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# GREEN TAXATION AND SUSTAINABLE GDP GROWTH IN EMERGING ECONOMIES: AN EMPIRICAL ANALYSIS

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**Abstract**

*This study examines the impact of green taxation on sustainable GDP growth in 22 emerging economies from 2005 to 2023, focusing on how environmental taxes interact with institutional quality, sectoral dynamics, and long-term economic growth. Grounded in theories like the Environmental Kuznets Curve and Porter Hypothesis, it develops a multidimensional framework incorporating green fiscal policies, institutional informality, and sectoral effects. Employing econometric techniques such as Fixed Effects, Random Effects, System GMM, and ARDL models alongside Principal Component Analysis to handle multicollinearity, the research analyses panel data to capture both immediate and delayed effects. Results show green taxation lacks significant short-term influence on GDP, but institutional strength, sectoral diversity, and sustainability efforts, especially targeted investments, play key roles in promoting growth. The study highlights that green taxes are more effective over the long run when combined with strong governance, transparent revenue recycling, and integration with broader development goals. It recommends embedding the environmental tax reforms within institutional and sectoral frameworks to improve effectiveness and public acceptance. This emphasizes the need to address informal sectors and ensure social equity through inclusive fiscal designs. By elucidating the complex nexus between fiscal policy and sustainable development, the research offers valuable policy guidance to support emerging economies in their transition toward green growth.*

**Keywords:** Green Taxation, Sustainable Growth, Institutional Quality, Revenue Recycling, Panel Data Analysis

## 1. Introduction

Taxation can be viewed as one of the most important components of government policy that not only influences behaviour and income distribution but also affects the growth and development of the economic system (Rahman, 2023). The last few years have been marked by the transformation of the concept of conservation beyond sustainability and toward increased degradation of the environment, climate, and loss of economic resources. Economists and policymakers are coming to the realization that the old modes of economic expansion using fossil fuels and environmentally harmful practices are not pertinent in the long run. Green taxation is currently being applied by governments and policymakers as a strategic tool for aligning intentions and ecological responsibilities (Perepechkina et al., 2024). Green taxation by economic bodies is exerted on activities that harm and damage the environment and strengthen cleaner production and consumption (Mpofu, 2022). Alongside the polluter-pays principle, these green taxes serve as a caution because those who commit to environmental destruction should be subject to paying the costs associated with environmental damage (Soufiene et al., 2025). The academic background of green taxes includes the "double dividend" theory, according to which green taxes could be beneficial to the economy and the environment at the same time (Greaver, 2021). Green taxation is a valuable contribution to solving market failure by considering the risk of environmental externalities that lead to the optimal allocation of scarce resources and the enhancement of economic growth (Chien et al., 2021). Research studies on G20 economies have mentioned that the introduction of green taxation leads to environmental sustainability without hindering economic growth and expansion (Bashir et al., 2024). Moreover, studies carried out on developing countries provided insight that green taxation does more than contribute to social sustainability; the tax enhances the sustainability of the environment with less pronounced links to economic sustainability (Uddin et al., 2023).

The overriding point in terms of tax policies is that they have a time effect on economic indicators like gross domestic product (GDP). Tax reforms always possess a lag effect, meaning that a complete effect takes time to materialize. This aspect of time is important in emerging economies because of many constraints such as institutional rigidities. For example, structural arrangements may restrain the response of economic players to new taxation policies and legislation. In one study conducted on South Asian developing economies, it was found that an initial increase in the taxation profile had a negative effect on GDP. This adverse effect on GDP growth wears off within ten years (Akram & Padda, 2009). This insight prioritizes the importance of legislators and policymakers in government adopting a long-term approach by disregarding short-term reductions in relation to the efficacy of taxation policies.

The efficiency and effectiveness of green taxation implementation are situational and are based on the broad spectrum of government and institutional structures in which it is implemented. In developing countries, many aspects—such as institutional quality—are important intermediary mechanisms that can provide a fair green growth effect with green taxes. The commitment of tax systems to the local institutional needs of emerging economies offers the highest potential for GDP growth. Institutions that are strong and well governed are determinants of the success of green taxation in achieving desired goals. Recent studies also show that institutions with good governance are more likely to be successful than those with poor governance. It is, therefore, relevant to address this attributed variation of institutions in designing the taxation policies of emerging countries to achieve an optimum GDP result.

Tax policies on different sectors of the economy have to be analysed with precision. Ahmed et al. (2024) demonstrate that global uncertainties can constrain insurance activity in major economies, suggesting that uncertainty and institutional conditions may influence the capacity of economic agents to respond to policy reforms. In most developing countries, the main issue in distributing primary resources arises from imbalances in how different economic groups are treated through taxation (Gupta & Jalles, 2022). The taxation regime allows agriculture to enjoy exemptions, despite its significant economic contribution, while service and industrial activities face an increased tax burden. Unequal taxation and unequal treatment encourage investments to be undertaken in industries that pay higher rates of taxes, hence reducing the overall performance of the economy. There is additional implementation challenges introduced with the implementation of green taxes because manufacturing-intensive businesses and energy-intensive industries have had to bear negative consequences more frequently (Shen & Zhang, 2022). To design balanced tax formulae to enhance economic growth without majorly affecting business heavily, there is a need to understand all these differences in business sectors well (Aijaz et al., 2023).

Taxation systems between countries do not resemble each other because countries sustain varied levels of administrative capacities as well as political choices, economic positions, and institutional instruments. Cross-country tax examination is an important analytical framework that could not only research the tax construction process of countries but also its related tax policy impacts on development performance. The ratio between total tax revenue and GDP is a crucial tool of analysis to consider the ability of tax collection against the level of the economy because this indicator is actively used by experts as a tool of fiscal analysis and assessment of development. Nations that have high tax-to-GDP ratios have better capacity in both provision of public goods and macroeconomic stabilization (Barro & Bianchi, 2023). Moreover, a huge burden of taxes in emerging economies repels investors and prevents economic growth (Mpofu et al., 2022). Good governance, particularly regulatory quality, control of corruption, and the rule of law, can moderate the environmental consequences of economic growth (Golo et al., 2026).

A set of empirical studies showed that government institutions possess greater potential to contribute to sustainable development and economic growth once tax collections rise to 15% of GDP. Pakistan's tax regime remains bogged down with a long-standing challenge, as its tax-to-GDP ratio remains at 11%, less than the tax mix of the region. The stable and quality amount of taxation systems provides equality while increasing equity, thereby creating the required levels of sustainable economic success (Ostry et al., 2014). A high level of application of indirect taxation policies in terms of the whole income level creates adverse impacts that may affect poor societies adversely and slow down the buying power of vulnerable categories of the population. Many studies have proven that indirect taxes contribute greater GDP growth compared to direct taxes in the Pakistani economy. When indirect tax is increased by 1%, more growth of 0.49% is created; when direct taxes are increased by 1%, growth is raised by 0.22%. The research findings prove that tax composition is critical to shaping economic performance (Munir et al., 2023). The success of taxation as policy is mainly influenced by the per capita GDP achieved by the country. High-income countries are more effective in charging taxes due to proper enforcement of complex regulations and avoidance of tax fraud owed to their administrative capacity.

Tax systems, in this case, can be wisely used to facilitate green investments, innovation, and social development. Conversely, low-income countries may be forced to decide between expanding the base and retaining dynamism, especially in informal sectors of the economy (Mpofu, 2021). Capacity building and phased tax reforms should be of utmost importance to the economic growth of those countries without making any deterring effect on the willingness of private initiatives. Despite growing interest in green fiscal reform on the global stage, empirical evidence on the role of green taxation in encouraging green economic growth is insufficient in Pakistan (Zahra et al., 2022). Regardless of research findings on the environmental and fiscal outcomes of green taxes in developed economies, little is known regarding their effect on the growth path of GDP in developing economies. This could be further narrowed down to the existence of structural problems such as tax collection capacity, institutional abnormalities, and sector misalignment. In addition, the current literature disregards the delayed effect of tax policies by assuming that taxation is a fixed input rather than a dynamic process that takes time to alter. This time factor is critical in emerging nations where the transfer of policy and five- to ten-year investment cycles may have a great impact on economic output.

### *1.1 Research Gap*

Most comparative studies using the taxation-to-GDP ratio prefer broader regional or income categories and are not relevant to cross-country examination in emerging nations, impeding knowledge about varieties in fiscal capacity, environmental subjection, and manufacturing plant. Sectoral aspects are also not efficiently covered, especially in Pakistan, as industry, energy, and agriculture are variously sensitive to tax measures and generate different outputs to GDP (Ali et al., 2024). This leaves a large missing link in comprehending how tax loads and tax benefits are linked to enhance sustainability and economic growth cohesively.

