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The Significance of Governance Indicators to Achieve Carbon Neutrality: A New Insight of Life Expectancy

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Abstract: This paper investigates the impact of life expectancy on carbon emission, in Saudi Arabia. Additionally, we examined the role of governance to achieve carbon neutrality status. We used the novel dynamic ARDL technique for estimations. This is one of the pioneer studies that analyze the role of life expectancy to control carbon emissions. The coefficients of life expectancy, education, and political stability are significantly negative. On contrary, governance effectiveness is an obstacle to achieving carbon neutrality. Empirical findings of life expectancy and governance effectiveness are quite surprising. In terms of Vision 2030 estimations, the coefficient of corruption control is significant and negative, indicating that the Saudi government has prioritized corruption control. While governance effectiveness remains positive, the Saudi government still requires governance reforms in order to achieve carbon neutrality goals.

Keywords: carbon neutrality; life expectancy; governance; Saudi Arabia; dynamic ARDL

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1. Introduction

Climate change is a term commonly used by researchers to describe environmental changes caused by the concentration of greenhouse gases in the atmosphere thereby affecting our planet's climate and ecosystem. However, it should be noted that climate change encompasses not only the rising normal temperatures we refer to as global warming, but also intense weather events, shifting natural life populations and environments, rising ocean levels, and a variety of other effects. Although many greenhouse gasses contribute to this problem, including methane, nitrogen oxide, and fluorinated gases; carbon dioxide [1] is the most prominent of these accounting for around 3/4 of all emissions. This is true for all countries, including Saudi Arabia, which has high per capita emissions of more than 19 tons per year, compared to the global average of around 4.8 tons per person/year. Though there are many reasons for this high level of carbon emission, one of the main reasons is that people expect to cool their homes as the desert country faces extreme temperatures, water shortages, and increasing desertification. Figure 1 depicts the severity of the problem by demonstrating that the country's current level and the rate of growth of carbon emission are exceptionally high.

It is assumed that carbon emissions are caused by numerous factors that, on the one hand, degrade the environment, but, on the other hand, are important for economic development. Industrialization, urbanization, transportation, agriculture, and other sectors require a greater amount of energy, such as fossil fuels, electricity, etc. As a result, increased consumption of these energy factors emits pollutant gasses into the environment. However, researchers are constantly attempting to find solutions to environmental issues, and some of them advised few practical solutions for this problem, such as forestation, industrial treatment plants, and green innovation to absorb the excess carbon from the atmosphere [2,3]. Another factor suggested by [4] is renewable energy consumption, which helps to mitigate environmental externalities.

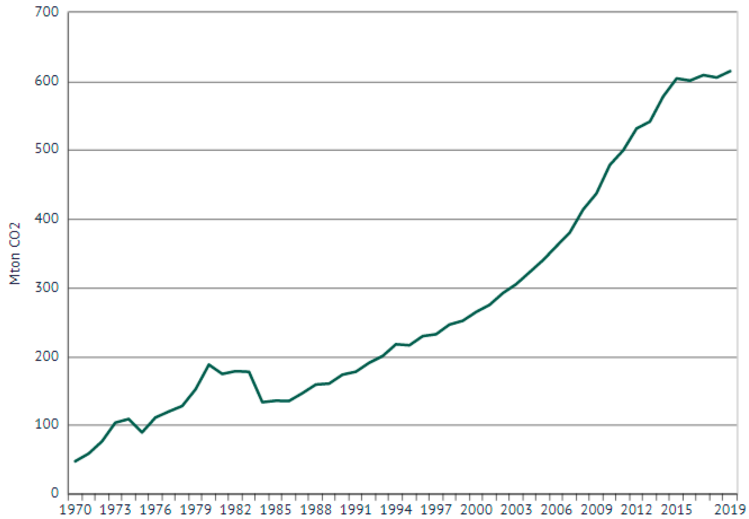

Figure 1. Saudi Arabia carbon emissions [5].

In addition to these direct measures to combat carbon emissions, [6] mentioned an indirect measure that could be a beneficial factor in terms of carbon reduction. An increase in income level can have an indirect effect on carbon reduction as it can be used for purchasing energy-efficient expensive products and driving the most recent vehicles that emit less amount of carbon. Ref. [7] found the same type of negative association between income level and carbon emission, which also proves the effectiveness of this factor to combat climate change. Additionally, education is mentioned as a viable solution to combat environmental problems because it informs people about the benefits of green living [8–10].

The world has recently faced COVID-19, which caused an economic downturn, unemployment, and other problems, but also reduced environmental pollution [11,12]. During COVID-19, industries and commercial activities suspended their operations, thus reducing industrial-based environmental pollution, in the form of carbon, nitrogen, sulfur, etc. [13,14]. The improvement in air quality is due to a significant decrease in fuel consumption by the urban population, industry, and transportation, among other things [15,16]. These findings enlightened the researchers and policy makers about the practicality of carbon neutrality if appropriate policies are formed to achieve environmental goals. However, we attempted to propose different measures that will assist the policy makers to form a long-term strategy.

Previous studies attempted to investigate the causes of carbon emissions and provided solutions based on their findings. However, it can be seen that the issue of environmental degradation caused by increased carbon emissions continues to exist. As a result, in order to provide more applicable solutions for this problem, this study proposed some practical solutions as well as the determinants of carbon emission. The current study contributes to the literature in three folds; firstly, the effect of life expectancy on carbon emission is assessed to verify if a shift in life expectancy leads to a change in the carbon emission level. Currently, no research explores this relationship; however, some studies reported the effect of carbon emission on life expectancy [17–19] and argued that the effect of carbon emission on human health reduces the life expectancy rate because with adverse health conditions people usually do not live long. However, we reason that life expectancy can also affect carbon emissions and there are many justifications to back this argument. To begin with, it should be noted that as people age and live longer lives, they tend to consume more energy, including fossil fuels [20]. The reason is remarkably simple, older people usually prefer a sedentary lifestyle and they do not participate in outside activities, rather they spend more time at home. Since they spend more time at home, they use more energy in the form of electricity, which eventually leads to higher carbon emissions [21]. However, staying at home is not the only reason for increased energy consumption; as people age, they often suffer from adverse health conditions and require a comfortable, warm environment.

This raises the demand for energy for heating, resulting in a significant increase in gas consumption, which triggers carbon emissions [22].

Secondly, this study contributes to the existing literature by examining the effect of governance indicators on carbon emissions in Saudi Arabia. Some studies tried to explore this nexus [23,24], but to the best of our knowledge, the relationship between governance indicators and carbon emissions in Saudi Arabia is still missing. It is more than important to study the influence of governance on environmental policies in Saudi Arabia, as the governance dynamics are different compared to western countries. It is a fact that good governance can take effective and efficient measures to address environmental issues and define a significant path to counter environmental challenges. One of these measures is the policy formulation, as well as the establishment of laws to tackle environmental degradation because with a weak governance system, laws would also be weak and implementation of a strict guideline for a clean environment within the contracts of businesses would be hindered [25]. Moreover, good governance enforces the rule of law essential to control carbon emissions; in the presence of environmental laws, the firms are bound to act accordingly. As a result of clear and articulated rules and laws, carbon control procedures can be easily enforced, binding firms to follow these procedures. However, [26] argued that with a loophole in laws and regulations, firms neglect the rules and degrade the environment by using technologically adverse procedures consuming a higher amount of energy and this happens due to non-compliance with carbon emission laws.

