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Impact of Green Innovation, Sustainable Economic Growth, and Carbon Emission on Public Health: New Evidence of Non-Linear ARDL Estimation

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Abstract: This study examines the impact of green innovation, sustainable economic growth, and carbon emission on public health issues in Saudi Arabia. As Saudi Arabia is struggling to increase human development that also incorporates public health, it is important to understand the determinant factors and significant solutions to curtail public health issues. The study pioneers investigation into the role of green innovation aimed at countering public health problems caused by environmental damage. For econometric estimates, a non-linear autoregressive distributed lagged approach is used, which confirms that economic growth and carbon emissions are the main sources of public health issues in Saudi Arabia. Further, the empirical results demonstrate that greater attention to green innovation, education, and health spending plays a significant role in minimizing health issues. The positive shock in green innovation is helpful in terms of reducing public health issues. The findings are significant for policy suggestions; some recommendations are as follows: (i) The Saudi government needs to enhance funding in research and development to increase green innovation within the country. (ii) Education and health sector should be improved and increase it outreach throughout the country.

Keywords: public health; green innovation; sustainable economic growth; carbon emission

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1. Introduction

Public health is deteriorating continuously worldwide, and recent statistics show that a large percentage of people, worldwide, are suffering from health issues [1]. Few health issues are natural and difficult to control; most health problems can be controlled through proper measures. In this regard, most health issues are linked with environmental problems caused by carbon emission, nitrogen emission, particulate matter 2.5 (PM2.5), etc. [2,3]. The health of the population of any given country is connected with government policies and regulations. According to [4], indoor and outdoor pollution is a significant risk factor in terms of health. It is noted that almost 7 million people recently died due to health issues caused by environmental issues [5]. The increased amount of carbon in the atmosphere is the leading cause of climate change. About 4.2 million deaths are confirmed to have been caused by the health issues stroke, cancer, lower respiratory infection, and chronic obstructive pulmonary disease, which are the outcome of climate change and an unhealthy environment [6]. These issues can be controlled if the public is aware of the problem and they have knowledge about the outcomes of their actions in terms of health. It is a fact that education and know-how are essential to understanding the link between individual actions and the environment. According to the United Nations Framework Convention on Climate Change (UNFCC), education is essential for an appropriate response to climate change issues [7]. This nexus exists because education and knowledge lead to behavior change and encourage individuals to develop pro-environment behavior changes. Moreover, awareness, which is essential to altering behaviour, is the outcome of knowledge. If people know about their actions and resulting environmental outcomes, they will change their behavior and actions to reduce this impact, ultimately reducing the health issues created by climate change and pollution.

Public health is a global issue, but Saudi Arabia is under particular pressure with respect to public health. Figure 1 clearly shows that public health is an issue for the country; hence, to cater for it, significant increases can be seen in public health spending by Saudi Arabia. Many factors cause health problems and spending in terms of public health. Nevertheless, as discussed earlier, climate change and environmental degradation stand at the top of the list. This problem is more pronounced in Saudi Arabia. It is also important to mention that despite efforts by the government and policymakers, carbon emission is continuously increasing. Being the primary producer and exporter of oil and petroleum products, Saudi Arabian economic sectors depend heavily on fossil fuels for energy generation. The domestic consumption of oil is also increasing in domestic use, energy generation, industrialization, etc. This surge in oil consumption is considered a primary culprit behind environmental degradation. Currently, the country emits 15.94 tons per capita of carbon, amounting to 1.45% of global emissions [8,9]. Hence, it is not wrong to say that environmental degradation is the main factor behind increased health issues in the country, as documented by [10]. Another factor which can result in lower health outcomes and increased healthcare spending is a lack of knowledge and education. It has been proved that education and know-how are essential to making better decisions. According to the statistics, a significant number of adults in the country do not have upper secondary level education, which is very low compared to group of 20 countries (G20) and Organisation for Economic Cooperation and Development (OECD) countries [11]. Likewise, early childhood education and care (ECEC) is not compulsory in Saudi Arabia; hence, there is the lowest enrolment rate in this group. These factors make the population less aware of the outcomes of their actions, and they do not try to alter these actions for better outcomes. The same is true in the case of the environment. Without proper knowledge and education, people do not control their actions for better environmental outcomes.

