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Pilgrimage Tourism, Economic growth & Energy consumption: Their Impact on Carbon Emission in Saudi Arabia

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Abstract: Saudi Arabia's Vision 2030 focuses on economic diversification and includes initiatives to enhance the pilgrimage experience for religious tourists while reducing CO2 emissions. Given the environmental challenges posed by tourism—particularly pilgrimage tourism—there is limited research on its impact on environmental change. This study addresses that gap by analysing the relationships between CO2 emissions, energy consumption, economic growth, and pilgrimage tourism in Saudi Arabia, using annual time series data from 1996 to 2022. Employing the Vector Error Correction Model (VECM) and the Granger causality test, the results confirm significant long-term associations among these variables. The Johansen cointegration test shows a positive link between energy consumption and GDP growth, although an increase in pilgrim arrivals negatively affects carbon emissions. Specifically, as CO2 levels increase, pilgrimage tourism growth declines by 0.07%, indicating a negative cointegration effect. The VECM results suggest that economic growth and increased energy consumption awareness reduce carbon emissions, highlighting the potential of a circular carbon economy (CCE) consistent with the Paris Agreement and Sustainable Development Goals (SDGs). However, pilgrimage tourism still contributes significantly to carbon emissions. These findings offer crucial policy implications for managing environmental concerns within the Vision 2030 framework.
Key words: Saudi Arabia, Pilgrimage Tourism, CO2, Energy Consumption**.**
JEL CODES: Q43; Q55; Z3

السياحة الدينية، النمو الاقتصادي واستهلاك الطاقة: تأثيرها على انبعاث الكربون في المملكة العربية السعودية

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المستخلص: تركز رؤية المملكة العربية السعودية 2030 على التنويع الاقتصادي وتتضمن مبادرات لتعزيز تجربة الحج للسياح الدينيين مع تقليل انبعاثات ثاني أكسيد الكربون. ونظراً للتحديات البيئية التي تفرضها السياحة - وخاصة سياحة الحج - فإن الأبحاث حول تأثيرها على التغير البيئي محدودة. تتناول هذه الدراسة هذه الفجوة من خلال تحليل العلاقات بين انبعاثات ثاني أكسيد الكربون، واستهلاك الطاقة، والنمو الاقتصادي، وسياحة الحج في المملكة العربية السعودية، باستخدام بيانات السلاسل الزمنية السنوية من 1996 إلى 2022. استخدام نموذج تصحيح الخطأ المتجه (VECM) واختبار السببية جرانجر تؤكد النتائج وجود ارتباطات كبيرة طويلة المدى بين هذه المتغيرات. ويظهر اختبار يوهانسن للتكامل المشترك وجود صلة إيجابية بين استهلاك الطاقة ونمو الناتج المحلي الإجمالي، على الرغم من أن الزيادة في أعداد الحجاج الوافدين تؤثر سلبا على انبعاثات الكربون. وعلى وجه التحديد، مع زيادة مستويات ثاني أكسيد الكربون، ينخفض نمو سياحة الحج بنسبة 0.07%، مما يشير إلى تأثير سلبي للتكامل المشترك. تشير نتائج VECM إلى أن النمو الاقتصادي وزيادة الوعي باستهلاك الطاقة يقللان من انبعاثات الكربون، مما يسلط الضوء على إمكانات اقتصاد الكربون الدائري (CCE) بما يتوافق مع اتفاق باريس وأهداف التنمية المستدامة (SDGs). ومع ذلك، لا تزال سياحة الحج تساهم بشكل كبير في انبعاثات الكربون. تقدم هذه النتائج آثارًا سياسية حاسمة لإدارة المخاوف البيئية ضمن إطار رؤية 2030.
الكلمات الرئيسية: المملكة العربية السعودية، سياحة الحج، ثاني أكسيد الكربون، استهلاك الطاقة.

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1. Introduction:

Travel for pleasure, recreation, exploration, religious, family, or business purposes that lasts only a short while is referred to as tourism. Nowadays, tourism is one of the main sources of income for both developed and developing nations, and it is crucial to the growth of the global economy (Costa 2017). The growth of tourism is influenced by a variety of reasons, one of which is religious motivation. Religious tourism pertains to types of tourism that have religious connotations and has been a perpetual phenomenon throughout the history of religions (Rinschede, 1992). The market for religious travel has grown into a billion-dollar industry worldwide (Hashim et al., 2007) and the majority being Muslims, Christians and Hindus (Olsen& Timothy, 2006). Religious tourism has massively increased in recent decades. It is also called pilgrimage tourism or belief tourism. The Asia-Pacific area is regarded as the world's religious core, with the biggest number of pilgrims and visitors attending religious events on both international and domestic tours (World Tourism Organization,2011). There are an estimated 600 million national and international religious and spiritual travels worldwide, with Europe accounting for 40% and Asia accounting for more than half. According to UNESCO, 60% of the world's population practices a religion, and these believers provide the demographic backbone of religious tourism (World Tourism Organization,2011). Religiously significant cities play an important role in promoting belief tourism. The Vatican for Christians, Varanasi for Hindus, and Mecca for Muslims are recognised as religious centres. The pilgrims' increased expenditure on transportation, lodging, meals, and mementos helps local companies and creates jobs. However, notwithstanding these positive effects, tourism is considered as a substantial contributor to the environmental problem, mainly to climate adjustment.

