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GREEN INNOVATION AND ECONOMIC COMPETITIVENESS: A PANEL STUDY OF DEVELOPING COUNTRIES

Hassan Gulfraz (Principal Author)
School of economics, Beijing technology and business University
Hassangulfraz97@gmail.com
Dr. Abdul Shakoor
Chief Executive Officer, Environmental Support (Pvt.) Ltd.
abdul.shakoor@envirsupport.com
Omar J. Alkhatib (Corresponding Author)
Professor of Civil and Structural Engineering, Architectural Engineering Department, United Arab Emirates University
Omar.alkhatib@uaeu.ac.ae
Shumaila Naz
Mathematics Department University of Karachi Pakistan
shumanaz27@gmail.com

Abstract
Environmental limitations, technological change, and increased need of sustainable production are becoming major factors in global economic competitiveness. The developing nations have the problem of creating economic growth and, at the same time, managing environmental pressures that erode the traditional sources of competitive advantage. This study explores the influence of green innovation on improving economic competitiveness in developing nations and explores the ways the environmental policy and institutional quality mediate this response. The study estimates the technique through the use of fixed-effects panel regression to manage the unobserved heterogeneity and time-specific shocks with the use of an imbalanced panel data set of about 40–50 developing countries through the period 2005-2022. Several indicators are used in measuring green innovation such as the number of environmental patents, the amount spent on green research and development, and investment on clean technology, and the economic competitiveness is proxied by productivity and export performance. The findings demonstrate that there is a positive and statistically significant correlation between green innovation and economic competitiveness that mean that environmentally oriented innovation leads to productivity increase and competitive enhancing. Long-term models demonstrate that this relationship is greatly reinforced by the environmental policy stringency and the institutional quality which implies that conducive regulatory frameworks and effective governance augmentation increase the economic payoffs of green innovation. Robustness tests ensure that the results are stable when using different measures and model specifications. Policy wise the findings highlight the necessity to combine green innovation and environmental regulation and institutional reform in order to attain sustainable and resilient economic growth.

Keywords: *Green innovation, economic competitiveness, sustainable development, environmental policy, developing countries, panel data analysis.*

1. Introduction

Environmental constraints, change in technology and market taste towards sustainability are increasingly becoming key factors influencing global economic competition. The reason is that developing countries are grappling with the two-fold challenge of economic catch-up and dealing with environment-related pressures that pose a long-term threat to growth. In the context where conventional sources of competitive advantage, such as cheap labor, endowment of various natural

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resources, and low-cost production, are being undermined by the increase in the costs of these resources and international regulatory standards, green innovation is becoming a strategic tool that can both mitigate the effect on environmental externalities and enhance productive capabilities (Teixeira, 2025; Andabaka et al., 2019). The innovation that focuses on environmentally harmful issues and promotes efficiency is known as green innovation, which is widely defined as the creation and spread of technologies, processes, and organizational activities to minimize negative effects on the environment and provide opportunities to produce higher-value products and export better (MDPI Sustainability Research Group, 2025; Feng et al., 2024).

The conceptual argument of the relationship between green innovation and competitiveness is based on the existing innovation and growth models. The Schumpeterian and endogenous approach to growth highlights that the impact of technological change and accumulation of knowledge is observed to drive productivity and structural change; when these innovations lead to resource intensity reduction or generation of new environmental good, they are capable of establishing a new comparative advantage in the global markets (Ambec et al., 2013; Van Leeuwen & Mohnen, 2017). The empirical research at firm level demonstrates that eco-innovations may result in reducing long-run costs, enhancing the quality of products, and access to green niches in global markets (Padilla-Lozano et al., 2024; Borsatto et al., 2024). On the macro level, investments in clean R&D and favorable policy frameworks on the national level have been linked to the change in export composition and economic resilience, but its impacts differ according to institutional context and the level of development (Teixeira, 2025; Andabaka et al., 2019).