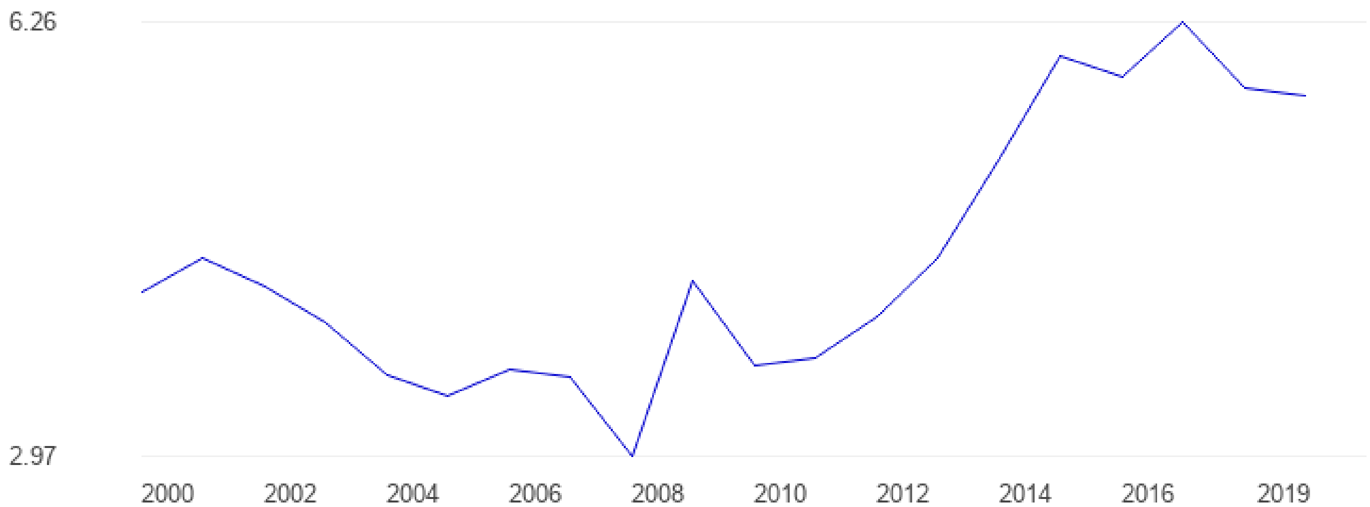

Figure 1. Current health expenditure of Saudi Arabia (percentage of GDP).

Researchers recognize the importance of public health and are trying to find practical and viable solutions to cater to public health problems that help to identify the factors behind declining public health worldwide. As [3,12,13] point out, economic growth leads to a decline in public health and good policies at the government and regional levels should ensure sustainable economic development without harming public health. Similarly, inequality in public health is also identified as a factor behind declining public health [14–18]. According to those studies, if inequality at all social levels is reduced, then everyone will be able to benefit from equal health facilities, and public health will improve automatically. Another strand of researchers argues that employment is also a main factor which can be associated with public health [19–22]. Hence, providing employment to the public can help them obtain paid health services, leading to better public health. These studies present a solution for the problems related to public health, but it has already been proved through recent statistics that public health is still a problem for countries, and the need for a practical solution is still valid. Hence, the current study put forward some solutions in the wake of recent health issues the world faces.

Considering the above discussion, this study provides two contributions. The first contribution is in the form of a discussion regarding the impact of green innovation on public health in light of the Vision 2030 perspective. As per our limited knowledge, the current study is the pioneering one that explores the significance of Saudi Vision 2030, discussing green innovation with respect to the mitigation of carbon emission. We include green innovation in the public health model to examine the usefulness of green innovation in tackling the health issues and lay out a significant path to countering health challenges. Green innovation not only contributes to the effectiveness of the healthcare sector by enabling a fast and sustainable healthcare sector but also reduces the environmental impact of this sector by providing sustainable energy options. Technological advances in the health system can improve the accessibility, efficiency, and cost of healthcare, which will help improve the health of the population. Any high-performing healthcare system must be created and maintained by ensuring its proper adoption and flow, and innovation is considered the key element. Green technologies are consistent with environmental legislation and ecological and digital economic principles. Therefore, they improve health by reducing energy use and eliminating environmental pollutants from different sectors of the economy. In the digital economy, green technology offers a good insight into sustainable growth and the contexts that foster health in health care settings. The main objective of this study is to explore how green innovation can be used to promote public health in Saudi Arabia.

