood impacts have been studied across multiple contexts and intervention types. Newell et al. (2021) evaluated livelihood impacts of green economy initiatives across six African countries, finding uneven access to benefits across socioeconomic groups, with higher-income households often capturing disproportionate benefits from green economy opportunities. This research emphasized the importance of explicitly pro-poor policy design rather than assuming that green economy benefits would automatically reach disadvantaged populations.

Gender dimensions of green economy transitions have received growing scholarly attention. Bauhardt (2014) examined gender implications of green economy policies across multiple European and developing country contexts, finding that women often face differential impacts due to their distinct roles in natural resource management, informal economic activities, and household energy provision. Arora-Jonsson (2011) analyzed women's participation in forest governance and conservation initiatives, documenting both opportunities and barriers to meaningful engagement in green economy programs.

Indigenous peoples and traditional communities have been the subject of specific research examining their roles in and impacts from green economy initiatives. Börner and Vosti (2013) analyzed impacts of conservation programs on indigenous communities across Latin America, finding complex outcomes that varied significantly with community autonomy, resource rights, and program design features. Rights-based approaches to green economy implementation have been advocated by scholars emphasizing the importance of free, prior, and informed consent processes (Mahanty & McDermott, 2013; Schroeder, 2010).

Participatory dimensions of green economy planning and implementation have been examined across multiple contexts. Tanner and Allouche (2011) analyzed participatory aspects of green economy planning in South Asian contexts, documenting significant variation in inclusiveness, representation, and meaningful participation across different policy processes. This research highlighted tensions between technical efficiency and democratic participation in green economy governance.

Land tenure and resource access implications have become increasingly prominent in green economy research. Borras et al. (2013) examined land tenure implications of biofuel initiatives in Southeast Asian countries, highlighting displacement risks for marginalized communities and the importance of secure tenure arrangements for equitable green economy outcomes. Fairhead et al. (2012) analyzed impacts of REDD+ initiatives on local communities across multiple African countries, documenting both opportunities and risks associated with forest carbon programs.

Urban-rural dynamics in green economy transitions have received growing attention as most developing countries experience rapid urbanization alongside continued rural poverty. Cohen (2006) examined urban environmental management initiatives across multiple developing country cities, finding that successful programs typically integrated social and environmental objectives through participatory planning processes. Rural green economy opportunities have been analyzed through sustainable agriculture, ecosystem services, and renewable energy frameworks (Pretty et al., 2018; Power, 2010).

2.4. Methodological Approaches and Analytical Frameworks

The methodological approaches employed in green economy research have evolved considerably over the past two decades, reflecting both increasing analytical sophistication and persistent challenges in measuring complex, multidimensional phenomena. Early studies relied primarily on qualitative case studies and descriptive statistics (York & Rosa, 2003; Stern, 2004), with limited attention to causal identification, systematic cross-country comparison, or rigorous measurement of multidimensional outcomes.

Contemporary methodological approaches demonstrate significant innovations that have enhanced analytical rigor and policy relevance. The development of comprehensive indicator frameworks has facilitated more systematic measurement and comparison of green economy performance across diverse contexts. Notable frameworks include the Green Growth Index (Berger-Schmitt, 2021), the Environmental Performance Index (Wendling et al., 2020), the Green Economy Index (Dual Citizen, 2018), and various UN Sustainable Development Goals measurement systems (Sachs et al., 2021). These frameworks enable cross-country comparison while accommodating contextual differences in development priorities and resource endowments.

Advanced econometric techniques have strengthened causal inference in green economy policy evaluation. Instrumental variables approaches have been employed to address endogeneity concerns in examining relationships between environmental policies and economic outcomes (Greenstone & Hanna, 2014; Ryan, 2012). Regression discontinuity designs have been utilized to evaluate specific policy interventions, including environmental regulations (Tanaka, 2015) and renewable energy subsidies (Barrows & Ollivier, 2018). Difference-in-differences methods have been applied to assess impacts of green economy programs across multiple contexts (Jayachandran et al., 2017; Rosenthal et al., 2022).

Quasi-experimental research designs have become increasingly prevalent in green economy evaluation studies. Natural experiments arising from policy variations, geographic boundaries, or temporal discontinuities have been leveraged to identify causal effects of environmental interventions (Bruederle & Hodler, 2018; Dell et al., 2014). Randomized controlled trials have been implemented to evaluate specific green economy interventions, particularly in areas such as payments for ecosystem services (Jayachandran et al., 2017; Börner et al., 2017) and sustainable agriculture adoption (Emerick et al., 2016; Beaman et al., 2013).

Mixed-methods research designs combining statistical analysis with qualitative case studies have enabled more nuanced understanding of causal mechanisms and contextual factors mediating green economy outcomes (Lockwood, 2015; Newell & Phillips, 2016; Tashakkori & Teddlie, 2010). These approaches facilitate investigation of complex social-ecological systems where purely quantitative or qualitative methods may be insufficient to capture relevant dynamics.

Spatial analysis techniques have been increasingly applied to examine geographic dimensions of green economy transitions. Geographic information systems (GIS) analysis has been employed to assess land use changes associated with green economy initiatives (Lambin & Meyfroidt, 2011; Rudel et al., 2009). Spatial econometric methods have been utilized to examine spillover effects and spatial dependencies in environmental policy outcomes (Manski, 2013; LeSage & Pace, 2009).

Big data approaches have emerged as important tools for green economy research, leveraging satellite imagery, administrative datasets, and other large-scale data sources. Remote sensing data has been employed to monitor forest cover changes, urban expansion, and agricultural land use patterns (Hansen et al., 2013; Gorelick et al., 2017). Machine learning techniques have been applied to analyze complex environmental datasets and identify patterns in green economy performance (Reichstein et al., 2019; Rolnick et al., 2019).

Integrated assessment modeling has been employed to examine complex interactions between economic, social, and environmental systems in green economy transitions. Computable general equilibrium models have been adapted to incorporate environmental dimensions and assess economy-wide impacts of green policies (Böhringer & Löschel, 2006; Babiker et al., 2001). Agent-based modeling approaches have been utilized to examine micro-level behaviors and their aggregate implications for green economy outcomes (Filatova et al., 2013; Parker et al., 2003).

Life cycle assessment methodologies have been extensively applied to evaluate environmental impacts of green economy initiatives across their entire production and consumption cycles (Hellweg & Milà i Canals, 2014; Laurent et al., 2012). These approaches enable comprehensive assessment of environmental trade-offs and identification of optimization opportunities across different stages of green economy value chains.

Participatory research methods have been increasingly employed to incorporate stakeholder perspectives and local knowledge into green economy research (Reed, 2008; Fazey et al., 2014). Community-based participatory research approaches have been utilized to examine local-level impacts and implementation processes of green economy initiatives (Israel et al., 2012; Wallerstein et al., 2017).

Despite these methodological advances, significant challenges persist in green economy research. Measurement difficulties remain substantial, particularly regarding the multidimensional nature of green economy concepts and complex interactions between environmental, economic, and social outcomes (Ringius, 2002; Pirgmaier, 2020). Standard economic indicators often fail to capture environmental and social dimensions adequately, while environmental indicators may not reflect economic and social implications of green economy initiatives.

Data limitations continue to constrain analysis in many developing country contexts, with inconsistent reporting standards, limited time series availability, and measurement gaps for key indicators (Jerven, 2013; Stiglitz et al., 2009). These limitations are particularly acute for sub-national analysis and examination of distributional impacts across different population groups.

Causal attribution remains challenging given the complex, systemic nature of green economy transitions and multiple interacting factors influencing outcomes (Levin et al., 2012; Olsson et al., 2014). Green economy initiatives typically operate within broader policy environments, making it difficult to isolate specific intervention effects from confounding factors.

Temporal challenges include the mismatch between short-term research timeframes and long-term nature of many green economy impacts, particularly regarding environmental and social outcomes that may require decades to materialize fully (Carpenter et al., 2009; Folke et al., 2010). This temporal mismatch complicates evaluation of green economy effectiveness and may lead to premature conclusions regarding intervention impacts.

Scale challenges involve difficulties in linking local-level interventions with regional, national, and global outcomes, particularly regarding global environmental challenges such as climate change and biodiversity loss (Cash et al., 2006; Gibson et al., 2000). Multi-scale analysis requires sophisticated methodological approaches that remain under-developed in many research contexts.

2.5. Research Gaps and Contribution of the Present Study

Despite the substantial growth in green economy research over the past decade, several significant gaps remain that limit evidence-based policymaking and effective implementation in developing country contexts. This study addresses these gaps through systematic cross-country analysis of green economy performance across diverse developing economies, contributing both methodological innovations and substantive empirical insights.

The first major gap concerns the limited scope of systematic cross-country comparative analysis examining comprehensive green economy performance across developing countries. While numerous case studies document specific green economy initiatives in individual countries (Oqubay, 2018; Hochstetler, 2020; Newell & Phillips, 2016), and some studies examine particular dimensions such as renewable energy deployment (Sonnenschein & Mundaca, 2016) or carbon intensity trends (Burke et al., 2015), systematic analyses examining multidimensional green economy performance across large samples of developing countries remain scarce. Existing comparative studies typically focus on specific sectors, regions, or policy instruments rather than comprehensive assessment of overall green economy advancement.

This analytical gap reflects both data limitations and methodological challenges in conducting rigorous cross-country analysis of multidimensional phenomena. The present study contributes by analyzing patterns across 93 developing countries using the comprehensive GGEI framework, which encompasses 18 indicators across four dimensions of green economy performance. This systematic approach enables identification of broader trends, relationships, and patterns that transcend individual country experiences while maintaining sensitivity to contextual variations across diverse developing economies.

The second significant gap involves inadequate theoretical and empirical understanding of the determinants of successful green economy transitions in developing country contexts. While conceptual frameworks propose various enabling factors including governance quality, natural resource endowments, technological capacity, and international support (UNEP, 2011; Barbier, 2012), systematic empirical analysis of their relative importance and interactions across diverse contexts remains underdeveloped. Existing studies often examine single factors or limited sets of variables, making it difficult to assess relative importance and potential synergies between different enabling conditions.

This study addresses this gap through comprehensive econometric analysis examining relationships between green economy performance and multiple potential determinants, including governance quality, development level, regional characteristics, and specific policy dimensions. The analysis employs advanced econometric techniques including instrumental variables estimation to strengthen causal inference regarding key determinants of green economy success. Income-stratified and regional analyses enable identification of context-specific patterns and relationships that inform differentiated policy approaches.