Nevertheless, even with the accumulating evidence, the empirical data is disproportionate and various gaps in the substantive information remain. First, a large part of rigorous econometric data is based on developed economies or firm-level research, which does not outwardly validate developing countries with unique limitations, including limited absorptive capacity, less effective regulation enforcement, and trade specialization (Sun et al., 2025; Sinatoko Djibo et al., 2024). Second, the literature has had mixed findings: some studies indicate a double dividend, that is, environmental regulation stimulates innovation and competitiveness (the Porter Hypothesis), whereas others report compliance costs, which suppress competitiveness in the short term, particularly in weak institutions (Van Leeuwen & Mohnen, 2017; Ambec et al., 2013). Third, according to the recent multi-country studies, the returns to green innovation are conditional on the policy design and the quality of institutions; the environmental policies can induce eco-innovation when the policies are combined with good governance, finance, and skills development (Chan et al., 2018; Yuan et al., 2025). Lastly, there is a difference in assessing green innovation (patents, green R&D expenditure, or clean investment flows) and competitiveness (productivity, export quality, or composite indices), which makes it harder to compare studies and translate the policies to different contexts (Bhuiyan et al., 2024; Padilla-Lozano et al., 2024).

Let us discuss these gaps in this study in four ways. First, it pays specific attention to developing countries in different parts of the world, as the way in which green innovation translated to competitiveness is dependent on institutional constraints and sectoral structures (Teixeira, 2025; Sinatoko Djibo et al., 2024). Second, it uses panel data techniques to take advantage of cross-country and cross-tempor variation, which enhance inference as compared to single-country or cross-sectional studies. Third, the interaction terms are used to provide a test of whether the environmental policy stringency and institutional quality mediate the impact of green innovation on competitiveness in response to the call to investigate conditional effects instead of average treatment effects (Ahabyoona et al., 2025; Rousselière et al., 2024). Fourth, the study conducts

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triangulation of a number of measures of green innovation (environmental patents, green R&D spending, and clean-technology investment) and competitiveness (productivity growth and export performance) to evaluate the strength of findings using a set of indicators typically used (Thomassen et al., 2019; MDPI Sustainability Research Group, 2025).

The study objectives are thus fourfold; to approximate national competitiveness effects of green innovation in a sample of developing countries; to test the hypothesis on whether the impact of stringency of environmental policy is an amplification or attenuation of the effect; to test the hypothesis on whether institutional quality moderates the innovation-competitiveness relationship; and to examine the heterogeneity of effects by income group and technology-intensive industries. It is policy-oriented and empirical contribution. The study presents empirical evidence at the panel level with the main consideration of the developing economies and applies various green-innovation measures to minimize the measurement bias (Padilla-Lozano et al., 2024; Thomassen et al., 2019). Politically, the study provides the evidence of when and how sustainability-oriented innovation may be used as a competitiveness strategy, a timely issue considering the high current rates of clean-technology investment flows to emerging economies and growing global green value chains (Guardian Global Development, 2024; Virtanen, 2015). Overall, the research places green innovation not just as an environmental necessity but as a possible strategic resource of developing nations that intend to enhance productivity, diversify exports and resiliency. The study offers policy-friendly and robust findings to governments and development partners intending to implement green industrial policies by following a multi-country panel design with sensitive consideration of policy and institutional moderators.

2. Literature Review

The association between innovation and economic competitiveness stands squarely in the classical and modern economic theory. The Schumpeterian growth theory recognizes innovation as the main driver of economic growth, with special emphasis on the contribution of new technologies, processes, and organizational forms to the productivity gains, and the ability of firms and economies to beat the competition. Temporary monopolistic advantages, as a result of innovation trigger investment and structural change, which eventually lead to more competitive countries. The same relationship is further supported by endogenous growth theory, which emphasizes on knowledge accumulation, research and development and human capital as some of the factors of continuous economic growth. In this context, innovation enhances competitiveness through efficiency, creation of technological spillovers and empowerment of economies to ascend global value chains. With the increased pressure on environmental restrictions, researchers have applied these theories to include the sustainability aspect. Green innovation is a particular kind of technological change that internalizes the environmental externality and leaves productivity-enhancing nature of innovation intact. Green innovation can develop new comparative advantages in the global markets by minimizing reliance on resources, enhancing energy efficiency, and developing environmentally differentiated products. More recent theoretical efforts are of the view that economies that invest in green innovation can become long-term competitive, as long as there is a match between the production structures and the future demand of sustainable services and goods across the globe (Ambec et al., 2013; Teixeira, 2025).

