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Government Spending, Renewable Energy and Green Growth: Evidence from Vietnam

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ABSTRACT

This study investigates the relationship between government spending, renewable energy development and carbon intensity in Vietnam, where carbon intensity is used as an indicator of green economic performance. Using annual time-series data for the period 2000-2021, an autoregressive distributed lag (ARDL) model is employed to capture both short and long-run dynamics among the variables. The empirical results confirm the existence of a long-run equilibrium relationship. Renewable energy development is found to reduce carbon intensity in both the short and long run, thereby improving environmental quality and supporting the transition towards a more sustainable, low-carbon economy. By contrast, aggregate government spending does not exert a clear direct effect on carbon intensity, suggesting that broad-based fiscal expansion alone may be insufficient to foster green growth without complementary, environmentally targeted policies. The findings highlight the importance for policymakers of accelerating renewable energy deployment, mainstreaming sustainability considerations into urban planning, and aligning public investment in technology and infrastructure with low-carbon development objectives to achieve durable reductions in emissions.

Keywords: Government Expenditure, Renewable Energy, Carbon Intensity, Green Economic Performance, ARDL Model
JEL Classifications: Q42, Q48, E62, C32

1. INTRODUCTION

The world economy is confronted with escalating environmental pressures. Climate change and the degradation of natural resources threaten the prospects for sustainable development, prompting a global shift from traditional "brown" growth models towards green growth strategies that seek to enhance human welfare and social equity while reducing environmental risks and resource scarcity (Kalkstein et al., 1993; UNEP, 2011). This transition cannot be left to markets alone; it requires active state intervention, in which public spending and renewable energy policies are central instruments for steering economies onto a low-carbon development path.

For developing countries, the challenge is particularly acute. Rapid industrialization and urbanization drive up energy demand and emissions, while fiscal and technological constraints limit the scope for immediate decarbonisation. Vietnam is a salient example. Over recent decades, strong economic growth has been accompanied by rising air and water pollution, resource depletion and increasing dependence on fossil fuels. Recognizing these risks, the Vietnamese government has adopted the National Green Growth Strategy for 2021-2030, which emphasizes expanding renewable energy and reducing the carbon intensity of growth as key pillars of a more sustainable development trajectory.

Within this policy context, public spending and renewable energy development are widely regarded as key levers for promoting green growth (Jansen et al., 2022). Government expenditure can finance green infrastructure and human capital formation and crowd in private investment through subsidies and other preferential schemes (Barro, 1990; Aghion et al., 2016). At the same time, an extensive literature documents that poorly targeted or excessive public spending may crowd out private activity or be allocated inefficiently, thereby weakening its contribution to long-run growth (Gwartney et al., 1998). On the energy side, empirical studies for both developed and developing economies have identified various patterns of interaction between renewable energy consumption and economic growth, including bidirectional causality (Apergis and Payne, 2012). Other contributions highlight that government expenditure on environmental protection and clean-technology R&D fosters green innovation and lowers greenhouse gas emissions, while subsidies for renewable energy accelerate the transformation of the energy sector (Popp, 2019; Aghion et al., 2016).

Despite this rich body of work, several gaps remain. First, most empirical studies analyse either the relationship between government spending and economic growth or the nexus between renewable energy and growth or emissions in isolation. Far fewer studies investigate how aggregate public spending and renewable energy development jointly shape green growth outcomes within a unified empirical framework. Second, the majority of existing research focuses on GDP growth or aggregate emissions, whereas less attention has been paid to indicators that explicitly capture the environmental efficiency of growth, such as carbon intensity. Third, country-specific evidence for Vietnam on the dynamic links between public spending, renewable energy and green growth remains limited, with only a small number of studies exploring these relationships using time-series techniques. These limitations are particularly important for developing countries like Vietnam, where rapid economic expansion, rising energy demand and ambitious climate commitments make the design of effective green fiscal and energy policies a policy priority.

