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Saudi Arabia's Green Vision: Examining the Kingdom's Path to Sustainability, Covering Energy, Economy, Tourism, and Carbon Dynamics

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ABSTRACT

This study examines the Green Vision of Saudi Arabia and its efforts towards achieving sustainability in various domains such as energy, economy, tourism, and carbon emissions. The research uses time-series data from 2002 to 2020 to analyze the dynamic impacts of these variables. To achieve this, it employs a co-integration regression test, Granger causality relationships, and one-way and two-way causal effects between carbon emissions, tourism, economic growth, and energy use. The findings of the study provide valuable insights into the challenges and opportunities for sustainability in the kingdom, considering the goals of sustainable development goals 8 and 13. This research contributes to the ongoing discourse on sustainable development in Saudi Arabia and offers significant insights for lawmakers, entrepreneurs, and researchers to influence the country's future direction. The research aims to guide strategic decision-making in line with Saudi Arabia's commitment to achieving a sustainable and resilient future by examining the interconnections between energy, economic growth, tourism, and carbon emissions.

Keywords: Sustainability, Carbon Emissions, Economic Growth; Sustainable Development Goals, Tourism, Energy
JEL Classifications: O44, Q56, Z32

1. INTRODUCTION

Saudi Arabia is taking an ambitious step towards sustainability in the Arabian Peninsula by attempting to balance economic growth and ecological consciousness and becoming a crucial player in the global conversation around sustainable development. The country has navigated through a complex set of challenges and is now working towards achieving ecological resilience. This research focuses on the factors shaping Saudi Arabia's journey towards sustainable development, including the energy sector, economic growth, tourism, and the need to reduce carbon emissions. Saudi Arabia hopes to bolster its ecological resilience and contribute meaningfully to the ongoing global conversation on sustainable development by taking a sophisticated approach to environmental challenges.

It has emerged as an essential participant in the 21st-century discussion of sustainable development, deftly negotiating the complex web of obstacles and plotting a path toward ecological resilience. The complex interplay of many variables influencing Saudi Arabia's path to sustainable development is the subject of this research. It focuses on the energy sector, economic development, increasing tourism, and the need to reduce carbon emissions as they influence Saudi Arabia's changing position internationally. Saudi Arabia aims to take a sophisticated approach to the environmental challenges at hand to strengthen ecological resilience and make essential contributions to the present discussion on sustainable development.

The inception of the sustainable development goals (SDGs) by the United Nations (UNs) in 2017 has ignited a renewed focus and a compelling sense of urgency worldwide, prompting both developed and developing nations to pursue sustainable development actively. The SDG agenda is central to this global effort, with a particular emphasis on climate action (Goal 13) and the pursuit of full and productive employment, along with sustained, inclusive, and sustainable economic growth (Goal 8). The larger context of the global SDG agenda, which reflects a commitment to address pressing global issues, initially motivated this study. By offering valuable insights, this research contributes meaningfully to the on-going discourse and policy considerations to steer Saudi Arabia towards a sustainable development path, aligning with the aspirations outlined in the SDGs.

Lenzen et al. (2018) conducted a study to determine the carbon footprint of tourism across 160 countries. Their findings revealed that between 2009 and 2013, tourism's global carbon footprint increased by four times more than previously estimated. This increase accounted for approximately 8% of global greenhouse gas emissions. According to Liu et al. (2023), global carbon emissions are still on the rise despite efforts to reduce the use of fossil fuels. This means there is less time to meet international climate targets. To combat this, the power, transportation, and industry sectors need to put in more significant efforts to decarbonize and increase the use of renewable energy sources. Countries must take immediate action to achieve their net-zero commitments, requiring international cooperation and coordinated efforts to support the transition to a low-carbon economy.

The increasing importance of tourism in the economy has raised concerns among academics, economists, and policymakers about its potential impact on individuals. It is now widely acknowledged that this sector plays a crucial role in the global economy and can significantly influence a country's progress and welfare. According to a study by Khan et al. (2023a), tourism can shape national economic environments and substantially contribute to a country's development. This study examines the relationship between carbon emissions, economic growth, tourism growth, and energy use in a multivariate framework. It also uses the latest data on Saudi Arabia and various time-series econometric techniques to investigate how tourism affects carbon emissions.