In Pakistan, empirical studies at times lack enough data or do not consider environmental conditions as elements that influence fiscal policies (Zahra et al., 2022). Consequently, a multi-fold analysis that applies time-lag modelling, cross-national comparison of developing economies, and sector-wise breakdown is required to offer practical recommendations to lawmakers. In addition, the tax composition factor, the role of direct and indirect taxes in emerging countries, and their effect on GDP sustainability are also to be analysed (Ajeigbe et al., 2024). Filling this research gap is very important to develop an effective green taxation framework where fiscal policy is integrated with the objective of green economic growth in Pakistan and other developing nations.

### *1.2 Significance of Study*

The study presents academic as well as practical significance. Academically, it helps enlarge the corpus of literature on green taxes by covering emerging economies with a particular focus on Pakistan and other developing countries, which are usually overlooked in empirical research (Bashir et al., 2021). Policy-wise, the findings of this study will be crucial to governments and global organizations intending to ensure ecologically sustainable tax frameworks without sacrificing economic growth. In Pakistan, where the tax-to-GDP ratio is low along with the increased occurrence of environmental degradation, determining the sector-specific and lagged effects of green taxation can pave the way to introduce equitable and effective tax policies (Ali et al., 2024). Cross-country comparisons would serve as a benchmark of performance for Pakistan in comparison to the rest of the emerging economies. This would guide upcoming fiscal and environmental policies. The overall goal of this study is to advance the idea of green fiscal policy that combines economic development with sustainability by targeting important Sustainable Development Goals (SDGs) such as SDG 8 (Decent Work and Economic Growth) and SDG 13 (Climate Action).

### *1.3 Research Objectives*

The following are the goals of this quantitative research study:

1. To analyse the trend analysis for green taxation and sustainable GDP growth in emerging economies.
2. To examine the effect of the lagged relationship between green taxation and GDP growth in emerging economies.
3. To examine the role of the sectoral effect of green taxes on sustainable growth of GDP.
4. To make policy recommendations to obtain resilient green taxation to maintain growth of GDP in emerging economies.

### *1.4 Framing Research Questions*

This study seeks to understand how green taxation works in emerging economies. It first asks how differences in tax design, such as bases, rates, and earmarking, affect outcomes like GDP growth, emissions, and income equity. It then looks at how institutions, including governance quality, regulation, and political stability, shape these effects. Another focus is on feedback loops, for example, when tax revenues are reinvested in clean infrastructure or social safety nets to reinforce sustainability and inclusiveness. This is crucial because over 80% of global GDP growth now comes from emerging economies such as China, India, and Brazil, which also account for 60% to 70% of emissions (UNDP, 2021; Bashir et al., 2024). While these economies show signs of the Environmental Kuznets Curve, they often face weak fiscal capacity, large informal sectors, and political constraints, which hinder reforms (Loayza, 2016; IMF, 2023). Many existing models fail to reflect these realities, making a tailored analysis essential. This study addresses these gaps by examining green taxation, economic growth, and the institutional factors that mediate their link in developing contexts.

## 2. Review of Literature

### *2.1 Evolution of Green Taxation*

Scandinavian countries were early leaders in green tax reforms, with Sweden's 1991 carbon tax serving as a model (Andersen, 2010). Green taxation, often called environmental taxation, seeks to internalize environmental costs by discouraging polluting activities and promoting sustainability (OECD, 2017). The EU has widely adopted such measures, especially energy-related levies that encourage shifts from fossil fuels to renewables (Streimikiene et al., 2018). Progress in developing countries is slower, but nations like China, India, and South Africa have introduced environmental taxes (Wang et al., 2018). The EU harmonizes minimum energy tax rates to align fiscal policies with the Paris Agreement and SDGs (European Commission, 2019; OECD, 2019). Taxes often take forms such as carbon, energy, water, and waste levies, reflecting the "polluter pays" principle (OECD, 2021). Empirical evidence shows mixed results. Some studies find positive links between environmental taxes, corporate taxation, and SDG progress (Halim & Rahman, 2022), or between green finance, renewable energy, and $CO_2$ reduction (Khan et al., 2022). Others stress the importance of institutional quality, innovation, and collaboration (Shen & Zhang, 2022; Okombi & Babouama, 2024). For instance, in Bangladesh, green taxes improved sustainability but had limited economic benefits without energy efficiency measures (Uddin et al., 2023).

Evidence from the G-20 suggests a "double dividend," boosting sustainability without hurting growth (Bashir et al., 2024), though structural inefficiencies limit effects in Morocco (Benkejiane et al., 2024). Green taxes also promote circular economy practices, including waste reduction and resource efficiency (Dokholyan et al., 2024). Despite wider adoption, gaps remain between developed and developing countries, with success relying on tailored policies, financing, and integration with broader green growth strategies (Soufiene et al., 2025).

*2.2 Conceptual Model*

**2.2.1 Theoretical Development**

***2.2.1.1 Environmental Kuznets Curve (EKC).*** The Environmental Kuznets Curve suggests an inverted U-shaped relationship between environmental degradation and income per capita. In the early stages of economic growth, industrialization and resource exploitation increase pollution. At higher income levels, demand for a cleaner environment rises, leading to cleaner technologies and stricter regulations that reduce pollution (Grossman & Krueger, 1995). Within this framework, green taxation can accelerate the shift to the downward slope of the curve by internalizing external costs and encouraging investment in cleaner production. While empirical evidence supports the EKC in many developed and emerging economies (Dinda, 2004), its applicability in developing countries remains debated.

***2.2.1.2 Porter Hypothesis.*** Proposed by Michael Porter in the 1990s, the Porter Hypothesis argues that well-designed environmental regulations, including green taxes, can stimulate innovation, turning compliance costs into competitive advantages (Porter & Linde, 1995). This contrasts with the traditional view that regulations impose only costs on firms. Evidence shows that such policies can increase research and development, as in U.S. manufacturing (Jaffe & Palmer, 1997) and OECD nations (Lanoie et al., 2011). In emerging economies, barriers like limited capital, weak intellectual property protection, and inadequate technology infrastructure may hinder innovation. However, targeted tax incentives and subsidies for green technologies can help overcome these challenges.

***2.2.1.3 Double Dividend Hypothesis.*** The double dividend hypothesis posits that environmental taxes can deliver two benefits: improved environmental quality by reducing pollution, and economic gains by using tax revenues to reduce distortionary taxes and enhance economic performance (Bovenberg & Mooij, 1994). While the environmental benefits are well supported, evidence for strong economic benefits is mixed (Bosquet, 2000). In developing economies, recycling revenues through green subsidies, infrastructure investment, or reductions in regressive taxes can improve both equity and efficiency (Fullerton & Metcalf, 1998).

***2.2.1.4 Sustainable Development Theory.*** Sustainable development, as defined in the Brundtland Report (1987), is development that meets present needs without compromising the ability of future generations to meet their own. It integrates economic, social, and environmental dimensions. Green taxation aligns with this theory by pricing environmental externalities, encouraging sustainable production and consumption, and generating revenues that can be reinvested into infrastructure, education, and healthcare. Empirical evidence indicates that economies adopting environmentally sound fiscal policies, such as carbon taxes, can achieve better sustainability outcomes with lower economic costs (OECD, 2019). For developing countries, integrating sustainable development principles into tax policy is crucial for balancing economic growth and environmental protection.

**2.2.2 Empirical Development.** Green taxation is now seen as a key policy tool for curbing environmental degradation and fostering sustainable growth, though its effects on GDP vary with tax design, institutional capacity, and development levels. Evidence shows that well-designed green taxes can stimulate innovation, improve efficiency, and support growth when revenues are recycled. For example, carbon taxes in high-income countries often enhance growth (Metcalf & Stock, 2020), and a potential carbon tax in Pakistan could both cut emissions and raise GDP if revenues reduce distortionary taxes (Alvi & Rehman, 2018). Studies confirm such taxes can boost productivity through cleaner technologies, but poor design or rushed implementation may harm output and jobs (Bento & Jacobsen, 2007), as seen in South Africa (Montmasson-Clair, 2019) and Eastern Europe (Markandya et al., 2002). Success depends on institutional capacity and revenue recycling.

**2.2.3 Green Taxation in New Economies.** Green taxation is gaining recognition as a way to align growth with environmental protection in developed countries, while its adoption in emerging economies, like China, India, Brazil, and South Africa, remains recent and constrained by institutional, political, and economic barriers (Ekins & Speck, 2014). Using support from organizations like the International Monetary Fund (IMF), United Nations Environment Programme (UNEP), and the World Bank, these countries have introduced measures like China's Environmental Protection Tax Law–2018 (Zhou et al., 2020), India's coal cess–2010 (Shukla et al., 2017), Brazil's renewable energy incentives, and South Africa's phased carbon tax (Montmasson-Clair, 2019). Yet fossil fuel subsidies, weak governance, and political resistance often undermine progress (IMF, 2021). Institutional capacity appears to be a key factor. Brazil's decentralization and India's inconsistent enforcement hindered reforms (Dubash & Ghosh, 2019), while South Africa's carbon tax was delayed by industry and citizen resistance (Boull, 2019).