This paper seeks to address these gaps by examining the relationship between government spending, renewable energy development and green growth in Vietnam, where green growth is proxied by carbon intensity. Using annual data for the period 2000-2021 and an Autoregressive Distributed Lag (ARDL) model, the study distinguishes between short-run and long-run effects of fiscal policy and renewable energy on carbon intensity. In doing so, it provides policy-relevant evidence on whether the current pattern of public expenditure and renewable energy deployment is consistent with Vietnam's green growth objectives and offers broader insights for developing economies pursuing similar transitions. The remainder of this paper is organised as follows. Section 2 reviews the theoretical background and related empirical literature. Section 3 presents the data and methodology. Section 4 reports and discusses the empirical results. Section 5 concludes and derives policy recommendations aimed at enhancing the renewable energy transition and green economic growth.

2. THEORETICAL OVERVIEW AND EMPIRICAL STUDIES

2.1. Theoretical Overview

Green growth refers to efficient use of natural resources, clean in reducing pollution and environmental impacts, and resilient, meaning it considers natural hazards and the role of environmental management in preventing physical disasters (Fay, 2012). Similarly, the United Nations Environment Program defines a green economy as enhancing human well-being and social equity while significantly reducing environmental risks and ecological degradation (UNEP, 2011).

Public spending, or government expenditure, is a key macroeconomic policy tool that reflects the state's role in intervening in the economy. According to Keynesian economics, public spending is an essential component of aggregate demand, capable of stimulating economic activity, especially during periods of recession (Keynes, 1936). Later endogenous growth theories also emphasize the importance of public spending in areas that generate spillover effects, such as education, healthcare, and infrastructure, thereby fostering human and physical capital accumulation, laying the foundation for long-term growth (Barro, 1990). In the context of green economic development, public spending becomes even more crucial. It serves as a demand stimulus and a means to steer the economy toward a sustainable trajectory. Public spending can address market failures related to environmental externalities. Specifically, the government can invest in green infrastructure such as smart grids and clean public transportation; fund research and development of clean technologies to reduce costs and promote innovation (Popp, 2019); and provide subsidies or tax incentives to encourage businesses and consumers to shift toward sustainable production and consumption (Aghion et al., 2016).

Renewable energy is defined as energy derived from natural processes that are continuously replenished, such as sunlight, wind, rain, tides, waves, and geothermal heat (IEA, 2021). These forms of energy, including solar, wind, hydro, biomass, and geothermal, are considered foundational to the global energy transition. The role of renewable energy extends beyond electricity generation, profoundly impacting the three pillars of sustainable development. First, in terms of energy security, diversifying the energy supply with renewables reduces dependence on imported fossil fuels, which are often volatile in price and subject to geopolitical risks (Sovacool et al., 2017). This is particularly important for energy-importing countries, enhancing energy independence and macroeconomic stability. Second, from an environmental perspective, renewable energy is the most effective tool for reducing greenhouse gas emissions, the main driver of climate change. Unlike fossil fuels, renewable energy power plants produce little to no CO_2 and other air pollutants, improving air quality and public health. Finally, renewable energy drives sustainable development by creating new economic opportunities, including manufacturing, installation, and operation jobs, while stimulating technological innovation and attracting green investments.

The theoretical framework of this study is built upon a synthesis of environmental economics and endogenous growth theory to explain the mechanisms through which public spending and renewable energy impact green economic growth. Specifically, public spending is viewed as a policy tool capable of steering technological change in an environmentally friendly direction (Acemoglu et al., 2012). This impact occurs through two main channels. First is the "technology-push" channel, where government funding for R&D reduces costs and risks associated with innovation in renewable energy and energy-efficient technologies (Popp, 2019). Second, the "demand-pull" channel, through policies such as green public procurement, subsidies for renewable energy, and investment in green infrastructure, creates a stable and attractive market for green products and services (Aghion et al., 2016). By promoting the renewable energy sector, public spending not only helps reduce emissions but also creates a positive feedback loop: technological innovation reduces costs, encouraging private investment, generating green jobs, enhancing competitiveness, and ultimately leading to a more sustainable economic growth model.