The paper focuses on Saudi Arabia's energy sector, economic development, increasing tourism, and the need to reduce carbon emissions. These factors significantly influence the country's changing position in the international arena. The findings of this study provide new insights that can inform broader discussions at regional and global levels on how to balance economic development with environmental preservation. It also examines Saudi Arabia's Green Vision and its efforts to achieve sustainability in various areas such as energy, economy, tourism, and carbon dynamics. The study delves into the country's planned strategies and initiatives to promote sustainable development and mitigate environmental degradation. By considering the Green Vision's multifaceted goals and objectives, this research aims to provide a comprehensive and critical appraisal of Saudi Arabia's path to sustainability, highlighting its challenges, achievements, and opportunities.

Ultimately, the paper seeks to contribute to the ongoing global dialogue on sustainable development and offer insights into the potential of a major oil-producing country to transition towards a greener and more sustainable future. The structure of the paper is as follows: Section 2 reviews the literature. Section 3 presents the methodology, and Section 4 discusses the data and results. Finally, Section 5 provides concluding remarks and policy suggestions.

2. LITERATURE REVIEW

Studying the relationship between economic growth, energy consumption, tourism, and carbon emissions in an integrated manner can have significant policy implications and aid in resolving misspecification issues. Magazzino et al. (2021) suggest that the direction of causality between energy and economic growth is essential for promoting sustainable energy and environmental policies. If the growth hypothesis, energy Granger, is accurate and causes economic growth, then implementing conservation policies to protect the environment may hinder economic growth. However, if the conservation hypothesis holds, conservation policies can reduce long-term carbon dioxide (CO_2) emissions and global warming without impeding growth. Therefore, understanding the relationship between energy and economic growth is crucial for ensuring sustained economic development while promoting sustainable energy and environmental policies. However, there is already a vast body of literature examining the correlation between energy consumption and economic growth and a separate, even more extensive literature exploring the connection between economic growth and carbon emissions.

The escalating carbon output substantially threatens our ecosystem, intensifying the issues associated with climate change. In recent years, there has been a growing focus on analyzing the economic issues that impact climate change and the intricate interrelationships between climate and the economy. Experts have notably concentrated on the ever-increasing concerns over the sources of carbon emissions and have pinpointed the tourism sector as one of the significant sources.

Several academic studies conducted by Khan (2023), Khan et al. (2022), Liu et al. (2021), Soylu (2020), Khan (2020a and b), Wang (2012), Simatupang (2018), and Jaforullah (2015) have consistently found that tourism has a positive impact on economic development. This underscores the significance of regulators, legislators, investors, organizations, and other societal stakeholders diligently overseeing and addressing these emissions.

Saudi Arabia stands at a critical juncture in pursuing sustainable development, navigating the intricate interplay between energy utilization, economic growth, tourism dynamics, and the imperative to address carbon emissions. This literature review embarks on a comprehensive exploration of existing research and scholarly discourse that delves into the intricate nexus of these pivotal elements. As the Kingdom undergoes transformative changes in its socio-economic landscape, there is a pressing need to understand the minute relationships and potential trade-offs in steering towards a sustainable path.

Zaman et al. (2017) conducted a study to analyze the effect of several factors on carbon dioxide emissions and per capita income for a group of 11 transition economies from 1995 to 2013. The factors included international tourism transportation expenses, energy consumption, foreign direct investment (FDI) inflows, trade openness, and urban population. According to the study, per capita income is directly correlated with increased carbon dioxide emissions, which leads to environmental degradation. The study also found that international tourism receipts and travel expenses contribute to the region's increased carbon emissions and per capita income. In addition, the study confirmed that energy, FDI, income, and trade led to emissions and growth.