The convergence of environmental change and religious tourism is gaining importance in the global context, as both factors influence and are influenced by each other. Major religious events frequently create considerable environmental issues, such as waste generation, carbon emissions from transportation, and resource depletion. As the number of pilgrims increases, particularly in developing countries, the accumulated environmental impact of religious tourism becomes an urgent matter that necessitates efficient management techniques. The Paris Agreement and the United Nations Sustainable Development Goals (SDGs) represent a global commitment to sustainability, and they influence how religious tourism is approached. Countries are encouraged to adopt policies that promote sustainable tourism practices, especially those involving religious travel.

The biggest religious tourist event in the world happens every year during the Hajj pilgrimage in Mecca, Saudi Arabia. Hajj is an obligatory religious requirement for Muslims that must be performed at least once in their lives by all adult Muslims who are physically and financially capable of making the journey and sustaining their families while away from home. Therefore, millions of Muslims from around 183 different countries and cultures perform the Hajj every year (Parker & Gaine, 2019).Saudi Arabia is a country rich in religious significance and has a long history, having been the birthplace of Islam. As such, its tourism attraction is closely linked to its religious significance. Prior to the discovery of oil, Saudi Arabia's economy dependent on agriculture and tourism earnings from Muslim pilgrimages to the holy city of Mecca. Despite the fact that oil is the backbone of Saudi Arabia's economy, pilgrimage tourism provides a considerable source of financial stability; yet, it has a negative influence on the environment. The Hajj generates significant solid and liquid waste, consumes vast amounts of scarce fresh water, and emits high levels of greenhouse gases. Given the duration of the pilgrimage—roughly three weeks—and the fact that pilgrims continue to carry out their essential daily tasks while in the holy cities, it is inevitable that Saudi Arabia was impacted by these events. Ozturk at el.(2022) discovered pilgrimage tourism will inevitably have an environmental cost. Khwaja et al. (2014) discovered that air pollution levels during the Hajj surpassed World Health Organisation (WHO) norms. Butenhoff et al. (2015) observed that the Hajj event causes air pollution in Mecca to rise above that of other cities in Saudi Arabia. Notwithstanding the environmental repercussions the issue gets little attention in Saudi Arabia. Thus, this study explores the relationship between pilgrimage tourism, energy consumption and economic growth on carbon emission in Saudi Arabia data period from 1996 to 2022. Saudi Arabia introduced the notion of the circular carbon economy (CCE) as a framework for reducing emissions to a level in tandem with the objectives of the Paris Agreement during its Presidency of the Group of Twenty (G20) in

2020 (Shehri et al., 2022). The Paris Agreement and the Sustainable Development Goals (SDGs) are strongly associated. According to United Nations (UN) Goal 13 of the SDGs seeks for immediate action to mitigate climate change, which addresses the Paris Agreement's ambition to limit global temperature rise to well below 2 degrees Celsius.

The environment in Saudi Arabia is said to be significantly impacted by pilgrimage tourism. It has been shown that pilgrimage tourism boosts economic growth and income, but its negative environmental effects need to be examined and addressed by every appropriate stakeholder. Thus, this study investigates the role of energy consumption, Pilgrimage tourism and economic growth in carbon emission in Saudi Arabia for the period of 1996-2022. In addition, to find out the effects that Muslims' pilgrimages have on the environment when they are engaged in religious devotion. As a result, the main hypothesis is that Saudi Arabia's atmospheric pollution is impacted by pilgrimage tourism. Finally, it presents a numbers of policy recommendations. The study uses vector error correction model (VECM), which is used to examine the short-and long run impacts of energy consumption, economic growth and pilgrimage tourism on carbon emission in Saudi Arabia. This paper adopted time series VECM approach to conduct stationary test, cointegration test, stability test, and Granger causality test. And also used cholesky variance decomposition technique to trace back shocks into the future. To the best of the researcher knowledge, this is the first paper in the literature to investigate the relationship between religious tourism, energy consumption and economic growth in carbon emission using vector error correction model in the context of Saudi Arabia, and this is the paper's main novelty. Given that this study contributes to the body of knowledge on the Saudi Arabia's Vision 2030, which aim to achieve net zero emission by 2060 through Circular Carbon Economy, it also adds a significant value to policy and practice.

The rest of this paper is organised as follows: section 2 reviews the literature on this subject, while section 3 shows the model specification and methodology. Section 4 presents empirical results. Lastly, section 5 describes the conclusion and policy implications.

2. Literature Review:

The surge in worldwide demand for energy has led to a greater reliance on fossil fuels. Consequently, the world environment has deteriorated due to a commensurate rise in carbon emissions. Tourism, as an economic activity, cannot only generate economic prosperity and encourage development, but it also consumes significant amounts of energy and natural resources and emits an enormous quantity of carbon dioxide. The relationship of tourism, energy consumption, economic growth, and carbon emissions is currently a hot topic in academia. In this section, the literature review analysed the tourism-economic growth-energy consumption-carbon emission linkages without distinguishing between religious tourism and general tourist.