Global agencies now promote carbon taxes and revenue recycling, with programs like the IMF's Climate Macroeconomic Assessment Program, UNEP's Green Fiscal Policy Network, and the World Bank's Partnership for Market Implementation (IMF, 2021; World Bank, 2022). However, these approaches differ. China integrates carbon markets (Wang et al., 2021), India relies on sector-specific levies (Shukla et al., 2017), Brazil favours incentives (Santos & Vale, 2019), and South Africa's tax remains constrained by coal dependency (Montmasson-Clair, 2019). Similarly, sectoral impacts also vary. In energy, Sweden's carbon tax reduced emissions without hurting competitiveness (Andersson, 2019), while the UK's Climate Change Levy boosted manufacturing efficiency (Martin et al., 2014). Emerging economies face slower transitions due to coal reliance, as in South Africa and India (Cloete, 2020; Dubash & Ghosh, 2019). Industry often bears costs, yet under the Porter Hypothesis, well-crafted green taxes can spur eco-innovation, as seen in the EU and Germany (Porter & Linde, 1995; Costantini & Mazzanti, 2012; OECD, 2010). Agriculture shows mixed outcomes. Denmark's nitrogen tax cut fertilizer use, but subsidies elsewhere offset gains, highlighting the value of combining taxes with green subsidies (UNEP, 2022). Transport taxes reduced emissions in Sweden, Germany, and the UK (Harding, 2014), but in Indonesia and Nigeria, subsidy removal and fuel tax hikes triggered protests, underscoring the need for social offsets (IMF, 2021). Firm size also matters. Large companies adapt cleaner technologies, while SMEs struggle without support. Targeted measures like tax credits and simplified compliance help, as shown in the EU Green Deal's assistance for SMEs (OliEuropean Commission, 2020).

***2.2.3.1 Social and Environmental Consequences of Green Taxes.*** Green taxation, designed to address environmental deterioration and climate change, carries wide social and environmental implications. While its main purpose is to internalize environmental costs, its influence also extends to income distribution, public behaviour, and ecosystem conditions. Understanding these impacts is essential for shaping fair and effective tax regimes that inspire public support and drive real environmental improvements.

One of the most debated concerns is the regressive effect of green taxation. Taxes on fossil fuels, electricity, and basic production often weigh more heavily on lower-income households, which spend larger portions of their income on energy and transport. Without corrective measures, such taxes risk deepening poverty and inequality. Evidence shows that fuel and carbon taxes can increase income disparities in both developed and developing economies. For example, Bento et al. (2009) found gasoline taxes in the USA to be regressive, particularly affecting rural and low-income households, while Sterner (2012) showed that fuel taxes in developing economies can reduce emissions but harm the poor if revenues are not recycled.

To counter these inequities, revenue recycling is widely recommended. Options include cash transfers, reducing other regressive taxes, or subsidizing services for communities (Coady et al., 2015). In British Columbia, Canada, a revenue-neutral carbon tax helped offset burdens by providing rebates and tax reductions, ultimately benefiting low-income groups (Murray & Rivers, 2015).

**2.2.4 Literature Gaps in Green Taxation and GDP Growth.** Although research on green taxation and sustainable development is growing, important gaps in emerging economies remain unaddressed. Much of the literature focuses on short-term effects such as emissions, energy intensity, or GDP changes, but long-term impacts on structural change, innovation, and employment are rarely examined. For example, Sweden's carbon tax cut emissions without hurting GDP (Andersson, 2019), and Metcalf and Stock (2020) analysed short-run price elasticities, yet both overlooked intergenerational and structural outcomes. As Fullerton and Monti (2013) note, ignoring adaptation over time can misrepresent the true trade-offs of environmental taxes.

The limitations of data deepen the problem. Most studies rely on OECD comparisons, while developing countries lack detailed fiscal reporting on green revenues or subsidies (IMF, 2019). This bias hides contextual realities. For instance, although Brazil and India have enacted levies, little econometric work measures their subnational effects (OECD, 2021). Informality, central in emerging economies, is often ignored even though it undermines tax effectiveness by shifting activities outside regulation (Loayza, 2016). Fuel taxes can disproportionately affect informal workers such as rickshaw drivers or small transport operators. In Sub-Saharan Africa and South Asia, informal agricultural and industrial activities reliant on biomass or diesel often remain untaxed, leaving emissions unpriced (Blackman, 2010).

Finally, research rarely integrates economic, environmental, and social dimensions. Many studies focus only on $CO_2$ reductions or GDP, neglecting links to income distribution, health, or resilience. While CGE models have explored tax effects in the EU (Böhringer et al., 2012), similar frameworks are missing in Africa, Asia, and Latin America. UNEP (2021) stresses that policies must consider multidimensional outcomes such as equity, energy poverty, and SDGs. Co-benefits like cleaner air and reduced healthcare costs, often ignored, can significantly strengthen cost–benefit assessments (Akbar et al., 2021).

In sum, advancing green taxation research requires longitudinal studies, enhanced data in emerging economies, explicit treatment of informality, and use of integrated frameworks. Addressing these gaps will make policies more balanced, realistic, and effective.

***2.2.4.1 Integration of Empirical and Theoretical Approaches.*** Historically, empirical and theoretical literature on sustainable development has tended to remain fragmented, often focusing on individual aspects of development such as economic growth, environmental quality, or social equity, rather than addressing their interconnections. Many studies either concentrated solely on the trajectories of GDP or were confined to analysing environmental degradation without considering the broader socioeconomic context. Only in rare and exceptional cases has the literature taken an integrated approach encompassing all three dimensions—economic, environmental, and social—simultaneously (Bashir et al., 2024; Fullerton & Monti, 2013). This lack of holistic perspective is especially problematic in the context of emerging economies, where development challenges are deeply interconnected. One significant constraint in this context is the scarcity of reliable data, especially in tracking informal economic activities that often escape official statistics and government oversight. Informality is prevalent in many emerging economies, distorting both policy formulation and implementation, and therefore limiting the reliability of empirical studies (Loayza, 2016). This disconnect between data systems and ground realities has created gaps in both theoretical modelling and practical policy applications.

***2.2.4.2 Theoretical Models and Extensions.*** Contemporary analytical frameworks increasingly rely on Computable General Equilibrium (CGE) and Integrated Assessment Models (IAMs), such as the Environment–Energy–Economy Model (ENVEEM), as foundational tools for evaluating green taxation impacts. These models have been adapted to better reflect the structural realities of emerging economies, where institutional weaknesses, high levels of informality, and revenue constraints complicate policy effectiveness (Gurkan, 2003; Qayum & Gupta, 2014). ENVEEM has been expanded to include additional modules beyond the traditional economic–environment–energy (3E) nexus, incorporating elements such as institutional quality, sectoral diversity, and mechanisms for revenue recycling. This adaptation enables a more nuanced exploration of how taxation policies interact with sociopolitical structures and how recycled revenues can be reinvested into sustainable infrastructure and social equity initiatives. As such, the model evolves into a more holistic planning tool that is uniquely suited to the diverse and dynamic challenges faced by emerging economies.

***2.2.4.3 Research Gaps and Emerging Needs.*** Despite promising developments, significant research gaps continue to hinder the formulation of an effective green tax policy in emerging economies. Studies that examine the long-term effects of environmental taxation on structural economic transformation and innovation-driven growth remain limited (Fullerton & Monti, 2013). Moreover, the lack of reliable data impedes efforts to model and analyse policy outcomes, particularly within the informal sector, which plays a critical role in many developing economies (IMF, 2023; Loayza, 2016). The informal economy is not only a significant source of emissions and labour but also poses challenges in terms of tax compliance, equity, and policy outreach. Another limitation is the failure of many existing models to integrate economic, environmental, institutional, and social dimensions into a unified analytical framework. This shortcoming is especially evident in non-OECD contexts, where policy responses must be holistic to account for overlapping vulnerabilities. There is a clear need for interdisciplinary research, more inclusive datasets, and better modeling tools that reflect the full spectrum of development dynamics in emerging markets.

**2.2.5 Framework of the Present Study.** Given these gaps, the present study develops a comprehensive conceptual framework that integrates green taxation policy, revenue recycling mechanisms, institutional governance, and multidimensional outcomes. The research aims to address existing lacunae in the literature by focusing on the dynamic interplay between fiscal instruments, institutional quality, and developmental objectives in emerging economies. These countries are currently at a critical juncture, experiencing rapid economic growth while also being major contributors to global emissions and home to severe social inequities. In this context, the study proposes a feedback-based design model where tax revenues are recycled into climate adaptation, SME support, social transfers, and infrastructure investments. Institutional mechanisms for accountability and public engagement are embedded within this framework to ensure transparency, trust, and long-term efficacy. By integrating formal and informal sector dynamics, the model aspires to generate nuanced policy insights tailored for high-impact and low-capacity environments.