Similarly, political stability, which addresses the political dimension of governance, also plays a role in improving the carbon emission issue by influencing the rule of law [24]. In terms of the economic dimension, we use governance effectiveness, which states that in countries where bureaucracy is kept to a minimum, public services are efficiently run, and financial integrity is upheld, producers usually gain confidence and help to enforce carbon emission rules and regulations. The third dimension of governance is an institutional dimension, which relates to corruption control. The countries with less corruption control are unable to pursue environmental laws, however, the firms focus on multiplying their profits instead of fulfilling their duties to preserve the environment. As a result, governance has an impact on how people interpret the rules and contributes to reducing carbon emissions.

Another major contribution of this study is considering the 2030 perspective while checking the nexus between life expectancy, governance, and environmental degradation. As a result, based on available data, we attempted to simulate the series and analyze the direction of the 2030 vision to control carbon emissions. Based on the above-mentioned contributions, the study draws three objectives: (i) how does life expectancy affects carbon emission in Saudi Arabia? (ii) Do governance indicators significantly reduce carbon emissions in Saudi Arabia? (iii) How does the Saudi Vision 2030 effectively counter the environmental hazards to achieve a sustainable environment in Saudi Arabia? The findings of the study would help policymakers to estimate the outcomes of the 2030 vision, which will enable them to take corrective measures if needed regarding carbon emission and climate change.

2. Literature Review

Previously, the researchers have investigated the key factors and practical solutions to minimize the carbon emission. According to [3,27–31], economic growth is one of the main sources of carbon emission. The relationship between energy consumption and carbon emission is confirmed by number of researchers, such as [32–35]. Trade and carbon emission are also linked with each other [36–39].

2.1. Impact of Economic Growth on Carbon Emission

Enhancement of GDP is the main motive for almost all types of economies either developed or developing; however, this improvement comes at the cost of environmental degradation, which is usually neglected. In 1991, [27] tossed the idea that an increase in GDP increases carbon emissions, and after that many researchers tried to investigate this relationship. In this regard, [40] used data from 17 countries from 1997–2014 and concluded, using various estimation techniques, that there is a long-run co-integration between GDP and carbon emissions. Similarly, [41] analyzed data from African countries and concluded that there is a causal relationship between the economic growth of these countries and their carbon emission. Although many researchers examined the relationship between GDP and carbon emissions in the short term, [28] attempted to investigate whether this relationship is valid in the long term as well. They studied data for a longer period and discovered that long-term co-integration exists between GDP and carbon emission using various co-integration techniques. Likewise, [42] analyzed data from BRICS countries and concluded that both the GDP of these countries and the level of carbon emission are significantly and positively related.

2.2. Impact of Energy Consumption on Carbon Emissions

Another main factor behind increased carbon emission is the increased use of energy products including oil and gas because previous researchers mostly found a positive association between energy consumption and carbon emission. In this regard, data from Portugal was used to conclude that countries' overall carbon emission is highly increased due to the augmented use of energy products [32]. Similarly, the nexus between all types of non-renewable energy products and carbon emissions are also found significant by [43] when they used the NARDL method on data from Africa-based countries. The positive relationship between energy consumption and carbon emissions is also valid for developing countries, as [44] discovered in Pakistan using the ARDL technique. Ref. [45] also asserted that since 1965, carbon emissions in Indonesia are significantly elevated due to the high consumption of energy products. Additionally, a recent study by [35] in China also revealed that increased use of coal and other energy products result in higher carbon emission.

2.3. Impact of Population on Carbon Emission

The population has also been shown to be a significant contributor to carbon emissions, as the need for energy products and urbanization increases, resulting in an increase in the amount of carbon in the atmosphere. Ref. [46] used data from four countries including India, China, Brazil, and Indonesia to check if the growing population in these countries is a factor that should be considered if these companies need to reduce carbon emissions. Through the ARDL approach, they concluded that two countries, including India and Brazil, are under the pressure of environmental degradation due to the growing population in these countries. Additionally, the same kind of positive nexus is also valid in Taiwan because [47] used 24-year data from Taiwan and proved that the growing population and carbon emissions in Taiwan are significantly and positively related. The dynamics between population and carbon emission can be different in the short term and long term as [48] used data from Pakistan and concluded that in the long term, the association between population and carbon emission is negative whereas in the short term this association is positive. According to [49], the current climate change issue is not the result of population growth, but rather an increase in carbon emissions caused by the growth in population. Ref. [36] examined the data of 139 countries and confirmed the impact of population on carbon emission. Another study by [37] confirmed a similar outcome in 208 countries.

2.4. Impact of Education on Carbon Emission

Aside from the numerous advantages, education has for any country, it also aids in the fight against environmental degradation by lowering carbon emissions. Many researchers attempted to investigate this link and discovered that with education, people attempt to reduce the environmental impact of their decisions. It is noted that a significant amount of reduction in terms of carbon emission is noted per university students [8]. Furthermore, [9] conducted a study on Dutch graduates to determine whether classroom education plays a role in carbon reduction or whether online education also has an impact. It is found by them that online education plays a significant role in carbon reduction by both students as well as educational staff.

2.5. Impact of Life Expectancy on Carbon Emission

Despite the fact that there are numerous contributors to carbon emissions, previous research has shown that changes in life expectancy can also affect carbon emissions, and an increase in life expectancy amplifies carbon emissions. In this regard, [50] studied the residential sector in the United States from 1987 to 2009 to see how life expectancy or age affects carbon emissions. According to them, as life expectancy rises and people age, they tend to consume more energy, which is the primary source of carbon emissions, raising overall carbon emissions. However, an opposite type of nexus between life expectancy and carbon emission is found [51]. They used data from developed countries and divided it into different age groups to discover that as people get older, they emit less carbon because they spend more time at home and use transportation and personal vehicles less frequently. As a result, carbon emissions are reduced because transportation is the primary source of carbon emissions due to high fossil fuel consumption.

2.6. Impact of Governance on Carbon Emission

Aside from the many factors that contribute to the increase of carbon in the atmosphere, there is a factor known as governance or good governance that can aid in mitigating this issue by enacting appropriate policies and laws to reduce carbon emissions. To check this relationship, [52] used 21 years of data from BRICS countries and asserted that there exists an inverse relationship between governance quality and carbon emission. Similarly, the same type of negative association is also valid for SSA countries. Ref. [53] concluded that good governance in these countries plays a vital role in combating the carbon emission problem. However, there is a difference in this relationship due to the oil-importing characteristics, as governance increases carbon emissions in countries where oil is produced, whereas governance has a negative impact on carbon emissions in non-producing countries. Another important way in which governance plays a significant role in combating carbon emissions is through human development and changing patterns of human behavior. Ref. [54] proved this assumption valid after researching MENA countries and concluded that both governance and carbon emission is significantly and negatively related to human development.