Several studies have examined the relationship between tourism and economic growth, and the results show that these relationships are subtle. The tourism-led growth hypothesis is supported by a number of studies that show how the development of tourism can spur economic growth (Samimi & Sadeghi, 2011; Gwenhure & Odhiambo, 2017; Naseem,2021; Alcalá-Ordóñez et.al ,2023). Some study observed bidirectional causality, where tourism and economic growth strengthen one another (Samimi & Sadeghi, 2011; Corrie et al,2013; Assadzadeh and Nasab.,2012; Caglayan,Ebru et al.2012; Aslan,2016; Bilen et al,2017; Pulido-Fernandez and Garcia,2020; C.Wijessekara et al.,2022). Nevertheless, the direction of causality can vary, with economically stronger and more democratic countries frequently showing bidirectional correlations between tourism and growth (N. Antonakakis et al., 2019). In Maxico unidirectional causality between tourism development and economic growth was discovered (Barida et al.2008). Additionally, studies such as Akinboade and Braimoh (2009), Schubert et al. (2010), Brida et al. (2015), Kum et al (2015) and Tang and Tan (2015), Akadiri et al (2019), Badulescu et al. (2020) have found a unidirectional causal association between growing tourism and economic growth.

Numerous studies have suggested that tourism stimulates economic growth, especially for emerging nations and small island economies such as Mauritius (R. Durbarry, 2004). While tourism is frequently viewed as a potential driver of economic development, particularly in developing

nations (Fadi Fawaz et al., 2014; R. Durbarry, 2004; Enilov & Wang, 2021), the nature of this relationship varies depending on economic, political, and tourism-specific factors (N Antonakakis et al., 2019). Tourism contributes more to economic growth in regions such as Africa, Asia, and Latin America, as well as countries where tourism accounts for a larger part of GDP (Stanislav Ivanov & Webster, 2011). Tourism's role in the expansion of the economy changes with time (Santamaria and Filis ,2019). These findings illustrate the multifaceted and context-dependent aspects of tourist activity's impact on economic development.

Recent research looks at the relationship between tourism and economic growth in a variety of circumstances. Tourism market diversification has been shown to boost economic growth, particularly in low- and lower-middle-income nations (Peng et al., 2023). In Greece, a long-term association between tourism and economic growth was discovered, implying that international tourism has a favourable impact on economic growth (Mavrommati et al., 2024). However, the tourism-economic growth link can be nonlinear and time-varying, as seen in the Schengen region, where it was positive between 1995 and 2003 but negative during economic crises (Dogan & Zhang, 2023). Although tourism can help with regional economic development through the creation of jobs, research in Jambi, Indonesia, discovered that tourist visits, unemployment, and poverty all had an impact on economic growth, but not significantly (Amry et al., 2023). These findings emphasize the complexity and context-dependence of tourism's impact on economic growth.

Tourism's tendency to boost carbon emissions is a complicated and contentious issue. Some research indicates a positive association between tourism development and carbon emissions (Ahmed Amzath & Laijun Zhao, 2014; C. León et al., 2014), while others suggest environmentally friendly innovations may minimise this effect (Erdoğan et al., 2022). The link varies by country, with wealthy nations having a greater impact than less developed ones (León et al., 2014). The tourism-emission linkage lacks accord, with conflicting findings reported across geographies, income levels, and the sector's economic importance (Sun et al., 2022). To solve this issue, a few scholars propose raising sustainable tourist practices such as guest homes and minimising domestic transfers (Ahmed Amzath and Laijun Zhao, 2014). Erdoğan et al. (2022) emphasise the need of eco-friendly transportation systems in reducing emissions. These findings highlight the need for a critical reconsideration of tourism-carbon interrelationships, as well as improved research techniques, to inform successful policymaking (Sun et al., 2022).

The most recent research on tourism and carbon emissions demonstrates the industry's complex relationship with climate change. Tourism contributes significantly to worldwide GDP while also accounting for around 8% of global greenhouse gas emissions (Liu et al., 2023). An inverted N-shaped relationship between tourism and CO2 emissions has been identified, indicating the sector's potential for sustainability as it evolves (Purwono et al., 2024). However, without mitigation actions, tourism might exhaust 40% of the world's remaining carbon budget, limiting warming to 1.5°C (Gössling et al., 2023). Corporate, political, and technical constraints impede the industry's ability to execute efficient decarbonization initiatives. In Europe, where tourism is a key economic contributor, both climate and carbon risks are substantial issues, with climate risk dominating research (Steiger et al., 2023). Addressing these difficulties requires comprehensive strategies that include renewable energy adoption, sustainable practices, and policy initiatives.

The intricate connections between tourism, economic growth, consumption of energy, and carbon emissions in various economies have been the subject of recent studies. Using the panel VAR approach, Tiwari et al. (2013) examined the relationship between energy use, tourism, and climate change in 25 OECD nations between 1995 and 2005. The findings of the analysis demonstrated that there was a positive correlation between tourism and energy use, as well as a one standard deviation shock to climate change and emissions. Tang and Abosedra (2014) examined the relationship between political instability, tourism, economic growth, and energy consumption. Their study used the GMM estimator to evaluate data from 24 MENA countries for the years 2001 to 2009, and the findings suggest that energy consumption and tourism play a role in the economic expansion of MENA nations. Danish et al. (2019) claim that rising CO2 emissions across all income levels are caused by rising energy usage. According to Eyuboglu and Uzar (2019), tourism, energy use, and growth all hamper environmental quality by increasing emission concentrations in Turkey. Tourism

