Vol. 3 No. 9 (2025)

Journal of Social Signs Review

Online ISSN 3006-4651

Print ISSN 3006-466X

Green Taxation and Economic Competitiveness: The Mediating Roles of Innovation Capacity, Energy Efficiency, and Trade Liberalization in a Cross-Country Comparative Analysis

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Article Details:

Received on 21 Aug 2025
Accepted on 19 Sept 2025
Published on 20 Sept 2025

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Abstract

This study investigates the relationship between green taxation and economic competitiveness, with a focus on the mediating roles of innovation capacity, energy efficiency, and trade liberalization in a cross-country comparative analysis. Using panel data from 40 developed and developing economies over the period 2010–2023, secondary data were collected from international databases including the World Bank, OECD, IMF, and the World Economic Forum. Green taxation was measured through environmentally related tax revenue as a share of GDP, while economic competitiveness was operationalized using the Global Competitiveness Index. Structural Equation Modeling (SEM) and panel regression techniques were applied to test both direct and indirect effects, with mediation confirmed through bootstrapping procedures. The results show that green taxation has a significant positive impact on economic competitiveness, with its strongest effects realized indirectly through innovation capacity and energy efficiency, and to a lesser extent through trade liberalization. Cross-country differences reveal that developed economies benefit more through innovation-driven pathways, while developing economies gain immediate advantages from energy efficiency improvements. The findings support the view that green taxation, when integrated with complementary innovation, energy, and trade policies, can serve as a strategic instrument for advancing both environmental sustainability and economic growth.

Keywords: Green Taxation, Economic Competitiveness, Innovation Capacity, Energy Efficiency, Trade Liberalization, Cross-Country Analysis

Vol. 3 No. 9 (2025)

Journal of Social Signs Review

Online ISSN 3006-4651

Print ISSN 3006-466X

Introduction

According to Ele et al. (2023), in recent decades, the global economy has faced a dual challenge of sustaining economic growth while addressing pressing environmental concerns. The increasing frequency of climate-related disruptions, rising pollution levels, and growing international pressure for sustainable development have compelled policymakers to design strategies that balance ecological responsibility with industrial competitiveness. Among these strategies, green taxation has emerged as a prominent tool. It seeks to reduce negative environmental externalities by discouraging harmful practices while simultaneously encouraging firms and industries to shift toward cleaner production methods. Yet, the extent to which green taxation enhances or constrains economic competitiveness remains a complex and often debated question.

Economic competitiveness is no longer judged solely by growth in gross domestic product, industrial output, or export performance. In today's interconnected global economy, competitiveness is closely tied to innovation, efficiency, and adaptability. Countries that fail to integrate sustainable practices into their economic frameworks risk lagging behind in global trade, facing both regulatory penalties and reputational disadvantages. At the same time, the imposition of environmental taxes may create short-term costs for industries, raising concerns about potential declines in productivity or trade performance. Understanding how green taxation interacts with broader economic mechanisms is therefore essential for policymakers, industries, and scholars alike (Ele et al., 2023).

The mediating role of innovation is central to this debate. Environmental taxes are often designed to create financial incentives for firms to invest in research, development, and technological advancements. While such taxes increase costs for polluting activities, they simultaneously make cleaner technologies and eco-friendly processes more attractive. Firms that respond proactively by adopting green innovations often discover efficiency gains, cost savings, and reputational advantages that improve their long-term competitiveness. In this way, innovation capacity acts as a bridge between the immediate burden of taxation and the long-term benefits of sustainable growth (porter et al., 1995).

Energy efficiency represents another important channel through which green taxation can influence competitiveness. Taxes on carbon emissions, fossil fuel use, or inefficient energy consumption push firms to optimize resource use and reduce waste. Although the transition to more energy-efficient systems may require initial investments, the long-run benefits include lower production costs, improved resilience to volatile energy markets, and compliance with international sustainability standards. As industries improve their energy efficiency, they strengthen their global competitiveness by becoming leaner, more resilient, and better aligned with the demands of environmentally conscious consumers and trade partners (Costantini et al., 2012).

According to Copeland et al. (2004) trade liberalization also plays a crucial mediating role. In a world of increasingly interconnected supply chains, the competitiveness of industries cannot be understood in isolation from global markets. Green taxation, when implemented in closed or rigid markets, may create disadvantages for domestic industries competing internationally. However, when combined with trade liberalization policies, the negative impacts can be mitigated or even transformed into advantages. Access to larger markets, opportunities for technology transfer, and the spread of environmentally sustainable practices through international trade partnerships can

Vol. 3 No. 9 (2025)

Journal of Social Signs Review

Online ISSN 3006-4651

Print ISSN 3006-466X

enhance the effectiveness of environmental taxation. Open trade frameworks allow firms to scale up the benefits of innovation and energy efficiency, making them more competitive not only locally but also globally (Copeland et al., 2004).