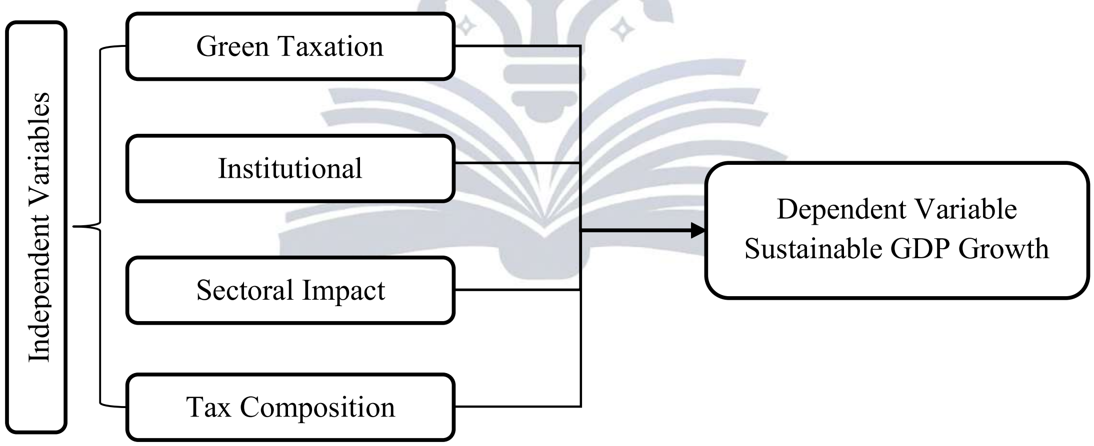
## 3. Methodology

### *3.1 Conceptual Framework*

The conceptual framework depicted in Figure 1 illustrates the relationship between key independent variables and the dependent variable, sustainable GDP growth. The model proposes that four main factors influence sustainable economic growth in emerging economies: Green Taxation, Institutional Informality, Sectoral Impact, and Tax Composition. Each of these components represents a distinct dimension of economic and fiscal policy.

**Figure 1**

*Conceptual Framework of the Study*




*Note.* Independent variables: green taxation, institutional informality, sectoral impact, and tax composition. Dependent variable: sustainable GDP growth. Adapted from the original study.

### *3.2 Research Hypotheses*

The study tests four primary hypotheses derived from the conceptual framework:

- **H1:** Green taxation positively impacts sustainable GDP growth, with stronger effects over longer time lags in emerging economies.
- **H2:** Institutional informality significantly impacts GDP growth outcomes in emerging economies.
- **H3:** Sector-specific impacts of green taxation differ significantly across service, agriculture, and manufacturing sectors.
- **H4:** Tax composition (direct versus indirect) significantly influences GDP growth sustainability.

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### *3.3 Research Design*

This study applies a panel data econometric design to analyse the impact of green taxation on sustainable GDP growth across 22 emerging economies from 2005 to 2023. Using ARDL and System GMM to address endogeneity and capture lagged effects, the model incorporates both cross-sectional and time-series dimensions. Data, sourced mainly from the World Bank's WDI, include GDP growth (dependent variable), institutional quality (proxied by tax measures), green taxation indicators (carbon intensity, adjusted savings, tax revenue shares), and sectoral contributions (agriculture, manufacturing, services). The sample spans diverse regions and captures major shocks such as the 2008 financial crisis and COVID-19, enhancing the analysis of short- and long-run effects. This methodological approach provides a robust framework to assess how fiscal and institutional factors shape sustainable growth in emerging economies.

### *3.4 Data Collection and Sources*

The study relies on secondary data from reputable international databases to ensure rigor and comparability. Key indicators such as GDP growth, sectoral value addition, taxes, and lagged variables are drawn from the World Bank's World Development Indicators (WDI). Tax revenue data are also sourced from the World Bank to measure institutional formality, ensuring reliable and consistent operationalization of the model.

### *3.5 Sample Selection*

The analysis uses a balanced panel of 22 emerging economies across Asia, Africa, Latin America, and Eastern Europe for 2005–2023. Countries were chosen for data availability, fiscal diversity, and varying environmental tax adoption, allowing robust testing of institutional quality and sectoral effects (see Table 1).

**Table 1**

*Emerging Economies in the Sample*

| Sr. No. | Country | Sr. No. | Country | Sr. No. | Country |
|---|---|---|---|---|---|
| 1 | Argentina | 9 | India | 17 | Russia |
| 2 | Bangladesh | 10 | Indonesia | 18 | South Africa |
| 3 | Brazil | 11 | Iran | 19 | Thailand |
| 4 | Chile | 12 | Korea | 20 | Türkiye |
| 5 | China | 13 | Malaysia | 21 | Ukraine |
| 6 | Colombia | 14 | Pakistan | 22 | Vietnam |
| 7 | Egypt | 15 | Philippines | | |
| 8 | Hungary | 16 | Qatar | | |

*Note.* This selection provides sufficient cross-country variation to generalize findings while maintaining empirical validity.

### *3.6 Study Period*

The study examines annual data for the period 2005–2023, a timeline sufficiently long to capture both short-term and long-term impacts of green taxation policies. This period encompasses significant global economic events, such as the 2008 global financial crisis, the post-2010 economic recovery, and the economic disruptions caused by the COVID-19 pandemic. These events serve as natural experiments to observe how fiscal and green tax policies interact with macroeconomic shocks. Furthermore, the chosen period aligns with increased global emphasis on sustainable development and the gradual mainstreaming of environmental taxation in many emerging economies.

### *3.7 Variables and Parameters*

In alignment with the conceptual framework, variables are organized into dependent, independent, and control variables.

The primary dependent variable is Sustainable GDP Growth, defined as the annual percentage growth in GDP adjusted for environmental performance indicators such as carbon intensity and the Environmental Performance Index (EPI). This operationalization reflects the study's focus on growth that is not merely quantitative but also environmentally resilient, consistent with SDG objectives.

### *3.8 Econometric Models*

The study models sustainable GDP growth as the dependent variable, measured by annual GDP growth rates adjusted for environmental indicators such as carbon intensity and the Environmental Performance Index. Key independent variables include green taxation (e.g., carbon tax revenue as a percentage of GDP, pollution charges, and other environmental tax instruments), institutional informality (proxied by tax rates as a percentage of profits and governance quality indicators), and sectoral impact (sector-specific tax ratios in agriculture, manufacturing, and services). Tax composition is also analyzed through the ratio of direct to indirect taxes. To account for delayed policy effects, the model incorporates distributed lag structures and dynamic panel estimators.

**3.8.1 Primary Panel Regression Model**

**Equation 1: Direct Effects Model**

$$Sus_{GDP_i} = \beta_0 + \beta_1 GreenTax_i + \beta_2 Inst.Informality_i + \beta_3 SectorImpact_i + \beta_4 Sustainability_i + \mu_i + \varepsilon_{it}$$

Where:

- $Sus_{GDP_i}$= sustainable GDP growth rate for country $i$in year $t$
- $GreenTax_i$= green taxation indicator
- $Inst.Informality_i$= institutional strength measure
- $SectorImpact_i$= sector-specific tax ratios
- $\mu_i$= country-specific fixed effects
- $\varepsilon_{it}$= idiosyncratic error term

Model selection: Hausman test determines Fixed Effects (FE) vs. Random Effects (RE) specification.

**3.8.2 Dynamic System GMM Model**

**Equation 2: Time-Lag Effects Model**

$$Sus_{GD\ \ i} = \alpha \cdot Sus_{GD\ \ i-1} + \beta_1 GreenTax_{i|t-k} + \beta_2 X_i + \mu_i + \varepsilon_{it}$$

Where:

- $Sus_{GD\ \ i-1}$= lagged dependent variable capturing growth persistence
- $GreenTax_{i|t-k}$= lagged green taxation values for delayed effects
- $X_i$= matrix of control variables
- $k$= lag structure determined by information criteria

**3.8.3 ARDL Error Correction Model**

**Equation 3: Short-Run and Long-Run Dynamics**

$$\Delta Sus_{GD\ \ i} = \gamma_0 + \sum_{i}^{0} + \lambda\left(Sus_{GDP_{i-1}} - \theta X_{i-1}\right) + \varepsilon_i$$

Where:

- $\Delta$= first difference operator for short-run dynamics
- $\lambda\left(Sus_{GD\ \ i-1} - \theta X_{i-1}\right)$= error correction term for long-run equilibrium

**3.8.4 Sectoral Analysis Model**

**Equation 4: Sector-Specific Effects**

$$GDP_{i,t-sector} = \alpha + \beta \cdot SectoralTax_{i,t} + \mu_i + \varepsilon_{i,t}$$

This specification tests heterogeneous impacts across agriculture, manufacturing, and services sectors.