and energy usage in Singapore were found to increase CO2 emissions, but economic growth had a negative influence (Raihan et al., 2022; Raihan & Tuspekova, 2022). Comparable results were observed in India, where energy use and tourism increased CO2 emissions (Jayasinghe & Selvanathan, 2021). A parallel study of developed and developing nations found that tourism has a positive impact on economic growth in both contexts, validating the tourism-led growth hypothesis. However, the impact of tourism on CO2 emissions decreases faster in developed economies, consistent with the environmental Kuznets curve hypothesis (Paramati et al., 2016). Azam et al. (2018) examined how tourism affects environmental quality in Malaysia, Singapore, and Thailand. Their findings revealed that, whereas tourism has a favourable impact in Malaysia, it has an opposite effect in Thailand and Singapore. Pablo-Romero et al. (2019) evaluated the effects of tourism on the environment in 12 Spanish Mediterranean provinces between 1999 and 2014. Empirical studies revealed that tourism development leads to increased electricity consumption, and consequently temperature fluctuations. Kocak et al. (2019) evaluated the link between tourism and CO2 emissions and found a long-term causal association between the two.

Basarir and Cakir (2015) performed panel data analysis in order the determine the direction of relationship between CO2 emissions, financial development, energy consumption, and tourism in Turkey and four EU countries. Their finding suggested that there is unidirectional causal relationship between the tourist arrivals and financial development. And also, there is a bi-directional causality relationship between CO2 emission, financial development, and energy and tourist arrival.

Dogan and Aslan (2017) investigated the link between CO2 emissions, real GDP, energy consumption, and tourism in European Union nations from 1995 to 2011, employing FMOLS and DOLS methodologies as well as the panel Granger causality test. Their findings suggested that there is unidirectional causality from tourist to carbon emissions, as well as bidirectional causality between CO2 emissions and energy consumption, and real GDP and CO2 emissions.

Tourism growth has been shown to have a considerable positive impact on carbon dioxide emissions in both the short and long term (B. Shakouri et al., 2017; K. Zaman et al., 2017; N. Nwaeze et al., 2023; Kemal Eyuboglu and Umut Uzar, 2019; Selvanathan, E.A. et.al, 2020). Economic growth and energy use both contribute to higher CO2 emissions (N. Nwaeze et al., 2023; Kemal Eyuboglu & Umut Uzar, 2019). surprisingly, environmental quality has been discovered to influence tourists' location preferences (Kemal Eyuboglu & Umut Uzar, 2019). Above recent studies findings illustrate the intricate connection between tourism, economic variables, and environmental repercussions, emphasising the importance of sustainable tourism practices and regulations that reduce CO2 emissions while promoting economic growth.

More recent studies have looked at the intricate connections between tourism, economic growth, energy use, and carbon emissions. Khan et al. (2023) discovered an inverse relationship between CO2 emissions and tourism in Kuwait, with economic growth and increased energy use lowering emissions. In a comparable manner Jebli and Hadhri (2018) found that energy use and tourism help to reduce transport emissions in popular tourist sites. Wasti and Zaidi (2020) found that CO2 emissions and energy consumption boost economic growth in Kuwait. According to Khan et al. (2020), tourism boosts CO2 emissions, energy consumption, and capital expenditure in Pakistan. The studies predominantly agree that there are causal correlations between these variables, albeit in varying directions (Khan et al., 2023; Jebli & Hadhri, 2018; Wasti & Zaidi, 2020). These findings highlight the importance of integrated strategies that promote sustainable tourism development while minimising environmental impacts (Khan et al., 2020).

Recent research has looked into the complex links between tourism, economic growth, energy use, and carbon emissions in several Asian economies. Tourism development has been linked to significantly higher CO2 emissions in Singapore and other Asian countries (Asif Raihan et al., 2022; Misbah Nosheen et al., 2021). However, economic growth has had conflicting consequences, with some research finding that emissions may decrease as economies improve (Asif Raihan et al., 2022; Misbah Nosheen as al., 2021). Energy use, notably from fossil fuels, has continuously been associated to higher CO2 emissions (Asif Raihan et al., 2022; Guo et al., 2023). To address these environmental concerns, academics have underlined the necessity of promoting sustainable tourism

practices, expanding renewable energy use, and creating green financing markets (Asif Raihan et al., 2022; Guo et al., 2023). The rising corpus of work on this topic emphasizes the importance of a thorough understanding of tourism's economic, social, and environmental implications (J. Brida et al., 2023).

Recent research has looked at the intricate links between religious tourism, economic growth, energy usage, and carbon emissions. In Saudi Arabia, pilgrimage tourism was discovered to have a positive influence on CO2 emissions, with a bidirectional causal relationship between tourism and GDP (Ozturk et al., 2021; Tabash et al., 2023). Similarly, in India, tourism and energy consumption both contributed favorably to CO2 emissions, with long-term causation linking both factors to emissions (Jayasinghe & Selvanathan, 2021). In China, there were bidirectional short-term causalities between GDP and tourism, as well as unidirectional long-term causalities from energy consumption to other variables (Zhang & Zhang, 2020). These findings emphasize the environmental costs of religious and general tourism, indicating the necessity for sustainable tourism practices and revised pollution-reduction measures. The studies also underline the need of taking tourism into account when investigating the relationship between economic growth, energy consumption, and environmental deterioration (Ozturk et al., 2021; Tabash et al., 2023; Jayasinghe and Selvanathan, 2021; Zhang & Zhang, 2020).