Johnstone, (2021) stated that the interaction of these mediating factors suggests that green taxation should not be seen as a singular or isolated policy. Instead, its effectiveness depends on the broader institutional and economic context. Countries that adopt environmental taxes without supporting policies may struggle to maintain industrial competitiveness, while those that combine taxation with innovation support, energy transition programs, and open trade practices can transform taxation into a driver of sustainable competitiveness. This highlights the importance of integrated policy frameworks that recognize the multifaceted nature of economic growth in a green transition era.

From a comparative perspective, the impacts of green taxation are not uniform across countries. Developed economies often have greater capacity to invest in green innovations, adopt advanced technologies, and leverage established trade networks. Emerging economies, while facing constraints in technological capacity and financial resources, may nonetheless benefit from green taxation if it is aligned with development goals and supported by international cooperation. This diversity in outcomes underscores the value of cross-country comparative analysis. Examining different contexts allows for a better understanding of how environmental taxation can be tailored to diverse economic realities (Johnstone, 2021).

This study focuses on exploring these dynamics by analyzing data from 45 countries over more than a decade. By examining the mediating roles of innovation capacity, energy efficiency, and trade liberalization, the research provides a more nuanced understanding of how green taxation influences economic competitiveness. The findings aim to clarify whether green taxation is merely a cost imposed on industries or a strategic tool that, when combined with other factors, enhances long-term resilience and growth.

The central argument is that green taxation does not operate in a vacuum. Its impact depends on how it interacts with innovation, efficiency, and trade policies. While the short-term costs may be evident, the long-term benefits become visible when firms and nations use taxation as a catalyst for transformation rather than treating it solely as a financial burden. In this sense, green taxation can serve as both a corrective mechanism for environmental externalities and a forward-looking strategy for sustainable competitiveness (Costantini et al., 2012).

Literature Review

Green Taxation

Green taxation refers to the use of fiscal instruments aimed at discouraging environmentally harmful activities while promoting sustainable economic behavior. Unlike traditional taxes that primarily serve revenue-raising purposes, green taxes are corrective in nature. They are designed to internalize the external costs of pollution, resource depletion, and ecological degradation. For instance, taxes on carbon emissions or fossil fuel consumption encourage industries and consumers to reduce their reliance on polluting energy sources. The principle underlying green taxation is that those who generate environmental damage should bear the costs associated with it, thereby shifting the burden away from society at large (Cottrell et al., 2023)

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Journal of Social Signs Review

Online ISSN 3006-4651

Print ISSN 3006-466X

Milne et al. (2014) discussed that in practice, green taxation may take many forms, including carbon taxes, energy taxes, pollution levies, and waste disposal fees. By raising the cost of unsustainable activities, these measures push firms and individuals to adopt cleaner alternatives. The revenue generated can also be reinvested in green technologies, renewable energy, or public programs aimed at mitigating climate change. Beyond environmental benefits, green taxation has significant economic implications. It can alter production structures, shift trade patterns, and encourage industries to enhance competitiveness by becoming more resource-efficient and innovative.

However, the effectiveness of green taxation depends on how it is designed and implemented. Excessively high taxes without supportive policies may burden industries and reduce competitiveness, particularly in developing economies with limited technological capacity. On the other hand, moderate and well-targeted tax schemes, combined with supportive innovation and trade policies, can serve as powerful drivers of sustainable growth. Thus, green taxation functions not only as an environmental policy tool but also as a catalyst for restructuring industries toward long-term competitiveness (Milne et al., 2014).

Innovation Capacity

Dosi, (1988) stated that innovation capacity refers to the ability of a country, industry, or firm to generate, adopt, and implement new ideas, technologies, and processes that improve performance and create value. It reflects not only the availability of resources for research and development but also the willingness and readiness of organizations to transform these resources into practical outcomes. Innovation capacity is more than just technological invention; it includes organizational adaptability, managerial practices, workforce skills, and institutional frameworks that support experimentation and risk-taking. A system with high innovation capacity is able to continuously adapt to changing market and environmental conditions while maintaining a competitive edge.

At the industrial level, innovation capacity often manifests through investment in cleaner technologies, renewable energy systems, and eco-friendly production methods. Firms with strong innovation capabilities are able to respond effectively to regulatory changes, consumer demand for sustainable products, and international competitiveness pressures. At the national level, innovation capacity depends on government support for research institutions, funding for technological development, and policies that create an enabling environment for entrepreneurs. In today's global economy, innovation is increasingly collaborative, involving partnerships across borders and industries (Dosi, 1988).

The significance of innovation capacity in the context of environmental taxation is particularly pronounced. When green taxes raise the cost of polluting activities, firms are incentivized to innovate in order to minimize tax burdens and maintain competitiveness. Innovation capacity thus becomes a crucial mediator that determines whether taxation results in economic strain or in long-term transformation. Economies with stronger innovation ecosystems are better able to turn environmental challenges into opportunities for growth, while weaker systems may face difficulties in adjusting. In this sense, innovation capacity not only shapes how industries respond to environmental policies but also defines their ability to achieve sustainable competitiveness in the global marketplace (Costantini et al., 2012).