Acheampong (2018) studied the relationship between economic growth, carbon emissions, and energy consumption in 116 countries from 1990 to 2014 using PVAR and System-GMM. The study found that economic growth does not cause energy consumption globally and regionally. Except for global and Caribbean-Latin America regions, economic growth does not have a causal impact on carbon emissions. However, it harms carbon emissions in the global and Caribbean-Latin America regions. Carbon emissions cause economic growth and energy consumption positively causes economic growth in sub-Saharan Africa but negatively in the global, MENA, Asia-Pacific, and Caribbean-Latin America regions. Energy consumption causes carbon emissions in MENA but negatively in sub-Saharan Africa and Caribbean-Latin America. Carbon emissions do not cause energy consumption except for MENA and the global sample.

In their study, Nosheen et al. (2021) analyze the long-term effects of output, tourism, energy use, trade, financial development, and urbanization on carbon emissions in Asian economies from 1995 to 2017 using the EKC framework. The results obtained from dynamic ordinary least squares (DOLS) indicate an inverted U-shaped relationship between economic growth and carbon emissions, where GDP and GDP squares have opposite signs. The researchers also found that tourism significantly increases environmental degradation in Asian economies, with a coefficient of 0.132. Furthermore, urbanization, energy use, trade, and financial development directly and profoundly impact environmental degradation. The study's findings suggest that tourism, trade openness, and urbanization have contributed to environmental degradation in the Asian region.

Raihan and Tuspekavo (2022) conducted a study on achieving environmental sustainability in Malaysia by reducing carbon dioxide (CO_2) emissions. They evaluated the impact of economic expansion, the use of renewable energy, and forested areas by analyzing time series data from 1990 to 2019 using the DOLS technique. The study found that economic growth strongly correlates with CO_2 emissions. Specifically, a 1% increase in economic growth leads to a 0.78% increase in CO_2 emissions. However, increasing the utilization of renewable energy by 1% results in only a negligible decrease of 0.10% in CO_2 emissions, and the correlation is not statistically significant. In contrast, the study found a significant inverse relationship between forested regions and CO_2 emissions. They were increasing forested areas by 1%, resulting in a significant decrease of 3.86% in CO_2 emissions.

A study conducted by Murshed et al. (2022), spanning from 2007 to 2018 across seven developing countries, revealed that progress in energy efficiency, renewable energy, financial inclusion, economic growth, globalization, and urbanization would positively impact carbon productivity. The research findings indicate that improvements in energy efficiency can help offset the adverse effects of international trade, financial inclusion, and urbanization on carbon production. Researchers Khan et al. (2023) conducted a study that analyzed data from 1997 to 2018 on the impact of increased use of renewable energy on the environment in G7 and E7 countries. The study took into account the size of the economies and populations. The study found that reduced load capacity factor levels indicate that economic expansion and population growth harm the environment. In addition, the findings suggest that economic growth and population increase have a unilateral impact on load capacity factor levels in both G7 and E7 countries.

In a recent study, Khan et al. (2022) used a panel ARDL methodology to investigate the relationship between carbon emissions and factors such as tourist numbers, economic growth, energy consumption, and oil consumption. The study covered the period from 1995 to 2019. The results showed that tourism has significant and harmful effects on the environment. The researchers also pointed out that environmentally-aware travellers comply with environmental regulations and laws in the countries they visit. The study found that the examined countries experienced an improvement in their environment of about 0.21% for every 1% increase in tourism. Moreover, the discussion covered the potential of 11 countries to achieve their goals for reducing carbon dioxide emissions. In a study conducted by Murshed et al. (2023), the authors analyzed the relationships between financial inclusion, the use of renewable energy, economic growth, international trade, and urbanization. Their research revealed that countries that adopted renewable energy sources experienced a significant decrease in carbon dioxide emissions. On the other hand, the increase in carbon dioxide emissions was linked to factors such as economic growth, the expansion of international trade, and urbanization.