***3.9 Statistical Analysis Approach***

This study applies a comprehensive econometric approach to examine how green taxation influences sustainable GDP growth. The analysis begins with descriptive statistics and Pearson correlations to summarize the data and identify initial relationships. Panel diagnostics are conducted using Fixed and Random Effects models, and the Hausman test helps select the appropriate specification. To address endogeneity, System GMM is employed, while ARDL models capture both long-run and short-run dynamics. The study also explores sector-specific impacts across agriculture, manufacturing, and services, and uses distributed lag models to understand time-varying effects. To reduce multicollinearity, Principal Component Analysis is applied, which generates composite indices such as the Green Tax Component, Institutional Component, Sectoral Structure Component, and Sustainability Savings Component. These indices strengthen the reliability of the models and provide a multidimensional perspective on the role of fiscal and environmental policies in shaping economic growth.

## 4. Results and Discussion

This chapter presents a comprehensive analysis of the descriptive statistics and empirical findings from the panel dataset comprising 22 emerging economies over the period 2005 to 2023.

### *4.1 Descriptive Statistics*

The analysis begins with descriptive statistics to understand the data structure and distribution of key variables used in the empirical models. Table 2 reports essential metrics such as the mean, median, standard deviation, skewness, kurtosis, and Jarque–Bera (JB) probability for each variable. These statistics offer insights into data variability, symmetry, and normality.

### *4.2 Environmental Indicators*

The variables capturing environmental pressure, such as carbon intensity per PPP USD (mean = 0.26) and carbon damage (mean $\approx 2.64 \times 10^{10}$), also display strong skewness and kurtosis. For example, $CO_2$ damage has a skewness of 4.63 and a kurtosis of 25.34, indicating the presence of extreme values. This reflects stark differences in environmental externalities across countries, with large economies or carbon-intensive sectors (e.g., China, India) contributing disproportionately to environmental degradation.

**4.2.1 Sectoral Composition of GDP.** Sectoral variables, including agriculture (mean = 8.71%), manufacturing (17.49%), and services (52.26%), exhibit moderate dispersion. Their distribution is closer to normality compared to other variables, though service value added shows slight negative skewness (−0.64). These sectoral shares will be used in constructing the sectoral composite index, which captures structural economic differences that could mediate the tax–growth relationship.

**4.2.2 Taxation Indicators.** Both tax ratios (e.g., tax revenue as % of GDP) and absolute values (e.g., total tax revenue in local currency) are reported. Notably:

- Tax revenue (% of GDP): Mean = 30.84%, skewness = 0.57
- Taxes on goods and services (% of revenue): Mean = 8.50%, relatively stable
- Other taxes (% of revenue): Skewed and low mean (2.26%)

In contrast, value-based tax indicators such as total tax revenue and taxes on goods and services in LCU are highly skewed, with large kurtosis (>20) and extremely high Jarque–Bera statistics. This justifies the use of percentage-based variables or composite indices to normalize across countries of varying economic sizes.

**4.2.3 Sustainability and Adjusted Savings.** Indicators such as adjusted net savings including/excluding particulate matter damage show very high dispersion and skewness (e.g., skewness > 4.4), reflecting differences in environmental policy, fiscal discipline, and resource management. These variables are integral to the sustainability composite, which attempts to reflect long-term economic resilience and green fiscal policy.

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**Table 2**
*Descriptive Statistics*

| Variable | Mean | Median | Std. Dev. | Min | Max | JB (p-value) | Obs. |
|---|---|---|---|---|---|---|---|
| AGRI_VA (% GDP) | 8.71 | 8.06 | 5.53 | 0.09 | 23.82 | 28.71 (0.0000) | 418 |
| CO2_DAMAGE (US$) | 2.64E+10 | 7.78E+09 | 6.71E+10 | 7.61E+08 | 4.83E+11 | 9120.04 (0.0000) | 374 |
| CARBINT_PPP (kg/PPP $) | 0.26 | 0.21 | 0.15 | 0.09 | 0.78 | 113.45 (0.0000) | 418 |
| CARBINT_USD (kg/USD) | 0.78 | 0.64 | 0.55 | 0.24 | 3.53 | 734.44 (0.0000) | 418 |
| GDP_CONST (US$) | 1.04E+12 | 3.56E+11 | 2.31E+12 | 4.99E+10 | 1.72E+13 | 12137.43 (0.0000) | 418 |
| GDP_GROWTH (%) | 3.98 | 4.50 | 4.43 | −28.76 | 26.17 | 1731.82 (0.0000) | 418 |
| GDP_CURR (US$) | 1.04E+12 | 3.62E+11 | 2.33E+12 | 4.45E+10 | 1.79E+13 | 15947.55 (0.0000) | 418 |
| GDPPC_CURR (US$) | 10,565.32 | 6,235.63 | 15,917.74 | 480.09 | 108,470.40 | 5192.97 (0.0000) | 418 |
| GDPPC_GROWTH (%) | 2.78 | 3.30 | 4.16 | −22.75 | 19.01 | 461.84 (0.0000) | 418 |
| MANUF_VA (% GDP) | 17.49 | 16.24 | 5.87 | 7.60 | 32.45 | 31.11 (0.0000) | 418 |
| NETSAV_EXCL (US$) | 1.52E+11 | 3.21E+10 | 4.17E+11 | −8.89E+10 | 2.95E+12 | 7211.77 (0.0000) | 350 |
| NETSAV_INCL (US$) | 1.51E+11 | 3.22E+10 | 4.11E+11 | −9.21E+10 | 2.87E+12 | 6639.03 (0.0000) | 341 |
| OTHERTAX_PCT (% rev.) | 2.26 | 1.70 | 2.33 | −4.87 | 15.34 | 294.01 (0.0000) | 295 |
| OTHERTAX_VAL (LCU) | 1.98E+12 | 1.95E+10 | 5.62E+12 | −1.85E+12 | 3.55E+13 | 2646.95 (0.0000) | 295 |
| SERVICE_VA (% GDP) | 52.26 | 53.17 | 6.12 | 28.48 | 64.61 | 42.86 (0.0000) | 412 |
| TAXGOODS_PCT (% rev.) | 30.84 | 29.50 | 10.49 | 2.30 | 77.69 | 46.40 (0.0000) | 302 |
| TAXGOODS_VA (LCU) | 8.50 | 7.45 | 4.27 | 0.63 | 19.76 | 39.66 (0.0000) | 302 |
| TAXGOODS_VAL (LCU) | 1.33E+13 | 1.18E+12 | 3.27E+13 | 2.00E+10 | 2.66E+14 | 7367.76 (0.0000) | 302 |
| TAXREV_VAL (LCU) | 3.37E+13 | 2.30E+12 | 8.55E+13 | 7.56E+10 | 6.59E+14 | 5109.45 (0.0000) | 302 |
| TAXREV_PCT (% of profit) | 14.74 | 14.17 | 4.45 | 5.94 | 26.01 | — | — |

*Note.* JB = Jarque–Bera. Adapted from the original study.

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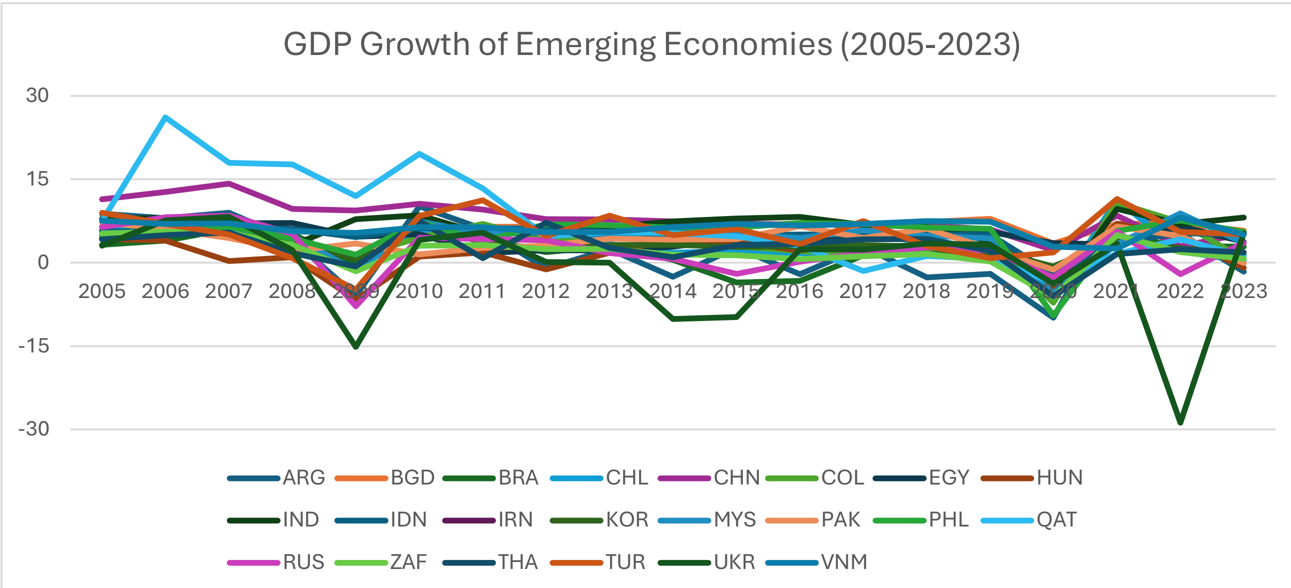
**Figure 2**