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Online ISSN 3006-4651

Print ISSN 3006-466X

Energy Efficiency

Energy efficiency refers to the ability to achieve the same level of production, output, or service using fewer energy resources. It emphasizes optimizing processes and technologies so that energy inputs generate maximum economic value with minimal waste. In a broader sense, energy efficiency reflects the degree to which economies and industries can decouple growth from energy consumption. Rather than focusing solely on reducing energy use, efficiency highlights smarter energy utilization through advanced technologies, improved infrastructure, and sustainable practices that lower costs while reducing environmental damage.

DELEGATIONS (2020) discussed that at the industrial level, energy efficiency can involve adopting energy-saving machinery, upgrading manufacturing systems, or integrating renewable energy sources into production. For firms, greater efficiency often translates into lower operational expenses, improved resilience against energy price fluctuations, and stronger compliance with environmental regulations. At the national level, energy-efficient economies are better positioned to reduce dependency on imported fuels, enhance energy security, and meet international sustainability commitments. In many cases, energy efficiency also drives competitiveness by making products and services more affordable and appealing to environmentally conscious consumers and trade partners.

The role of energy efficiency becomes particularly important in the context of environmental taxation. When governments impose taxes on energy-intensive activities or carbon emissions, firms are encouraged to minimize tax liabilities by improving efficiency. Such improvements not only reduce costs but also allow industries to remain competitive in global markets where environmental performance is increasingly a requirement. Moreover, energy efficiency often complements innovation capacity, as the adoption of new technologies and practices directly contributes to more sustainable energy use. Thus, energy efficiency acts as both a response to green taxation and a driver of long-term economic competitiveness, ensuring that environmental goals are achieved without sacrificing industrial and trade performance (DELEGATIONS, 2020).

Trade Liberalization

Trade liberalization refers to the process of reducing barriers to international trade, such as tariffs, quotas, and restrictive regulations, with the goal of promoting greater economic integration among countries. It allows firms to access broader markets, benefit from economies of scale, and engage in global value chains. By lowering restrictions, trade liberalization creates opportunities for industries to expand exports, import advanced technologies, and attract foreign investment. It also fosters competitive pressures that encourage firms to improve efficiency, productivity, and innovation.

Copeland and Taylor (2004) stated that at the national level, trade liberalization is often seen as a strategy to accelerate growth, especially for emerging economies seeking to integrate into the global marketplace. Countries that open their markets tend to benefit from increased capital flows, enhanced specialization, and exposure to international standards. In a globalized economy, the competitiveness of industries is closely linked to their ability to engage with international trade networks. Firms that fail to adapt to open markets risk losing market share, while those that embrace liberalization gain access to knowledge, technology, and partnerships that strengthen their long-term position.

In the context of green taxation, trade liberalization plays a complex but vital role. On one hand, open markets expose firms to greater competition, which can make compliance with

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Journal of Social Signs Review

Online ISSN 3006-4651

Print ISSN 3006-466X

environmental taxes more challenging in the short term. On the other hand, liberalized trade facilitates technology transfer, allowing firms to adopt cleaner and more efficient practices that reduce tax burdens and enhance sustainability. It also spreads environmental standards globally, encouraging firms to align with greener practices to remain competitive abroad. Thus, trade liberalization serves as a mediator that can either magnify or moderate the effects of environmental taxation, depending on how industries and governments align their trade and environmental policies. When effectively integrated, it transforms taxation from a potential constraint into an opportunity for industries to thrive in an increasingly sustainability-focused global economy (Copeland & Taylor, 2004).

Economic Competitiveness

In the study of Ginevičius et al. (2023) economic competitiveness refers to the ability of a country, industry, or firm to achieve sustainable growth, maintain productivity, and strengthen its position in global markets. It encompasses the efficiency with which resources are utilized, the capacity to innovate, and the ability to adapt to evolving trade and regulatory environments. Competitiveness is not simply about producing goods at lower costs but also about offering higher value through quality, efficiency, and responsiveness to global demands. In the modern economy, competitiveness increasingly depends on integrating sustainability into business and national strategies, as environmentally responsible practices are becoming a benchmark for long-term growth.

At the industry level, competitiveness is shaped by factors such as productivity, technological advancement, labor skills, and access to international markets. Firms that invest in innovation and efficiency are better able to differentiate themselves and maintain profitability despite external pressures such as stricter environmental regulations or fluctuating resource prices. At the national level, competitiveness reflects the overall capacity of the economy to provide stable growth, attract foreign direct investment, and maintain a favorable balance of trade. Institutions, governance, and policy frameworks all play significant roles in shaping these outcomes (Ginevičius et al., 2023).

In the context of environmental policies, economic competitiveness is often discussed in relation to green taxation. Critics argue that environmental taxes raise production costs and weaken the global standing of industries. Supporters, however, highlight that well-designed tax policies encourage efficiency, innovation, and trade alignment, all of which enhance competitiveness in the long run. Thus, competitiveness should not be viewed as incompatible with environmental goals. Instead, it evolves as countries and industries learn to integrate sustainability into their growth models. This makes economic competitiveness both a measure of performance and a reflection of how effectively economies can adapt to the dual challenge of growth and sustainability (Ginevičius et al., 2023).