A thorough examination of the relationships between energy, economic growth, tourist growth, and their effects on carbon emissions may be necessary to fill the gaps in the current literature on sustainable development in Saudi Arabia. More clarity is required regarding the relationship between the country's energy transition objectives and the carbon emissions from its efforts to diversify its economy through tourism development. This review aims to shed light on the current state of affairs, identify gaps in understanding, and provide a foundation for informed decision-making in charting Saudi Arabia's sustainable future by examining the existing body of knowledge on energy policies, economic development strategies, the impact of tourism, and efforts to mitigate carbon emissions within the Saudi context.

3. METHODOLOGY

3.1. Data

This model utilizes World Development Indicators (WDIs) and British Petroleum (BP) statistics data. BP offers data on primary energy consumption, measured in exajoules, and carbon dioxide emissions, stated in millions of tonnes, resulting from how much energy is used. Conversely, WDIs provide:

- Information on economic growth, measured as GDP in constant US dollars;
- Tourist growth, measured by international tourism expenditure.

The study spans from 2002 to 2020 to include a larger dataset necessary for a more in-depth analysis of the past. This duration adequately clarifies the connections between the examined variables in the short and long term.

3.2. Model Specification

Carbon emissions, energy consumption, economic growth, urbanization, and tourism growth represent a subset of the study variables scrutinized through econometric models employed by previous researchers (Khan and Khan, 2021; Khan et al. 2023). The formulation of the model is articulated as follows:

Carbon emission = f (energy consumption, economic growth, tourism growth) (1)

Several studies have recommended the initial normalization of data series to facilitate integration into an econometric model. Using a natural logarithmic transformation on all of the variables in our study can keep measurements consistent across the board. This can help with problems related to the distributional properties and could lead to stationarity in the series of variables. This is particularly pertinent for variables such as carbon dioxide emissions from energy and primary energy consumption, measured as indices, and other variables measured in diverse units. Consequently, all variables are expressed realistically and subjected to a logarithmic transformation.

$$lnc_t=\beta_o + \beta_1 lnen_t + \beta_2 lng_t+\beta_3 lnr_t+\varepsilon_t \quad (2)$$

In the equation 2, β0 represents the constant term, β1 denotes the coefficient corresponding to the variable (energy consumption), β2 signifies the coefficient linked to the variable (economic growth), and β3 stands for the coefficient associated with the variable (tourism growth). Additionally, "t" denotes the time trend, and εt is the random error term assumed to be normally distributed, independent, and identically distributed.

Stationarity tests are employed to ascertain the order of integration for each variable within a system. Numerous tests are utilized in analytical and empirical research to gauge the integration order, considering various factors. In our empirical stationarity analysis, we will utilize the augmented dickey-fuller (ADF) test, considering intercepts, trends, and intercepts with trends.

The subsequent regression presents the general formulation of the ADF test:

$$\Delta Yt = \alpha + \beta Yt - 1 + \sum \beta i\ ni = 0\ \Delta Yi + \varepsilon t \quad (3)$$

The guideline stipulates that the ADF statistical test should surpass each variable's critical value at various significance levels while ensuring that the associated probability is <5%. This criterion holds for the tests conducted. In this instance, if the variable meets these conditions, it is considered stationary at the given level and order of integration.

Co-integration analysis is conducted in two phases. The initial phase involves determining the appropriate number of lags for our model. Subsequently, co-integration tests are employed in the second phase to identify interactions among variables exhibiting co-integration.

Various information criteria, such as AIC, Schwarz Criterion (SC), HQ, LR, and FPE, are considered to ascertain the number of lags in our estimation. In this instance, the SC is selected based on its frequent usage in empirical studies. The SC criteria indicate that the optimal number of lags for the estimated variables is two. With this information, we proceed to the next stage, employing co-integration tests to identify the number of co-integration relationships among the variables.