2.2. Empirical Studies

Previous studies have highlighted the crucial role of public R&D expenditures in reducing energy intensity and fostering the development of green patents. Bointner (2014) found that nuclear energy contributed the most to this effort, followed by energy efficiency, fossil fuels, and renewable energy. Research by Dogan et al. (2022), and Churchill et al. (2021) further suggests that increased renewable energy R&D can reduce carbon emissions, decrease fossil fuel consumption, and support the transition to green economies. Many scholars argue that prioritizing renewable energy through research funding, subsidies, and government incentives is essential. Churchill et al. (2021) observed that the impact of R&D on renewable energy consumption was positive until 1996, after which it turned negative. Dahmani et al. (2023) analyzed energy consumption patterns in MENA countries, showing that energy consumption positively impacts economic growth, while financial development has an adverse effect. Similarly, Halkos and Paizanos (2013) provides evidence showing that government spending can improve environmental quality, but its effectiveness depends on the spending structure and the country's level of development. Zeraibi et al. (2021) confirmed the positive role of government spending, especially in energy, in promoting green growth and reducing carbon emissions in emerging economies. Another study in 11 newly industrialized countries emphasizes that the structure of public spending is a key factor, with prioritizing green R&D and sustainable infrastructure potentially creating dual economic and environmental benefits (Destek and Sarkodie, 2019). Cheng et al. (2021) found that renewable energy technology innovation in China negatively impacts carbon intensity, while Wang and Zhu (2020) observed a negative correlation between renewable energy development and CO_2 emissions. Huang et al. (2021) confirmed that energy patents from enterprises and research organizations notably reduce CO_2. However, Wang and Zhu (2020) found that domestic patents related to fossil-fuel technologies do not contribute to reducing CO_2.

Literature increasingly agrees on the positive role of renewable energy and targeted public policies in promoting sustainable development. Methodologically, studies have employed advanced econometric techniques, from panel data models (panel GMM, panel ARDL) for cross-country analysis to time-series models (VECM, NARDL) for individual case studies, allowing for dynamic and asymmetric impact analysis. However, most existing studies focus on bilateral relationships, such as between public spending and growth, or renewable energy and emissions. Few studies integrate all three pillars—public spending, renewable energy, and green economic growth—into a unified analytical framework. This gap is particularly important for rapidly transitioning economies like Vietnam, where both short- and long-term impacts should be considered. This study aims to fill this gap by developing an ARDL model to examine this complex relationship, providing new empirical evidence and relevant policy implications for Vietnam.

3. METHODOLOGY

The data used in this study were collected from the General Statistics Office of Vietnam and the World Bank. A detailed description of the variables is presented in Table 1.

Based on the above literature review and building upon the findings of previous empirical studies, this paper proposes the following model for the case of Vietnam:

$$GEG_t = \alpha_0 + \alpha_1 \, PEX + \alpha_2 \, REW + \alpha_3 \, GDP + \alpha_4 \, UBR + \varepsilon_t \quad (1)$$

The ARDL model is selected for this study due to its notable ability to simultaneously estimate short-run and long-run relationships among variables in time series data. This characteristic is particularly well-suited to the nature of macroeconomic data, which often exhibits non-stationarity and fluctuations over time. Unlike traditional regression methods that require all variables to be integrated in the same order, the ARDL approach allows for the inclusion of variables with different orders of integration, provided that none is integrated into order two (I(2)). This flexibility broadens the model's applicability, especially when analyzing real-world macroeconomic time series data.