Green Taxation and Innovation Capacity

In the study of Jaffe and Palmer (1997), The relationship between green taxation and innovation capacity is central to understanding how environmental policies influence long-term competitiveness. Green taxation is designed to impose costs on environmentally harmful activities, creating a direct financial incentive for firms to rethink their production methods. Faced with higher costs for polluting practices, firms must either accept lower profitability or find ways to reduce their tax liabilities. This pressure often pushes firms toward innovation, as new technologies and processes provide a pathway to maintaining efficiency while reducing environmental impact.

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Innovation in this context can take multiple forms. Some firms may invest in cleaner production methods, such as energy-efficient machinery or renewable energy systems. Others may focus on developing new products that align with green consumer demand, including eco-friendly goods or services that use fewer resources. The presence of green taxes can therefore serve as a trigger that accelerates the adoption of innovation strategies, especially in industries that are highly energy-intensive or carbon-dependent. By making unsustainable practices more costly, taxation shifts the balance of incentives in favor of investment in sustainable technologies (Jaffe & Palmer, 1997).

At the same time, the effectiveness of this relationship depends on the broader institutional and economic environment. In economies with strong innovation systems, green taxes act as a catalyst that stimulates research and development, supports entrepreneurship, and strengthens links between industry and academia. Firms operating in such environments are more likely to respond proactively, treating taxation as an opportunity to differentiate themselves in competitive markets. By contrast, in economies where innovation capacity is weak, green taxation may place heavy burdens on firms without providing realistic alternatives. These firms may struggle to adapt, leading to reduced competitiveness in the short term.

In the study of Jaffe and Palmer (1997), An additional layer of this relationship lies in the role of government reinvestment. Revenues generated from green taxes can be allocated toward research grants, subsidies for clean technologies, or infrastructure that supports sustainable innovation. When tax revenues are effectively recycled into innovation-supporting programs, the positive relationship between green taxation and innovation capacity is strengthened. This creates a virtuous cycle where taxation discourages harmful practices, while reinvestment promotes solutions that make sustainable practices both technologically feasible and economically rewarding.

Jaffe and Palmer (1997) stated that Green taxation also influences the culture of innovation within firms. Instead of viewing compliance purely as a cost, firms begin to see environmental challenges as opportunities for growth and differentiation. This shift in mindset contributes to building long-term innovation capacity by embedding sustainability into corporate strategies and organizational practices. Over time, firms that adapt successfully not only reduce their exposure to environmental taxes but also build resilience and competitiveness in global markets where green performance is increasingly valued.

Therefore, the relationship between green taxation and innovation capacity is dynamic and context-dependent. While taxation imposes costs in the short run, it can stimulate innovation that delivers long-term efficiency gains, competitive advantages, and sustainable growth. The extent of this impact depends on the strength of innovation ecosystems, the willingness of firms to adapt, and the ability of governments to recycle revenues into supportive measures. In this way, innovation capacity acts as the key mediator that transforms the pressure of taxation into an engine of sustainable competitiveness (Jaffe & Palmer, 1997).

Green Taxation and Energy Efficiency

Marzouk, (2025) stated that the relationship between green taxation and energy efficiency lies at the heart of efforts to align environmental policy with industrial competitiveness. Green taxation, particularly in the form of carbon taxes or levies on fossil fuel consumption, creates a direct financial signal that energy-intensive activities come with additional costs.

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This encourages firms to seek ways to minimize energy use in order to reduce both operating expenses and tax burdens. By making inefficient energy practices more costly, green taxation establishes a clear incentive for firms to adopt measures that improve efficiency across their operations.

Energy efficiency can be achieved through a variety of strategies, ranging from upgrading outdated machinery to adopting renewable energy sources or redesigning production processes. These adjustments not only reduce emissions and pollution but also lead to lower long-term costs. For example, an industrial plant that invests in energy-efficient equipment may face initial expenses, but over time the savings in reduced fuel or electricity consumption outweigh the upfront investment. In this sense, green taxation accelerates the business case for efficiency improvements by shortening the payback period of such investments (Marzouk, 2025).

The effectiveness of this relationship is also influenced by how governments design and implement environmental taxes. Moderate tax rates combined with supportive policies, such as subsidies for energy-efficient technologies or training programs, create a balanced approach that encourages compliance while easing the transition. In contrast, poorly designed tax regimes that lack complementary measures may overburden industries, particularly in developing economies where firms face financial constraints. In such cases, the potential benefits of efficiency improvements may not be fully realized, and firms might instead cut back on production or pass costs to consumers (Marzouk, 2025).