The preceding discussion revealed that there is no such study in Saudi Arabia that can determine what type of relationship exists between life expectancy and carbon emissions. Alongside this, it is noted that good governance can effectively reduce carbon emissions in developing countries. Hence, it is essential to check if good governance can reduce environmental degradation in Saudi Arabia as well. Thus, the purpose of the current research is to fill this gap by exploring the effect of life expectancy and good governance carbon emission in Saudi Arabia. Furthermore, no previous research has investigated how effective the 2030 vision is in controlling carbon emissions. As a result, the impact of life expectancy and the government on carbon emissions is explored in light of the 2020 perspective.

3. Data and Methodology

3.1. Data and Models

The aim of this study is to explore the significant factors of carbon emissions in Saudi Arabia. Previously, a number of studies have confirmed the significant relationship between economic growth and carbon emission, [45,55–57] (Ahmad et al., 2016; Baloch et al., 2021; Bimanatya and Tri Widodo, 2016; Qin et al., 2021). Similarly, energy consumption, population, and education have been studied [30,58–62]. This study is the pioneer which investigates the impact of life expectancy on carbon emission. There are two opposite perceptions of life expectancy [50] argued that higher life expectancy leads to an increase in energy consumption, however, in Saudi Arabia, the main source of energy is oil. This higher energy consumption points toward higher carbon emissions. On contrary, [51] proposed that, usually, people of older ages, consume less energy. With the consumption of less energy, the higher life expectancy is not responsible for the increase in carbon emission. Due to these contradicting arguments, we attempt to study the significance of life expectancy. Lastly, we included the governance factors to observe the role of governance in Saudi Arabia to counter the environmental issues. In contrast to previous studies, we use the pre-Vision 2030 and post-Vision 2030 data which highlight the key impact of Vision 2030 to decrease the environmental degradation process. For this purpose, we transform the yearly data into monthly data, which is used for post-Vision 2030 estimations. Post-Vision 2030 includes the data of 2016, 2017, 2018, and 2019, which made 48 observations. The statistical model of the study is represented by Equation (1)

$$CO_2 = f(EG, EC, POP, EDU, LIFE,\ Governance) \tag{1}$$

where, CO_2 represents the carbon emission, EG and EC are the economic growth and energy consumption, respectively. POP, EDU, and $LIFE$ represent the population, education, and life expectancy, respectively. *Governance* is further divided into three parts, political dimension, economic dimension, and institutional dimension.

$$CO_2 = f(EG, EC, POP, EDU, LIFE,\ PS) \tag{2}$$

$$CO_2 = f(EG, EC, POP, EDU, LIFE,\ GE) \tag{3}$$

$$CO_2 = f(EG, EC, POP, EDU, LIFE,\ CC) \tag{4}$$

$$CO_2 = f(EG, EC, POP, EDU, LIFE,\ PS,\ GE,\ CC) \tag{5}$$

where, PS, GE, and CC are political stability which shows the political dimension, governance effectiveness represents the economic dimension, and control of corruption is under the institutional dimension, following the [63]. Where, political stability is "Measured as the likelihood of a government being destabilized by unconstitutional or violent means, including terrorism and domestic violence" that have a direct relation with political stability. Governance effectiveness is "Measured as public services' quality, their capacity and their independence from political pressures, as well as the policy formulation's quality" that represents the quality and implementation of policies, such as economic policies, commercial policies, industrial policies, urban policies, educational policies, etc. In the case of strong governance effectiveness, the planning and implementation are helpful to generate business activities that have a direct impact on the economy. Resultantly, this increase in economic activities has a significant impact on carbon emissions [30]. However, there represents a strong connection between governance effectiveness and carbon emission. The control on corruption represents "Measured as the degree of trust and compliance of agents with the rules of society, especially with regard to the quality of property rights, the police, and the courts, as well as the risk of crime". The significance of the control on corruption helps to strengthen the institutions of the country, however, this reflects the institutional quality. Based on these equations, we construct four models for this study.

$$CO_2 = \beta_0 + \beta_1\ EG + \beta_2\ EC + \beta_3\ POP + \beta_4\ EDU + \beta_5\ LIFE + \beta_6\ PS + \varepsilon \text{ Model-1}$$

$$CO_2 = \beta_0 + \beta_1\ EG + \beta_2\ EC + \beta_3\ POP + \beta_4\ EDU + \beta_5\ LIFE + \beta_6\ GE + \varepsilon \text{ Model-2}$$

$$CO_2 = \beta_0 + \beta_1\ EG + \beta_2\ EC + \beta_3\ POP + \beta_4\ EDU + \beta_5\ LIFE + \beta_6\ CC + \varepsilon \text{ Model-3}$$

$$CO_2 = \beta_0 + \beta_1\ EG + \beta_2\ EC + \beta_3\ POP + \beta_4\ EDU + \beta_5\ LIFE + \beta_6\ PS + \beta_7\ GE + \beta_8\ CC + \varepsilon \text{ Model-4}$$

where, CO_2 represents carbon emission which is defined by carbon emission (matric tons per capita), EG represents a gross domestic product (current US$), EC is a proxy of energy consumption that is defined by fossil fuel energy consumption. POP represents the total population ages 15–64. EDU is the data of secondary education. $LIFE$ mentions the life expectancy, that is life expectancy at birth in numbers. PS, GE, and CC are the governance quality index. ε is the error term of the model. The sample data of the current study is collected from World Development Indicators (WDI), over the period of 1996–2019.

3.2. Methodology

3.2.1. Zivot and Andrews Unit Root Test

For preliminary analysis, we have to examine the presence of a unit root in economic data, however, the study adopts the [64] unit root test. The Zivot and Andrews (ZA) unit root test considers the endogenous structural breaks of study data without pre-defined break time, so it performs better than the traditional test. The null hypothesis of the ZA test claims the presence of unit root $y_t = \mu + y_{t-1} + e_t$. ZA test is used to minimize the one-sided test statistics for $\alpha = 1$. However, a large number of time series studies have focused on Zivot and Andres unit root test [65,66].

3.2.2. Cointegration Test

The ZA test confirms the presence of stationary at mix; life expectancy and political stability are stationary at level, while others are at first difference. However, we have to examine the cointegration test to confirm the existence of the long-run relationship of the studied variables. For cointegration analysis, we used the bound test [67], where the joint null hypothesis is $H_0^F : (\rho = 0) \cap \left(\sum_{T-0}^{q} \beta_T = 0\right)$, whereas, the alternate hypothesis are $H_1^F : (\rho \neq 0) \cup \left(\sum_{T-0}^{q} \beta_T \neq 0\right)$. The F-statistics estimates the joint null hypothesis. However, for rejection of the null hypothesis, t-statistics are used for single hypothesis testing, where the null hypothesis is $H_0^t : \alpha = 0$ and alternate hypothesis is $H_1^t : \alpha \neq 0$.