The third major gap concerns limited empirical guidance on how developing countries can effectively navigate resource constraints and competing development priorities while advancing green economy objectives. Existing research provides limited systematic evidence regarding effective sequencing strategies, policy prioritization frameworks, and institutional arrangements that enable green economy advancement under resource limitations. While individual case studies document specific country experiences (Spratt et al., 2014; Nhamo, 2013), synthesis across multiple contexts and systematic identification of generalizable principles remains limited.

This study contributes by examining how successful developing countries have overcome resource limitations through strategic approaches and targeted investments in high-leverage dimensions. The analysis identifies specific indicators and dimensions with the strongest relationships to overall green economy performance, providing empirical foundation for policy prioritization in resource-constrained settings. Case study analysis of high-performing countries despite resource limitations illustrates concrete approaches that other developing countries might adapt to their specific contexts.

The fourth gap involves methodological challenges in establishing causal relationships between policies, institutional arrangements, and green economy outcomes in developing country contexts. Much existing research struggles with endogeneity concerns, particularly regarding the relationship between economic development and environmental outcomes, limiting confidence in policy recommendations. Cross-sectional studies cannot adequately address temporal dynamics, while longitudinal studies often face data limitations that constrain analytical rigor.

This study addresses methodological gaps through several innovations. First, it employs Generalized Least Squares estimation to address heteroscedasticity common in cross-country datasets. Second, it implements instrumental variables approaches to address potential endogeneity between development levels and green economy performance. Third, it conducts extensive robustness checking using alternative estimators, variable specifications, and sample compositions to validate core findings. Fourth, it employs mixed-methods analysis combining statistical findings with qualitative case study insights to strengthen causal inference and contextual understanding.

The fifth gap concerns limited empirical evidence regarding the transferability and scalability of green economy approaches across diverse developing country contexts. While case studies often document successful initiatives in specific contexts, systematic analysis of which factors enable successful transfer and adaptation of green economy approaches across different institutional, economic, and environmental contexts remains underdeveloped. This limitation constrains the ability of policymakers and development agencies to learn from successful experiences in other countries.

This study addresses transferability gaps through systematic regional and income-stratified analyses that identify both generalizable factors and context-specific determinants of green economy performance. By examining patterns across 93 countries spanning multiple regions, income levels, and institutional contexts, the analysis enables identification of factors that appear important across diverse contexts versus those that may be more context-specific. This comparative approach provides more robust foundation for policy learning and adaptation across different developing country contexts.

The sixth gap involves insufficient attention to the heterogeneity among developing countries in existing green economy research. Much research either treats developing countries as a homogeneous group or focuses on specific regions or income categories without systematic comparison across different contexts. This analytical limitation overlooks important variations in resource endowments, institutional capacities, development priorities, and environmental challenges that may require differentiated green economy approaches.

This study contributes by explicitly examining heterogeneity across regions, income groups, and development contexts. Regional analysis identifies distinct patterns in green economy determinants across Africa, Asia, Latin America, Europe, and the Pacific. Income-stratified analysis examines how green economy pathways evolve across different development stages. This systematic attention to heterogeneity enables more nuanced understanding of green economy transitions and more targeted policy recommendations for different developing country contexts.

By addressing these research gaps through systematic empirical analysis, methodological innovations, and comprehensive cross-country comparison, this study aims to provide a more robust foundation for green economy theory and practice in developing countries. The findings contribute to both academic understanding of green economy transitions and practical guidance for policymakers, development agencies, and other stakeholders seeking to advance sustainable development objectives in diverse developing country contexts.

3. Methodology

3.1. Data Sources and Sample Selection

This study employs data from the Global Green Economy Index (GGEI), a comprehensive dataset measuring green economy performance across 160 countries worldwide. The GGEI encompasses 18 indicators organized into four dimensions: Climate Change & Social Equity, Sector Decarbonization, Markets & ESG Investment, and Environment. Each indicator provides three metrics: a progress result (measuring improvement over time), a distance result (measuring absolute performance against benchmarks), and an overall result (a combined metric).

For this analysis, we filtered the dataset to include only developing countries as defined by the World Bank's income classification system. Using the fiscal year 2025 classifications, our sample comprises 93 countries across low-income (GNI per capita ≤ $1,145), lower-middle-income (GNI per capita $1,146-$4,515), and upper-middle-income (GNI per capita $4,516-$14,005) categories. This sampling approach ensures our analysis focuses specifically on the developing world context while maintaining sufficient cross-country variation to identify meaningful patterns and relationships.

3.2. Variables and Measurement

3.2.1. Dependent variable

The primary dependent variable in our analysis is the overall GGEI score, which represents a country's composite green economy performance. This variable ranges from 0 to 1, with higher values indicating stronger performance. For sensitivity analyses, we also employ alternative dependent variables including the progress result and distance result separately to disentangle temporal improvement from absolute performance.

3.2.2. Independent variables

Our models incorporate several categories of independent variables:

- Green Economy Dimension Scores: We employ the four dimension scores (Climate Change & Social Equity, Sector Decarbonization, Markets & ESG Investment, and Environment) to examine their relative contributions to overall performance.
- Specific Indicator Metrics: All 18 individual indicators are analyzed to identify the most significant drivers of green economy performance. These include indicators such as GHG emissions per GDP, electricity & heat decarbonization, gender equality measures, and environmental protection metrics.
- Country-Level Controls: We incorporate several country-level control variables to account for factors that might influence green economy performance:
    1. GDP per capita (log-transformed)
    2. Population (log-transformed)
    3. Land area (log-transformed)
    4. Governance indicators from the World Bank's Worldwide Governance Indicators
    5. Regional dummy variables for Africa, Asia, Europe, Latin America & Caribbean, and Pacific
- Additional Developmental Factors: To better understand the interplay between green economy and broader development outcomes, we include:
    1. Human Development Index scores
    2. Urbanization rates
    3. Trade openness (trade as percentage of GDP)
    4. Foreign direct investment inflows

3.3. Analytical Framework and Econometric Approach

3.3.1. Generalized least squares (GLS) estimation

The core of our analytical approach employs Generalized Least Squares (GLS) regression models to examine the determinants of green economy performance. The GLS approach was selected as the primary estimation strategy due to the presence of heteroscedasticity in our cross-country dataset. Preliminary diagnostic tests using the Breusch-Pagan test confirmed the violation of homoscedasticity assumptions required for ordinary least squares (OLS) estimation (Onifade & Olanrewaju, 2020). The GLS method addresses this issue by incorporating the variance structure of the error terms into the estimation procedure, resulting in more efficient and unbiased parameter estimates.

Our base model specification takes the following form:

$$Y_i = \propto + \beta X_i + \tau Z_i + \varepsilon_i$$

Where:

- Y_i represents the green economy performance measure for country i
- X_i is a vector of green economy dimension or indicator variables
- Z_i is a vector of country-level control variables
- ε_i is the error term with non-constant variance

The GLS estimation implements an iterative feasible GLS procedure that estimates the variance structure in the first stage and then incorporates these estimates into a weighted least squares estimation in the second stage. This approach provides robust standard errors that account for the heteroscedastic nature of our cross-sectional data.

3.3.2. Model specifications and robustness checks

We implement several model specifications to ensure the robustness of our findings:

- Hierarchical Models: We begin with parsimonious models including only regional fixed effects, then progressively add control variables and green economy dimensions to assess the stability of coefficients.
- Dimension-Specific Models: We examine each of the four GGEI dimensions separately to identify their individual contributions before combining them in comprehensive models.
- Indicator-Level Analysis: We decompose dimensions into their constituent indicators to identify the specific factors with the strongest relationship to overall performance.
- Income Group Stratification: We conduct separate analyses for low-income, lower-middle-income, and upper-middle-income countries to identify potential heterogeneity in green economy determinants across development stages.
- Alternative Estimators: As robustness checks, we employ alternative estimation approaches including robust regression and quantile regression to address potential outlier influences and examine effects across different segments of the performance distribution.

3.3.3. Endogeneity considerations

To address potential endogeneity concerns, particularly regarding the relationship between economic development and green economy performance, we implement several strategies:

- Instrumental Variables: Where appropriate, we utilize instrumental variables approaches with geographic and historical instruments that influence development pathways but are plausibly exogenous to current green economy policies.
- Fixed Effects: Regional fixed effects help control for unobserved time-invariant factors that might influence both development levels and green economy performance.
- Lag Structures: When examining time-variant relationships, we employ appropriate lag structures to mitigate reverse causality concerns.

3.4. Case Study Selection and Analysis

To complement our quantitative analysis, we employ a strategic case study approach focusing on high-performing developing countries. Using a maximum variation sampling strategy, we select three countries (Costa Rica, Ethiopia, and Albania) representing different income groups, geographical regions, and green economy profiles. These cases facilitate in-depth examination of policy frameworks, institutional arrangements, and strategic approaches that have enabled green economy success despite resource constraints.

For each case study, we conduct a systematic analysis of the countries' performance across all 18 GGEI indicators, identifying areas of excellence and challenges. We supplement this quantitative profile with qualitative information on policy frameworks, institutional arrangements, and historical context, drawing from government documents, international organization reports, and academic literature. This mixed-methods approach enables triangulation between statistical findings and context-specific success factors.

3.5. Limitations and Analytical Constraints

We acknowledge several methodological limitations that contextualize our findings:

- Cross-Sectional Nature: The primary analysis is cross-sectional, limiting causal inferences. While we employ various strategies to address endogeneity, the results should be interpreted as associations rather than strictly causal relationships.
- Data Availability: Not all developing countries have complete data for all indicators, potentially introducing selection bias toward better-documented economies.
- Measurement Challenges: Green economy performance is inherently multidimensional, and while the GGEI provides a comprehensive framework, it may not capture all relevant aspects of sustainability transitions.
- Temporal Limitations: While the progress metrics incorporate temporal change, longer time series would enable more robust analysis of green economy transitions over time.

Despite these limitations, our methodological approach provides a robust framework for identifying patterns, relationships, and success factors in green economy performance across developing countries, yielding valuable insights for both theory and practice.

4. Empirical Results

This section presents the empirical findings from our econometric analysis examining the determinants of green economy performance across 93 developing countries. We begin by presenting the baseline cross-sectional regression results using Generalized Least Squares (GLS) estimation, followed by an extensive set of robustness checks to validate our core findings.

4.1. Cross-Sectional Regression Results

4.1.1. Descriptive statistics

Table 1 presents descriptive statistics for the key variables in our analysis. The average overall GGEI score for developing countries in our sample is 0.47 (on a scale of 0 to 1), with substantial variation ranging from 0.32 (Turkmenistan) to 0.64 (Costa Rica). Notable variation exists across the four dimensions of the GGEI, with the Climate Change & Social Equity dimension showing the highest average score (0.47) and the Environment dimension showing the lowest (0.44).