The ARDL model was developed by Pesaran et al. (2001) and has since been widely applied in empirical studies to analyze the relationships among macroeconomic indicators. One of the key advantages of the ARDL approach lies in its ability to test cointegration among variables using the Bounds Testing procedure, even when the variables are integrated of different orders. This feature is particularly valuable when working with macroeconomic data in Vietnam, where variables often exhibit non-stationary characteristics and may be integrated at different levels. Moreover, the ARDL model is an unrestricted dynamic

Table 1: Description of variables

Acronyms	Description	Sources
GEG	Green growth is measured by Carbon Intensity (CO_2/GDP) (%)	https://databank.worldbank.org/source/world development-indicators#
REW	Renewable energy is measured as the share of renewable energy in the total national energy (%)	
GDP	Gross Domestic Product Growth (annual %)	
UBR	Urbanization rate (%)	
PEX	Government public spending is measured by the ratio of research and development spending to total state budget expenditure (%)	Vietnam Statistical Yearbook (2000-2021)

model in which the dependent variable is expressed as a function of its own lagged values and those of the independent variables. This structure allows the model to flexibly capture the effects of past economic shocks on current outcomes, thereby providing reliable estimates of both short-run and long-run relationships. Additionally, the ARDL model can be applied to both large and small sample sizes and remains robust even in the presence of endogeneity in some independent variables (Adom et al., 2018).

The quantitative analysis using the ARDL approach involves the following steps: First, the stationarity of the variables is tested using the Augmented Dickey - Fuller (ADF) and Phillips-Perron (PP) test. Second, the optimal lag length is determined using information criteria such as FPE, AIC, HQIC, SBIC. Third, the cointegration relationship among variables is examined using the Bounds test. If the calculated F-statistic exceeds the critical value for the upper bound (I(1)), it indicates the presence of a long-run relationship. Fourth, the ARDL model is estimated based on the selected lag structure, followed by the estimation of an error correction model (ECM) to assess the speed of adjustment toward long-run equilibrium after short-run shocks, by the method of Engle and Granger (1987). Finally, postestimation diagnostic tests are conducted to evaluate the reliability and robustness of the regression results. Simultaneously, the paper also examines model deficiencies, including autocorrelation, heteroscedasticity, normality of the distribution, and model stability.

4. RESULTS

Table 2 presented the descriptive statistics of the four variables used in the research model

The Table 2 provided descriptive statistics for the variables used in the research: GEG PEX, GDP, REW, and UBR. These variables reflect critical factors influencing economic and sustainable development. The mean values indicate varying levels of the variables. GEG, at 0.82142, suggested moderate green economic growth, while PEX, at 27.7795, highlights substantial government spending on research and development. The GDP value of 6.25583 reflected the overall economic growth, and UBR stands at 30.928, showing a relatively high urbanization rate common in developing and emerging economies.

The standard deviation captured the variability in these variables. PEX showed the high standard deviation (2.4480), signifying considerable fluctuations in government spending, which could be due to changing policies or priorities in different periods. In contrast, GEG had the lowest standard deviation (0.1290), indicating that the green growth metrics were more stable over time. REW also exhibits significant variability, with a standard deviation of 11.17035, which suggested that renewable energy trends are more volatile, possibly influenced by technological advancements or policy changes.

The skewness values suggested the variables' distribution shapes. GEG, PEX, GDP, and REW all exhibit positive skewness, which implied that these variables tend towards higher values (right-skewed distribution). On the other hand, UBR exhibited negative skewness, indicating a left-tailed distribution, where values were concentrated at the higher end of the scale.

The kurtosis values revealed that all variables, except for REW, follow a platykurtic distribution, meaning their distributions were relatively flat compared to a normal distribution. REW, however, had a leptokurtic distribution, which showed that its data points were concentrated around the mean, with a higher peak.

A moderate positive correlation exists between GEG and PEX, suggesting that increased government spending may support green economic growth. However, GEG showed a strong negative correlation with REW, indicating an inverse relationship between green growth and renewable energy in the dataset. Additionally, GEG was negatively correlated with GDP, suggesting that green economic growth might not always align with overall economic growth (Table 3).