Before we can count the number of co-integrating vectors, we must determine the order of integration. This is accomplished by computing two statistics: Trace statistics s ($\boldsymbol{\lambda} Trace$) and maximal Eigenvalues (λMax). This VAR is computed through the utilization of trace information.

$$\Delta yt = r1\Delta\ yt-1+ r2\Delta\ yt-2+\dots\ \dots\ \dots\ .\ .rP\Delta\ yt-p+1 \quad (4)$$

Conversely, the subsequent VAR is computed when the Eigenvalue reaches its maximum:

$$yt = r1\Delta\ yt-1+ r2\Delta\ yt-2+\dots\ \dots\ \dots\ .\ .\ rP\Delta\ yt-p+1 \quad (5)$$

In the above equation, *yt* stands for the vector of the model's variables, and *p* stands for the order of the auto-regression. The null hypothesis in Johansen's co-integration test asserts that there is no co-integrating vector (r = 0), while the alternate hypothesis indicates that there are one or more co-integrating vectors (r > 1) in the data.

According to the econometric criteria for this test, a co-integration link is proven when the trace statistic is higher than the critical value and the chance of it happening is <5%. Given the confirmation of co-integration among the variables, we employed the co-integration regression analysis by fully modified ordinary least squares (FMOLS) and DOLS as the other researchers, Khan et al. (2022).

We can use the Granger causality test to investigate whether y is a causal factor for c. To explore this, we will analyze the direct and indirect relationships among our variables. The first step is to select the appropriate lags of y to include in a univariate autoregressive model.

$$ct = \alpha 0 + \alpha 1ct-1 + \alpha 2ct-2 + \dots + \alpha mct-m + error_t \quad (6)$$

The auto-regression is then improved by incorporating lagged x values:

$$ct = \alpha 0 + \alpha 1ct-1 + \alpha 2ct-2 + ... + \alpha mct-m + bpyt-p +. + bqyt-q + error_t \quad (7)$$

The regression analysis includes any lag value of y that is statistically significant and improves the overall predictive ability of the F-test. The lagged value of y is essential in the enhanced regression equation only within the range of minimum and maximum lag lengths, P and q, respectively. The null hypothesis assumes no explanatory power.

4. RESULTS AND DISCUSSION

Table 1 presents the descriptive statistics summarising the critical attributes of four variables: carbon emissions, economic growth, energy consumption, and tourism growth. The mean, often known as the average, is a statistical measure that depicts the central tendency of a set of data. The average carbon emissions are 6.14, the average economic growth is 27.02, the average energy consumption is 2.14, and the average tourism growth is 23.37. The median represents the central value of a dataset. It exhibits lower sensitivity to outliers compared to the mean. The carbon emissions have a median value of 6.21, the economic growth has a median value of 27.06, the energy consumption has a median value of 2.22, and the tourism growth has a median value of 23.61. The maximum value recorded in the dataset for each variable. The maximum carbon emissions are 6.43, the maximum economic growth is 27.29, the maximum energy consumption is 2.41, and the maximum tourism growth is 23.95. The dataset exhibited the minimum value for each variable. As an illustration, the lowest recorded carbon emissions amount to 5.69, the minor level of economic growth is 26.59, the lowest energy consumption is 1.67, and the minimum tourism growth rate is 22.15. The standard deviation quantifies the dispersion of the data. A more significant standard deviation signifies increased variability. The standard deviation values for carbon emissions, economic growth, energy consumption, and tourism growth are 0.25, 0.22, 0.26, and 0.53, respectively. Skewness quantifies the lack of symmetry in the distribution of a variable. A negative skewness denotes a skewed distribution towards the left, whereas a positive skewness denotes a skewed distribution towards the right.

The table shows that carbon emissions, economic growth, energy consumption, and tourism growth all exhibit negative skewness values. The Jarque-Bera test is a statistical test used to assess the normality of a distribution. It assesses whether the data adheres to a normal distribution. The test yields a test statistic, where a more significant number indicates a deviation from normalcy. The P-value corresponding to the test is provided in the adjacent column. The column displays the P-value that is linked to the Jarque-Bera test. A P-value below 0.05 indicates strong evidence to reject the null hypothesis that the data conforms to a normal distribution. All the P-values in this table are more significant than 0.05, suggesting that the data does not deviate significantly from normality according to the Jarque-Bera test. Table 1 presents a thorough summary of the measures of central tendency, variability, skewness, and normality for the four variables in the dataset.