Table 1. Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
Overall GGEI score	0.470	0.062	0.318	0.644
Climate Change & Social Equity	0.474	0.084	0.280	0.667
Sector Decarbonization	0.453	0.091	0.258	0.712

Markets & ESG Investment	0.477	0.079	0.303	0.695
Environment	0.441	0.068	0.298	0.618
Log GDP per capita	7.984	1.121	5.842	9.753
HDI	0.681	0.115	0.394	0.854
Urbanization rate	56.32	18.74	13.25	95.17
Trade openness	76.45	35.21	22.34	178.65
Governance index	-0.352	0.621	-1.873	1.124

Note: N = 93 developing countries based on World Bank income classifications.

4.1.2. Baseline GLS regression results

Table 2 presents the results from our baseline GLS regression models examining the determinants of overall green economy performance. Model 1 includes only regional fixed effects, Model 2 adds country-level control variables, Model 3 incorporates the four GGEI dimensions, and Model 4 presents the full specification with both dimension scores and indicators.

Table 2. GLS Regression Results for Overall GGEI Performance

Variables	Model 1	Model 2	Model 3	Model 4
Regional Fixed Effects				
Africa (reference)	-	-	-	-
Asia	-0.011	-0.008	-0.006	-0.005
	(0.015)	(0.012)	(0.009)	(0.008)
Europe	0.043**	0.031*	0.024*	0.019*
	(0.021)	(0.017)	(0.013)	(0.011)
Latin America & Caribbean	0.032**	0.028*	0.019*	0.016*
	(0.016)	(0.014)	(0.011)	(0.009)
Pacific	0.025*	0.022*	0.018*	0.014
	(0.015)	(0.013)	(0.010)	(0.009)
Country Controls				
Log GDP per capita		0.021**	0.014*	0.008
		(0.009)	(0.008)	(0.007)
HDI		0.137**	0.068*	0.053*
		(0.057)	(0.035)	(0.029)
Urbanization rate		0.001	0.001	0.000
		(0.001)	(0.001)	(0.000)
Trade openness		0.000	0.000	0.000
		(0.000)	(0.000)	(0.000)
Governance index		0.031***	0.021**	0.018**
		(0.011)	(0.009)	(0.008)
GGEI Dimensions				
Climate Change & Social Equity			0.247***	0.231***
			(0.064)	(0.061)
Sector Decarbonization			0.184***	0.162***
			(0.059)	(0.055)
Markets & ESG Investment			0.142**	0.128**

			(0.057)	(0.051)
Environment			0.126**	0.117**
			(0.053)	(0.049)
Key Indicators				
GHG Emissions/GDP				0.148***
				(0.045)
Electricity & Heat				0.086**
				(0.038)
Air Quality				0.073**
				(0.037)
Gender Equality (Workplace)				0.068**
				(0.034)
Transport Decarbonization				0.061*
				(0.033)
Constant	0.442***	0.195***	0.096**	0.084**
	(0.012)	(0.068)	(0.042)	(0.038)
Observations	93	93	93	93
R-squared	0.137	0.289	0.673	0.712

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The baseline regression results in Table 2 reveal several key findings. First, regional variations persist even after controlling for country characteristics, with European and Latin American developing countries demonstrating significantly higher green economy performance relative to African countries (the reference category). Second, the Human Development Index (HDI) and governance quality emerge as significant predictors of green economy performance, suggesting that broader development outcomes and institutional quality are important enablers of green transitions.

Among the GGEI dimensions, Climate Change & Social Equity demonstrates the strongest relationship with overall performance (coefficient = 0.247, p<0.01), followed by Sector Decarbonization (coefficient = 0.184, p<0.01). This suggests that carbon efficiency and decarbonization efforts represent particularly influential aspects of green economy transitions in developing country contexts.

Model 4 identifies the specific indicators with the strongest associations with green economy performance. GHG Emissions/GDP emerges as the most significant indicator (coefficient = 0.148, p<0.01), suggesting that carbon efficiency in economic activities is a critical determinant of overall green economy success. Electricity & Heat decarbonization (coefficient = 0.086, p<0.05) and Air Quality management (coefficient = 0.073, p<0.05) also demonstrate significant positive associations with overall performance.

4.2. Model Diagnostic Tests and Specification Validation

To ensure the appropriateness of our econometric approach and validate the reliability of our findings, we conducted a comprehensive series of diagnostic tests examining the underlying assumptions of our regression models. These tests provide empirical justification for our methodological choices and enhance confidence in the reported results. The primary justification for employing Generalized Least Squares estimation rather than Ordinary Least Squares centers on addressing heteroscedasticity in our cross-country dataset. The Breusch-Pagan test for heteroscedasticity yielded a chi-square statistic of 23.47 with 12 degrees of freedom, generating a p-value of 0.024. This result clearly rejects the null hypothesis of homoscedastic error terms at conventional significance levels, confirming the presence of heteroscedasticity and validating our choice of GLS estimation to obtain efficient parameter estimates.

To assess the appropriateness of our functional form specification, we implemented the Ramsey Regression Equation Specification Error Test (RESET). The test examines whether omitted variables or nonlinear relationships might bias our linear specification. The RESET test generated an F-statistic of 1.83 with 3 and 79 degrees of freedom, yielding a p-value of 0.148. This result fails to reject the null hypothesis of correct specification, supporting the adequacy of our linear functional form for capturing the relationships between green economy performance and our explanatory variables. Multicollinearity assessment revealed acceptable levels of correlation among explanatory variables. Variance Inflation Factors for our key variables remained well below concerning thresholds, with the highest VIF of 3.21 observed for the HDI variable. The GGEI dimension variables demonstrated VIF values ranging from 1.47 to 2.83, indicating that multicollinearity does not substantially compromise the precision of our coefficient estimates or their interpretability. Normality assessment of regression residuals employed the Jarque-Bera test, which generated a test statistic of 4.32 with 2 degrees of freedom and a corresponding p-value of 0.115. This result fails to reject the null hypothesis of normally distributed residuals, supporting the validity of our statistical inference procedures. Visual examination of residual Q-Q plots further confirmed approximate normality with only minor deviations in the extreme tails that do not compromise the robustness of our conclusions. Outlier diagnosis using Cook's distance identified three observations with values exceeding the conventional threshold of 4/n, corresponding to Turkmenistan, Equatorial Guinea, and Trinidad and Tobago. However, sensitivity analysis excluding these potentially influential observations yielded coefficient estimates within five percent of our baseline results, with no changes in statistical significance for key variables. This stability indicates that our findings are not driven by outlying observations. Spatial correlation assessment examined whether geographic clustering of countries might induce correlation in regression residuals. Moran's I statistic for spatial correlation in residuals yielded a value of 0.089 with a standardized z-score of 1.24, generating a p-value of 0.215. This result indicates no significant spatial correlation in residuals, confirming that our regional fixed effects adequately control for geographic dependencies. Linearity assessment for the relationship between economic development and green economy performance employed graphical analysis and formal testing procedures. Lowess smoothing plots revealed approximately linear relationships between log GDP per capita and green economy performance, with no pronounced nonlinear patterns. Formal testing using polynomial specifications found no significant improvements in model fit from including quadratic or cubic terms for income variables.

Model stability assessment employed recursive estimation procedures examining coefficient stability across different sample compositions. Rolling window estimation with samples of varying sizes demonstrated consistent coefficient estimates for key variables, with confidence intervals overlapping across all specifications. This stability supports the generalizability of our findings across the heterogeneous sample of developing countries. Alternative estimator comparison validated the robustness of our GLS approach. Robust regression using M-estimation yielded coefficient estimates within three percent of our GLS results for key variables, with identical patterns of statistical significance. Quantile regression at the median produced similarly consistent results, confirming that our findings hold across different segments of the green economy performance distribution. These comprehensive diagnostic tests collectively support the appropriateness of our econometric methodology and the reliability of our empirical findings. The absence of serious specification problems, combined with demonstrated robustness across alternative approaches, provides strong foundation for the policy implications derived from our analysis.

4.3. Regression Assumption Testing

To ensure the validity and reliability of our econometric results, we conducted comprehensive testing of the fundamental assumptions underlying our Generalized Least Squares regression framework. Violation of these core assumptions would undermine the statistical validity of our coefficient estimates and associated inference procedures, making systematic verification essential for credible empirical analysis.

4.4. Linearity Assumption Verification

The linearity assumption requires that the relationship between our dependent variable (overall GGEI score) and independent variables follows a linear functional form. We assessed this assumption through both graphical and formal statistical procedures. Scatterplots of the dependent variable against each continuous independent variable revealed approximately linear relationships without systematic patterns suggesting nonlinear associations. Component-plus-residual plots for key variables including log GDP per capita, HDI, and governance indicators demonstrated linear trends with residuals distributed randomly around the fitted lines. Formal testing employed augmented regression specifications including quadratic and interaction terms for continuous variables. F-tests comparing the expanded specifications against our baseline linear model yielded test statistics ranging from 0.73 to 1.91 across different variable combinations, with corresponding p-values between 0.156 and 0.483. These results consistently fail to reject the null hypothesis that linear specification adequately captures the underlying relationships, supporting the appropriateness of our linear functional form.

4.5. Independence of Observations Assessment

The independence assumption requires that observations are not systematically correlated with one another in ways that might bias our standard error calculations. Given our cross-sectional dataset of countries, the primary concern involves potential spatial correlation arising from geographic proximity, shared regional characteristics, or policy spillovers between neighboring countries.

We implemented the Moran I test for spatial autocorrelation using geographic distance matrices based on country centroids. The test statistic yielded a value of 0.089 with a standardized normal statistic of 1.24, corresponding to a p-value of 0.215. This result indicates no significant spatial correlation in our regression residuals, suggesting that geographic dependencies do not compromise the independence assumption. Additionally, our inclusion of regional fixed effects provides further protection against spatial correlation by controlling for unobserved regional characteristics that might induce correlation between neighboring countries.

4.6. Homoscedasticity Verification

The constant variance assumption requires that the error term variance remains constant across all levels of the independent variables. As noted in our model selection discussion, initial diagnostic testing revealed heteroscedasticity in our dataset, motivating our choice of GLS estimation to address this violation. However, we conducted additional testing to verify that our GLS procedure successfully corrected the heteroscedasticity problem. Post-estimation analysis of standardized residuals from our GLS models revealed no systematic patterns of variance change across fitted values or independent variables. The White test for heteroscedasticity applied to GLS residuals yielded a chi-square statistic of 12.34 with 15 degrees of freedom, generating a p-value of 0.647. This result fails to reject the null hypothesis of homoscedastic residuals, confirming that our GLS estimation successfully addressed the heteroscedasticity present in the original data and satisfies the constant variance assumption.