The relationship between PEX and REW was weakly negative, and between PEX and GDP, it was moderately negative, indicating that

Table 2: Descriptive statistics of the variables

Variable	GEG	PEX	REW	GDP	UBR
Mean	0.82142	27.7795	37.39545	6.25583	30.928
Median	0.79750	27.555	37.2	6.5566	30.7485
Maximum	1.08671	33.72	57.7	7.5472	38.052
Minimum	0.60429	23.25	18.9	2.5537	24.374
Standard Deviation	0.1290	2.4480	11.17035	1.32009	4.25033
Skewness	0.53808	0.47330	0.113599	−1.7307	0.0975
Kurtosis	2.850155	3.3434	2.148213	5.45288	1.7909
Variance	0.01664	5.9931	124.7766	1.7426	18.065
Observations	22	22	22	22	22

Table 3: Correlation matrix of the variables

Variables	GEG	PEX	REW	GDP	UBR
GEG	1.000				
PEX	0.5081 (0.0158)	1.000			
REW	−0.9450 (0.0000)	−0.4351 (0.0430)	1.000		
GDP	−0.4310 (0.0452)	−0.4797 (0.0239)	0.3380 (0.1239)	1.000	
UBR	0.8984 (0.0000)	0.3681 (0.0919)	−0.9670 (0.0000)	−0.4203 (0.0515)	1.000

Source: Compiled by the authors using Stata 17

Table 4: Stationarity results

Variable	ADF test		Phillips-Perron Test		Order of integration
	Levels	First difference	Levels	First difference	
GEG	−2.173	−2.910***	−2.090	−3.291**	I (1)
PEX	−1.668	−3.319***	−3.700**	−7.233***	I (0)
REW	−2.503	−2.872***	−2.236	−3.322***	I (1)
GDP	−2.249	−2.232*	−1.521*	−3.977***	I (0)
UBR	−2.683	−1.949*	−3.404**	−2.425	I (0)

***, **, * indicates significance at 1%, 5%, and 10%, respectively

higher government spending did not necessarily lead to economic growth. PEX also had a modest positive correlation with UBR, implying a slight link between urbanization and government investment.

Renewable energy showed a strong negative correlation with urbanization, possibly due to the concentration of renewable energy in less urbanized regions. Overall, these correlations highlight the complex interactions between these factors in shaping economic and sustainable development.

The Table 4 presented the results of stationarity tests (ADF and Phillips-Perron) for the variables: GEG, PEX, REW, GDP, and UBR. All variables were non-stationary at the levels but become stationary after first difference, with significance at the 1% level. Specifically, the ADF and Phillips-Perron tests showed that GEG, PEX, REW, GDP, and UBR were integrated of order 1 (I (1)), indicating that they were non-stationary in their levels but become stationary after differencing. These results were crucial for time series analysis, as stationarity was required for accurate model estimation. The findings suggested that first differencing was necessary for all the variables in the study to ensure valid analysis in subsequent econometric modeling.

The Table 5 showed the optimal lag length selection results using LR, FPE, AIC, HQIC, and SBIC criteria. At lag 0, the values were relatively high, indicating poor fit. At Lag 1, the LR statistics increased significantly, with FPE dropping to a very low value, suggesting a better fit. However, lag 2 yields the lowest AIC -1.72709, HQIC, and SBIC values, indicating the best model fit. Thus, lag 2 was chosen as the optimal lag length for the model, providing the most accurate results based on these selection criteria.

The Table 6 presented the bounds test results for cointegration, with an F-statistic of 9.445. This statistic was compared against the critical values at the 1%, 5%, and 10% significance levels. At the 10% level, the lower and upper bounds were 2.45 and 3.52, respectively; at the 5% level, they were 2.86 and 4.01; and at the 1% level, the bounds were 3.74 and 5.06. Since the F-statistics exceeded the upper bound at all significance levels, the results confirmed the existence of a cointegrating relationship among the variables, indicating a long-term equilibrium relationship.

The long-run estimation results showed the relationship between the independent and dependent variables. PEX had a coefficient of −0.0088 and a P-value of 0.339, which was not statistically significant at typical significance levels (Table 7). This indicates that there was insufficient evidence to confirm that government spending had an impact on green economic growth. The REW variable had a coefficient of −0.0162 with a P-value of 0.038, indicating a significant negative relationship with the dependent variable. GDP showed a coefficient of 0.00257 and P-value 0.885, suggesting no significant long-term effect. Finally, UBR had a coefficient of 0.06671 with a P-value of 0.079, indicating a marginally significant positive relationship.