Table 1: Descriptive statistics

Variable	LNC	LNG	LNE	LNTE
Mean	6.14	27.02	2.14	23.37
Median	6.21	27.06	2.22	23.61
Maximum	6.43	27.29	2.41	23.95
Minimum	5.69	26.59	1.67	22.15
Standard deviation	0.25	0.22	0.26	0.53
Skewness	–0.41	–0.38	–0.47	–1.24
Jarque-Bera	1.9	1.38	1.97	4.97
Prob.	0.39	0.5	0.37	0.08

Table 2 displays the outcomes of the Johansen co-integration test. In the extended period, both economic growth (LNG) and tourism growth (LNTE) exhibited a favourable impact on carbon emissions from energy (LNC). Conversely, primary energy consumption (LNE) revealed a reciprocal relationship in its outcomes during long-term convergence. Even though these factors are statistically significant, the null assumption that there is no co-integration in the model is wrong compared to the alternative, suggesting a co-integration link at a lag of 1.

The co-integration test result, which is statistically significant at the 0.05 level, provides evidence for the existence of short-run and long-run relationships between carbon dioxide emissions from energy, primary energy consumption, economic growth, and tourism expenditure. The co-integrating coefficient, which has been normalized, concisely represents this phenomenon:

$lnc = 0.13(lne) - 1.48(lng) - 0.029(lnte)$

Our objective is to examine whether the long-term changes in carbon dioxide emissions from energy (LNC) and tourism expenditure (LNTE) positively and statistically significantly influence this variable. A one percent increase in tourism expenditure (LNTE) corresponds to a 0.029% increase in carbon dioxide emissions from energy. Similarly, economic growth (LNG) exhibits a comparable impact, leading to a 1.48% point increase in energy-related carbon dioxide emissions for every percentage of GDP growth. Notably, carbon dioxide emissions from energy display a negative correlation with energy consumption.

Johansen's co-integration test demonstrates that there is co-integration among all variables. This leads to paving the way for the co-integration regression using the FMOLS and DOLS methods, which will be used for the analysis. These methods are frequently employed in econometrics to examine the enduring connections between variables. The findings of a co-integration regression analysis using FMOLS and DOLS methods are presented in Table 3. The dependent variable in this analysis is carbon emissions. The model aims to elucidate the relationship between carbon emissions and other variables. Within this framework, the variable in question is the dependent variable. The regression model includes energy consumption, economic growth, tourism expenditure, and C as independent variables. They are indicators of variables that could impact carbon emissions.

The FMOLS coefficients reveal that the coefficient for energy consumption is 0.97. Based on the FMOLS approach, this implies that a one-unit rise in energy consumption is linked to a 0.97-unit increase in carbon emissions. The coefficient for economic growth

Table 2: Johansen co-integration test for carbon emission as a dependent variable

S	Eigen	Trace			Maximum eigenvalue			Decision
	value	Trace statistics	0.05 Critical value	Prob.*	Max-eigen statistics	0.05 Critical value	Prob.*	
None*	0.87	67.87	47.856	0.0002	34.37	27.58	0.006	Co-integration Regression
At most 1	0.69	33.49	29.797	0.02	20.13	21.13	0.07	
At most 2	0.4	13.36	15.495	0.1	8.68	14.26	0.314	
At most 3*	0.24	4.68	3.84	0.03	4.68	3.84	0.03	
LNC		LNE		LNG		LNTE		
1		0.13		–1.48		–0.029		
		0.15		0.18		0.017		

Table 3: Co-integration regression tests results

Variable	FMOLS		DOLS	
	Coefficient	Prob.	Coefficient	Prob.
Energy consumption	0.97	0	0.26	0.25
Economic growth	0.02	0.78	0.86	0.03
Tourism expenditure	–0.003	0.68	0.05	0.08
C	3.5	0.13	–18.7	0.05
R-squared	0.998		0.9997	
Adjusted R-squared	0.998		0.999	

FMOLS: fully modified ordinary least squares, DOLS: Dynamic ordinary least squares

(0.02) indicates a slight positive correlation but lacks statistical significance (P = 0.78). The coefficient for tourism expenditure (–0.003) suggests a little negative correlation with carbon emissions. However, it is not statistically significant (P = 0.68). The constant term (C) has a value of 3.5. However, it is not statistically significant, with a P-value of 0.13.