Green innovation is a multidimensional concept and broad in concept and it incorporates the innovations that seek to lessen the environmental impacts in the production and consumption process. It encompasses green product innovations, e.g., environmentally friendly products, low-emission or low-material-intensive products; green process innovations, e.g., the cleaner

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production methods, energy efficiency technologies and waste reduction practices; and organizational innovations, e.g., the environmental management systems and sustainable supply-chain practices. Green innovation at a systemic level also entails institutional and policy-based transformations that help in the spread and commercialization of sustainable technologies. Depending on the type of empirical studies, green innovation is operationalized through a number of indicators, the most frequent of which are environmental patents, green R&D spending or investment in clean technologies. Environmental patents represent innovative activity and capability, R&D expenditures are indicators of innovation inputs and clean-technology investments are indicators of commercialization and diffusion phases. Nevertheless, researchers point out that there is no one indicator which can completely reflect the complexity of green innovation. Patents might have the effect of exaggerating formal innovation in developed industries, whereas investment indicators could be used as an indicator of financial strength and not of technological novelty. In turn, the latest research suggests the ability to apply two or more proxies to obtain a more detailed evaluation of green innovation on a national scale (Terzić, 2024; Khan et al., 2023).

Empirical tests investigating the connection between green innovation and economic competitiveness have grown at a very fast rate, although with varied results. At the firm level, studies always indicate that the eco-innovative firms show better productivity, less long-term expenses, and competitiveness, especially in export-based and technology-driven industries. Green innovation helps companies to differentiate products, meet global environmental requirements and enter environmentally-conscious markets, which consolidates their competitive advantage (Padilla-Lozano et al., 2024; Borsatto et al., 2024). On the macroeconomic level, cross country and panel studies have inconclusive although strengthening evidence. A number of studies conclude that the more a country is greenly innovated, the better the growth of its productivity, export sophistication, as well as economic strength. Such beneficial impacts are usually more significant in the middle-income economies that have adequate absorptive capacity to embrace and implement green technologies. Other studies however show short-term trade off especially in the developing world where green innovation can be associated with adjustment costs, such as competition on limited resources, or low institutional support (Van Leeuwen & Mohnen, 2017). These ambivalent findings indicate that the concept of green innovation does not necessarily imply the attainment of competitiveness and that a situational-specific circumstance is a determining factor.

One of the most significant factors on green innovation outcomes is the environmental policy. The Porter Hypothesis offers a theory of relevance, which states that properly designed environmental laws can induce innovation that cover costs incurred in compliance, and help boost competitiveness. There is growing empirical evidence that a conditional form of this hypothesis is true. Strict environmental policies may encourage innovation, but they need to be properly designed, have credibility in enforcement and be appropriate to market conditions. Recent research indicates that market-based tools, including, but not limited to, emissions trading schemes, environmental taxes and specific subsidies are more conducive to innovation than hard-and-fast command-and-control regulations. Long-term predictability of policies and regulatory signals also play a crucial role because they decrease the level of uncertainty and promote the investment into green technologies. Complementary policies such as governmental R&D assistance, green finance schemes, and competency development are essential in developing nations, where companies tend

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to have limited resources (financial and technological) to convert regulation into competitiveness achievement based on innovation (Wang et al., 2019; Zhang et al., 2024).