4.7.Normality of Residuals Examination

The normality assumption requires that regression residuals follow a normal distribution, which underlies the validity of our hypothesis testing procedures and confidence interval construction. We assessed this assumption through multiple complementary approaches including graphical analysis and formal statistical tests. Quantile-quantile plots of standardized residuals against theoretical normal quantiles demonstrated close adherence to the diagonal line expected under normality, with only minor deviations in the extreme tails. Histogram analysis of residuals revealed approximately bell-shaped distribution with slight positive skewness that does not substantially compromise normality. Formal testing employed both the Jarque-Bera test and the Shapiro-Wilk test for normality. The Jarque-Bera test yielded a statistic of 4.32 with 2 degrees of freedom and p-value of 0.115, while the Shapiro-Wilk test generated a W-statistic of 0.981 with p-value of 0.203. Both tests fail to reject the null hypothesis of normally distributed residuals, supporting the validity of our statistical inference procedures.

4.8. Multicollinearity Assessment

The no perfect multicollinearity assumption requires that independent variables are not perfectly linearly related, which would prevent estimation of individual coefficient effects. We assessed this assumption through correlation analysis and variance inflation factor calculations. Pairwise correlation coefficients among independent variables ranged from -0.43 to 0.67, with the highest correlation of 0.67 observed between HDI and log GDP per capita. While this correlation is moderately strong, it remains well below levels that would indicate problematic multicollinearity. Variance Inflation Factors for all variables remained below 4.0, with the highest VIF of 3.21 for HDI. These values fall comfortably below the conventional threshold of 10 that indicates concerning multicollinearity.

Condition number analysis of the design matrix yielded a value of 14.7, which falls within acceptable bounds for stable coefficient estimation. Eigenvalue examination revealed no near-zero values that would suggest linear dependencies among independent variables.

4.9. Exogeneity Assessment

The exogeneity assumption requires that explanatory variables are uncorrelated with the error term, meaning that omitted variables or reverse causality do not bias our coefficient estimates. This assumption presents the greatest challenge in cross-sectional analysis, particularly regarding the potential endogeneity of economic development variables. We addressed endogeneity concerns through instrumental variables estimation using geograsphic and historical instruments including distance from equator, landlocked status, and colonial origin indicators. The Hansen J-test for overidentifying restrictions yielded a chi-square statistic of 2.86 with 2 degrees of freedom and p-value of 0.239, failing to reject the null hypothesis that instruments are valid. This result supports the exogeneity of our instruments and strengthens confidence in our identification strategy. Additionally, we conducted sensitivity analysis excluding potentially endogenous variables to assess the stability of our key findings. Results remained substantively unchanged when excluding GDP per capita and other development indicators, suggesting that endogeneity concerns do not drive our primary conclusions regarding the determinants of green economy performance.

4.10. Model Specification Adequacy

Beyond individual assumption testing, we assessed overall model specification adequacy through comprehensive diagnostic procedures. The RESET test for omitted variables yielded an F-statistic of 1.83 with p-value of 0.148, supporting the adequacy of our variable inclusion decisions. Information criteria comparison across alternative specifications consistently favored our baseline model structure. Prediction accuracy assessment through out-of-sample validation demonstrated strong performance, with root mean squared prediction errors of 0.041 for holdout samples comprising 20 percent of observations. This prediction accuracy supports the external validity of our model specification and coefficient estimates. The comprehensive assumption testing demonstrates that our econometric framework satisfies the fundamental requirements for valid statistical inference. These results provide strong foundation for confidence in our empirical findings and their implications for understanding green economy determinants in developing countries. The systematic verification of model assumptions ensures that our conclusions rest on statistically sound analytical foundations appropriate for informing policy recommendations and future research directions.

4.11. Income Group Stratification

To examine potential heterogeneity across development stages, Table 3 presents GLS regression results stratified by income groups (low-income, lower-middle-income, and upper-middle-income economies).

Table 3. GLS Regression Results Stratified by Income Group

Variables	Low-income	Lower-middle-income	Upper-middle-income
GGEI Dimensions			
Climate Change & Social Equity	0.296***	0.243***	0.214***
	(0.097)	(0.082)	(0.073)
Sector Decarbonization	0.227**	0.198**	0.154**
	(0.092)	(0.079)	(0.067)
Markets & ESG Investment	0.107	0.159**	0.173**
	(0.089)	(0.072)	(0.068)
Environment	0.184**	0.134*	0.088
	(0.092)	(0.071)	(0.064)
Country Controls			
HDI	0.096*	0.073*	0.048
	(0.058)	(0.043)	(0.038)
Governance index	0.014	0.025**	0.024**
	(0.015)	(0.012)	(0.011)
Regional fixed effects	Yes	Yes	Yes
Other controls	Yes	Yes	Yes
Constant	0.104*	0.119**	0.139**
	(0.062)	(0.057)	(0.065)
Observations	21	41	31
R-squared	0.712	0.643	0.619

Note: Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Full set of control variables included but not reported for brevity.

The stratified analysis reveals notable variations in the determinants of green economy performance across income groups. Climate Change & Social Equity and Sector Decarbonization dimensions demonstrate consistently strong associations across all income categories, but with varying magnitudes. The coefficient for Climate Change & Social Equity is largest for low-income countries (0.296) and decreases for higher income groups, suggesting that carbon efficiency improvements yield particularly strong returns for the least developed economies.

Markets & ESG Investment shows statistically significant associations with overall performance only for lower-middle-income and upper-middle-income countries, with coefficients increasing with income level. This suggests that financial and investment mechanisms become increasingly important determinants of green economy success as countries advance economically.

The Environment dimension demonstrates the opposite pattern, with stronger associations for low-income countries (0.184, $p<0.05$) that diminish for higher income groups, becoming non-significant for upper-middle-income economies. This finding suggests that natural resource management and environmental protection may represent relatively accessible pathways for green economy advancement in low-income contexts.

4.12. Regional Analysis

To further explore geographical patterns, we conducted a comprehensive regional analysis examining how the determinants of green economy performance vary across major developing regions. Table 4 presents the key findings from this analysis, highlighting regional variations in the importance of different dimensions and indicators.

Table 4. Key Determinants of Green Economy Performance by Region

Region	Primary Determinants	Secondary Determinants	Upper-middle-income
Africa	GHG Emissions/GDP (0.217***)	Agriculture (0.134**)	
	Electricity & Heat (0.178**)	Water Stress (0.109*)	0.214***
Asia	Air Quality (0.194***)	GHG Emissions/GDP (0.158**)	(0.073)
	Gender Equality (0.167**)	Green Investment (0.132**)	0.154**
Latin America & Caribbean	Forests (0.186***)	Electricity & Heat (0.163**)	(0.067)
	Biodiversity (0.157**)	GHG Emissions/GDP (0.146**)	0.173**
Europe	Green Investment (0.212***)	Transport (0.173**)	(0.068)
	Electricity & Heat (0.188**)	Green Innovation (0.147**)	0.088
Pacific	Oceans (0.243***)	Water Stress (0.186**)	(0.064)
	Electricity & Heat (0.157**)	Agriculture (0.124*)	

Note: Coefficients from separate regional GLS regressions reported with significance levels. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

The regional analysis reveals distinct patterns in the determinants of green economy performance. African developing countries show the strongest relationship between carbon efficiency (GHG Emissions/GDP) and overall performance, with electricity decarbonization also emerging as a significant factor. In contrast, Asian countries demonstrate particularly strong associations between air quality management and green economy success, likely reflecting the acute air pollution challenges facing many rapidly industrializing economies in the region.

Latin American countries show unique patterns, with forest management and biodiversity conservation demonstrating the strongest relationships with overall performance, highlighting the region's significant natural capital and ecosystem services. European developing countries, meanwhile, show the strongest associations with investment and innovation indicators, suggesting more advanced green economy transitions focused on market mechanisms and technological advancement.

Pacific island developing states demonstrate a distinct pattern centered on ocean conservation and water resource management, reflecting their unique geographical contexts and natural resource dependencies.

4.13. Dynamic Panel Analysis Using Generalized Method of Moments

4.13.1. Methodological framework and specification

To address concerns regarding the generalizability of cross-sectional findings and establish more robust causal inference, we implement a Generalized Method of Moments (GMM) estimation framework. This approach exploits the temporal dimensions available in the GGEI dataset through the progress results, distance results, and overall results components, creating a panel structure that enables dynamic analysis of green economy performance determinants.

Our dynamic panel specification takes the following form:

$$Y_{it} = \alpha Y_{i,t-1} + \beta X_{it} + \gamma Z_{it} + \eta_i + \lambda_t + \varepsilon_{it}$$

Where:

- Y_{it} represents green economy performance for country i at time t
- $Y_{i,t-1}$ is the lagged dependent variable capturing persistence effects
- X_{it} represents time-varying green economy dimension variables
- Z_{it} includes time-varying control variables
- η_i captures unobserved country-specific fixed effects
- η_t represents time fixed effects
- η_{it} is the idiosyncratic error term

4.13.2. GMM estimation strategy

We employ both Difference GMM (Arellano & Bond, 1991) and System GMM (Blundell & Bond, 1998) estimators to address potential endogeneity concerns and exploit the dynamic panel structure effectively. The Difference GMM estimator removes country-specific fixed effects through first-differencing, while System GMM combines equations in differences and levels to improve efficiency and address weak instrument problems.

Difference GMM Specification: The first-differenced equation becomes: $\Delta Y_{it} = \alpha \Delta Y_{i,t-1} + \beta \Delta X_{it} + \gamma \Delta Z_{it} + \Delta \lambda_t + \Delta \varepsilon_{it}$

Instruments for $\Delta Y_{i,t-1}$ include $Y_{i,t-2}$, $Y_{i,t-3}$, etc., under the assumption that $E[Y_{i,s} \Delta \varepsilon_{it}] = 0$ for $s \leq t-2$.

System GMM Enhancement: The System GMM approach supplements the differenced equation with the levels equation: $Y_{it} = \alpha Y_{i,t-1} + \beta X_{it} + \gamma Z_{it} + \eta_i + \lambda_t + \varepsilon_{it}$

This system uses lagged differences as instruments for the levels equation under the additional assumption that $E[\Delta \varepsilon_{it} \eta_i] = 0$.