3.2.3. Autoregressive Distributed Lag Model

The mix stationarity of series at the level and first difference and presence of cointegration leads us to apply the auto regressive distributed lag (ARDL), which was proposed by [67]. ARDL estimation presents the sort-run and long-run relationship between variables. The ARDL equations are given in Equations (6)–(9).

$$\begin{aligned}\Delta CO_{2\,t} = {} & \beta_o + \beta_1 CO_{2,\,t-1} + \beta_2 EG_{t-1} + \beta_3 EC_{t-1} + \beta_4 POP_{t-1} + \beta_5 EDU_{t-1} + \beta_6 LIFE_{t-1} + \beta_7 PS_{t-1} + \textstyle\sum_{k=1}^{n} \gamma_{1k} CO_{2,\,t-k} + \\ & \textstyle\sum_{k=0}^{n} \gamma_{2k} EG_{t-k} + \sum_{k=0}^{n} \gamma_{3k} EC_{t-k} + \sum_{k=0}^{n} \gamma_{4k} POP_{t-k} + \sum_{k=0}^{n} \gamma_{5k} EDU_{t-k} + \sum_{k=0}^{n} \gamma_{6k} LIFE_{t-k} + \sum_{k=0}^{n} \gamma_{7k} PS_{t-k} + V_T\end{aligned} \tag{6}$$

$$\begin{aligned}\Delta CO_{2\,t} = {} & \beta_o + \beta_1 CO_{2,\,t-1} + \beta_2 EG_{t-1} + \beta_3 EC_{t-1} + \beta_4 POP_{t-1} + \beta_5 EDU_{t-1} + \beta_6 LIFE_{t-1} + \beta_7 GE_{t-1} + \textstyle\sum_{k=1}^{n} \gamma_{1k} CO_{2,\,t-k} + \\ & \textstyle\sum_{k=0}^{n} \gamma_{2k} EG_{t-k} + \sum_{k=0}^{n} \gamma_{3k} EC_{t-k} + \sum_{k=0}^{n} \gamma_{4k} POP_{t-k} + \sum_{k=0}^{n} \gamma_{5k} EDU_{t-k} + \sum_{k=0}^{n} \gamma_{6k} LIFE_{t-k} + \sum_{k=0}^{n} \gamma_{7k} GE_{t-k} + V_T\end{aligned} \tag{7}$$

$$\begin{aligned}\Delta CO_{2\,t} = {} & \beta_o + \beta_1 CO_{2,\,t-1} + \beta_2 EG_{t-1} + \beta_3 EC_{t-1} + \beta_4 POP_{t-1} + \beta_5 EDU_{t-1} + \beta_6 LIFE_{t-1} + \beta_7 CC_{t-1} + \textstyle\sum_{k=1}^{n} \gamma_{1k} CO_{2,\,t-k} + \\ & \textstyle\sum_{k=0}^{n} \gamma_{2k} EG_{t-k} + \displaystyle\sum_{k=0}^{n} \gamma_{3k} EC_{t-k} + \textstyle\sum_{k=0}^{n} \gamma_{4k} POP_{t-k} + \sum_{k=0}^{n} \gamma_{5k} EDU_{t-k} + \sum_{k=0}^{n} \gamma_{6k} LIFE_{t-k} + \sum_{k=0}^{n} \gamma_{7k} CC_{t-k} + V_T\end{aligned} \tag{8}$$

$$\begin{aligned}\Delta CO_{2\,t} = {} & \beta_o + \beta_1 CO_{2,\,t-1} + \beta_2 EG_{t-1} + \beta_3 EC_{t-1} + \beta_4 POP_{t-1} + \beta_5 EDU_{t-1} + \beta_6 LIFE_{t-1} + \beta_7 PS_{t-1} + \beta_7 GE_{t-1} + \beta_7 CC_{t-1} \\ & + \textstyle\sum_{k=1}^{n} \gamma_{1k} CO_{2,\,t-k} + \sum_{k=0}^{n} \gamma_{2k} EG_{t-k} + \sum_{k=0}^{n} \gamma_{3k} EC_{t-k} + \sum_{k=0}^{n} \gamma_{4k} POP_{t-k} + \sum_{k=0}^{n} \gamma_{5k} EDU_{t-k} + \sum_{k=0}^{n} \gamma_{6k} LIFE_{t-k} + \\ & \textstyle\sum_{k=0}^{n} \gamma_{7k} PS_{t-k} + \sum_{k=0}^{n} \gamma_{7k} GE_{t-k} + \sum_{k=0}^{n} \gamma_{7k} CC_{t-k} + V_T\end{aligned} \tag{9}$$

Equations (6)–(9) Δ shows the difference operator and V_T shows the error term. β_0 is the constant term, $\beta_1,\ \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7, \beta_8, \beta_9, \beta_{10}, \beta_{11}$ mentions the coefficients of long-term estimations. Error correction dynamics are presented by $\gamma_1, \gamma_2, \gamma_3, \gamma_4, \gamma_5, \gamma_6, \gamma_7, \gamma_8, \gamma_9, \gamma_{10}, \gamma_{11}$.

In addition to ARDL estimation, we use the novel dynamic ARDL estimation technique which deals with the shocks in regressors. Dynamic ARDL incorporates the potential shocks that are caused by the independent variable. In our case, we account for the potential shocks of life expectancy in Saudi Arabia, where the simulation is constructed on a 10 percent increase in the upcoming years. The dynamic ARDL simulation is utilized by using the STATA command "parmby".

4. Results

4.1. Descriptive Statistics

Table 1 presents the descriptive statistics for the main variables of this study, including carbon emission, economic growth, energy consumption, population, education, life expectancy, and governance. Economic growth is showing the highest mean value, however;

the lowest value corresponds to education. In terms of volatility, political stability, which is a political dimension of governance proved to be highly volatile whereas life expectancy is less volatile in Saudi Arabia.

Table 1. Descriptive statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
CO_2	24	12.88033	0.3298546	12.24376	13.38027
EG	24	28.03987	0.6079944	27.03393	28.7208
EC	24	8.703638	0.2388506	8.399528	9.224427
POP	24	16.62281	0.2750687	16.1849	17.01735
EDU	24	3.593493	0.4677923	2.848009	4.261283
LIFE	24	4.320864	0.012212	4.298074	4.340671
PS	24	20.66635	23.03318	−6.000303	62.7456
GE	24	−7.004411	4.746142	−15.15276	−1.128562
CC	24	−1.911053	0.8673192	−3.205284	−0.4236099

Notes: CO_2 is the carbon emission, EG stands for economic growth, EC is the energy consumption, POP presents population, EDU depicts education. LIFE shows life expectancy. In governance indicators, PS, GE, and CC represent political stability, governance effectiveness, and corruption control, respectively.