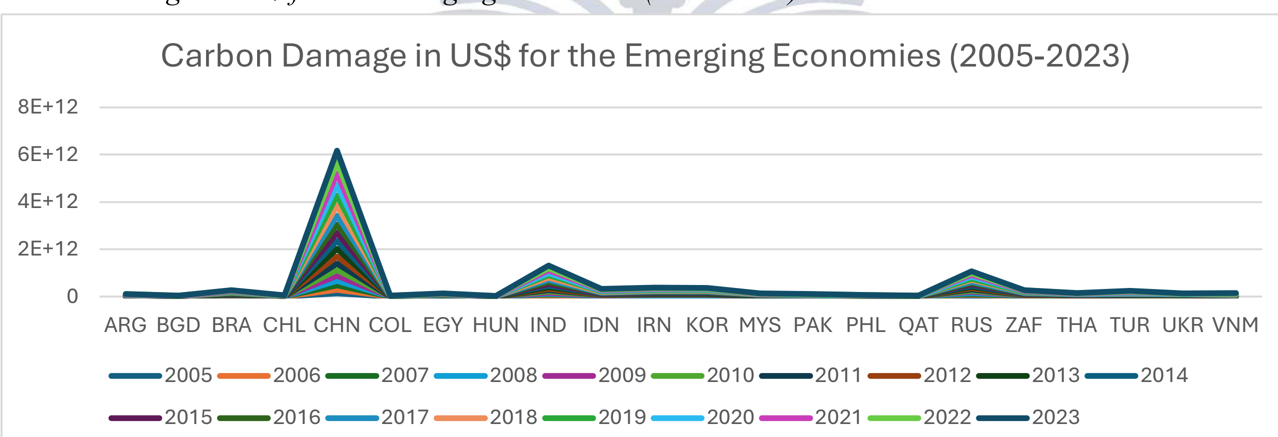
*GDP Growth of Emerging Economies (2005–2023)*




*Note.* The figure illustrates annual GDP growth rates for 22 countries, highlighting fluctuations shaped by major shocks. The 2008–2009 global financial crisis and the 2020 COVID-19 pandemic caused sharp contractions across most economies, followed by recoveries. Qatar showed strong energy-driven growth, Ukraine faced severe downturns from conflict in 2022–2023, and Iran experienced volatility tied to sanctions and oil prices. China, Indonesia, and Vietnam maintained more stable growth. Adapted from the original study.

**Figure 3**

*Carbon Damage in US$ for the Emerging Economies (2005–2023)*




*Note.* China (USD 60 million) faced the highest economic damages from carbon emissions, followed by India and Russia at about USD 23 million each. These costs reflect the scale of industrialization, fossil fuel reliance, and associated greenhouse gas emissions. Adapted from the original study.

**4.2.4 Implications for Econometric Analysis.** The descriptive statistics show strong deviations from normality, especially in local currency variables, indicating skewness and kurtosis. To correct this, transformations such as first-differencing, logarithms, and composite indices are used to stabilize variance, reduce extremes, and summarize related measures. Considerable variability across macroeconomic and tax indicators highlights structural differences among countries, supporting the use of panel regressions that account for heterogeneity and time dynamics. Moreover, several variables, including GDP growth, carbon intensity, and tax measures, are non-stationary, justifying dynamic panel methods like System GMM to address endogeneity, serial correlation, and unobserved heterogeneity while capturing adjustment processes.

### *4.3 Correlation Analysis*

Table 3 presents the Pearson correlation coefficients among the key variables used in the study over the period 2005–2023 for 22 emerging economies. These results provide preliminary insights into the linear relationships among economic, fiscal, environmental, and sectoral indicators.

**4.3.1 Green Tax and Environmental Indicators.** The analysis shows a strong positive correlation (0.53) between carbon intensity (PPP) and $CO_2$ damage, indicating that carbon-intensive economies face higher economic losses through environmental degradation, health impacts, and productivity declines. $CO_2$ damage also correlates strongly with net savings and GDP (above 0.97) and moderately with manufacturing value added (0.39), highlighting that while industrial growth boosts output, it also amplifies environmental harm and long-term sustainability risks. A negative correlation (−0.26) exists between carbon intensity and agriculture's GDP share, suggesting that more industrialized economies shift away from agriculture toward higher-carbon sectors. Finally, carbon intensity measures in USD and PPP terms are strongly aligned (0.70), confirming the robustness of the metric for cross-country comparisons.

**4.3.2 Economic Output and Structural Composition.** Results show an extremely high correlation (~0.99) between GDP and $CO_2$ damage, indicating that economic expansion in sampled countries remains tied to carbon-intensive activities. GDP growth also strongly correlates with GDP per capita growth (0.98) and moderately with agriculture's value added (0.33), suggesting agriculture still supports short-term growth in some emerging economies. GDP per capita negatively correlates with agriculture's GDP share (−0.73) and carbon intensity (−0.26), reflecting structural shifts toward cleaner, service-oriented economies as income rises. Finally, GDP per capita shows positive correlations with tax revenue (0.45) and taxes on goods and services (0.44), highlighting stronger fiscal capacity in higher-income countries to fund environmental protection and green investments.

**4.3.3 Sectoral Contributions.** Agriculture's share of value added is strongly negative with both services (−0.59) and GDP per capita (−0.73), reflecting the classic shift from agriculture to manufacturing and then services as economies grow. Manufacturing, in turn, shows a positive link with $CO_2$ damage (0.39) and carbon intensity (0.27), underscoring the environmental costs of industrialization driven by fossil fuel use and resource-intensive production. Services display a negative correlation with GDP growth (−0.45) and manufacturing (−0.40), but a positive one with GDP per capita (0.30). This pattern indicates that service-led economies, while experiencing slower growth, tend to achieve higher income levels and reduced environmental pressures compared to manufacturing-driven growth.

**4.3.4 Taxation and Green Fiscal Indicators.** Taxes on goods and services in value terms (TAXGOODS_VAL) show a near-perfect correlation with total tax revenue (0.996), reflecting their dominant role in fiscal systems. As VAT, sales, and excise duties often make up the largest share of revenue, this highlights the reliance of developing and emerging economies on consumption-based taxes, which are easier to administer and more stable than direct taxes.

Other taxes as a share of GDP (OTHERTAX_PCT) show negative correlations with $CO_2$ damage (−0.31) and carbon intensity (−0.52), suggesting that economies relying more on non-environmental taxes may lack strong carbon pricing or pollution-control incentives. Taxes on profits (TAXREV_PCT) also display strong negative correlations with GDP, $CO_2$ damage, and carbon intensity, implying that high-emission economies often impose lower business taxes to maintain competitiveness or protect energy-intensive industries. While this may aid short-term growth, it weakens incentives for energy efficiency and carbon reduction.

The agricultural share of value added (AGRI_VA) is negatively correlated with major tax indicators (e.g., −0.03 with TAXGOODS_PCT and −0.56 with TAXREV_PCT), reflecting the limited integration of agriculture into formal tax systems. Smallholders and informal production reduce fiscal capacity, restricting

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resources for environmental policies and green taxation measures, thereby constraining investment in sustainable agriculture and rural protection.

**4.3.5 Savings and Sustainability.** Net savings, whether adjusted for $CO_2$ damage or not, show an almost perfect correlation (≈0.999), as both derive from the same base data. They also correlate strongly with $CO_2$ damage, GDP, and carbon intensity, underscoring how energy-intensive growth erodes natural capital and inflates traditional savings measures when environmental costs are excluded. Correlations reveal structural trade-offs: net savings are negatively linked with services (−0.25) and only weakly positive with agriculture (0.06), suggesting that both manufacturing and service-oriented economies can accelerate resource depletion. These results highlight a policy dilemma—structural transformation boosts modernization and incomes but risks greater ecological degradation unless paired with green investments, sustainable practices, and safeguards.