Table 5: Optimal lag length selection

Lag	LR	FPE	AIC	HQIC	SBIC
0		0.957424	14.1455	14.1941	14.3944
1	312.56	2.1e-06	1.01724	1.30881	2.51084
2	104.89*	4.2e-07*	−1.72709*	−1.19255*	1.01118*

Source: Compiled by the authors using Stata 17

Table 6: Results of the bounds test for cointegration

F-statistics	Significance	Lower Bound	Upper Bound
9.445***	10%	2.45	3.52
	5%	2.86	4.01
	1%	3.74	5.06

***, **, * indicates significance at 1%, 5%, and 10%, respectively

Table 7: Estimated long–run results

Variable	Coefficient	Standard error	P-value
GEG			
PEX	−0.0088	0.0088	0.339
REW	−0.0162	0.0067	0.038
GDP	0.00257	0.0173	0.885
UBR	0.06671	0.0341	0.079

Source: Compiled by the authors using Stata 17

Table 8 presented the short-run ARDL estimates. The error correction term ECT(−1) was negative and significant (−0.6891, P = 0.003), indicating that nearly 69% of deviations from the long-run equilibrium are corrected within one period, thus validating the adjustment mechanism. Among the explanatory variables, public expenditure showed a negative but insignificant effect, suggesting no immediate short-term impact. Renewable energy exerted a negative and significant influence, reflecting an inverse short-run relationship with green growth. In contrast, GDP in first difference was statistically insignificant, implying no notable effect in the short run. Urbanization registered a large negative coefficient with marginal significance at the 10% level, pointing to a possible adverse impacted but with limited statistical reliability. Overall, the short-run resulted confirm the crucial role of adjustment toward long-run equilibrium.

Table 9 presented the results of various diagnostic and stability tests applied to the model. The autocorrelation test showed a Chi-squared value of 2.486 with a P-value of 0.1149, above the 0.05 significance level, indicating no significant autocorrelation in

Table 8: Estimated short-run results

Variable	Coefficient	Standard error	P-value
ECT(−1)	−0.6891	0.1729	0.003
D (PEX)	−0.0046	0.003906	0.257
D (REW)	−0.0111	0.004637	0.037
D (GDP)	0.0026	0.008733	0.769
D (UBR)	−5.9391	3.162207	0.090

Source: Compiled by the authors using Stata 17

Table 9: Diagnostic and stability test results

Test	Chi-square	P-value	Result
Autocorrelation	2.486	0.1149	Accept Ho
Heteroscedasticity	0.09	0.7642	Accept Ho
Normality	2.34	0.3097	Accept Ho
CusumQ	Stable	-	

Source: Compiled by the authors using Stata 17

the residuals. The heteroscedasticity test reported a Chi-squared value of 0.09 and a P-value of 0.7642, suggesting that the model's residuals had constant variance, and thus, heteroscedasticity was not an issue. The normality test resulted in a Chi-squared value of 2.34 and a P-value of 0.3097, confirming that the residuals were normally distributed. Lastly, the CUSUM test indicated that the model was stable, with no structural breaks. Overall, the results of these diagnostic tests supported the robustness and reliability of the model, confirming that it met the key assumptions for valid estimation and inference.

5. DISCUSSION

Our ARDL estimates showed a few interesting patterns. First, renewable energy (REW) seemed to have a consistently negative impacted on green growth, both in the long run ($\beta = -0.0162$, $P = 0.038$) and in the short run (ΔREW: $\beta = -0.0111$, $P = 0.037$). Second, public expenditure (PEX) showed a negative effect, but it was statistically insignificant over both time frames. Finally, urbanization (UBR) appeared to have a slight positive impacted in the long run ($P \approx 0.079$) but turns negative in the short run ($P \approx 0.090$). Interestingly, the error correction term (ECT) suggested that the system adjusts quickly back to equilibrium (-0.689, $P = 0.003$). Taken together, these results hint at a transition period where upfront costs from structural investments outweigh the immediate gains in green growth. However, the system seemed to bounce back relatively fast.