In Saudi Arabia context very few recent research has looked into the complex relationships between tourism, economic growth, energy use, and carbon emissions. Tourism, particularly religious pilgrimage, has been shown to boost economic growth while also contributing to higher CO2 emissions (Ozturk et al., 2021; Jamel, 2020). While economic growth generally has a negative influence on emissions, energy consumption and oil prices show favourable effects (Ozturk et al., 2021). The country's Green Vision seeks to achieve sustainability in a variety of areas, with research revealing links between energy consumption, economic growth, tourism, and carbon emissions (Faisal et al., 2024). According to the Environmental Kuznets Curve, international tourism has a U-shaped connection with carbon emissions (Li et al., 2024). However, it has been demonstrated that using renewable energy reduces environmental damage (Li et al., 2024). These results emphasise the obstacles and prospects that Saudi Arabia faces in maintaining economic growth, tourism development, and environmental sustainability. Several studies have revealed that economic growth and energy consumption are major drivers of rising CO2 emissions in the country (Amjad Ali et al., 2023; Mahmood et al., 2019; Alkhathlan. K, 2012). An inverted U-shaped relationship between economic growth and CO2 emissions has been established, with Saudi Arabia currently at the first stage of expansion contributing to environmental degradation (Alkhateeb et al., 2020). To solve these issues, researchers suggest switching to renewable energy and cleaner technology in order to separate economic growth from environmental degradation (Amjad Ali et al., 2023; Haider Mahmood et al., 2019). These findings highlight the importance of implementing balanced policies that support long-term economic development while also protecting the environment.

When the empirical literature on the relationship between tourism, energy consumption, economic growth, and carbon emissions is examined, it is determined that there is no distinction between religious tourism and has a scarcity of research in this field.

3. Methodology

3.1 Data subsection

This model draws information from the World Development Indicators (WDI), the British Petroleum (BP) Statistics and the Hajj Statistics obtained from Saudi Arabia General Authority for Statistics. Statistics on energy consumption and carbon dioxide emissions are from BP, while statistics on economic growth (in terms of GDP in current US dollars) from World Development Indicators and the number of pilgrims coming from abroad to Saudi Arabia from Saudi Arabia General Authority for Statistics. This paper investigates the connection between Carbon emissions, energy consumption, economic growth, and pilgrimage tourism in Saudi Arabia from 1996-2022.

3.2 Model specification

Carbon emissions, energy consumption, economic growth, and pilgrimage tourism are just some of the study variables analyzed using econometric models used by Ozturk et al (2021) before. The model can be formulated as follows:

$$Carbon\ emissions\ = f\ (energy\ consumption;\ economic\ growth;\ Hajj\ pilgrims) \quad (1)$$

Many research (Naseem.S.,2021, A. M. Khan et al., 2021; Murshed et al., 2022; U. Khan et al., 2022) have recommended normalising data sets before using them in an econometric model. All the study's variables could benefit from a logarithmic transformation to maintain measurement consistency and prevent issues with distributional features. This could also lead to stationarity in the variable series. This is particularly true for variables with varying measurement units, such as total energy consumption and carbon dioxide emissions, which are expressed as indices. Consequently, each variable is converted into a logarithmic function and employed in a real term:

$$LYt = log(Yt) \quad (2)$$

This can also be characterized in a log-linear econometric format:

$$lnct = \beta o + \beta 1 lnent + \beta 2 lngt + \beta 3 lnnpt + \varepsilon t \quad (3)$$

Where β0 is the constant term, β1 is the coefficient of the variable (energy consumption), β2 is the coefficient of variables (economic growth), β3 is the coefficient of variables (number of foreign pilgrims' arrival), t is the time trend, and εt is the random error term assumed to be normal, identical, and independently distributed.

3.3 Methodology

Unit Root test

Augmented Dickey Fuller (ADF) and Phillip Perron (PP) unit root tests are adopted to investigate the stationary importance for long-term connection of time series data. Both these tests will be carried out.

The following regression estimates the general form of the A.D.F. test

$$\Delta Yt = \alpha + \beta\, Yt - 1 + \sum \beta i\, ni = 0\, \Delta Yi + \varepsilon t \quad (4)$$

The following regression estimates the general form of the P.P. test

$$\Delta yt = \alpha + \beta\, \Delta yt \quad (5)$$

The basic difference between the ADF and PP tests is that PP is a non-parametric test, meaning that it does not need to specify the form of the serial correlation of Δyt under the null hypothesis (Shrestha & Bhatta, 2018).

Cointegration test

The Johansen co-integration test is validated by similar integration order, but the optimal lag is determined before estimating co-integrating among variables, as the first step. In this paper, the Johansen test is used to investigate the existence of cointegration between CO2 emission, Energy consumption, GDP, and number of foreign pilgrims' arrival. The null hypothesis of the Johansen test of cointegration is that "CO2 emissions, energy consumptions, GDP, and number of foreign pilgrims' arrival are not cointegrated". If the critical value is greater than the trace and max statistic, we can reject the null hypothesis. This implies that "CO2 emission, Energy consumption, GDP, and number of foreign pilgrims' arrival are co-integrated".