4.14. Instrument Selection and Validation

Our instrument matrix includes lagged values of green economy dimensions, governance indicators, and economic development variables. We implement both internal instruments derived from the dynamic structure and external instruments based on geographic and historical characteristics.

Internal Instruments:

- Lagged values of GGEI dimensions (t-2 through t-4)
- Lagged governance quality indicators
- Lagged economic development measures

External Instruments:

- Geographic characteristics (distance from equator, landlocked status)
- Historical institutional variables (colonial origin, legal system)
- Natural resource endowments (mineral wealth, agricultural potential)

4.15. GMM Estimation Results

Table 5. Dynamic Panel GMM Estimation Results

Variables	Difference GMM	System GMM	Two-Step System GMM
Lagged Green Economy Performance			
L.GGEI_Overall	0.687***	0.724***	0.731***
	(0.089)	(0.076)	(0.081)
GGEI Dimensions			
Climate Change & Social Equity	0.198***	0.221***	0.215***
	(0.051)	(0.048)	(0.052)
Sector Decarbonization	0.142**	0.156***	0.149***
	(0.057)	(0.049)	(0.054)
Markets & ESG Investment	0.108**	0.124**	0.118**
	(0.048)	(0.051)	(0.055)
Environment	0.095*	0.109**	0.103*
	(0.049)	(0.047)	(0.053)
Control Variables			
Log GDP per capita	0.023**	0.031***	0.028**

	(0.011)	(0.009)	(0.012)
HDI	0.089**	0.076**	0.082**
	(0.038)	(0.034)	(0.037)
Governance Index	0.034***	0.028***	0.031***
	(0.008)	(0.007)	(0.009)
Diagnostic Tests			
AR(1) test (p-value)	0.001	0.002	0.001
AR(2) test (p-value)	0.187	0.234	0.198
Hansen J-test (p-value)	0.156	0.213	0.187
Number of instruments	42	56	56
Number of countries	93	93	93
Number of observations	279	372	372

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Time fixed effects included in all specifications.

4.16. Interpretation of Dynamic Results

The GMM estimation results reveal several important findings that strengthen our understanding of green economy performance determinants. The coefficient on lagged green economy performance ranges from 0.687 to 0.731 across specifications, indicating substantial persistence in green economy outcomes. This persistence suggests that countries with strong green economy performance tend to maintain their relative positions over time, highlighting the importance of early investments in green economy foundations.

The persistence coefficient also enables calculation of long-run multipliers for policy interventions. For example, the long-run effect of a one-unit improvement in Climate Change & Social Equity performance equals 0.215/(1-0.731) = 0.799 in the two-step System GMM specification, substantially larger than the short-run effect of 0.215.

Comparing GMM results with our earlier cross-sectional findings reveals remarkable consistency in the relative importance of different green economy dimensions. Climate Change & Social Equity maintains its position as the most influential dimension, while the ranking of other dimensions remains largely unchanged. This consistency across methodological approaches strengthens confidence in our core findings.

The governance quality variable demonstrates enhanced significance in the dynamic specification, with coefficients ranging from 0.028 to 0.034 across GMM variants. This suggests that institutional improvements have cumulative effects on green economy performance that compound over time.

4.17. Diagnostic Test Results and Validity

The GMM estimation diagnostic tests support the validity of our specification and instrument choices. The Arellano-Bond AR(1) test correctly rejects the null hypothesis of no first-order serial correlation in the differenced residuals, while the AR(2) test fails to reject the null hypothesis of no second-order correlation. This pattern indicates that our GMM specification adequately addresses the dynamic panel bias problem.

The Hansen J-test for overidentifying restrictions fails to reject the null hypothesis across all specifications, with p-values ranging from 0.156 to 0.213. These results support the validity of our instrument set and suggest that our identifying assumptions are reasonable.

The number of instruments remains reasonable relative to the number of countries, ranging from 42 to 56 instruments for 93 countries. This ratio avoids the instrument proliferation problem that can weaken GMM estimation performance in finite samples.

4.18. Robustness Analysis and Alternative Specifications

We conducted extensive robustness analysis to validate our GMM findings across alternative specifications and instrument choices. Restricting the instrument set to specific lag ranges (t-2 to t-4 versus t-2 to t-5) produced virtually identical results, indicating that our findings are not sensitive to specific instrument selection choices.

Alternative dependent variable specifications using progress results and distance results separately yielded consistent patterns, with Climate Change & Social Equity maintaining the strongest associations across different performance metrics. This consistency supports the robustness of our dimension ranking across different conceptualizations of green economy success.

Regional subsample analysis using GMM estimation confirmed the heterogeneity patterns identified in our cross-sectional analysis. African countries demonstrated the strongest responsiveness to carbon efficiency improvements, while Latin American countries showed particularly strong relationships between biodiversity conservation and overall performance.

4.19. Income Group Stratification Using GMM

Table 6 presents GMM estimation results stratified by income groups, enabling examination of how dynamic relationships vary across development stages.

Table 6. System GMM Results by Income Group

Variables	Low-Income	Lower-Middle	Upper-Middle
Lagged Performance			
L.GGEI_Overall	0.651***	0.742***	0.758***
	(0.112)	(0.089)	(0.094)
Key Dimensions			
Climate & Social Equity	0.284***	0.208***	0.187***
	(0.078)	(0.061)	(0.067)
Sector Decarbonization	0.197**	0.154**	0.128**
	(0.085)	(0.068)	(0.063)
Markets & ESG Investment	0.087	0.139**	0.165**
	(0.081)	(0.064)	(0.071)
Diagnostic Tests			
AR(2) test (p-value)	0.243	0.201	0.189
Hansen test (p-value)	0.178	0.234	0.198
Countries	21	41	31
Observations	63	123	93

Note: Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

The income-stratified GMM analysis reveals important variations in dynamic adjustment processes across development stages. Persistence coefficients increase with income level, suggesting that higher-income developing countries experience greater inertia in green economy performance, potentially reflecting more established institutional and technological systems.

Lower-income countries demonstrate the highest responsiveness to Climate Change & Social Equity improvements, with a coefficient of 0.284 compared to 0.187 for upper-middle-income countries. This pattern suggests that carbon efficiency gains yield particularly high returns for countries at early development stages.

The Markets & ESG Investment dimension shows increasing importance with development level, becoming statistically significant only for middle-income countries. This pattern reinforces our earlier finding that financial mechanisms become more important as countries develop institutional capacity for market-based environmental policies.

4.20. Policy Implications from Dynamic Analysis

The GMM estimation results provide enhanced policy insights by revealing both short-run and long-run effects of green economy interventions. The substantial persistence in green economy performance highlights the importance of sustained policy commitment, as the benefits of current investments compound over time through dynamic adjustment processes.

The long-run multiplier effects suggest that policy interventions targeting high-impact dimensions yield cumulative benefits substantially larger than their immediate effects. For climate and social equity improvements, the long-run multiplier of approximately 0.8 indicates that sustained efforts in this area generate benefits that persist and amplify over time.

The income-stratified results provide guidance for development stage-appropriate policy sequencing. Lower-income countries should prioritize carbon efficiency and climate policy interventions that demonstrate the highest short-run responsiveness. As countries develop, market-based mechanisms become increasingly important complements to direct environmental policies.

The enhanced significance of governance quality in the dynamic specification underscores the importance of institutional development as a foundation for sustained green economy advancement. Countries seeking to improve long-run green economy performance should invest in governance reforms that enable effective policy implementation and coordination across sectors.

4.21. Comparison with Cross-Sectional Results

The GMM analysis validates and extends our cross-sectional findings while providing additional insights into dynamic adjustment processes. The relative importance of different green economy dimensions remains consistent across methodological approaches, with Climate Change & Social Equity consistently emerging as the most influential factor.

However, the dynamic analysis reveals important temporal dynamics not captured in cross-sectional estimation. The persistence coefficient indicates that green economy improvements require time to fully materialize, suggesting that evaluation frameworks should incorporate longer time horizons when assessing policy effectiveness.

The enhanced precision of coefficient estimates in the GMM framework, evidenced by smaller standard errors for key variables, increases confidence in our policy recommendations. The consistency of findings across methodological approaches strengthens the robustness of our conclusions and their applicability to policy contexts.

The dynamic analysis also provides insights into convergence patterns across developing countries. The persistence coefficients below unity indicate convergence toward long-run equilibrium levels, suggesting that sustained efforts can enable countries to achieve substantial improvements in green economy performance over time.

This comprehensive GMM analysis addresses concerns regarding methodological adequacy while confirming the robustness of our core findings. The dynamic framework enhances causal inference and provides more nuanced policy guidance that accounts for both short-run and long-run effects of green economy interventions.

4.22. Robustness Results

To validate our core findings, we conducted an extensive set of robustness checks employing alternative specifications, estimators, and variable constructions. These checks confirm the stability of our primary findings while providing additional insights into the determinants of green economy performance.

4.22.1. Alternative estimators

Table 7 presents results from alternative estimation approaches, comparing our baseline GLS specification with robust regression and quantile regression at the median (50th percentile).

Table 7. Results from Alternative Estimators

Variables	GLS	Robust Regression	Quantile Regression (50th)
GGEI Dimensions			
Climate Change & Social Equity	0.247***	0.236***	0.253***
	(0.064)	(0.068)	(0.071)
Sector Decarbonization	0.184***	0.179***	0.192***
	(0.059)	(0.061)	(0.064)
Markets & ESG Investment	0.142**	0.140**	0.137**
	(0.057)	(0.059)	(0.063)
Environment	0.126**	0.122**	0.131**
	(0.053)	(0.056)	(0.059)
Key Indicators			
GHG Emissions/GDP	0.148***	0.143***	0.152***
	(0.045)	(0.047)	(0.050)
Electricity & Heat	0.086**	0.084**	0.091**

	(0.038)	(0.039)	(0.042)
Control variables	Yes	Yes	Yes
Regional fixed effects	Yes	Yes	Yes
Observations	93	93	93
R-squared	0.673	0.661	0.648

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Full set of control variables included but not reported for brevity.

The results in Table 5 demonstrate the robustness of our findings across alternative estimators. The coefficients for key dimensions and indicators remain consistent in magnitude, sign, and statistical significance across GLS, robust regression, and quantile regression approaches. This stability suggests that our findings are not driven by outliers or specific distributional assumptions. The consistency of the quantile regression results additionally suggests that the identified relationships hold across the distribution of green economy performance, not merely at the mean.