**Table 3**

*Pearson Correlation Matrix*

| Variable | AGRI_VA | CO2_DAMAGE | CARBINT_PPP | CARBINT_USD | GDP_CONST | GDP_GROWTH | GDP_CURR | GDPPC_CURR | GDPPC_GROWTH | MANUF_VA |
|---|---|---|---|---|---|---|---|---|---|---|
| AGRI_VA | 1.000 | | | | | | | | | |
| CO2_DAMAGE | 0.031 | 1.000 | | | | | | | | |
| CARBINT_PPP | 0.262 | 0.527 | 1.000 | | | | | | | |
| CARBINT_USD | 0.040 | 0.225 | 0.704 | 1.000 | | | | | | |
| GDP_CONST | 0.000 | 0.989 | 0.477 | 0.142 | 1.000 | | | | | |
| GDP_GROWTH | 0.331 | 0.230 | 0.098 | 0.015 | 0.219 | 1.000 | | | | |
| GDP_CURR | 0.020 | 0.979 | 0.447 | 0.136 | 0.992 | 0.197 | 1.000 | | | |
| GDPPC_CURR | −0.732 | 0.010 | −0.046 | 0.261 | 0.051 | 0.180 | 0.075 | 1.000 | | |
| GDPPC_GROWTH | 0.263 | 0.267 | 0.118 | 0.057 | 0.254 | 0.983 | 0.233 | 0.117 | 1.000 | |
| MANUF_VA | 0.188 | 0.387 | 0.269 | 0.025 | 0.395 | 0.273 | 0.356 | 0.097 | 0.283 | 1.000 |

*Note.* Adapted from the original study.

### *4.4 Principal Component Analysis*

To address the issue of high correlation among certain variables, the study used Principal Component Analysis (PCA) to reduce dimensionality and create new composite indices for use in the regression analysis.

**4.4.1 Green Taxation.** A composite index for green taxation was developed to provide a consolidated measure of fiscal and environmental policy efforts across countries. This index was constructed using the first principal component obtained from five key indicators: (i) tax on goods and services (value terms), (ii) $CO_2$ damage expressed in monetary value, (iii) taxes as a percentage of total revenue, (iv) other taxes as a percentage of total revenue, and (v) carbon intensity measured in purchasing power parity (PPP) terms. The application of PCA allowed for the integration of these related but distinct variables into a single synthetic measure, thereby reducing dimensionality while preserving the most important patterns of variation. The first principal component explained approximately 37% of the total variance across these variables, indicating a moderate but meaningful ability to capture the common underlying factor that links fiscal measures with

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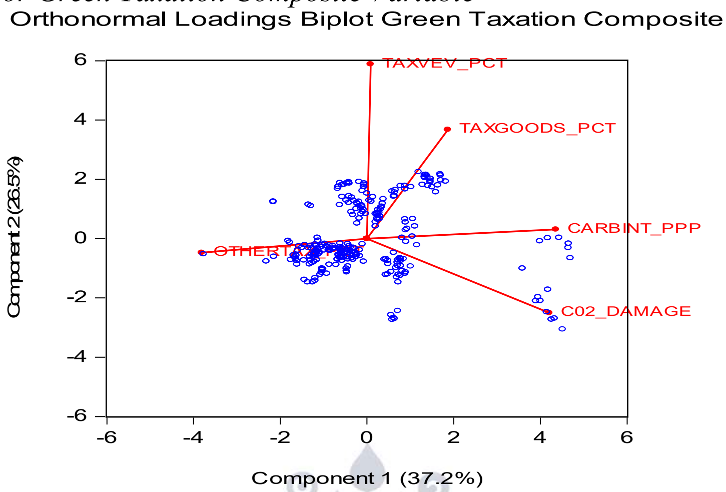
environmental outcomes. This resulting measure, referred to as the Green Taxation Index, is illustrated in Figure 4 and serves as an essential explanatory variable in the subsequent regression analysis.

**Figure 4**

*Orthonormal Loadings for Green Taxation Composite Variable*

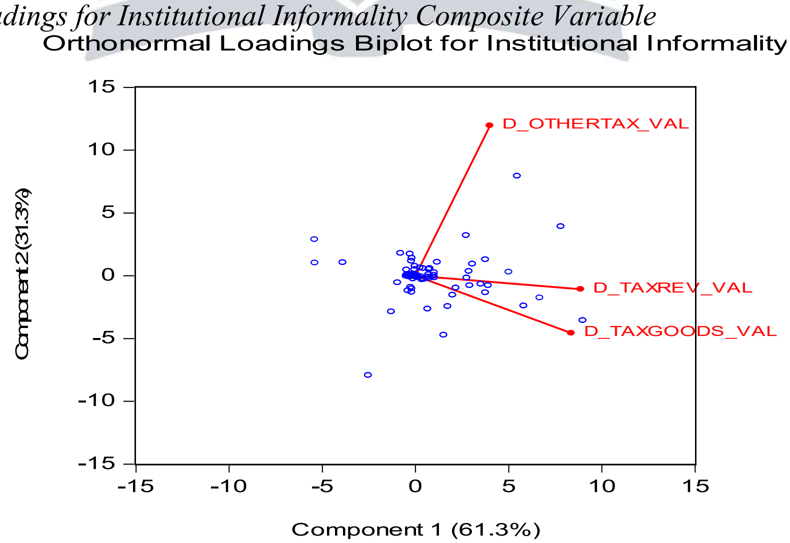



*Note.* GTC = 0.589676 CARBINT_PPP + 0.514352 OTHERTAX_PCT + 0.252766 TAXGOODS_PCT + 0.568946 CO2_DAMAGE + 0.011562 TAXREV_PCT. Adapted from the original study.

**4.4.2 Institutional Informality.** To capture the influence of institutional quality and informality in the tax system, a separate composite index was created. This index draws upon three variables that collectively reflect both the strength of fiscal capacity and the degree of informality: (i) current total tax revenue, (ii) tax on goods and services (value), and (iii) other taxes (current value terms). The first principal component extracted from these variables explained approximately 61.3% of the total variance, substantially higher than the green taxation index, indicating a strong and coherent representation of institutional and fiscal dynamics. This Institutional Informality Index, shown in Figure 5, offers a more structural dimension to the empirical analysis by reflecting the interplay between tax system performance and the prevalence of informal economic activities.

**Figure 5**

*Orthonormal Loadings for Institutional Informality Composite Variable*

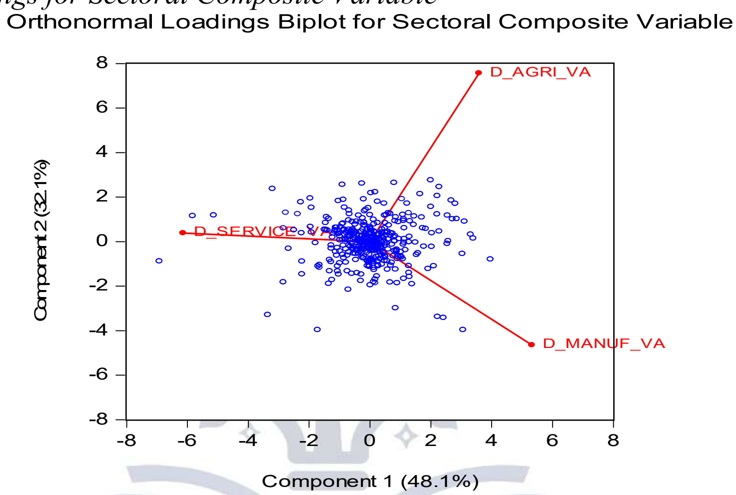



*Note.* ININFCI = 0.382729 TAXGOODS_VAL + 0.413419 TAXREV_VAL + 0.826198 OTHERTAX_VAL. Adapted from the original study.

**4.4.3 Sustainability and Sectoral Composites.** In addition to fiscal and institutional measures, the study also incorporates indices for sustainability and sectoral structure. These were constructed using the first principal components of their respective underlying variables to ensure that the model captures broader dimensions of economic performance and environmental stewardship. The sustainability index consolidates environmental and resource-based indicators into a single measure, enabling a more holistic assessment of long-term economic viability. The sectoral composite index, on the other hand, integrates measures of agricultural, manufacturing, and service value-added to summarize the structural composition of each economy. By employing PCA for these constructs, the regression model benefits from a reduction in multicollinearity while ensuring that key multidimensional aspects, such as environmental responsibility, industrial development, and economic diversification, are captured in a more meaningful and analytically tractable form.

**Figure 6**

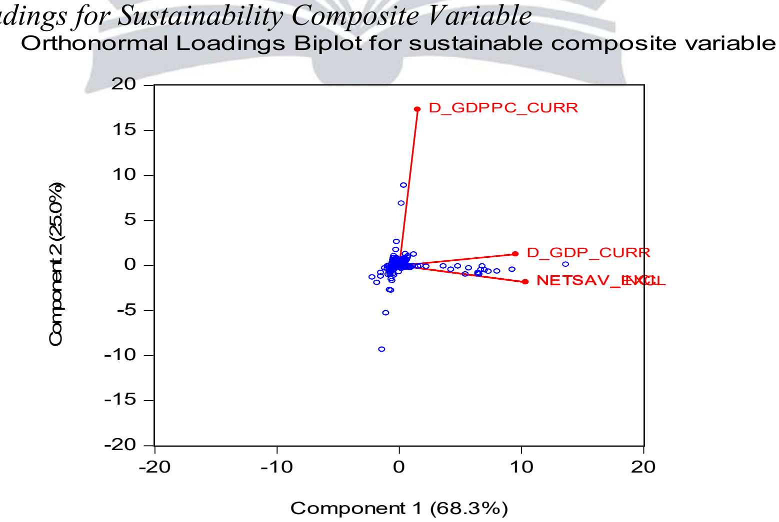
*Orthonormal Loadings for Sectoral Composite Variable*




*Note.* SecComp = 0.659895 SERVICE_VA + 0.469572 MANUF_VA + 0.586550 AGRI_VA. Adapted from the original study.