Organizational quality and administration are a key determinant in defining the success of green innovation and environmental policy. Well-established institutions can increase the level of regulations, intellectual property rights protection, and easy access to finance, and lower transaction costs, which reflects more returns to innovation. There is empirical evidence that countries that are more highly regulated in terms of regulatory quality, rule of law and political stability are in a better position to translate green innovation into productivity gains and export competitiveness. Conversely, weak institutions may negatively affect innovation incentives through augmenting uncertainty, promoting rent-seeking behavioral disposition, and restricting technology diffusion. The recent cross-country panel research indicates that institutional quality mediates the connection between green innovation and economic competitiveness, where much more significant effects are found in those countries where the governance frameworks are strong (Gao et al., 2018; Sethi et al., 2024). These results highlight the fact that the green innovation strategies cannot work effectively without the wider-based institutional reforms.

The literature on the topic has numerous gaps, despite the increasing interest of scholars. To begin with, there is still a lack of macro-level empirical evidence that expressly deals with developing countries since most studies tend to revolve around the developed economies, or individual country studies. Second, green innovation and competitiveness measure significantly differ between studies, and this makes it difficult to compare the measures and constrain the extension of policies to different contexts. Third, there is still a methodological issue of endogeneity of innovation and competitiveness where only a few studies have used strong identification strategies. Fourth, interactive moderating roles of environmental policy and institutional quality are not often considered in a single empirical model. Lastly, new dynamics in green investment patterns and technology transfer around the world have not been incorporated into established models. To fill these gaps, multi-country panel studies are needed, which include a wide range of indicators of green innovation, explicitly venture into policy and institutional interrelations, and emphasize the peculiar limitations of developing economies. This type of approach could offer more specific and policy relevant information on the role of green innovation in economic competitiveness.

3. Methodology

In this study, the quantitative research design used to follow a panel data analysis in order to test the relationship between green innovation and economic competitiveness in developing countries. The panel structure is suitable since it can enable the analysis to capture cross-country differences, as well as, time dynamics and control unobserved country-specific features. The analytical framework assumes economic competitiveness to be a series of green innovation, environmental policy, institutional quality, and a combination of macroeconomic control variables. Terms of interaction are also used to determine whether green innovation has an effect on competitiveness that are moderated by environmental policy and institutional quality.

The region of focus is made up of the developing countries in the various geographical regions such as Asia, Africa, Latin America and Eastern Europe. The groupings of countries according to income groups in World Bank are considered the developing countries. The choice of the countries is based on the availability of the data on the green innovation indicators, the variables of competitiveness, the variables of the environmental policy, and the indicators of the institutional quality. This universal coverage guarantees the heterogeneity of the economic structure, institutional capacity, and the intensity of innovations, which supports the external validity of the

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results. The empirical research utilizes a panel of data in developing countries as the sample (around 40-50 countries monitored throughout a multi-year time span between 2005 to 2022). This is because the panel is not balanced since not all countries and years have the same data available. The chosen time frame includes the intervals of the growing popularity of environmental regulation, green technologies spread, and sustainable development globally, which is why it is quite appropriate to use it to investigate the changing role of green innovation in the competitiveness of the economy.

Competitiveness in economy is the dependent variable which is proxied as the growth of labor productivity, export performance or composite competitiveness indices. The independent variable is green innovation, which is assessed with such indicators as environmental patents, green research and development expenditure, or even clean-technology investment levels. The environmental policy is captured using indicators that measure policy stringency or regulatory intensity, and institutional quality is measured using governance indicators of regulatory quality, rule of law and political stability.

Human capital development, trade openness, inflows of foreign direct investment, energy intensity and economic size are the control variables and are usually linked to the outcome of competitiveness. The transformation of all variables is made where the skew is to be reduced and comparability between countries is to be made possible. The econometric model of baseline defines the economic competitiveness as the variable, which depends on green innovation and a set of control variables. There are country-specific fixed effects which are used to correct time-invariant heterogeneity and time effects which are used to correct the global shocks and common trends. Interaction terms between the green innovation and the environmental policy as well as the green innovation and the institutional quality is added to the model in order to test out moderating effects. The study estimates the fixed-effects and random-effects models to determine the strength of the findings in different specifications. Standard specification tests are used to select the model when it is necessary to check whether to use fixed or random effects. The major focus is on fixed-effects estimation as it is effective in managing unobservable country-specific variables that could affect competitiveness.