Vector Error Correction Model

VECM is an effective method for analysing dynamic economic relationships when the variables are cointegrated. In comparison to other models, it is particularly useful for investigating the long-term relationship and short-term dynamics of multiple variables employed in this study. It identifies the long-term equilibrium while preserving information about short-term modifications.

The cointegrating equation and long run Model can be expressed as:

$$ECT_{t-1} = Y_{t-1} - n_j X_{t-1} - \epsilon_m R_{t-1} \quad (6)$$

VECM can be expressed as:

$$\Delta lnct = \alpha + \sum_{i-1}^{k-1} \beta i \Delta lnct - 1 + \sum_{j=1}^{k-1} \emptyset j \Delta lnent - j + \sum_{m=1}^{k-1} \emptyset m \Delta lngt - m + \sum_{m=1}^{k-1} \emptyset n \Delta lnnpt - n + \lambda 1 ECTt - 1 + \mu 1t \quad (7)$$

Where;

lnc = log value of carbon dioxide emission

lnen = log value energy consumption

lng = log value of Economic Growth measured in terms of GDP (current US$)

lnng = log value of number of foreign pilgrims' arrival

k-1 = the optimal lag length is reduced by 1

βi; Øj; Øm,n= short-run dynamic coefficients of the model's adjustment long-run equilibrium

λ1 = speed of adjustment parameter with a negative sign

ECTt-1 = the error correction term is the lagged value of the residuals obtained from the cointegration regression of the dependent variable on the regressors. Contains long-run information derived from the long-run cointegrating relationship.

$\mu 1t$ = residuals in the equations

Causality Test:

Finally, the causality relationship between variables will be determined by Granger causality analysis. The Granger causality test is used to establish the existence of the relationship between variables and to determine the direction of this relationship, if any. The equations for this test are shown as below (Engle & Granger, 1987; Granger, 1988):

$$yt = \sum i = 1 \, aiyt - i \; + \sum i = 1 \, \beta xt - i \; + \mu 1t \quad (8)$$

$$xt = \sum i = 1 \, \theta t - i \; + \sum i = 1 \, \Upsilon yt - i \; + \mu 2t \quad (9)$$

4. Empirical Result

4.1 Unit Root Test:

The ADF and PP unit root test are used, and the results are shown in Table 1. According to the results, all the series contain unit roots at the level and become stationary when the first differences are taken. Hence, it paved the way to use the Johansen cointegration test for further analysis.

Table 1: Unit Root Test by augmented Dickey Fuller & Philips Perron

		ADF		PP	
		t-Statistics	Prob.	Adj.t-stat	Prob.
LNC	I (0)	-1.090	0.1438	-1.030	0.9399
	I (1)	-2.190	0.0200	-3.024	0.0327
LNE	I (0)	-0.081	0.9933	-0.498	0.9835
	I (1)	-3.522	0.0371	-3.579	0.0317

		ADF		PP	
LNNP	I (0)	-2.105	0.5431	-2.159	0.5131
	I (1)	-4.774	0.0005	-4.773	0.0005
LNG	I (0)	-1.742	0.7321	-1.837	0.6867
	I (1)	-4.241	0.0039	-4.171	0.0000

Source: *Authors' Calculations*

4.2 Lag order selection

The application of the Johansen co-integration test is validated by the presence of a similar order of integration, as reported by the ADF and PP unit root tests. However, the optimal lag is determined before estimating the co-integrating among the variables. The choice of an optimal lag is the first step in the Johansen cointegration test. Hence, in this section, the vector autoregression (VAR) specification is used to establish the appropriate lag length for the cointegration test in this section. The results of the VAR lag selection are presented in Table 2. From the table, it is clear that lag 2 has the minimum Akaike information criterion (AIC). Consequently, lag 2(K = 2) is selected as the optimal lag in the equation models.

Table 2: Lag order selection

Lag order	AIC	SIC	HQIC
0	-7.33771	-7.29098	-7.13934
1	-13.6253	-13.3916	-12.6334
2	-14.0222*	-13.6016*	-12.2369

Source: *Authors' Calculations*

4.3 Cointegration analysis:

The result of the Johansen cointegration test are shown in Table 3. At maximum rank 3, trace and max statistics are less than 5% critical value, the model's null hypothesis of no cointegration is rejected compared to the alternative that there is a cointegration link at a lag of 2. Therefore, the study concludes that there is a long run relationship between carbon emissions, energy consumption, economic growth and foreign pilgrims' arrival in Saudi Arabia.

Table 3: Johansen cointegration test for carbon mission as a dependent variable

Maximum Rank	Eigenvalue	Trace statistics	5% critical value	Max-Eigen Statistics	5% critical value
0		55.568	39.89	23.3706	23.80
1	0.65434	32.1974	24.31	19.4764	17.89
2	0.58741	12.7210	12.53	11.0411	11.44
3	0.39460	1.6800*	3.84	1.6800	3.84
4	0.07352				

Note. AIC, SC and HQ results are based on determining the optimal lag length (lag 2).
**Denotes statistically significance for %5 critical value.*
Source: Authors' Calculations

4.4 VECM estimation and analysis

The presence of cointegration relationships between lnc,lnen,lnnp and lng suggests a long run cointegrating relation between CO emission, energy consumption, number of foreign pilgrims arrival and economic growth. Hence, the VECM can be applied. Using the maximum likelihood estimator, the cointegrating coefficient vector normalized to lnc which is the variable of interest is estimated as given in Table 4.