The DOLS coefficients indicate that the energy consumption coefficient (0.26) implies a positive correlation, although it is not statistically significant (P = 0.25). The coefficient for economic growth is 0.86, indicating a positive relationship. The P = 0.03, which indicates the significance level, indicates that this relationship is statistically significant. The coefficient for tourism expenditure (0.05) is positively correlated with the variable of interest and shows a slight statistical significance (P = 0.08). The constant term (C) is –18.7, deemed statistically significant at 0.05. The R-squared and adjusted R-squared values are high (0.998 and 0.998 for FMOLS, 0.9997 and 0.999 for DOLS), indicating that the independent variables in the model account for a substantial percentage of the variation in carbon emissions.

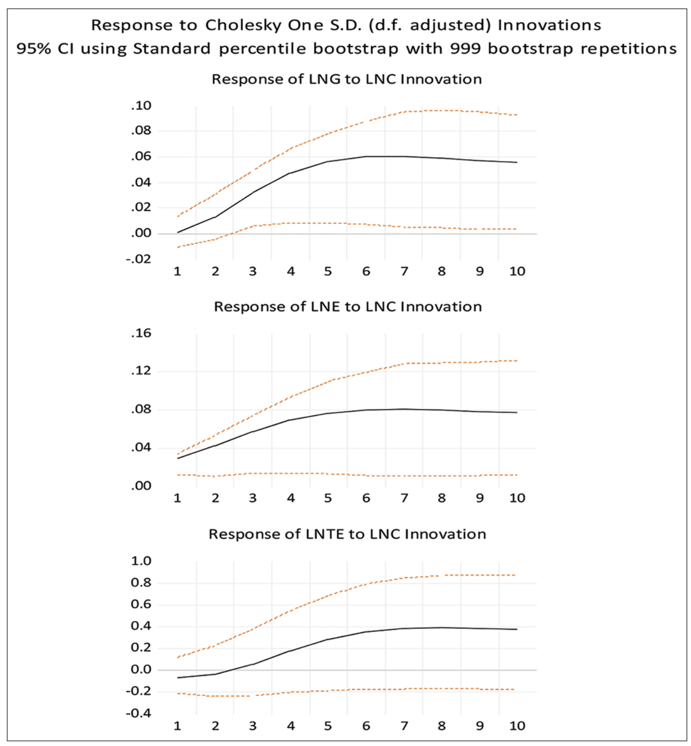
Table 4 shows the F-statistic and P-values for each pair of variables at one lag, which shows whether Granger causality is accepted or rejected. The "Inference" column succinctly outlines the results, indicating the presence (→) or absence (≠) of evidence for Granger causality. Supporting our Granger causality findings, Apergis and Paynes (2009), Al-Mulali et al. (2015a), Wu et al. (2018), Adebayo (2020), and Khan (2023) all endorse the notion of bidirectional causality between economic growth and carbon emissions from primary energy.

Furthermore, our observation of bidirectional causality between energy consumption and economic growth receives strong backing from Belloumi (2009), Mutascu (2016), Antonakakis et al. (2017), and Khan and Khan (2024). Jebli et al. (2014) contribute to these findings, highlighting a unidirectional causality from tourism to carbon emissions, as demonstrated in our study.