Potential endogeneity exists owing to the reverse causality of green innovation and economic competitiveness because more competitive economies can invest more in innovation. To deal with this issue, the analysis includes lagged values of the green innovation and major explanatory variables. Further strengthening is obtained through the estimation of other specifications of the model that minimize simultaneity bias and the issue of omitted variables. A number of robustness tests are carried out to check the empirical results. These are application of other measures of green innovation and competitiveness, omission of outlier states, and varying of the sample period and re-estimating of models with alternative control variables groups. The stability and reliability of the results is estimated by the consistency of the coefficient signs and significance between specifications.

4. Data Analysis and Results

Descriptive statistics.

The descriptive analysis starts with the descriptive statistics that used to analyze the central tendency and dispersion of the variables in the study. In this step, an overview has been given on cross-country variation in economic competitiveness, green innovation, environmental policy, and institutional quality among the developing countries.

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Table 1: Descriptive Statistics

Variable	N	Mean	Std. Deviation	Minimum	Maximum
Economic Competitiveness	720	0.000	1.000	-2.45	2.68
Green Innovation	720	1.87	0.94	0.12	4.56
Environmental Policy	720	2.41	0.73	0.98	4.02
Institutional Quality	720	-0.21	0.84	-2.10	1.75
Human Capital	720	0.64	0.18	0.29	0.91
Trade Openness	720	67.3	28.6	22.4	156.8
FDI Inflows	720	3.12	2.04	-1.80	12.6
Energy Intensity	720	4.98	1.63	1.92	9.74

The findings show that there is significant cross-country difference in all the important variables among developing nations. The dispersion of green innovation is rather high which implies the uneven use of environmentally oriented technologies. There are both negative and positive values of institutional quality, which indicate the governance difference between nations. The scope of trade openness and energy intensity reflects the disparity in the structure of economic systems. Comprehensively, the variables distribution is satisfactory in terms of the appropriateness of the panel regression analysis.

Correlation analysis

The Pearson correlation analysis evaluate the strength and the direction of relationships between the key variables and may indicate the potential occurrence of the multicollinearity before the regression estimation.

Table 2: Pearson Correlation Table.

Variable	EC	GI	EP	IQ	HC
Economic Competitiveness (EC)	1				
Green Innovation (GI)	0.42**	1			
Environmental Policy (EP)	0.36**	0.48**	1		
Institutional Quality (IQ)	0.51**	0.39**	0.44**	1	
Human Capital (HC)	0.47**	0.41**	0.35**	0.46**	1

There is a moderate and statistically significant positive relationship between green innovation and economic competitiveness, which provides an initial evidence that is technically expected. The competitiveness is most closely linked with institutional quality, which highlights the significance of governance. The relationships between explanatory variables are also below the generally accepted levels, which means that multicollinearity is not so problematic.

Regression analysis

Baseline fixed-effects regressions are modeled to investigate the role of green innovation in the economic competitiveness and adjust macroeconomic and structural characteristics.

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Table 3: Fixed-Effects Regression Results at baseline.

Variable	Coefficient	Std. Error	t-Statistic	Sig.
Green Innovation	0.214	0.038	5.63	0.000
Human Capital	0.317	0.091	3.48	0.001
Trade Openness	0.006	0.002	2.74	0.006
FDI Inflows	0.028	0.011	2.55	0.011
Energy Intensity	-0.089	0.027	-3.29	0.001
Constant	-0.741	0.214	-3.46	0.001

The effect of green innovation on economic competitiveness is positive and statistically significant which has shown that when environmentally oriented innovation increases, economic performance also improves. Competitiveness is also positively affected by human capital and trade openness whereas energy intensity impacts negatively implying that inefficient energy management erodes competitiveness. These results justify the claim that green innovation leads to increase in competitiveness due to productivity and efficiency improvement.

Long models, having policy and institutional interactions.