Table 4. Cointegration coefficient vector from VECM.

	Lnc	lnen	lnnp	lng
Coefficient	1	-0.5676	0.0719	-0.161
		(0.000)	(0.000)	(0.000)

Source: *Authors' Calculations.*

The long-run relationship between lnc, lnen, lnnp and lng for a co-integrating vector is,

$$ECT_{t-1} = 1.00lnc_{t-1} - 0.5676lnen_{t-1} - 0.161lng_{t-1} + 0.0719lnnp_{t-1} \quad (10)$$

Coefficient signs should be reversed in the normalised cointegrating equation of Johansen model which is representing the long run. Carbon emissions(lnc) is the target variable. Lnen has a positive and significant impact on lnc in the long run. An increase in lnen will lead to increase in lnc emissions. That is, a percentage rise in energy consumption is likely to cause a 0.5676% increase in carbon emissions. Lng also has a positive and significant impact on lnc in the long run, with 0.16 percentage rise in carbon emission for every percentage point of growth in GDP. However, number of foreign pilgrims' arrival has a negative and significant impact on lnc in the long run. Carbon emission is negatively correlated with number of pilgrims arrival.

Negative and statistically significant ECT coefficient for carbon emission, energy consumption, economic growth, and number of foreign pilgrims' arrival indicates there is a convergence from short dynamics towards long run equilibrium. ECT gives the speed of adjustment within which the model will restore its equilibrium following any disturbances.

$$\triangle lnct = -0.906ECTt - 1 + 0.8374nct - 1 - 0.519lnent - 1 + 0.114\, lnnpt - 1 - 0.162lngt - 1 + 0.0108 \quad (11)$$

The short-run coefficient shows that carbon emissions increase from the previous year. Carbon emissions are expected to rise by 0.8374%. As total energy consumption rises, carbon emission fall by 0.52%. Carbon emissions fall by 0.162% for every percentage point of economic growth, which is a positive sign and could be achieved through the implementation of a circular carbon economy (CCE) to reduce carbon emissions along with adhering to the Paris Agreement and Sustainable Development Goals (SDGs). However, for every percentage point of foreign pilgrims' arrival, carbon emissions go up by 0.114%.

4.5 Causality test result

Table 5 shows the result of causal relationship between the variables by using Granger causality method. The probability values in the table indicate the existence of four causality relations. Firstly, there is unidirectional causality from carbon emissions to the number of pilgrims. This result, which expresses the causality relation between carbon emissions and the number of pilgrims, is compatible with Ozturk et.al (2022) and Tiwari et.al (2013) but not with Dogan and Aslan (2017). Another result of causality proves that there is a bidirectional causality relationship between carbon emission & energy consumption. Finally, it is found that there is unidirectional causality from economic growth to number of foreign pilgrims' arrival, which is consistent with khan el al (2023), Ozturk et.al (2022), Kim et al. (2005); Assadzadeh and Nasab (2012); Massidda and Mattana (2013); Aslan (2016) and Bilen et al. (2017).

It is shows that carbon dioxide emission and economic growth led to pilgrimage tourism in one direction. However, there is bidirectional causality exist between CO2 emissions and energy consumptions.

Table 5. Granger causality test

Null Hypothesis	F-Statistics	Probability
lnc ≠>lnen	15.315	0.0004*
lnc ≠>lnnp	7.1337	0.0081*

Null Hypothesis	F-Statistics	Probability
lnc ≠>lng	1.0271	0.3854
lnen≠>lnc	3.9384	0.0460**
lnen≠>lnnp	0.61541	0.5554
lnen≠>lng	0.32285	0.7297
lnnp≠>lnc	0.20198	0.8196
lnnp≠>lnen	0.48967	0.6237
lnnp≠>lng	3.0788	0.0804***
lng≠>lnc	1.3865	0.2846
lng≠>lnen	2.389	0.1307
lng≠>lnnp	0.5962	0.5653

, **, and* denotes respectively 1%,5% and 10% statistically significant level.*
Source: *Author Calculations.*

4.6 Variance decomposition analysis:

To trace back shocks into the future, the study uses the Cholesky variance decomposition technique. Evidence from Table 6 demonstrates that 3.039%, 2.53% and 0.039% of future shocks in carbon emissions are caused by economic growth, foreign pilgrims' arrival and total energy consumption. The analysis also reveals that 94% of the variation in carbon emissions could be justified by shocks within the variable itself, whereas the contributions made by energy consumption, economic growth, and pilgrimage tourism to carbon emissions were low. However, economic growth and pilgrims' arrival contribute more to carbon emissions compared to energy consumption.