4.2. Correlation

Figure 2 presents the results of the correlation analysis between the studied variables. It can be seen that economic growth, population, and education are highly correlated with carbon emissions and this correlation is positive which suggests that all these factors increase the carbon emission in Saudi Arabia. Additionally, the correlation between governance effectiveness and carbon emission is high. Besides this, energy consumption, political stability, and corruption control are less correlated with carbon emission, but the correlation between energy consumption and political stability is positive, whereas corruption control is negatively correlated with the carbon emission of Saudi Arabia. It is evident that all variables, as well as two indicators of governance, are significantly and positively correlated with economic growth, however, corruption control is negatively correlated with economic growth. This suggests that all variables of the study except corruption control are playing a role in increasing the economic growth of the country. As far as energy consumption is concerned, all variables are playing a significant role in increasing energy consumption, whereas only corruption control is decreasing energy consumption.

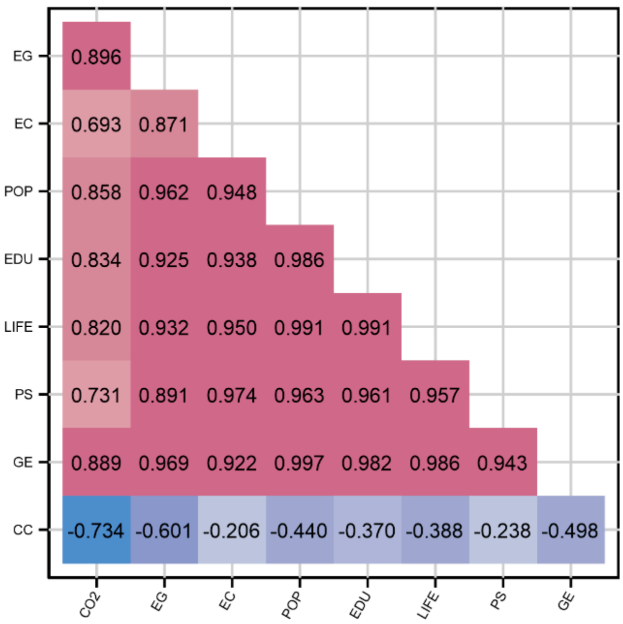

Figure 2. Correlation among studied variables.

The result of multicollinearity is reported in Table 2, the values of VIF indicate the non-existence of multicollinearity issue, for the full model.

Table 2. VIF of full model.

At level	VIF
EG	7.41
EC	6.93
POP	9.06
EDU	4.82
LIFE	6.64
PS	2.87
GE	8.88
CC	7.39
Mean VIF	6.75

4.3. Unit Root Test

Table 3 presents the results of the Zivot-Andrews unit root test with a structural break to check the stationarity of the data. It can be seen that all variables have a unit root at a level, except life expectancy and political stability. Whereas all series becomes stationary at first difference. Hence, it can be suggested that ARDL co-integration test would be appropriate to apply to this data.

Table 3. Zivot-Andrews unit root test with structural break.

At level	Statistics	Break	Result
CO_2	−0.921	2015	Unit Root
EG	−3.821	2014	Unit Root
EC	−1.704	2015	Unit Root
POP	−2.981	2002	Unit Root
EDU	−3.919	2004	Unit Root
LIFE	−5.369 ***	2004	Stationary
PS	−5.931 ***	2001	Stationary
GE	0.155	2015	Unit Root
CC	−1.706	2014	Unit Root
At difference	Statistics	Break	Result
Δ CO_2	−6.295 ***	2016	Stationary
ΔEG	−5.552 ***	2012	Stationary
ΔEC	−5.468 ***	2015	Stationary
ΔPOP	−6.264 ***	2001	Stationary
ΔEDU	−4.807 **	2009	Stationary
ΔLIFE	−4.598 *	2013	Stationary
ΔPS	−8.357 ***	2003	Stationary
ΔGE	−9.572 ***	2015	Stationary
ΔCC	−5.345 ***	2016	Stationary
CV	1%	5%	10%
	−5.34	−4.8	−4.58

Notes: Zivot-Andrews unit root test has null hypothesis "time series has a unit root with structural break". CO_2 is the carbon emission, EG stands for economic growth, EC is energy consumption, POP presents population, EDU depicts education. LIFE shows life expectancy. In governance indicators, PS, GE, and CC represent political stability, governance effectiveness, and corruption control, respectively. "Δ" is the difference of a variable; "CV" mentions the critical value; ***, **, * present the level of significance at 1%, 5%, and 10%, respectively.

4.4. Empirical Results

4.4.1. Co-Integration Test Using ARDL

Table 4 presents the results of the [67] Pesaran et al. (2001) bounds test for ARDL with appropriate critical upper and lower bound values along with the value of F- statistics. It is evident from the table that in model 1 the F-statistics of all variables and lagged dependent variable is higher than upper bound critical values. The same is the case with the remaining three models as well, which suggests that there exists co-integration between variables of the study. Hence, these results suggest that ARDL estimation is appropriate to check the long-run relationship between the variables of the study.

Table 4. Ref. [67] bounds test for ARDL.

Model 1: CO_2 = f (EG, EC, POP, EDU, LIFE, PS)		
	I(0)	I(1)
10% critical value	2.457	3.797
5% critical value	2.97	4.499
1% critical value	4.27	6.211
F	5.222	CI exist
Model 2: CO_2 = f (EG, EC, POP, EDU, LIFE, GE)		
	I(0)	I(1)
10% critical value	2.457	3.797
5% critical value	2.97	4.499
1% critical value	4.27	6.211
F	9.409	CI exist
Model 3: CO_2 = f (EG, EC, POP, EDU, LIFE, CC)		
	I(0)	I(1)
10% critical value	2.457	3.797
5% critical value	2.97	4.499
1% critical value	4.27	6.211
F	8.669	CI exist
Model 4: CO_2 = f (EG, EC, POP, EDU, LIFE, PS, GE, CC)		
	I(0)	I(1)
10% critical value	2.384	3.728
5% critical value	2.875	4.445
1% critical value	4.104	6.151
F	8.109	CI exist

Notes: Where I(0) and I(1) show the lower and upper band critical values at 10%, 5%, and 1% level of the [67] bounds test; - CI stands for Cointegration.

4.4.2. ARDL estimation

Long-Run Analysis

Table 5 shows the results for ARDL estimations with short-run and long-run results in detail. The findings regarding the long-term relationship between study variables and carbon emissions in Saudi Arabia indicate that economic growth is not significantly associated with carbon emissions in the country. This suggests that, in the long run, economic growth is no longer a cause for concern in terms of environmental degradation; similar findings have been reported by [3,30]. The same is the case for energy consumption because, in all models, the coefficients of energy consumption are insignificant, which means the consumption of energy products does not add to the carbon emission of Saudi Arabia. Only model 2 shows a significant negative sign in the case of the population at a 10% level of significance. This inverse relationship between population and carbon emissions corresponds to the findings of [68]. However, in the remaining models, it shows an insignificant but negative signature. These findings suggest that in Saudi Arabia, an increasing trend in population has no role in carbon emissions.