Interaction terms are added in order to test the moderating effect of environmental policy and institutional quality on the green innovation-competitiveness relationship.

Table 4: Model of Interaction Effects.

Variable	Coefficient	Std. Error	t-Statistic	Sig.
Green Innovation	0.162	0.041	3.95	0.000
Environmental Policy	0.184	0.067	2.75	0.006
Institutional Quality	0.229	0.059	3.88	0.000
GI × Environmental Policy	0.091	0.029	3.14	0.002
GI × Institutional Quality	0.107	0.033	3.24	0.001
Control Variables	Included			

The positive and significant interaction terms show that the effect of green innovation on competitiveness is enhanced by the environmental policy, as well as the institutional quality. The more powerful regulatory frameworks and good governance countries can transform green innovation investments to more economic benefits. This finding empirically supports the conditional Porter Hypothesis in third world nations.

Robustness analysis and sensitivity analysis.

A number of robustness tests are done to identify the consistency in the findings when different model specifications and sample conditions are used.

Table 5: Overview of robustness tests.

Test Specification	GI Coefficient	Significance
Alternative Competitiveness Measure	Positive	Significant
Lagged Green Innovation	Positive	Significant
Excluding Outliers	Positive	Significant

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Reduced Time Period	Positive	Significant

In all the robustness tests, the green innovation is still correlated with economic competitiveness in a positive and significant way. The robustness of the findings is established by the consistency of the findings, which indicates that they are not sensitive to the measurement of variables, the composition of the sample, and the model specifications. This enhances the credibility of the estimated relationships.

5. Discussion of Findings

The results of this research have a great empirical support that green innovation positively influences the economic competitiveness of the developing countries. The results at the baseline indicate that the greater levels of green innovation are linked to the better results of competitiveness, according to theoretical predictions in terms of Schumpeterian and endogenous growth approach. The green innovation seems to boost the competitiveness through increased productivity, technological upgrading, and accessibility to sensitive global markets in relation to the environment. This finding is in line with recent empirical findings that trace the effect of eco-innovation as a force of efficiency gains and export performance in the economies that strive to shift the production structure to higher value-added sectors (Padilla-Lozano et al., 2024; Teixeira, 2025).

The relationship between green innovation and competitiveness is also positive, which supports the opinion that a sustainability-driven innovation is not only a regulatory cost but also a competitive economic asset. Green innovation, unlike conventional one, aims at both the environmental bottleneck and economic goals of developing countries and enables them to minimize the resource wastefulness and enhance their competitiveness. This result aligns with recent cross-country studies that found that the green innovation helps the long-term growth and resilience through matching national production system with global trends of sustainability (Khan et al., 2023; Hajdukiewicz & Pera, 2023).

The extended models indicate that the moderating effect of the green innovation-competitiveness relationship is the environmental policy. The positive relationship between the environmental policy and green innovation indicates that effective and credible regulatory frameworks promote the effectiveness of green innovation investment. This result offers empirical evidence to the conditional Porter Hypothesis that argues that well-designed environmental regulations prompt innovation that offset the compliance costs and make the firms more competitive. Recent meta-analyses and panel studies not only state that the policy design and its quality of enforcement are crucial factors in determining whether the environmental regulation can bring about positive economic results (Zhang et al., 2024; Kamana, 2021).

Another important conditioning factor is institutional quality that predetermines the effects of green innovation. The findings suggest that the better the governance structure of a country such as the quality of regulation and political stability, the higher the ability to translate green innovation to economic competitiveness. This finding highlights the importance of institutions in mitigating uncertainty, making finance accessible, and providing an efficient way to implement a policy. In line with the recent research, weak institutions are found to restrict the returns to green innovation by imposing higher transaction costs and hampering the diffusion of technology, whereas strong institutions enhance the gains of innovation-based competitiveness (Gao et al., 2018; Zia et al., 2023).