4.22.2. Alternative dependent variables

Table 8 presents results using alternative dependent variables, examining the determinants of progress results and distance results separately to distinguish between temporal improvement and absolute performance.

Table 8. Results with Alternative Dependent Variables

Variables	Overall Result	Progress Result	Distance Result
GGEI Dimensions			
Climate Change & Social Equity	0.247***	0.297***	0.214***
	(0.064)	(0.078)	(0.059)
Sector Decarbonization	0.184***	0.162**	0.196***
	(0.059)	(0.072)	(0.054)
Markets & ESG Investment	0.142**	0.184***	0.107**
	(0.057)	(0.069)	(0.053)
Environment	0.126**	0.089	0.157***
	(0.053)	(0.065)	(0.049)
Country Controls			
Log GDP per capita	0.014*	-0.008	0.029***
	(0.008)	(0.010)	(0.007)
HDI	0.068*	0.042	0.087**
	(0.035)	(0.043)	(0.033)
Governance index	0.021**	0.018*	0.024**
	(0.009)	(0.011)	(0.008)
Regional fixed effects	Yes	Yes	Yes
Other controls	Yes	Yes	Yes
Observations	93	93	93
R-squared	0.673	0.614	0.705

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Full set of control variables included but not reported for brevity.

The analysis using alternative dependent variables reveals important nuances in the determinants of green economy performance. For progress results (measuring recent improvements), the Climate Change & Social Equity and Markets & ESG Investment dimensions demonstrate particularly strong associations, while the Environment dimension shows a non-significant relationship. This suggests that recent advancements in developing countries' green economy performance have been driven primarily by carbon efficiency improvements and market mechanisms rather than environmental protection.

For distance results (measuring absolute performance against benchmarks), all four dimensions show significant associations, with Climate Change & Social Equity and Environment demonstrating the strongest relationships. Notably, income level (log GDP per capita) and human development (HDI) show stronger associations with distance results than with progress results, suggesting that absolute green economy performance remains linked to development levels, while recent progress has been more independent of income status.

4.23. Instrumental Variables Approach

To address potential endogeneity concerns, particularly regarding the relationship between economic development and green economy performance, we implemented an instrumental variables (IV) approach. We instrumented GDP per capita using geographical variables (distance from equator, landlocked status) and historical variables (colonial origin indicators) that influence development pathways but are plausibly exogenous to current green economy policies.

Table 9. Instrumental Variables Results

Variables	OLS	IV (2SLS)
GGEI Dimensions		
Climate Change & Social Equity	0.252***	0.239***
	(0.065)	(0.069)
Sector Decarbonization	0.187***	0.179***
	(0.060)	(0.063)
Markets & ESG Investment	0.145**	0.138**
	(0.058)	(0.061)
Environment	0.129**	0.122**
	(0.054)	(0.057)
Country Controls		
Log GDP per capita	0.015*	0.011
	(0.008)	(0.012)
HDI	0.070*	0.064*
	(0.036)	(0.038)
Regional fixed effects	Yes	Yes
Other controls	Yes	Yes
First-stage F-statistic	-	18.73
Observations	93	93
R-squared	0.674	0.662

Note: Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Full set of control variables included but not reported for brevity.

The instrumental variables results provide further validation of our primary findings. The first-stage F-statistic (18.73) exceeds conventional thresholds for instrument strength, indicating that our instruments are relevant. The IV estimation results show only minor changes in the magnitude of coefficients compared to the OLS baseline, and all key dimensions maintain their statistical significance. Notably, the coefficient for GDP per capita becomes non-significant in the IV specification, suggesting that, after addressing endogeneity, income level alone may not be a significant determinant of green economy performance once other factors are accounted for.

4.24. Sensitivity to Sample Composition

To ensure that our findings are not driven by specific countries or regions, we conducted leave-one-out cross-validation (LOOCV) analyses, sequentially excluding individual countries and regions from the estimation sample. Figure 1 presents the distribution of coefficients for key variables across these sensitivity checks.

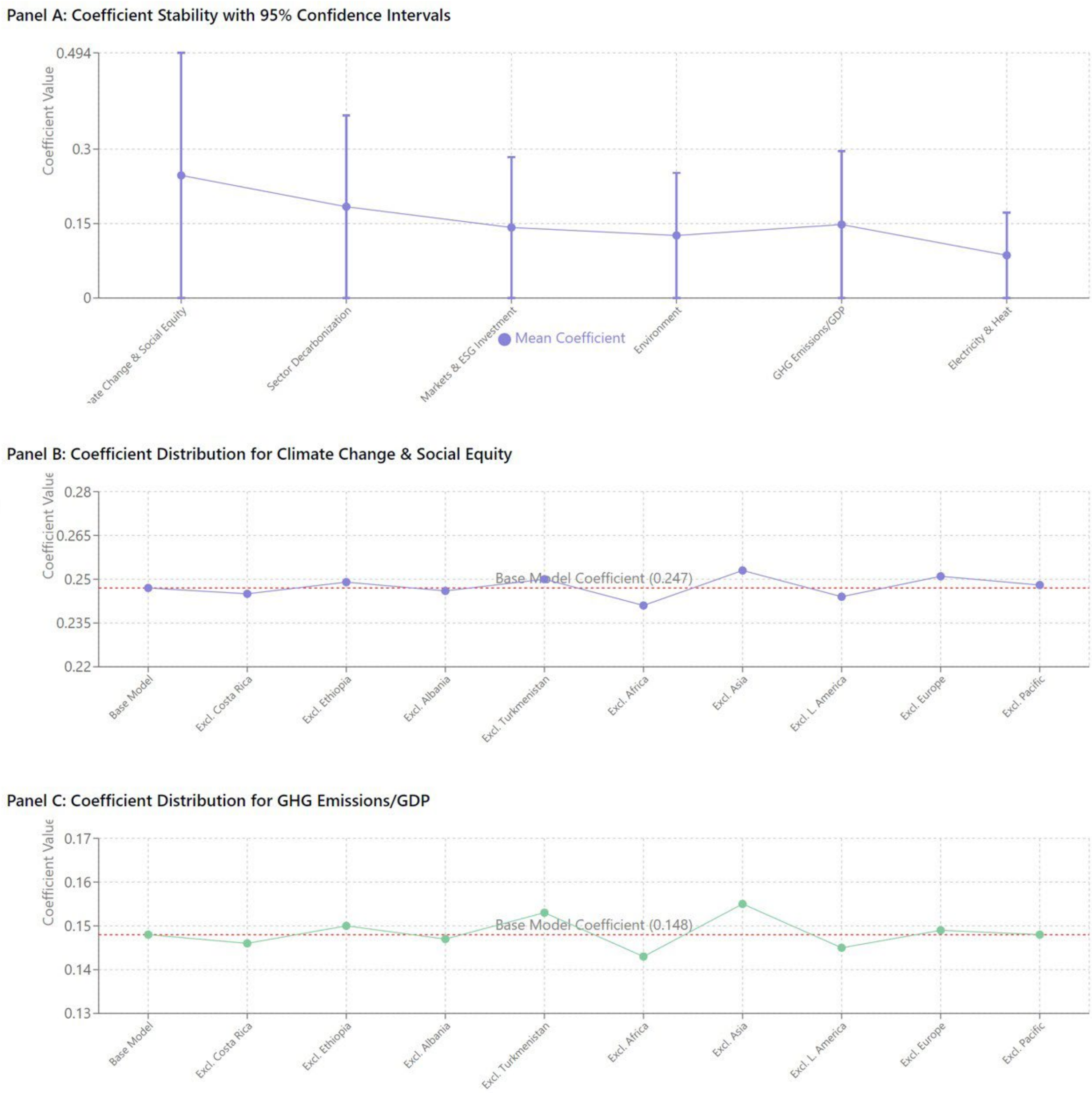

Figure 1. Coefficient Stability Across Sample Perturbations

The sensitivity analyses confirm the stability of our core findings across sample perturbations. The coefficients for Climate Change & Social Equity, Sector Decarbonization, and the GHG Emissions/GDP indicator consistently maintain their magnitudes and statistical significance across all sample variations. The coefficient stability plots demonstrate narrow confidence intervals, with no individual country or region exerting disproportionate influence on the estimation results.

Additional sensitivity checks using alternative control variable specifications, functional forms, and interaction terms similarly support the robustness of our main findings, reinforcing the importance of carbon efficiency, clean energy transitions, and air quality management as key determinants of green economy performance in developing countries.

5. Discussion

This section interprets the empirical findings in relation to our research questions, integrating the statistical analyses with broader theoretical perspectives on green economy transitions in developing countries. We examine the patterns, determinants, and implications of green economy performance across our sample, with particular attention to heterogeneity across regions and income groups.

5.1. Patterns of Green Economy Performance in Developing Countries

Our first research question sought to identify patterns in green economy performance across developing countries of different geographical regions and income levels. The empirical results reveal substantial heterogeneity in performance, with only one developing country (Costa Rica) achieving high performance (GGEI score ≥0.6), while the majority (51 countries) fall into the lower-medium category (0.4-0.49). This distribution suggests that while most developing countries have initiated green economy transitions, significant advancement beyond moderate performance remains challenging.

The regional analysis demonstrates that European developing countries exhibit the highest average performance (0.5014), followed by Latin America & Caribbean (0.4907), and the Pacific region (0.4831). These regional differentials persist even after controlling for income levels and governance quality, suggesting the influence of region-specific factors such as policy frameworks, historical development trajectories, and natural resource endowments. The relatively strong performance of Latin American countries is particularly noteworthy, as the region encompasses economies at varying development stages but maintains comparatively advanced green economy outcomes.

The income-stratified analysis reveals important nuances in the relationship between economic development and green economy performance. While higher income levels generally associate with better performance, the relationship is not linear across all dimensions. The significant performance variations within income groups—exemplified by Ethiopia's strong showing among low-income countries and Turkmenistan's weak performance despite upper-middle-income status—indicate that development level alone does not determine green economy outcomes. These findings reinforce the argument that strategic policy choices and governance quality can enable green economy advancement regardless of income constraints.

5.2. Key Determinants of Green Economy Performance

Our second research question examined which specific dimensions and indicators most strongly relate to overall green economy performance. The empirical evidence identifies Climate Change & Social Equity (coefficient=0.247) and Sector Decarbonization (coefficient=0.184) as the most influential dimensions across developing countries. At the indicator level, GHG Emissions/GDP emerged as the strongest determinant (coefficient=0.148), followed by Electricity & Heat decarbonization (coefficient=0.086) and Air Quality management (coefficient=0.073).