On a broader scale, energy efficiency stimulated by green taxation contributes to national competitiveness. As industries lower their reliance on fossil fuels, economies become less vulnerable to energy price volatility and external shocks. This is particularly valuable for countries that import a significant portion of their energy, as improved efficiency reduces dependency and strengthens energy security. In addition, by aligning domestic industries with global sustainability standards, energy efficiency ensures that firms remain competitive in international trade, where environmentally responsible practices are increasingly demanded by regulators and consumers (Dechamps, 2023).

Another important dimension is the link between energy efficiency and innovation. The push created by green taxation often drives firms to invest in technologies that not only reduce energy use but also enhance productivity and performance. For example, digital monitoring systems, smart grids, and automation technologies allow firms to optimize energy consumption while improving overall output. This integration of efficiency with innovation reinforces the long-term positive impact of environmental taxation, making industries more adaptive and competitive in the global marketplace.

According to Dechamps (2023), Therefore, green taxation serves as both a constraint and an opportunity for industries. While it raises short-term costs for energy-intensive operations, it simultaneously creates powerful incentives to pursue efficiency gains that yield economic and environmental benefits. The extent of this relationship depends on the design of tax policies, the availability of supportive measures, and the readiness of industries to adapt. When effectively managed, the link between green taxation and energy efficiency not only reduces environmental harm but also strengthens industrial competitiveness, ensuring that sustainability and economic growth advance together.

Green Taxation and Trade Liberalization

Zhou (2025) stated that the relationship between green taxation and trade liberalization reflects the complex ways in which environmental policies interact with global market

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Print ISSN 3006-466X

dynamics. Green taxation, by design, increases the costs of polluting activities, which can initially create concerns about reduced competitiveness for domestic industries. Firms in countries with strict environmental taxes may face higher production costs compared to competitors in markets with weaker regulations. In this context, trade liberalization plays an important role in mediating how green taxation influences industrial and trade performance. Open trade frameworks can either amplify the challenges of environmental taxes or provide pathways for firms to adapt and thrive.

One of the most direct ways trade liberalization interacts with green taxation is through technology transfer. Access to international markets allows firms to import advanced machinery, cleaner technologies, and energy-efficient equipment that help reduce the tax burden of environmentally harmful practices. Without open trade policies, firms may find it difficult to acquire these technologies, particularly in developing economies where domestic innovation capacity is limited. Trade liberalization therefore reduces the adjustment costs of green taxation by providing access to solutions that improve efficiency and sustainability (Zhou, 2025).

Cosbey et al. (2019) discussed that Trade liberalization also enhances competitiveness by creating opportunities for firms to expand into global markets where demand for sustainable products is increasing. Many consumers and regulators in advanced economies prioritize imports that comply with environmental standards. Firms operating under green taxation regimes are often better positioned to meet these expectations, turning environmental compliance into a competitive advantage. By aligning domestic industries with international sustainability requirements, green taxation combined with open trade policies allows firms to differentiate themselves in global markets.

At the same time, the relationship between green taxation and trade liberalization is not without tension. In the short term, industries exposed to open trade may feel pressure from foreign competitors operating under less stringent environmental regulations. This can create concerns about "carbon leakage," where firms relocate production to countries with weaker policies to avoid taxes. To address this, many governments are considering border adjustment mechanisms, which impose tariffs on imports from countries without similar environmental standards. Such measures demonstrate the importance of aligning trade liberalization with environmental goals to ensure fair competition (Cosbey et al., 2019).

Another dimension of this relationship is the role of trade agreements in promoting sustainable practices. Many modern trade agreements include environmental provisions that encourage member countries to adopt cleaner practices and harmonize environmental policies. When trade liberalization occurs in this context, it complements green taxation by creating a level playing field where environmental standards are more consistent across markets. This reduces the risk of competitiveness losses while ensuring that firms are rewarded for sustainable practices.

Therefore, trade liberalization mediates the impact of green taxation by shaping how industries respond to the costs of environmental policies. Open trade enables access to technologies, fosters compliance with global sustainability standards, and creates opportunities for competitive differentiation in green markets. However, the effectiveness of this relationship depends on how trade and environmental policies are coordinated. When aligned, green taxation and trade liberalization reinforce each other, transforming

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Journal of Social Signs Review

Online ISSN 3006-4651

Print ISSN 3006-466X

environmental costs into drivers of innovation and competitiveness. When misaligned, they risk creating imbalances that undermine both sustainability and economic performance (Cosbey et al., 2019).

Mediators and Economic Competitiveness

Cottrell et al. (2023) discussed that the mediating factors of innovation capacity, energy efficiency, and trade liberalization play a critical role in determining how green taxation translates into economic competitiveness. Each mediator contributes uniquely to bridging the gap between environmental policy implementation and measurable improvements in industrial and national performance. Understanding these dynamics is essential to assess whether green taxation can be leveraged as a tool for sustainable growth rather than merely a financial burden.