Table 5. ARDL estimations.

	Model 1	**Model 2**	**Model 3**	**Model 4**
ADJ	−0.536	−0.912 ***	−0.513 *	−0.709 **
	(0.066)	(0.001)	(0.016)	(0.004)
Long run				
EG	0.353	0.102	−0.00482	0.329
	(0.412)	(0.459)	(0.986)	(0.306)
EC	−2.529	1.224	−0.91	1.777
	(0.123)	(0.071)	(0.348)	(0.096)
POP	1.357	−9.938 *	−1.227	−10.92
	(0.620)	(0.012)	(0.598)	(0.066)
EDU	0.512	−0.794 *	−6.798	2.659
	(0.632)	(0.039)	(0.130)	(0.055)
LIFE	18.95	−56.64 *	−0.909	−64.30 *
	(0.766)	(0.013)	(0.983)	(0.031)
PS	−0.00779			−0.0122
	(0.475)			(0.079)
GE		0.619 **		0.627 *
		(0.002)		(0.027)
CC			−0.308 *	−0.0638
			(0.042)	(0.534)
Short run				
D.EG				−0.276
				(0.134)
D.EC	1.464 *		1.031*	
	(0.012)		(0.014)	
D.POP		8.611		
		(0.063)		
D.EDU		−0.638	−0.557	−0.574
		(0.062)	(0.171)	(0.125)
D.GE		−0.333 **		−0.233
		(0.004)		(0.115)
Constant	−43.22	374.4 **	20.22	316.9 **
	(0.702)	(0.002)	(0.819)	(0.006)
N	23	23	23	23
R-square	0.789	0.846	0.870	0.895
F-statistics	2.873	4.221	5.140	2.999

Notes: CO_2 is the carbon emission, EG stands for economic growth, EC is the energy consumption, POP presents population, EDU depicts education. LIFE shows life expectancy. In governance indicators, PS, GE, and CC represent political stability, governance effectiveness, and corruption control, respectively. "( )" contains the standard error; ***, **, * presents the level of significance at 1%, 5%, and 10%, respectively.

The same is true for education, as its coefficient is negative in two of four models, and one coefficient is both significant and negative at the 10% level. This means that education can help to mitigate the negative effects of carbon emissions. Refs. [8,30,58] reported that education plays a vital role in decreasing carbon emissions. The most significant findings of this study concern life expectancy, and it is surprising to see that in Saudi Arabia, life expectancy is significantly and negatively related to carbon emission in two models at a 10% level of significance, with an extremely high coefficient value. This means that increased life expectancy reduces carbon emissions in the country; a similar result has been reported by [69]. Governance indicators are another important policy variable in the study. Political stability has a negative and insignificant impact on carbon emission, whereas governance effectiveness is significantly and positively related to carbon emission in both models at a 5% level of significance, implying that governance effectiveness is futile in controlling carbon emission. At a 10% level of significance, corruption control is significantly and negatively related to carbon emission in one of two models, indicating that corruption control is helping to reduce carbon emissions. This result is consistent with the results of [70].

Short-Run Analysis

Short-run analysis suggests that economic growth is significantly and positively related to carbon emission at a 10% level of significance in Saudi Arabia. However, population and education have an insignificant coefficient, revealing that these variables have no impact on carbon emission in the short-run analysis. Whereas governance effectiveness shows a significant negative coefficient in one out of two models, which suggests that in the short run, governance effectiveness is helpful in decreasing carbon emissions in Saudi Arabia. This result is consistent with the findings of [53].

Table 6 reports the diagnostics of models, which consist of autocorrelation, heteroskedasticity, normality, model stability, and structural breaks. Most of the diagnostics for all models are mentioning satisfactory results, which assist to conclude the validity of ARDL results.

Table 6. ARDL diagnostics.

Diagnostics	Model 1	Model 2	Model 3	Model 4
Autocorrelation				
Durbin-Watson	2.009	2.604	2.354	2.584
ARCH LM	0.317	0.435	0.383	0.084
Breusch-Godfrey LM	0.851	0.063	0.219	0.063
Heteroskedasticity				
Cameron & Trivedi's	0.402	0.402	0.402	0.402
Breusch Pagan	0.282	0.041	0.270	0.115
Normality				
Pr (Skewness)	0.733	0.923	0.347	0.465
Pr (Kurtosis)	0.334	0.470	0.380	0.659
pnorm	normal	normal	normal	normal
qnorm	normal	normal	normal	normal
Stability				
Custom	stable	stable	stable	stable
Structural break				
recursive	1.110	0.414	0.403	0.388
ols	0.352	0.632	0.633	0.406

4.4.3. Co-Integration Test Using Dynamic Simulated ARDL

Table 7 presents the results of the [67] bounds test for dynamic simulated ARDL. These results imply that there is cointegration between variables because, in all models, the value of F-statistics is higher than upper-bound critical values. Here it is appropriate to apply dynamic ARDL simulation techniques to know the in-depth association between the independent and dependent variables of this study.

Table 7. Ref. [67] bounds test for Dynamic simulated ARDL.

Model 1: CO_2 = f (EG, EC, POP, EDU, LIFE, PS)		
	I(0)	I(1)
10% critical value	1.75	2.87
5% critical value	2.04	3.24
1% critical value	2.66	4.05
F	5.407	CI exist
Model 2: CO_2 = f (EG, EC, POP, EDU, LIFE, GE)		
	I(0)	I(1)
10% critical value	1.75	2.87
5% critical value	2.04	3.24
1% critical value	2.66	4.05
F	9.908	CI exist
Model 3: CO_2 = f (EG, EC, POP, EDU, LIFE, CC)		
	I(0)	I(1)
10% critical value	1.75	2.87
5% critical value	2.04	3.24
1% critical value	2.66	4.05
F	7.229	CI exist
Model 4: CO_2 = f (EG, EC, POP, EDU, LIFE, PS, GE, CC)		
	I(0)	I(1)
10% critical value	1.7	2.83
5% critical value	1.97	3.18
1% critical value	2.54	3.91
F	7.548	CI exist

Notes: Where I(0) and I(1) show the lower and upper band critical values at 10%, 5%, and 1% level of the [67] bounds test; CI stands for Cointegration.

4.4.4. Dynamic ARDL Estimations

In view of the unit root and cointegration results, we conclude the existence of stationarity at mix (level and first difference) and affirmed the cointegration in studied models. In this scenario, the best approach is the autoregressive distributed lagged (ARDL) model. However, we used the advanced version of ARDL, which is Dynamic ARDL that simulate, estimate, and forecast simultaneously. However, we employed the Dynamic ARDL approach for econometric estimations.