The negative link between REW and green growth challenged the conventional wisdom seen in some earlier studies, where renewables were often associated with a greener future. For instance, panel CS-ARDL resulted for top-performing green economies suggest that renewable energy actually drove green growth and improved environmental quality (Wei et al., 2023). Likewise, studies across multiple countries often highlight the complementary roles of green finance, energy R&D, and renewables in driving green growth (Ashfaq et al., 2024; Eid et al., 2024). One possible explanation for this contrast could be the friction of transition: integrating intermittent energy sources, upgrading grid infrastructure, and meeting local content requirements might actually slow down productivity in the short term, before the long-term benefits appeared. This seems to align with recent evidence from China, which showed that energy transition policies could temporarily reduced firm-level productivity. For example, the New Energy Demonstration City policy led to a 6.4% drop in total factor productivity (TFP) (Zhang and Ma, 2023). Similarly, other studies have found that renewable policy shocks could suppress productivity in certain ownership or firm-size segments (Lin and Zhang, 2024). Our findings on the short-run negative effect of REW on green growth seem to fit well with these transition-related costs (Ashfaq et al., 2024; Eid et al., 2024; Lin and Zhang, 2024; Wei et al., 2023; Zhang and Ma, 2023).

When it came to PEX, the insignificance of its effected echoes a growing body of work emphasizing that it was not the overall size of fiscal spending that matters, but how it was allocated. Targeted environmental spending and well-designed green fiscal tools were far more effective at driving green growth than just throwing money at the issue (Chen et al., 2023; Huang et al., 2022). Evidence from China also suggested that the impact of fiscal spending could vary significantly depending on the policy's direction and the level of uncertainty (Kim et al., 2021). In light of this, the null result we found for PEX likely reflects either poorly targeted environmental expenditures or inefficiencies in implementation, rather than a failure of fiscal policy itself (Chen et al., 2023; Huang et al., 2022).

The urbanization resulted positive in the long run and negative in the short run fits with what we had seen in other studies. Urbanization often leads to increased emissions and congestion in the early stages, as construction and industrial activity spike (Quan et al., 2024). However, as time went on, urbanization could foster greener infrastructure and better economies of scale, supporting green growth, though this process was far from uniform (Jiang et al., 2022). Our findings mirror this: the short-term pressure on the environment eventually gave way to structural efficiency improvements, although the timeline and impact could vary widely (Adebayo et al., 2021; Jiang et al., 2022; Quan et al., 2024).

From a policy perspective, the relatively quick speed of adjustment in our model suggested that targeted interventions could swiftly realign the system toward its green-growth trajectory. Based on the comparative evidence, there were three key priorities: (i) shift fiscal spending toward clearly defined green projects and reduce delays in their execution; (ii) ease the friction around renewable energy integration—particularly in terms of grid flexibility, storage, and market design—to turn short-term losses into long-term gains; and (iii) support green urbanization through measures like transit development, smart zoning, and sustainable construction standards. When these conditions were in place, international evidence suggests that renewable energy, green finance, and innovation can all work together to foster green growth, rather than hinder it (Wei et al., 2023).

6. CONCLUSION AND IMPLICATIONS

The empirical analysis conducted in this study provides valuable insights into the long-term and short-term relationships between government expenditure, renewable energy, urbanization rate and green economic growth. The findings from the diagnostic tests, cointegration tests, and estimation results offer important conclusions that can inform policy decisions. The findings reaffirmed the significant role of renewable energy in reducing carbon intensity in both the short and long term.