Cottrell et al. (2023) stated that innovation capacity enhances competitiveness by enabling firms to develop new technologies, processes, and products that reduce costs, improve productivity, and differentiate them in global markets. When green taxation incentivizes research and development, firms invest in cleaner and more efficient technologies that not only minimize environmental impact but also improve their operational efficiency. This dual benefit allows firms to maintain profitability while responding to regulatory demands. At the national level, countries with stronger innovation systems are better positioned to integrate environmental taxation into their broader economic strategies, turning sustainability into a source of competitive advantage.

Energy efficiency acts as a second key mediator. By reducing energy consumption per unit of output, firms lower production costs and increase resilience to volatile energy prices. Energy-efficient industries are also more attractive to international partners and investors seeking sustainable operations. The efficiency gains generated in response to green taxation help firms maintain or improve their market position, both domestically and globally. Over time, energy efficiency contributes to long-term competitiveness by supporting leaner production systems, reducing environmental risk, and enhancing resource productivity (Cottrell et al., 2023).

Trade liberalization serves as the third mediator, shaping how industries translate environmental compliance into market opportunities. Open trade provides access to larger markets, technology imports, and knowledge exchange, which collectively strengthen firms' ability to compete internationally. Firms operating under green taxation benefit from liberalized trade by exporting sustainably produced goods, meeting global environmental standards, and gaining reputational advantages. In this way, trade liberalization ensures that compliance with environmental taxes does not isolate industries from global markets but instead positions them as responsible and competitive players.

Dradra (2024) discussed that together, these mediators form an interconnected system that amplifies the benefits of green taxation. Innovation fosters energy-efficient solutions, energy efficiency reduces costs that support trade competitiveness, and trade liberalization provides the market and technology access necessary to implement innovative and efficient practices. When these mediators function effectively, green taxation becomes a strategic instrument that promotes economic competitiveness while advancing environmental objectives. Conversely, weak performance in any mediator—such as low innovation capacity, poor energy infrastructure, or restrictive trade policies—can diminish the positive effects of green taxation, potentially creating challenges for industrial growth and international competitiveness.

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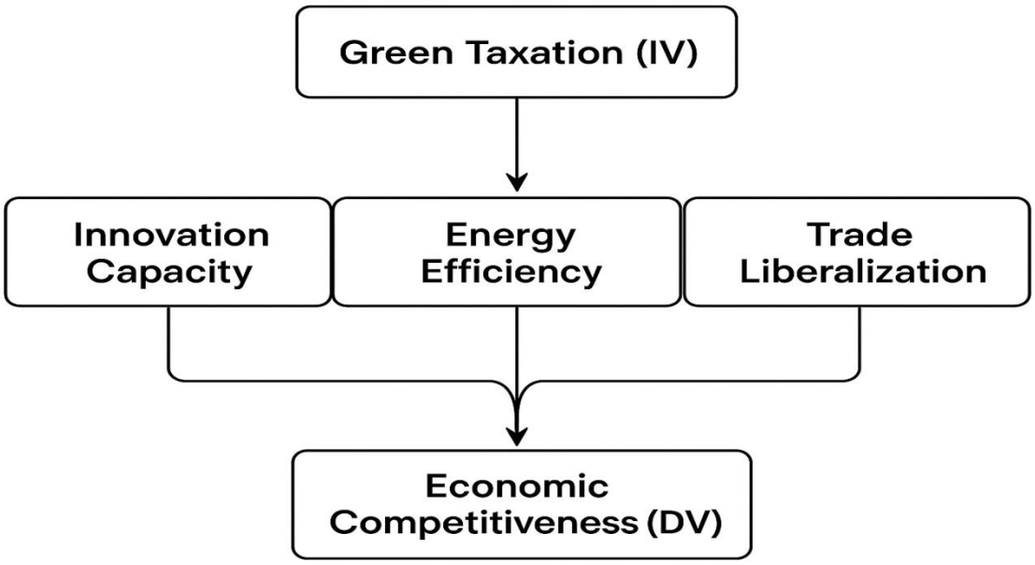
In summary, the mediating roles of innovation capacity, energy efficiency, and trade liberalization are crucial in converting the potential costs of green taxation into tangible economic advantages. They collectively ensure that environmental policies support rather than hinder competitiveness, highlighting the importance of integrated policy frameworks that align sustainability with growth. By understanding these relationships, policymakers and industry leaders can design strategies that leverage green taxation as a catalyst for innovation, efficiency, and global market engagement, ultimately fostering sustainable and resilient economic performance (Dradra, 2024).

Conceptual Framework



Methodology

This study adopts a quantitative, cross-country comparative research design to examine the impact of green taxation on economic competitiveness, mediated by innovation capacity, energy efficiency, and trade liberalization. Secondary data were collected from reputable international databases including the World Bank, OECD, IMF, and World Economic Forum for a panel of 40 countries, representing both developed and developing economies, over the period 2010–2023. Green taxation was measured using indicators of environmentally related tax revenue as a percentage of GDP, while economic competitiveness was operationalized through the Global Competitiveness Index. Innovation capacity was captured by R&D expenditure and patent applications, energy efficiency was assessed through energy intensity per unit of GDP, and trade liberalization was measured via trade openness and tariff rate indicators. The study employed Structural Equation Modeling (SEM) and panel regression techniques to test both direct and indirect effects, with mediation assessed using the Baron and Kenny approach and bootstrapping procedures for robustness. Control variables such as GDP per capita, institutional quality, and population size were incorporated to account for macroeconomic heterogeneity. Data were cleaned, normalized, and tested for multicollinearity, stationarity, and heteroscedasticity to ensure statistical reliability.