Table 4: Pairwise granger causality tests

X	Y	F-Stats	Prob.	Inference
LNE	LNC	2.77	0.12	LNE≠LNC
LNC	LNE	0.93	0.35	LNC≠LNE
LNG	LNC	3.94	0.06	LNG→LNC
LNC	LNG	20.37	0.0004	LNC→LNG
LNTE	LNC	9.54	0.008	LNTE→LNC
LNC	LNTE	0.001	0.97	LNC≠LNTE
LNG	LNE	4.17	0.05	LNG→LNE
LNE	LNG	15.95	0.001	LNE→LNG
LNTE	LNE	7.57	0.015	LNTE→LNE
LNE	LNTE	0.0005	0.98	LNE≠LNTE
LNTE	LNG	1.14	0.3	LNTE≠LNG
LNG	LNTE	0.017	0.897	LNG≠LNTE

Figure 1: Impulse response function



We conducted 999 iterations of the standard percentile bootstrap to ensure that the impulse response function remained within the 95% confidence interval. We assessed the sensitivity of LNC to a one-standard deviation shock, as shown in Figure 1. The graph in

Figure 1 illustrates 10-year periods, which are further divided into short (1-2 years), medium (3-5 years), and long-term (5-10 years) periods.

The analysis of economic growth reveals a predictively increasing trend in the short and medium periods. However, over an extended period, it stabilizes, and by the tenth period, it exhibits a downward trend from economic growth towards carbon emissions from energy. A similar pattern is observed in energy consumption, mirroring the findings related to carbon emissions from energy. Additionally, the trend in tourism expenditure shows an increase from periods 1 to 6, then a consistent pattern towards carbon emissions from energy in subsequent periods.

5. CONCLUSION

In examining the nexus of energy, economic growth, tourism, and carbon emissions in Saudi Arabia, it is evident that the nation is navigating a sustainable path with a complex interplay of these critical factors to validate the UNs SDGs 8 and 13. The descriptive statistics shed light on the central tendencies, variabilities, and distributions of carbon emissions, economic growth, energy consumption, and tourism growth. The results of co-integration regression suggest that according to the FMOLS and DOLS methods, energy consumption positively affects carbon emissions, while economic growth and tourism expenditure have mixed effects. Furthermore, the Granger causality tests offer insights into the temporal relationships among these variables, indicating their potential influence on each other. Granger causality revealed bidirectional causality between economic growth and carbon emissions. Also, there is bidirectional causality between economic growth and energy consumption. Unidirectional causality runs from tourism towards carbon emissions. Saudi Arabia's commitment to sustainable development is crucial to addressing environmental concerns while fostering economic growth and promoting tourism. The findings provide a foundation for policymakers, researchers, and stakeholders to make informed decisions, fostering a balance between economic prosperity and environmental responsibility in Saudi Arabia's journey toward a sustainable future.

5.1. Policies Suggestion

Saudi Arabia may deepen its dedication to sustainability by adopting these policy suggestions, which will help the country achieve a better balance between environmental protection, economic development, energy independence, and the expansion of its tourist industry. This all-encompassing strategy will help Saudi Arabia's ecosystems thrive and put the country at the forefront of sustainable development worldwide.

Sustainable tourism aims to preserve cultural and natural resources by promoting eco-friendly accommodations, increasing public understanding of the need for responsible travel, and funding measures to lessen the industry's adverse environmental effects.

Create all-encompassing planning frameworks that combine environmental sustainability with economic development objectives by considering the environmental implications of different sectors to seek economic growth in a way compatible with conservation initiatives.

Carbon pricing systems should be implemented to make people pay for the external costs of carbon emissions. Establishing measurable and aggressive goals for reducing emissions incentivizes businesses to use cleaner technology and lessen their environmental impact.

Funding research and development programs is crucial to discovering innovative ways to accomplish sustainable development. To support technical advancements that promote eco-friendly practices in all sectors, boost energy efficiency, and reduce carbon emissions.

Spread the word about the significance of sustainable practices to the general public, companies, and tourists through educational initiatives and public awareness campaigns. To promote eco-conscious actions and instil a sense of personal responsibility for the environment.

Sharing information, gaining access to technical skills, and securing funds for sustainable development initiatives through collaboration with Non-Governmental Organizations, governments, and UNs. To address common environmental issues by forming worldwide partnerships.

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