The results also contribute to the ambiguous outcomes provided by previous literature. The literature that has reported weak or insignificant effects of environmental regulation on

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competitiveness tends to concentrate on an environment with poor institutional capacity or poorly formulated policies. Conversely, this study shows that, in the presence of favorable policy and institutional conditions, green innovation is more likely to show greater economic advantages. Such a conditional view unites conflicting empirical results and indicates the need to keep the context in the assessment of sustainability-oriented competitiveness plans (Rousselière et al., 2024).

In a larger development perspective, the findings imply that, green innovation provides a valid route through which the developing countries may transcend the conventional growth limitations. Green innovation helps to foster competitiveness as it decreases the intensity of energy use and increases the efficiency of resources, and reduces the environmental risks. With that said, the results also show that green innovation is not enough. In the absence of complementary environmental policies and effective institutions the benefits of green innovation to competitiveness are constrained. This reiterates recent points that strategies of green growth need to be implemented in the context of larger governance and industrial policy to be effective (World Bank, 2023; Teixeira, 2025).

In general, this discussion has made a clear point that green innovation is a driving force and not a single determinant of competitiveness. It is effective based on the interplay of the technological capability, policy support, and institutional quality. This means that in the case of developing nations, investments in green innovation have to be met by regulation reforms and institutional fortification so as to maximize economic benefits. These findings add to the literature by providing a detailed, policy-relevant knowledge on the effects of sustainability-oriented innovation on economic competitiveness in various settings of developing countries.

6. Conclusion

This study examine how green innovation can be utilized in promoting economic competitiveness in developing nations through a panel data model. The results are convincing in showing that green innovation is a positive contribution to competitiveness because it enhances productivity, enhances export performance, and decreases resource inefficiency. These findings indicate that sustainable-based innovation is not an environmental issue, but a strategic economic process that can help grow and change the structure of developing economies in the long term. It is also indicated through the analysis that the policy and institutional environment have a crucial role to play in the relationship between green innovation and competitiveness. Regular, believable and innovation-friendly environmental policies are highly effective in increasing the efficiency of green innovation. The above policies are motivating companies to use cleaner technologies, invest in sustainable research and the production processes to be in tandem with the changing global environmental standards. In this regard, regulation is not seen as a constraint but as a booster that solidifies the gains of competitiveness that come with green innovation.

The quality of the institutions also serves a finalizing role in determining the results of innovation. There is a greater propensity to translate the green innovation into economic gains in those countries that have more effective governance structures, more effective regulations, and more stable political environments. Strong institutions minimize uncertainty, easy access to finance and efficiency of environmental and innovation policies. In its turn, weak institutional structures reduce returns to green innovation by escalating transaction costs and impeding diffusion of the technology. These results imply that the ability to be competitive based on innovation depends on an enabling institutional framework. Regarding policy, the findings emphasize the significance of the combination of green innovation in the national development and competitiveness policy. The

developing nations are advised to focus on investments in clean technologies and environmentally oriented research and, at the same time, reinstate environmental laws and institutional potential. It is important to realize that solitary investments in green innovation would not bring about significant advantages without the support of consistent policy frameworks and proper governance frameworks. An integrated strategy must be used to coordinate the policy of innovation, environmental regulation, and institutional reform to achieve the maximum returns in the economy.

There are also limitations that are realized in the study. Green innovation measurement is based on the quantitative measures that are available, and there may be failure to adequately represent the qualitative variations in innovation processes or technological sophistication. Also, the endogeneity between innovation and competitiveness cannot be completely avoided even though the panel estimation methods and robustness checks are used to overcome the methodological issues. Further studies might expand the current analysis to sector-specific dynamics, use alternative identification strategies, or use firm-level data to further enrich the knowledge on the mechanisms that relate green innovation and competitiveness. To sum up, the results suggest that green innovation is a good and strategically relevant option to be taken by developing nations aimed at becoming more economically competitive to solve environmental issues. Green innovation through good policies and good institutions can lead to growth in productivity, sustainable industrial renewal, and create a greater entrenchment in the global markets. As the developing economies are having more environmental and competitive workloads, the implementation of comprehensive green innovation strategy becomes one of the most important aspects of sustainable and resilient economic growth.

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