Table 8 reports the result of dynamic simulated ARDL estimation to suggest that economic growth is not a hurdle to attain carbon neutrality, as mentioned in panel A and panel B (Panel A reports the impact of the independent variable at time (*t*) on dependent variable at time t. Whereas, Panel B depicts the effect of the independent variable at time (*t*−*1*) on the dependent variable at time (*t*)). However, energy consumption has a positive effect on carbon emission, in panel A, as the majority of the models are showing a significant positive effect at a 5% level of significance. In the case of panel B, the effect of energy consumption on carbon emission is significantly negative, suggesting that an increase in lagged energy consumption decreases carbon emission. This effect is highest in model 1 where a 1% increase in energy consumption decreases carbon emission by 1.27%. This result is aligned with the findings of [32].

Table 8. Dynamic simulated ARDL estimations.

Panel A	**Model 1**	**Model 2**	**Model 3**	**Model 4**
EG	0.1893	0.0932	−0.0025	0.2334
EC	1.3549 **	1.1166 **	−0.4665	1.2595 **
POP	0.7272	−9.0653 ***	−0.6290	−7.7424 **
EDU	0.1906	−0.7902 **	0.7457	−1.0450 **
LIFE	10.1534	−51.6684 **	−0.4657	−45.5795 *
PS	−0.0042			−0.0087 *
GE		0.5645 ***		0.4443 **
CC			−0.1580 ***	−0.0452
Constant	−43.2236	374.4042 ***	20.2182	316.9150 ***
N	23	23	23	23
R-square	0.736	0.888	0.847	0.911
F-statistics	4.867	9.520	7.991	8.492
Panel B				
CO_2 (t-1)	−0.618 **	−0.650 ***	−0.764***	−0.748 ***
EG (t-1)	0.156	0.193	0.0205	0.118
EC (t-1)	−1.274 **	−0.861 *	−1.048 **	−0.768 *
POP (t-1)	1.567	−3.453 *	0.669	−2.456
EDU (t-1)	0.213	−0.104	0.337	0.0583
LIFE (t-1)	−2.767	16.15 **	1.349	12.66
PS (t-1)	−0.008			−0.001
GE (t-1)		0.217 **		0.163
CC (t-1)			−0.125 *	−0.0565
N	23	23	23	23
R-square	0.703	0.813	0.760	0.829
F-statistics	5.407	9.908	7.229	7.548

Notes: CO_2 is the carbon emission, EG stands for economic growth, EC is the energy consumption, POP presents population, EDU depicts education. LIFE shows life expectancy. In governance indicators, PS, GE, and CC represent political stability, governance effectiveness, and corruption control, respectively. ***, **, * presents the level of significance at 1%, 5%, and 10%, respectively.

In both panels, the population shows that the effect of population on carbon emission is negative. However, in panel A, this effect is significant in three out of four models. Whereas, in panel B, only one model shows a significant effect. Likewise, education is affecting carbon emission in panel A, but in panel B, the coefficients of education are not significant. In panel A, two models are showing significant and negative coefficients at the

5% level, indicating a 1% increase in education reduces carbon emission by a maximum of 1.04%. Refs. [30,32] also found that education is essential for improving awareness in people regarding climate change.

In the current study, two policy variables introduced for carbon neutrality are life expectancy and governance. Life expectancy is significantly and negatively related to carbon emission with an exceptionally large value of coefficients in the two models. This means any increase in life expectancy results in a reduction of carbon emissions. If life expectancy increases by 1%, carbon emission decreases by 51.67%. The negative association between life expectancy and carbon emission is also found by [71]. However, carbon neutrality can be achieved without bothering life expectancy.

Additionally, political stability, a political dimension of governance, demonstrate a significant negative association in panel A, under model 4, which suggests that political stability can help in decreasing carbon emission. However, this effect is insignificant in panel B. Governance effectiveness, which is an indicator of the economic dimension of governance, shows a significant positive association with carbon emission in both panels. The positive and significant coefficients of governance effectiveness conflict with previous studies [26,31,53,54]. This positive and significant relation depicts that governance effectiveness is not mature enough to participate in its impact to achieve carbon neutrality targets. In both panels, corruption control, which reflects the institutional dimension of governance, has a significant negative association with carbon emissions. Ref. [72] also demonstrate that with less corruption, carbon emissions can be controlled effectively. However, it is important to note that carbon neutrality can be achieved through significant governance in Saudi Arabia.

4.5. Vision 2030

After ARDL and Dynamic ARDL analysis, we aim to examine the role of the studied variables to control carbon emissions, specifically after the implementation of Vision 2030. In 2015, Saudi Arabia has introduced a long-term plan to achieve sustainable objectives which is named Vision 2030. To analyze the impact of Vision 2030, we use the data for 2016, 2017,2018, and 2019 which is transformed into a monthly basis. The findings of Vision 2030-based estimations are reported in Table 9. This helps to overlook the progress of Vision 2030 to combat carbon emissions and leads towards carbon neutrality. The findings confirm that higher economic growth leads to an increase in carbon emissions. Most of the models report negative and significant coefficients for electricity consumption, population, education, and life expectancy, indicating that the Saudi government is successful in educating and spreading awareness about the importance of environmental protection. Political stability is significant in model 1, but insignificant in model 4, whereas corruption control is significant in both models 3 and 4. These findings portray that the political and institutional dimension is useful to manage carbon emissions. However, the coefficients of economic dimension and governance effectiveness are confirming positive values. The findings of governance effectiveness are quite surprising; the coefficients indicate that Vision 2030 policies, in terms of governance effectiveness, are useless in mitigating carbon emissions. The finding contradicts previous literature [26,31,53,54]. To summarize, the Saudi government must be more focused on governance in order to achieve the long-term environmental goals and carbon neutrality outlined in Vision 2030.

Table 9. Dynamic simulated ARDL estimations after implementation of Vision 2030.

	Model 1	**Model 2**	**Model 3**	**Model 4**
CO_2	−0.0240 ***	−0.0260 ***	−0.0336 ***	−0.0303 ***
	(0.000)	(0.000)	(0.000)	(0.000)
EG	0.0262 ***	−0.0103	0.0404 ***	0.00251
	(−0.001)	(−0.112)	(0.000)	(−0.760)
EC	0.00575	0.00917	−0.0111 **	−0.0169 **
	(−0.192)	(0.713)	(−0.012)	(−0.049)
POP	−0.0663 ***	−0.00368	−0.0404 ***	−0.00166
	(0.000)	(−0.736)	(0.000)	(−0.878)
EDU	0.0777	−0.505 ***	−0.0167	−0.439 ***
	(−0.194)	(0.000)	(−0.479)	(0.000)
LIFE	−0.149 **	−2.019 ***	−0.279 ***	−1.800 ***
	(−0.030)	(0.000)	(0.000)	(0.000)
PS	−0.000714 ***			0.0001
	(0.000)			(−0.450)
GE		0.0253 ***		0.0209 ***
		(0.000)		(0.000)
CC			−0.0134 ***	−0.00538 **
			(0.000)	(−0.001)
Obs.	287	287	287	287
R-Square	0.408	0.587	0.512	0.603
F-Statistics	27.521	56.926	41.937	46.952

Notes: CO_2 is the carbon emission, EG stands for economic growth, EC is the energy consumption, POP presents population, EDU depicts education. LIFE shows life expectancy. In governance indicators, PS, GE, and CC represent political stability, governance effectiveness, and corruption control, respectively. ***, **, presents the level of significance at 1% and 5%, respectively.