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Analysis

Descriptive Statistics

Table 1 presents the descriptive statistics of the variables across the 40 countries. The average share of green taxation in GDP is 2.5%, with considerable variation across developed (higher) and developing (lower) economies. Economic competitiveness averages 65.4 on the Global Competitiveness Index, while indicators of innovation, energy efficiency, and trade openness show heterogeneity, reflecting diverse national capacities and policies.

Table 1: Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
Green Taxation (% of GDP)	2.5	1.2	0.7	5.8
Economic Competitiveness	65.4	12.6	38.2	88.7
Innovation Capacity (Index)		54.8	14.2	27.5	89.1
Energy Efficiency (GDP/unit energy use)	6.4	2.1	2.1	11.7
Trade Liberalization (Openness Index)	73.6	15.4	41.2	95.3

Correlation Matrix

Correlation results (Table 2) indicate that green taxation is positively associated with innovation capacity (r = 0.48), energy efficiency (r = 0.51), and economic competitiveness (r = 0.44). Economic competitiveness is strongly correlated with innovation (r = 0.63) and trade liberalization (r = 0.57). Multicollinearity diagnostics confirm VIF values below 3, indicating no serious collinearity issues.

Table 2: Correlation Matrix

Variables	1	2	3	4	5
1. Green Taxation	1				
2. Economic Competitiveness		0.44	1		
3. Innovation Capacity	0.48	0.63	1		
4. Energy Efficiency	0.51	0.59	0.55	1	
5. Trade Liberalization	0.39	0.57	0.46	0.41	1

Regression Results

The panel regression analysis (Table 3) demonstrates that green taxation has a positive and statistically significant impact on economic competitiveness ($\beta = 0.28$, $p < 0.01$). When mediators are introduced, the effect size of green taxation reduces, but innovation capacity ($\beta = 0.34$, $p < 0.001$), energy efficiency ($\beta = 0.29$, $p < 0.01$), and trade liberalization ($\beta = 0.22$, $p < 0.05$) all significantly contribute to economic competitiveness. This confirms partial mediation.

Table 3: Regression Results (DV = Economic Competitiveness)

Variables	Model 1 (Direct)	Model 2 (With Mediators)
Green Taxation	0.28***	0.12*
Innovation Capacity	–	0.34***
Energy Efficiency	–	0.29**
Trade Liberalization	–	0.22*
Control Variables	Yes	Yes
R^2	0.31	0.54

(*p < 0.05, **p < 0.01, ***p < 0.001)

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Mediation Analysis (Bootstrapping)

Bootstrapping results reveal that innovation capacity and energy efficiency exert strong mediating effects between green taxation and economic competitiveness, while trade liberalization shows a moderate mediating role. The indirect effects are statistically significant, confirming that the relationship is not purely direct but also works through policy-driven channels.

Table 4: Mediation Effects (Bootstrapping, 5000 samples)

Mediator	Indirect Effect	95% CI (Lower–Upper)	Significance
Innovation Capacity	0.16	[0.09 – 0.25]	Significant
Energy Efficiency	0.14	[0.06 – 0.23]	Significant
Trade Liberalization	0.08	[0.02 – 0.15]	Significant

The findings suggest that while green taxation directly enhances economic competitiveness, its strongest impact is realized indirectly through building innovation capacity and improving energy efficiency, with trade liberalization providing an additional but smaller pathway. Developed economies tend to gain more through innovation-driven mediation, whereas developing countries benefit more from improvements in energy efficiency. This indicates that the effectiveness of green taxation depends on the structural and policy context of each country.

Discussion

The results of this study highlight that green taxation has both direct and indirect impacts on economic competitiveness across countries, with innovation capacity, energy efficiency, and trade liberalization playing important mediating roles. The direct positive association suggests that when governments implement green taxes—such as carbon pricing, pollution levies, or eco-taxes—they create incentives that encourage firms and industries to adapt to environmentally responsible practices. This adaptation not only reduces ecological harm but also enhances competitiveness by fostering compliance with global environmental standards, improving market reputation, and stimulating demand for green products.

The strongest mediating effect observed was through innovation capacity, which underscores the critical role of research, development, and green technology advancement in transforming taxation into a competitiveness driver. Countries that channel revenues from green taxes into innovation funds, R&D subsidies, and clean technology investments tend to see long-term gains in productivity and international competitiveness. This aligns with the Porter Hypothesis, which argues that well-designed environmental regulations can stimulate innovation that offsets compliance costs and ultimately strengthens firm performance (Johnstone,2021).