**Figure 7**

*Orthonormal Loadings for Sustainability Composite Variable*




*Note.* Sust_Comp = 0.1052 NETSAV_EXCL + 0.1042 NETSAV_INCL + 0.0771 D_GDP_CURR + 0.986 D_GDPPC_CURR. Adapted from the original study.

### *4.5 Fixed vs. Random Effects Model: Hausman Test*

To determine whether the Fixed Effects (FE) or Random Effects (RE) estimator is more appropriate for analyzing the impact of green taxation and institutional factors on economic growth, a Hausman test was conducted. The test summary is presented in Table 4.

**Table 4**

*Hausman Test Summary*

| Test Type | Chi-Sq. Statistic | d.f. | p-value |
|---|---|---|---|
| Cross-section random | 16.0788 | 4 | 0.0029 |

*Note.* The p-value (0.0029) is below the 5% threshold, indicating that the null hypothesis favoring the Random Effects model should be rejected. Hence, the Fixed Effects model is preferred.

Further analysis of individual coefficient differences between the FE and RE models (Table 5) reveals that two variables, namely the institutional/informality composite (INST_INFR_COMP) and sustainability composite (SUST_COMP), show statistically significant differences between the two models.

**Table 5**

*Comparison of Fixed Effects and Random Effects Coefficients*

| Variable | Fixed Coeff. | Random Coeff. | Var. (Diff.) | p-value |
|---|---|---|---|---|
| GREEN_TAX_COMP | 0.4332 | 0.0408 | 0.3032 | 0.3893 |
| INST_INFR_COMP | 1.4144 | 0.9446 | 0.0399 | 0.0186 |
| SECT_COMP | 1.4135 | 1.4756 | 0.0053 | 0.3941 |
| SUST_COMP | 1.2314 | 0.1856 | 0.1932 | 0.0173 |

*Note.* Significant differences suggest that the RE estimator is inconsistent, especially due to endogeneity in INST_INFR_COMP and SUST_COMP. Therefore, the FE model results should be interpreted.

### *4.6 Fixed Effects Model Output*

**Table 6**

*Fixed Effects Regression Coefficients*

| Variable | Coefficient | p-value | Interpretation |
|---|---|---|---|
| GREEN_TAX_COMP | 0.4332 | 0.4963 | Not significant |
| INST_INFR_COMP | 1.4144 | 0.0000 | Strong positive and highly significant |
| SECT_COMP | 1.4135 | 0.0000 | Positive and significant |
| SUST_COMP | 1.2314 | 0.0131 | Positive and significant |

*Note.* This model suggests that while green taxation does not have a statistically significant effect, institutional informality, sectoral composition, and sustainable development indicators positively and significantly influence GDP growth.

### *4.7 Dynamic Panel GMM: Initial Model*

A two-step GMM estimation was run using lagged GDP (LGDP) and GREEN_TAX_COMP as predictors. The output is summarized in Table 7.

**Table 7**

*GMM Regression Output (Model 1)*

| Variable | Coefficient | Std. Err. | t-Statistic | p-value | Interpretation |
|---|---|---|---|---|---|
| C (Constant) | 0.343 | 0.307 | 1.118 | 0.265 | Not significant |
| LGDP | 0.601 | 0.075 | 7.960 | 0.000 | Strong negative effect confirms mean reversion |
| GREEN_TAX_COMP | 0.650 | 0.631 | 1.030 | 0.304 | Not statistically significant |

*Note.* The strong negative coefficient of lagged GDP suggests mean reversion in GDP growth, consistent with economic cycles. However, the green tax composite does not exhibit a statistically significant short-run effect.

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### *4.8 Dynamic Panel GMM: Extended Model with Composite Variables*

An expanded GMM model was estimated to include all four composite indices. Table 8 summarizes the results.

**Table 8**

*GMM Regression Output (Model 2)*

| Variable | Coefficient | Std. Err. | t-Statistic | p-value | Interpretation |
|---|---|---|---|---|---|
| C (Constant) | 0.330 | 0.363 | 0.910 | 0.365 | Not significant |
| LGDP | 0.631 | 0.075 | 8.457 | 0.000 | Strong, negative, significant |
| GTC_COMP_ORG | 0.472 | 0.795 | 0.593 | 0.554 | Not significant; green taxation lacks a short-term impact |
| INST_INFR_ORG | 2.022 | 0.995 | 2.032 | 0.043 | Significantly, institutions drive GDP growth |
| SECT_COMP_ORG | 3.680 | 0.866 | 4.251 | 0.000 | Strong positive effect from sectoral balance |
| SUS_COMP_ORG | 2.646 | 0.643 | 4.113 | 0.000 | Strong effect from sustainability metrics |

*Note.* Adapted from the original study.

### *4.9 Model Diagnostics and Insights*

**Table 9**

*Model Diagnostics Summary*

| Statistic | Value | Interpretation |
|---|---|---|
| R-squared | 0.251 | Moderate explanatory power (25% variation explained) |
| Adjusted R-squared | 0.173 | Adjusted for the number of variables |
| Durbin–Watson stat | 2.04 | No autocorrelation |
| J-statistic | ~0 | The model is just identified; instrument validity test is not possible |
| Instrument Rank | 23 | Adequate, but needs monitoring for overfitting |

*Note.* The regression model shows moderate explanatory power with an R-squared of 0.251 and an adjusted R-squared of 0.173. The Durbin–Watson value of 2.04 confirms no autocorrelation, while a near-zero J-statistic indicates the model is just identified. The instrument rank of 23 is sufficient but cautions against overfitting.

## 5. Conclusion

This study examined the impact of green taxation on sustainable GDP growth in Pakistan and 21 other emerging economies from 2005 to 2023. Using panel data techniques including Fixed and Random Effects, System GMM, correlation analysis, and Principal Component Analysis, the research explored how environmental fiscal tools interact with institutional, sectoral, and sustainability factors. Findings show that while green taxation is essential for addressing externalities and steering economies toward ecological sustainability, its effect on short-term GDP growth is limited. Instead, green taxes serve as long-term levers, redirecting investment and production toward cleaner alternatives, as indicated by the statistical insignificance of the composite green tax index for short-run GDP changes.

Institutional quality, sectoral diversification, and sustainability-focused investments, however, emerged as strong drivers of growth. Economies with better governance, balanced structures, and forward-looking fiscal strategies such as investment in human capital and environmental protection showed more consistent growth. Fixed Effects results, supported by the Hausman test, emphasized the role of country-specific institutions and policy stability in shaping environmental tax outcomes. System GMM further confirmed the dynamic nature of growth, highlighting the need to account for both short-term fluctuations and long-term structural trends.

### *5.1 Policy Implications*

This research emphasizes that green taxation is vital for sustainability but not a quick fix for growth. It must be part of a long-term strategy that builds institutional capacity, diversifies sectors, and invests in sustainable infrastructure and innovation. On its own, green taxation is limited unless supported by these foundations. Reforms also need to be socially fair and politically feasible, with equity measures such as revenue recycling, clean technology subsidies, and support for low-income households to ensure public trust and acceptance. Strong institutions, effective tax administration, and reduced corruption are equally crucial. With credible governance and inclusive design, green taxation can meaningfully advance sustainable development in emerging economies.

### *5.2 Limitations and Future Research Directions*

This study highlights key directions for future research, particularly the need to explore the long-term impacts of green taxation beyond 2023, assess its effects on high-emission industries, and examine its potential to drive innovation. Incorporating advanced modelling and understanding the political economy and role of informality can offer deeper insights. Aligning this research with the SDGs will ensure green taxation contributes meaningfully to inclusive and sustainable growth.

### Author Contributions

All authors participated in ideation, development, and writing the manuscript. All authors read and approved the final manuscript.

### Conflict of Interest Statement

The authors declare that there is no conflict of interest regarding the publication of this article.

### Funding Statement

The authors did not receive financial support from any funding agency or external organization for the research, authorship, or publication of this article.

### Informed Consent

Not applicable. This study did not involve human participants requiring informed consent. The data used in this research were obtained from anonymized financial records with all personally identifiable information removed. No private or sensitive information was collected from individuals.

### Data Availability

The datasets generated and analysed during the current study are available from the corresponding author upon reasonable request. Due to privacy and confidentiality considerations, raw financial data may not be publicly distributed but can be accessed through the corresponding author with appropriate data use agreements and institutional approvals. The authors are committed to transparency and will provide detailed methodological information, model specifications, and analysis protocols upon request.

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