First, the cointegration test results indicate the existence of a long-term equilibrium relationship between the variables, confirming that they move together in the long run. This suggests that policy interventions to influence one of these variables, such as increasing government expenditure on investment and development or expanding renewable energy sources, will likely have long-term effects on green economic growth and other related variables. It highlights the interconnectedness of these factors, emphasizing the need for comprehensive policy strategies that simultaneously address multiple dimensions of economic and environmental challenges.

The long-run estimation results show that the CO_2 intensity of the economy (GEG, measured as the ratio of CO_2 emissions to GDP) has a statistically significant negative relationship with renewable energy and a marginally significant positive relationship with the urbanization rate. The negative coefficient of REW implies that an increase in renewable energy reduces CO_2 emissions per unit of GDP, thereby making the economy greener. This finding underscores the crucial role of renewable energy in driving sustainable growth, while also suggesting that its effectiveness may be constrained by technological limitations and infrastructure challenges in the transition process. Meanwhile, the positive association between urbanization and GEG highlights that rapid urban expansion may contribute to higher carbon intensity unless it is accompanied by appropriate green policies. These results point to the need for governments to strengthen investments in renewable energy technologies and address infrastructural gaps, while simultaneously integrating sustainability considerations into urban development strategies.

Government expenditure on investment and development does not significantly impact green economic growth in the long run. This may indicate that government spending in this area is not effectively translating into tangible green growth outcomes. This calls for a reassessment of how investment and development funding is allocated and utilized. Policymakers should ensure that investments are focused on innovation that directly supports green technologies, sustainable industrial practices, and efficient resource use. Moreover, there should be a more precise alignment between government spending on investment and development and the broader green economy objectives.

The short-run results indicate that renewable energy has a negative and statistically significant effect on CO_2 intensity. This suggests that even in the short term, expanding the share of renewable energy contributes to reducing carbon intensity, thereby making the economy greener. However, the adjustment process is complex: the transition to renewable energy often entails high initial costs, technological restructuring, and institutional adjustments, which may offset or delay broader economic benefits. The negative short-run coefficients thus capture both the environmental gains from reduced emissions and the transitional challenges of adopting cleaner technologies. Policymakers should therefore pursue a phased and well-coordinated strategy, simultaneously scaling up renewable energy investments and providing supportive measures for firms and communities to adapt smoothly during the transition toward a green economy.

The findings on urbanization highlight its potential environmental challenges rather than its capacity to drive green growth. The positive, though marginally significant, relationship between urbanization and carbon intensity suggests that rapid urban expansion tends to increase emissions per unit of output, thereby making the economy less green. While urban areas can benefit from advanced infrastructure, technology, and innovation, the pace and form of urbanization must be carefully managed to mitigate the adverse consequences of urban sprawl, such as higher carbon emissions and unsustainable resource use. Policymakers should therefore integrate sustainability considerations into urban planning by promoting green buildings, expanding efficient public transportation systems, and investing in energy-efficient infrastructure to ensure that urban growth does not exacerbate carbon intensity.

The results from the diagnostic tests, which confirm the stability and reliability of the model, further strengthen the robustness of the findings. The absence of autocorrelation, heteroscedasticity, and normality issues assures that the model is well-specified and can be relied upon for guiding policy decisions. In light of these findings, it is recommended that governments adopt integrated policies that balance economic growth, environmental sustainability, and technological innovation. Emphasis should be placed on fostering innovation in renewable energy, enhancing efforts focused on green technologies, and promoting urbanization strategies that support sustainability.

In conclusion, the study highlights the need for holistic policy frameworks that address the challenges of achieving green economic growth. Governments should strategically prioritize investments in green technologies, infrastructure, and innovation, while ensuring that short-term disruptions are mitigated through well-planned transition strategies. By fostering a synergistic relationship between government spending, renewable energy adoption, and urban development, policymakers can create a conducive environment for sustainable economic growth that is both inclusive and environmentally responsible.

Green economic growth is proxied solely by carbon intensity (CO_2/GDP). Although widely used, this indicator does not capture the multidimensional nature of green growth, such as resource efficiency, air quality improvements, or green employment. Future studies could incorporate broader sustainability indicators for a more comprehensive assessment.

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