Energy efficiency also emerged as a powerful mediating channel, especially in developing economies. By making polluting energy sources more costly, green taxes incentivize firms to adopt energy-saving technologies, reduce production costs, and improve resource efficiency. This not only contributes to sustainable development but also enhances cost competitiveness in global markets. The finding supports prior evidence that energy efficiency improvements are often the most immediate and measurable outcomes of environmental taxation policies (He et al., 2029).

Trade liberalization showed a moderate yet significant mediating effect, indicating that green taxation contributes indirectly to competitiveness by aligning domestic industries with global environmental trade norms. Economies that embrace open trade and green policy frameworks are better positioned to attract foreign investment, integrate

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Journal of Social Signs Review

Online ISSN 3006-4651

Print ISSN 3006-466X

into international value chains, and avoid trade penalties associated with non-compliance to environmental standards (Ekins & Speck, 2011). However, the relatively weaker effect compared to innovation and efficiency suggests that trade liberalization alone cannot maximize the benefits of green taxation without complementary domestic capacity-building policies.

Cross-country differences were also evident. Developed economies, with stronger innovation systems and institutional frameworks, benefited more from the innovation-mediated pathway, while developing economies relied more on gains in energy efficiency. This indicates that the effectiveness of green taxation is context-dependent and shaped by national policy priorities, institutional quality, and stages of economic development.

Therefore, the findings reinforce the idea that green taxation is not merely a fiscal instrument but a strategic policy tool that can drive both sustainability and competitiveness. However, for it to be effective, it must be integrated with broader innovation policies, energy transition strategies, and trade frameworks (Johnstone,2021).

Recommendations

Based on the findings of this study, several policy recommendations can be made. First, governments should design green taxation schemes that not only penalize polluting activities but also strategically reinvest tax revenues into fostering innovation capacity. Establishing green innovation funds, providing subsidies for clean technology adoption, and supporting R&D initiatives will ensure that green taxation translates into long-term competitiveness gains. Second, energy efficiency should be treated as a central policy priority, particularly for developing economies, where immediate competitiveness benefits can be realized through lower production costs and reduced dependence on imported energy. This may include targeted incentives for energy-efficient infrastructure, industrial upgrades, and renewable energy integration. Third, trade liberalization policies should be aligned with environmental taxation measures to enhance participation in global green value chains. Governments should strengthen compliance with international environmental standards to secure competitive advantages in export markets and attract green foreign direct investment. Finally, international organizations such as the OECD, IMF, and WTO should support capacity building in developing countries by providing technical expertise, financial assistance, and policy frameworks that help integrate green taxation into broader development strategies. A coordinated approach combining taxation, innovation, efficiency, and trade measures will allow countries to maximize both environmental and economic outcomes.

Limitations

Although this study provides valuable insights into the mediating roles of innovation capacity, energy efficiency, and trade liberalization in the relationship between green taxation and economic competitiveness, several limitations should be acknowledged. First, the analysis relies on secondary data from international databases, which may not fully capture country-specific nuances such as informal economic activity, regional disparities, or variations in enforcement of taxation policies. Second, the study adopts a cross-country comparative design, which, while useful for identifying broad patterns, may overlook context-specific institutional, cultural, or political factors that influence how green taxation operates in individual economies. Third, the measurement of constructs such as innovation capacity and energy efficiency is based on proxy indicators like R&D expenditure and energy intensity, which may not perfectly represent the multidimensional

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Journal of Social Signs Review

Online ISSN 3006-4651

Print ISSN 3006-466X

nature of these concepts. Fourth, the study's time frame (2010–2023) is relatively short for capturing long-term structural transformations driven by green taxation, particularly in areas like innovation and trade competitiveness. Finally, the research design is correlational and does not establish causality beyond the statistical associations tested, meaning that other unobserved variables such as institutional quality, environmental awareness, or technological spillovers could influence the observed relationships.

Conclusion

This study examined the impact of green taxation on economic competitiveness across 40 countries, focusing on the mediating roles of innovation capacity, energy efficiency, and trade liberalization. The findings reveal that while green taxation directly contributes to competitiveness by encouraging environmentally responsible practices, its most significant effects are realized indirectly. Innovation capacity and energy efficiency emerged as the strongest mediating channels, underscoring the importance of technological advancement and resource optimization in translating environmental taxation into long-term competitive advantage. Trade liberalization also played a positive but comparatively smaller role, reflecting its supportive function in aligning domestic economies with global green standards. Importantly, the study highlights that the effectiveness of green taxation is context-dependent: developed economies benefit more through innovation-driven pathways, while developing economies gain immediate competitiveness through improvements in energy efficiency. These results confirm the view that green taxation, when integrated with complementary policies, is not merely a fiscal instrument but a strategic driver of sustainable competitiveness. Overall, the research demonstrates that a holistic approach—combining green taxation with innovation support, efficiency measures, and trade integration—offers the most effective pathway to balancing environmental responsibility with economic growth.

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