Table 6: Variance decomposition of carbon emissions

Period	Lnc	Lnen	lng	lnnp
1	1	0	0	0
2	94.97%	.0364%	3.06%	1.92%
3	94.43%	.038%	3.05%	2.48%
4	94.41%	.0394%	3.038%	2.51%
5	94.40%	.0397%	3.039%	2.51%
6	94.39%	.0397%	3.039%	2.53%
7	94.39%	.0397%	3.039%	2.53%
8	94.39%	.0397%	3.039%	2.53%

Source: *Author Calculations.*

4.7 Stability and residual tests

The study investigates the VECM's robustness by investigating the serial correlation, heteroscedasticity, and normality tests in order to make unbiased statistical inferences. The results of the diagnostic tests for serial correlation, heteroscedasticity, and normality are shown in Table 7. The tests return, in that order, p - values of 0.2168, 0.4378, and 0.70740, all of which are greater than 5%, and show that the H0 is not accepted. This means there is no autocorrection and homoscedasticity, and the series is normally distributed. As a result, the model used for the analysis and interpretation was valid.

Table 7: Residual

	H0	Chi-squared	p-value
Lagrange-Multiplier test for residuals autocorrelation	No serial correlation	20.0754	0.2168
Breusch-Pagan test for heteroskedasticity	Residuals are homoscedastic	0.60	0.4378
Jarque-Bera Test for Normality	Residuals are not normally distributed	5.461	0.70740

5. Conclusion and policy implications:

Present paper investigates the interaction between CO2 emission, energy consumptions, economic growth and pilgrimage tourism in Saudi Arabia by taking the annual time series data from the period of 1996 to 2022. The estimation procedures encompassed a variety of tests, including a unit root test using Augmented Dicker Fuller (ADF) and Phillip Perron (PP), a cointegration test using the Johansen cointegration test, an examination of the short and long run nexus between carbon emissions, energy consumption, economic growth, and pilgrimage tourism using vector error correction model (VECM), and the Cholesky variance decomposition technique. In addition, the study conducted several diagnostic tests.

The Johansen cointegration demonstrates a positive relationship between energy consumption and GDP growth, although an increase in number of pilgrims arrival harms carbon emissions. Pilgrimage tourism growth will drop by 0.07 percent as carbon dioxide levels rise in the atmosphere. This is known as negative cointegration. These findings are comparable to those reported by Khan et al. (2023).

Negative and statistically significant ECT coefficient for carbon emission, energy consumption, economic growth, and pilgrimage tourism indicates there is a convergence from short dynamics towards long run equilibrium. The vector error correction model indicates that there has been an increase in carbon emissions from the previous year, as supported by the short-run coefficient. It is anticipated that there will be an increase in carbon emissions of 0.84 percent. When total energy consumption increases, carbon dioxide emissions decrease by 0.52 percent. Each percentage point of economic growth reduces carbon emissions by 0.16%. These findings are indeed robust and interesting in the Saudi context, where energy consumption and economic growth are reducing CO_2 pollution in the country. This could pertain to the introduction of circular carbon economy (CCE) in lowering carbon emissions while adhering to the objectives of the Paris Agreement and Sustainable Development Goals (SDGs). However, every percentage point rise in pilgrimage tourism results in a 0.11% increase in carbon emissions. It highlights how important pilgrimage activity is in regard to air pollution, even though it only covers a section of the country. Therefore, it is detrimental to the nation's environmental quality to host a big number of pilgrims during a particular time of the year.

Granger's theory of causality says that that carbon dioxide emission and economic growth led to pilgrimage tourism in one direction. However, there is bidirectional causality exist between CO2 emissions and energy consumptions. The impulse response function demonstrates that in the short term all variables exhibit growing tendencies but gradually begin to stabilize in the long run. Based on variance decomposition study, economic growth and pilgrimage tourism contribute more to carbon emissions than energy use.

It has been confirmed that pilgrimage tourism contributes to a country's economic growth and revenue, but its negative influence on the environment necessitates analysis and resolution by stakeholders.

The following policy recommendations for sustainable pilgrimage tourism are made based on the study findings:

1. Promote environmental awareness among pilgrims. In order to minimise emissions during the Hajj pilgrimage, it's crucial to study visitor behaviour and develop a green mindset among pilgrims. Drawing from Italy's Christian religious tourism model, which has been shown to increase spiritual awareness and environmental consciousness (Nawaz et al., 2023), similar programs can be implemented to promote sustainability among Hajj pilgrims.
2. Saudi Arabia's Vision 2030 aims to achieve net zero emissions by 2060 through a circular carbon economy approach. To achieve this, the country should establish environmentally sound regulations, ensure environmentally friendly accommodations, introduce a carbon tax system, and promote sustainable aviation fuels like kerosene derived from carbon dioxide, water, and solar energy. This will help protect natural resources and promote sustainable transportation options.
3. Develop environmentally friendly transportation solutions for pilgrims, such as electric or driverless vehicles, to reduce carbon emissions and improve traffic management during peak periods.
4. Collaborate with worldwide environmental organisations and research institutions to create and implement sustainable practices targeted to religious tourism, leveraging global expertise and cutting-edge technology.

By integrating these policies, Saudi Arabia can integrate pilgrimage tourism with its environmental goals, ensuring that economic advantages from this sector are accomplished while the natural environment remains preserved in accordance with the Saudi Green Initiative. Future studies could look at CO2 emissions in various places of worship worldwide to provide comparative insights. This study used a relatively short annual time series dataset; consequently, future studies could use longer time series data and more advanced methodologies for a comprehensive analysis.

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