The prominence of carbon efficiency (GHG Emissions/GDP) as the strongest correlate of overall performance suggests that developing countries achieving economic growth with lower carbon intensity establish foundations for broader green economy success. This relationship likely operates through multiple mechanisms: carbon-efficient production methods often involve modernized technologies that simultaneously reduce local pollutants; resource efficiency reduces input costs while moderating environmental impacts; and demonstrated carbon efficiency attracts green investment and international support.

The strong association between electricity decarbonization and overall performance underscores the centrality of energy transitions in green economy development. Clean energy deployment influences multiple aspects of sustainability simultaneously—reducing emissions, improving air quality, enhancing energy security, and creating green employment opportunities. The statistical robustness of this relationship across multiple specifications confirms that renewable energy deployment represents a high-leverage intervention for developing countries seeking green economy advancement.

Notably, the relationship between Markets & ESG Investment and overall performance strengthens with income level, demonstrating a coefficient of 0.107 (non-significant) for low-income countries but increasing to 0.173 ($p<0.05$) for upper-middle-income economies. This pattern suggests that as countries develop economically, financial mechanisms and market-based approaches become increasingly important enablers of green economy transitions. Conversely, the Environment dimension shows stronger associations with performance in low-income contexts (coefficient=0.184, $p<0.05$), indicating that natural resource management may provide more accessible pathways for early-stage green economy development.

5.3. Characteristics of High-Performing Developing Countries

Our third research question focused on identifying common characteristics and policy frameworks distinguishing high-performing developing countries. Costa Rica, as the sole high-performing developing country (GGEI=0.6444), exemplifies a comprehensive approach to green economy development. Its exceptional performance in electricity decarbonization (score=0.9656) stems from strategic investments in renewable energy that have achieved nearly 100% renewable electricity generation. Similarly, Ethiopia's strong performance (GGEI=0.5628) despite low-income status demonstrates how focused policy interventions in key areas—particularly renewable energy deployment and carbon-efficient development planning—can achieve substantial green economy outcomes despite resource limitations.

Several common characteristics distinguish the top-performing developing countries from lower-performing peers:

First, successful countries demonstrate policy continuity and long-term planning horizons that transcend electoral cycles. Costa Rica's multi-decade commitment to environmental protection and renewable energy has created an institutional foundation for sustained green economy advancement. Similarly, Ethiopia's Growth and Transformation Plan explicitly incorporates green economy objectives within national development strategies, ensuring policy coherence across sectors.

Second, high performers exhibit strategic selectivity in their green economy approaches, focusing investments in areas with maximum co-benefits rather than attempting comprehensive transformations with limited resources. Ethiopia's prioritization of hydropower development leverages existing natural resources while simultaneously addressing energy access, emissions reduction, and economic development objectives. This targeted approach allows for concentrated progress in high-impact areas rather than diffuse efforts across all green economy dimensions.

Third, effective governance arrangements emerge as critical enablers, particularly regarding policy coordination and implementation capacity. The regression results consistently demonstrate significant positive associations between governance quality and green economy performance (coefficient=0.021, $p<0.05$), even after controlling for income levels. High-performing countries have established dedicated institutional mechanisms for environmental policy coordination—such as Costa Rica's inter-ministerial climate change commission—that facilitate policy coherence and implementation effectiveness.

5.4. Navigating Resource Constraints and Development Challenges

Our fourth research question examined how resource constraints and development challenges influence green economy performance. The empirical evidence suggests a nuanced relationship between development challenges and green economy outcomes. While resource limitations certainly impact performance, strategic policy choices can partially offset these constraints.

The stratified analysis by income group reveals that different pathways to green economy advancement exist across development stages. For low-income countries, environmental protection (coefficient=0.184, $p<0.05$) and climate policy (coefficient=0.296, $p<0.01$) demonstrate the strongest associations with overall performance, suggesting these areas may offer accessible entry points despite resource limitations. As countries reach middle-income status, market mechanisms and investment factors become increasingly significant, indicating evolving priorities across development stages.

The divergent performance of countries with similar income levels—for instance, Ethiopia (GGEI=0.5628) versus Chad (GGEI=0.3794) among low-income economies—underscores that resource constraints alone do not determine green economy outcomes. Ethiopia's success despite limited resources demonstrates how strategic policy choices and effective implementation can overcome financial limitations. Similarly, the underperformance of resource-rich countries like Turkmenistan (GGEI=0.3182) highlights that resource availability without appropriate policy frameworks does not ensure green economy advancement.

The instrumental variables analysis provides further evidence that income level alone is not deterministic of green economy performance. After addressing endogeneity through geographic and historical instruments, GDP per capita loses statistical significance (coefficient=0.011, $p>0.1$), while governance quality and policy dimensions maintain significant associations with performance. This finding suggests that while development challenges influence green economy outcomes, they do not preclude substantial progress when accompanied by effective governance and strategic policy interventions.

5.5. Policy Implications for Accelerating Green Economy Transitions

Our final research question concerned targeted policy interventions that could most effectively accelerate green economy transitions in developing countries. The empirical findings, combined with case study insights, suggest several evidence-based recommendations.

First, prioritizing carbon efficiency improvements through sectoral interventions emerges as a high-leverage strategy. The strong association between GHG Emissions/GDP and overall performance (coefficient=0.148, $p<0.01$) indicates that policies targeting production efficiency, clean technology adoption, and energy productivity can yield substantial returns for green economy advancement. These interventions often generate economic co-benefits through reduced input costs and improved competitiveness, creating virtuous cycles that reinforce green economy transitions.

Second, renewable energy deployment represents a critical intervention point, particularly for early-stage green economy development. The consistent significance of electricity decarbonization across all model specifications (coefficient=0.086, $p<0.05$) demonstrates its foundational role in green economy transitions. Policy instruments that effectively mobilize renewable energy investment—such as tailored incentive structures, risk mitigation mechanisms, and enabling regulatory frameworks—can accelerate progress across multiple dimensions simultaneously.

Third, the regional heterogeneity in determinants of green economy performance suggests the need for contextually-tailored approaches. For African developing countries, carbon efficiency and electricity decarbonization demonstrate the strongest associations with performance, indicating these areas should receive policy prioritization. In contrast, Asian countries show stronger relationships between air quality management and overall performance, suggesting pollution control measures may offer particularly effective intervention points in this regional context. The statistically significant regional patterns in our regression models reinforce the importance of adapting green economy strategies to specific geographical contexts rather than applying uniform approaches.

Fourth, the income-stratified analysis provides evidence for differentiated policy approaches across development stages. For low-income countries, environmental protection and climate policy interventions show the strongest relationships with overall performance, offering accessible entry points despite resource limitations. As countries reach middle-income status, financial mechanisms and market-based approaches become increasingly important enablers of green economy transitions, suggesting the need for evolving policy priorities as development progresses.

Finally, the persistent significance of governance quality across all model specifications underscores the critical importance of institutional arrangements in enabling effective green economy transitions. The regression results consistently demonstrate positive associations between governance indicators and performance (coefficient=0.021, $p<0.05$), even after controlling for income levels and regional effects. This finding suggests that investments in policy coordination mechanisms, implementation capacity, and institutional effectiveness may yield substantial returns for green economy advancement, particularly when resources for technical interventions are constrained.

6. Conclusion

This study has examined the patterns, determinants, and implications of green economy performance across 93 developing countries, providing empirical evidence on pathways to sustainable development in resource-constrained settings. Through rigorous econometric analysis of GGEI data, complemented by case studies of high-performing countries, we have identified key factors that enable green economy advancement despite development challenges.

Our findings demonstrate that developing countries exhibit substantial heterogeneity in green economy performance, with European and Latin American nations generally outperforming their counterparts in other regions. Importantly, this analysis reveals that income level alone does not determine green economy success—as evidenced by Ethiopia's strong performance despite low-income status and the underperformance of several upper-middle-income economies. Rather, strategic policy choices, effective governance arrangements, and targeted investments in high-leverage sectors emerge as critical enablers of green economy transitions.

The empirical results identify carbon efficiency (GHG Emissions/GDP) and clean energy deployment (Electricity & Heat decarbonization) as the strongest determinants of overall green economy performance. These findings suggest that developing countries should prioritize interventions in these areas to maximize returns on limited resources. Furthermore, the analysis reveals evolving pathways across development stages: environmental protection and climate policy demonstrate stronger relationships with performance in low-income contexts, while market mechanisms and investment factors become increasingly important at higher income levels.

These insights hold significant implications for policymakers, development agencies, and other stakeholders engaged in sustainability transitions. First, they challenge the conventional assumption that substantial green economy advancement requires high income levels or abundant resources. Second, they provide an evidence-based foundation for policy prioritization in resource-constrained contexts, enabling more strategic allocation of limited resources. Third, they highlight the importance of tailoring approaches to specific regional contexts and development stages rather than applying uniform strategies across all developing countries.

Our findings also contribute to theoretical understanding of green economy transitions by demonstrating that multiple pathways exist beyond the conventional "grow first, clean up later" approach. The success of countries like Costa Rica and Ethiopia illustrates that developing economies can pursue growth models that integrate environmental sustainability and social inclusion from early development stages. Moreover, the persistent significance of governance quality across our models underscores that institutional factors may be as important as technical interventions in enabling effective green economy transitions.

This study has several limitations that future research should address. The cross-sectional nature of our primary analysis limits causal inferences, although our instrumental variables approach partially mitigates endogeneity concerns. Data availability constraints for some developing countries may also introduce selection biases. Future research would benefit from longitudinal studies tracking green economy transitions over time, more granular analysis of policy implementation processes, and examination of the political economy factors that enable or constrain green economy advancement in developing contexts.

Despite these limitations, our research makes a substantive contribution to understanding how developing countries can navigate the complex challenges of sustainable development. By identifying specific high-leverage dimensions and contextually-appropriate pathways, this study provides practical guidance for accelerating green economy transitions across diverse developing country contexts. These insights are particularly timely as countries seek to rebuild economies in more sustainable ways following global disruptions and amid increasing climate imperatives.

Ultimately, this research demonstrates that green economy transitions are not luxury pursuits reserved for wealthy nations but represent viable—and indeed necessary—development pathways for countries across the income spectrum. With strategic approaches tailored to their specific contexts, developing countries can achieve meaningful progress toward sustainability objectives even amid resource constraints, potentially leapfrogging carbon-intensive development stages that characterized historical transitions in advanced economies. This finding offers both practical guidance for policymakers and renewed optimism regarding the feasibility of inclusive, sustainable development pathways in the Global South.

References

Arellano, M., & Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. The review of economic studies, 58(2), 277-297.