4.6. Discussion

The current study is an attempt to find a workable solution to Saudi Arabia's increased carbon emissions. Based on the literature, two variables are proposed for this purpose: life expectancy and governance. According to previous literature and theory, an increase in life expectancy can escalate carbon emissions because as people age, they tend to stay indoors due to health issues. Therefore, energy consumption arises due to the increased need for heating and electricity. However, the findings of this study show that increasing life expectancy reduces carbon emissions, which is quite surprising and contradicts previous findings [50,73]. There could be a variety of reasons for this negative association, such as increased life expectancy, which raises people's awareness of the benefits of staying active and spending time in nature through activities such as hiking, fishing, or camping. This awareness motivates them to participate in green activities and other environmental initiatives. As a result, they will put pressure on the government to develop policies to protect the natural environment, resulting in lower carbon emissions. Moreover, [74] stated in their study that life expectancy will have a negative impact on carbon emissions because as technology advances energy-efficient products are introduced, reducing the negative effects of life expectancy on the environment.

Regarding life expectancy, the plausible explanation for the negative association between life expectancy and carbon emission is education. According to the findings of this study, an increase in education helps to reduce carbon emissions. As with education, people become more aware of the green environment, energy efficiency, clean technology, etc. However, they try to adopt environment-friendly life that mitigates their carbon footprint [8]. Similarly, population growth has a negative impact on carbon emissions. The reason is linked to increased education and awareness among people; however, in this scenario, population growth plays no role in degrading the environment.

Governance is the third policy variable that is used with three dimensions, including political stability, governance effectiveness, and corruption control. It is noted that political stability is playing a positive role in decreasing carbon emissions, in Saudi Arabia. Ref. [75]

explained this negative effect through green activities, stating that when a country has a politically stable government, it will reduce land cleared for agricultural use, promote forestation activities, stimulate energy-efficient products, which help to minimize carbon emissions [31]. In addition, [24] defines political stability as the primary component of good governance because it ensures the proper implementation of other dimensions such as rule of law and regulatory quality. As a result, it turns easy for a government to introduce short-term and long-run environmental strategies, as well as to implement those strategies to achieve environmental objectives. Thus, it can be concluded that political stability reduces carbon emissions through the proper implementation of governance indicators.

The results of governance effectiveness, which is an economic dimension of good governance, are surprising because they contradict expectations. The results of the study prove that governance effectiveness leads to increased carbon emissions. This positive effect can be explained in the light of fiscal decentralization in the country, as well as promotion incentives that create competition between local governments. It is believed that when there is fiscal decentralization, deregulations by the government in terms of the business environment, as well as reduction of taxes, becomes common because local governments usually do this to attract foreign investment and to boost economic activities in their areas [76]. Such actions compel local governments to develop less stringent environmental quality regulations in order to attract more investment, which leads to job creation and revenue generation. However, this act of deregulation leads to low environmental quality [77]. In this way, governance plays a key role in boosting the economy; however, carbon emissions can still arise.

The third dimension of governance is corruption control, and it is proved from the majority of the estimations that an increase in the control of corruption tends to lower carbon emissions. When there is less corruption in the country, public office will not be misused for private gain through bribes and lobbying, resulting in strict environmental policies [72].

5. Conclusions and Policy Implication

The main purpose of the current study is to explore the contributors to carbon emissions in Saudi Arabia and advise some practical solutions to this problem, which assists to achieve carbon neutrality status. Based on previous research and current literature, it is noted that the impact of life expectancy as a contributor to carbon emission is not yet explored. Empirical analysis revealed that life expectancy, political stability, and corruption control are negatively related to carbon emissions in Saudi Arabia. However, governance effectiveness is positively related to carbon emissions. The findings of life expectancy and governance effectiveness are relatively surprising, and a significant value added to existing literature. Contrary to the previous studies, this study indicates that Saudi Arabia has to emphasize policy and governance effectiveness through implementing the policies at district and city levels. Another reason for the adverse impact of governance effectiveness is related to fiscal decentralization and usage of a nonrenewable energy source for urbanization, industrialization, and economic development, rather than a shift from nonrenewable to renewable energy sources. Even the government has planned to modify the energy mix and use 50% renewable energy [31]. However, the negative association of life expectancy is caused by the higher awareness level and easy approach towards energy-efficient appliances in the country, which subsides the negative impacts of life expectancy on the environment. Moreover, education creates awareness regarding the green environment, energy efficiency, etc. Such attraction toward a green environment encourages the local community to shift their buying behavior, from traditional products to energy-efficient and green products.

In light of the results presented above, some important policy implication for government and policymakers includes more comprehensive awareness policies to enhance the perception regarding the importance of a green environment. The adverse impact of energy consumption needs to be addressed on a priority basis. A large proportion of this energy is consumed by private transportation, high-energy appliances at home, etc., that can be controlled by environmental laws. As far as the reduction in transportation-based carbon emissions, the government has to strengthen the public transportation system that helps to minimize private transportation on roads. The Saudi government has to form an implementable mechanism that motivates the public to buy and use energy-efficient cars, appliances, etc. The shift in energy prices is also a beneficial tool that motivates the public towards energy-efficient products.

Education is an effective instrument to reduce carbon emissions, the educated persons are aware of the environmental damages and its consequences. However, they put their full efforts to minimize this environmental degradation process through the adoption of green products, spread awareness about the environment in the community, try to build a greener environment in their surroundings, etc. This wise behavior is one of the key reasons for the negative coefficients of life expectancy. Despite this, the government has to launch continuous and effective campaigns to educate the public and spread awareness, regarding environmental protection, through advertisements, starting green incentive schemes, etc. For governance effectiveness, the Saudi government should follow a few actions: (i) prepare the carbon tax policy, (ii) force industries to install carbon treatment plants, (iii) it is required policies regarding education, energy, and the environment should be implemented by local and provincial governments. Due diligence is also required to overlook the outcomes of these policies to minimize the environmental degradation process.

This study has some limitations, such as the non-availability of data before 1990 which restricts us to apply specific econometric tests and long-period data analysis. As for future research, we recommend using other proxies of life expectancy and re-evaluating their role in carbon neutrality. Due to the similarity in GCC countries, the researchers should investigate the role of life expectancy in other GCC countries. Moreover, the upcoming studies have to introduce new governance indicators and evaluate the relationship between governance and carbon emission.

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