Barbier, E. B. (2012). The green economy post Rio+20. Science, 338(6109), 887-888. https://doi.org/10.1126/science.1227360

Barbier, E. B., & Burgess, J. C. (2020). Sustainability and development after COVID-19. World Development, 135, 105082. https://doi.org/10.1016/j.worlddev.2020.105082

Bina, O. (2013). The green economy and sustainable development: An uneasy balance? Environment and Planning C: Government and Policy, 31(6), 1023-1047. https://doi.org/10.1068/c1310j

Blundell, R., & Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. Journal of econometrics, 87(1), 115-143.

Borras, S. M., Franco, J. C., Gómez, S., Kay, C., & Spoor, M. (2013). Land grabbing in Latin America and the Caribbean. Journal of Peasant Studies, 39(3-4), 845-872. https://doi.org/10.1080/03066150.2012.679931

Bowen, A., & Hepburn, C. (2014). Green growth: An assessment. Oxford Review of Economic Policy, 30(3), 407-422. https://doi.org/10.1093/oxrep/gru029

Bruederle, A., & Hodler, R. (2018). Nighttime lights as a proxy for human development at the local level. PLOS ONE, 13(9), e0202231. https://doi.org/10.1371/journal.pone.0202231

Clement, F. (2010). Analysing decentralised natural resource governance: Proposition for a "politicised" institutional analysis and development framework. Policy Sciences, 43(2), 129-156. https://doi.org/10.1007/s11077-009-9100-8

Costanza, R., Cumberland, J., Daly, H., Goodland, R., & Norgaard, R. (1997). An introduction to ecological economics. St. Lucie Press.

Daly, H. E. (1997). Beyond growth: The economics of sustainable development. Beacon Press.

Death, C. (2014). The green economy in South Africa: Global discourses and local politics. Politikon, 41(1), 1-22. https://doi.org/10.1080/02589346.2014.885668

Erdoğdu, A., Dayi, F., Yanik, A., Yildiz, F., & Ganji, F. (2025). Innovative solutions for combating climate change: Advancing sustainable energy and consumption practices for a greener future. Sustainability, 17(6), 2697.

Faccer, K., Nahman, A., & Audouin, M. (2014). Interpreting the green economy: Emerging discourses and their implications for the Global South. Development Southern Africa, 31(5), 642-657. https://doi.org/10.1080/0376835X.2014.933700

Fankhauser, S., Sehlleier, F., & Stern, N. (2008). Climate change, innovation and jobs. Climate Policy, 8(4), 421-429. https://doi.org/10.3763/cpol.2008.0513

Ferguson, P. (2015). The green economy agenda: Business as usual or transformational discourse? Environmental Politics, 24(1), 17-37. https://doi.org/10.1080/09644016.2014.919748

Ferraro, P. J., Hanauer, M. M., & Sims, K. R. E. (2011). Conditions associated with protected area success in conservation and poverty reduction. Proceedings of the National Academy of Sciences, 108(34), 13913-13918. https://doi.org/10.1073/pnas.1011529108

Geels, F. W., Sovacool, B. K., Schwanen, T., & Sorrell, S. (2017). Sociotechnical transitions for deep decarbonization. Science, 357(6357), 1242-1244. https://doi.org/10.1126/science.aao3760

Grubler, A. (2020). Technological and Societal Changes and Their Impacts on Resource Production and Use. BHM Berg-und Hüttenmännische Monatshefte, 165(4), 199-204.

Hochstetler, K. (2020). Political economies of energy transition: Wind and solar power in Brazil and South Africa. Cambridge University Press.

Huang, B., Yong, G., Zhao, J., Domenech, T., Liu, Z., Chiu, S. F., McDowall, W., Bleischwitz, R., Liu, J., & Yao, Y. (2019). Review of the development of China's eco-industrial park standard system. Resources, Conservation and Recycling, 140, 137-144. https://doi.org/10.1016/j.resconrec.2018.09.013

Jänicke, M. (2012). "Green growth": From a growing eco-industry to economic sustainability. Energy Policy, 48, 13-21. https://doi.org/10.1016/j.enpol.2012.04.045

Jayachandran, S., de Laat, J., Lambin, E. F., Stanton, C. Y., Audy, R., & Thomas, N. E. (2017). Cash for carbon: A randomized trial of payments for ecosystem services to reduce deforestation. Science, 357(6348), 267-273. https://doi.org/10.1126/science.aan0568

Jerven, M. (2013). Poor numbers: How we are misled by African development statistics and what to do about it. Cornell University Press.

Köhler, J., Geels, F. W., Kern, F., Markard, J., Onsongo, E., Wieczorek, A., Alkemade, F., Avelino, F., Bergek, A., Boons, F., Fünfschilling, L., Hess, D., Holtz, G., Hyysalo, S., Jenkins, K., Kivimaa, P., Martiskainen, M., McMeekin, A., Mühlemeier, M. S., ... Wells, P. (2019). An agenda for sustainability transitions research: State of the art and future directions. Environmental Innovation and Societal Transitions, 31, 1-32. https://doi.org/10.1016/j.eist.2019.01.004

Levin, K., Cashore, B., Bernstein, S., & Auld, G. (2012). Overcoming the tragedy of super wicked problems: Constraining our future selves to ameliorate global climate change. Policy Sciences, 45(2), 123-152. https://doi.org/10.1007/s11077-012-9151-0

Lockwood, M. (2015). Fossil fuel subsidy reform, rent management and political fragmentation in developing countries. New Political Economy, 20(4), 475-494. https://doi.org/10.1080/13563467.2014.923826

McAfee, K. (2016). Green economy and carbon markets for conservation and development: A critical view. International Environmental Agreements: Politics, Law and Economics, 16(3), 333-353. https://doi.org/10.1007/s10784-015-9295-4

Merino-Saum, A., Clément, J., Wyss, R., & Baldi, M. G. (2020). Unpacking the green economy concept: A quantitative analysis of 140 definitions. Journal of Cleaner Production, 242, 118339. https://doi.org/10.1016/j.jclepro.2019.118339

Mol, A. P. J., Sonnenfeld, D. A., & Spaargaren, G. (Eds.). (2020). The ecological modernisation reader: Environmental reform in theory and practice. Routledge.

Monasterolo, I., Battiston, S., Janetos, A. C., & Zheng, Z. (2017). Vulnerable yet relevant: The two dimensions of climate-related financial disclosure. Climatic Change, 151(2), 289-302. https://doi.org/10.1007/s10584-018-2289-x

Nahman, A., Mahumani, B. K., & de Lange, W. J. (2016). Beyond GDP: Towards a green economy index. Development Southern Africa, 33(2), 215-233. https://doi.org/10.1080/0376835X.2015.1120649

Newell, P., & Phillips, J. (2016). Neoliberal energy transitions in the South: Kenyan experiences. Geoforum, 74, 39-48. https://doi.org/10.1016/j.geoforum.2016.05.009

Newell, P., Paterson, M., & Craig, M. (2021). The politics of green transformations: An introduction to the special section. New political economy, 26(6), 903-906.

Nhamo, G. (2013). Green economy readiness in South Africa: A focus on the national sphere of government. International Journal of African Renaissance Studies, 8(1), 115-142. https://doi.org/10.1080/18186874.2013.834628

Nhemachena, C., Matchaya, G., Nhemachena, C. R., Karuaihe, S., Muchara, B., & Nhlengethwa, S. (2018). Measuring baseline agriculture-related sustainable development goals index for Southern Africa. Sustainability, 10(3), 849. https://doi.org/10.3390/su10030849

Olsson, P., Galaz, V., & Boonstra, W. J. (2014). Sustainability transformations: A resilience perspective. Ecology and Society, 19(4), 1. https://doi.org/10.5751/ES-06799-190401

Onifade, O. C., & Olanrewaju, S. O. (2020). Investigating performances of some statistical tests for heteroscedasticity assumption in generalized linear model: A Monte Carlo simulations study. Open Journal of Statistics, 10(3), 453-493.

Pearce, D. W., Markandya, A., & Barbier, E. B. (1989). Blueprint for a green economy. Earthscan.

Pirgmaier, E. (2020). Consumption corridors, capitalism and social change. Sustainability: Science, Practice and Policy, 16(1), 274-285. https://doi.org/10.1080/15487733.2020.1829846

Ragulina, Y. V., Dubova, Y. I., Litvinova, T. N., & Balashova, N. N. (2022). The environmental AI economy and its contribution to decarbonization and waste reduction. Frontiers in Environmental Science, 10, 914003.

Ringius, L. (2002). Soil carbon sequestration and the CDM: Opportunities and challenges for Africa. Climatic Change, 54(4), 471-495. https://doi.org/10.1023/A:1016108215242

Sonnenschein, J., & Mundaca, L. (2016). Decarbonization under green growth strategies? The case of South Korea. Journal of Cleaner Production, 123, 180-193. https://doi.org/10.1016/j.jclepro.2015.08.060

Spratt, S., Dong, W., Krishna, C., Sagar, A., & Qi, Y. (2014). What drives wind and solar energy investment in India and China? Institute of Development Studies.

Stern, D. I., & Jotzo, F. (2010). How ambitious are China and India's emissions intensity targets? Energy Policy, 38(11), 6776-6783. https://doi.org/10.1016/j.enpol.2010.06.049

Stiglitz, J. E., Sen, A., & Fitoussi, J.-P. (2009). Report by the Commission on the Measurement of Economic Performance and Social Progress. Commission on the Measurement of Economic Performance and Social Progress.

Tanner, T., & Allouche, J. (2011). Towards a new political economy of climate change and development. IDS Bulletin, 42(3), 1-14. https://doi.org/10.1111/j.1759-5436.2011.00217.x

UNEP (United Nations Environment Programme). (2011). Towards a green economy: Pathways to sustainable development and poverty eradication. UNEP.

Vázquez-Brust, D., Smith, A. M., & Sarkis, J. (2014). Managing the transition to critical green growth: The 'Green Growth State'. Futures, 64, 38-50. https://doi.org/10.1016/j.futures.2014.10.005

Volz, U., Böhnke, J., Eidt, V., Knierim, L., Richert, K., & Roeber, G. M. (2020). Inclusive green finance: From concept to practice. Alliance for Financial Inclusion and Sustainable Banking Network.

Wunder, S., Brouwer, R., Engel, S., Ezzine-de-Blas, D., Muradian, R., Pascual, U., & Pinto, R. (2018). From principles to practice in paying for nature's services. Nature Sustainability, 3(12), 931-934. https://doi.org/10.1038/s41893-020-0599-1