Secondly, the current study addresses sustainable economic growth and carbon emissions to investigate the impact on public health issues. According to previous literature studies, sustainable economic growth assists governments in constructing long-term policies, such as educational policy, environmental policy, etc. Long-term health policies assist in reducing health issues. As for carbon emission, there is a direct relationship between carbon emission and health issues [2]. We attempt to explore the relationship between carbon emission and health issues in Saudi Arabia. Thirdly, this study uses the non-linear econometric estimation techniques that provide detailed results by considering the negative and positive shocks. Non-linear estimations address issues that are raised by linear regressions. The discussion and analysis, along with the findings, will help policymakers analyze the outcomes of Vision 2030, enabling them to take corrective measures if needed.

Based on the above discussion, this study attempts to answer a few questions: (i) Does green innovation help to control public health issues in Saudi Arabia? (ii) Does sustainable economic growth lead to a minimization of public health issues in Saudi Arabia? (iii) Do carbon emissions increase public health issues in Saudi Arabia? (iv) Do, as Saudi Vision 2030 suggests, green innovation, sustainable economic growth, and carbon emission reduction help to control public health issues?

2. Literature Review

2.1. Impact of Sustainable Economic Growth on Health

Sustainable economic growth and public health go hand in hand. On one the one hand, public health is necessary for sustainable development, and on the other hand, sustainable development improves public health through better policies. Ref. [23] used data from European countries to find that sustainable economic development enhances public health in these countries. Ref. [24] concluded that low public health outcomes are due to unsustainable development in Asian and African countries. Similarly, ref. [25] used data from OECD economies and found that renewable energy and other components of sustainable economic growth are essential to reducing the negative impacts of economic growth on public health. Another study by [18] asserts that a high level of economic growth in China negatively affects public health, and the solution is to pursue sustainable economic growth. Ref. [18] also concluded that sustainable development and public health are vital for each other. This is because, due to a lower level of public health, economic growth declines, and to cater to this issue, sustainable development leads to a higher level of economic growth without damaging health. Ref. [26] also studied the nexus between sustainable economic growth, renewable energy, and public health. Ref. [27] examines data from the United States over the period of 2011–2018. The panel data analysis reported a significant relationship between economic growth and public health. In the case of China, ref. [13] empirically analyzed the significance of economic growth in controlling health issues. The findings suggested that the significance varies across regions.

2.2. Impact of Carbon Emission on Health

Due to increasing economic growth, many environmental issues arise, including a high level of carbon emission, which is dangerous for the health outcomes of people. Researchers are trying to check whether carbon emission is a health concern. Interestingly, ref. [28] found an inverse relationship between carbon emission and public health. The public health sector also emits a significant amount of carbon. Likewise, ref. [29] explore whether black carbon emission in rural areas also causes public health to deteriorate and found that public health for selected reasons is reduced due to increased emission of black carbon. In an analysis, the authors of [30] found that increased carbon emission in China significantly and negatively affects public health because the number of both patients and out-patients is increased due to carbon emission. In the same line, ref. [31] discussed the co-benefits of peaking carbon emission for air quality improvement and public health. They concluded that if efforts are made to help countries peak carbon emissions, this can lead to better air quality which is essential for public health. Moreover, the authors of ref. [32] assert that oil and gas consumption is a significant carbon emission source, leading to low public health. Hence, better monitoring of upstream emissions from these sources is required to improve public health. Ref. [2] used the panel data of Chinese provinces to investigate the impact of carbon emission on public health. The findings confirmed there is a significant and positive relationship between carbon emission and health issues. Another study [3] used world data to investigate the impact of carbon emission on public health. The findings suggested there is a positive relationship between carbon emission and public health issues; the authors mention that higher environmental degradation leads to a boost in health issues. Ref. [33] reinvestigated the empirical relationship between carbon emission, economic growth, and public health by using advanced panel data analysis. The results confirmed there is a significant relationship between carbon emission and public health in cases of long-run estimations.

2.3. Impact of Health Spending on Health

Public health obviously cannot improve without significant improvements in public health infrastructure, which can be achieved through increasing health spending. To check the validity of this proposition [34], a semantic literature review was conducted. The authors of the review found that the majority of studies found a positive link between health spending and public health. According to [35], healthcare spending in Australia significantly improved public health. Ref. [36] explores the significance of health care spending for reducing the infant mortality rate. They found a significant negative association between healthcare spending and infant mortality. Likewise, ref. [37] empirically concluded that public health spending reduces inequality in India's healthcare system. Hence, more people can make use of better health facilities, and public health improves automatically. Ref. [38] drew an opposite conclusion from this one. In the wake of the recent COVID-19 pandemic, they argue that positive outcomes cannot be achieved without thoughtful spending on resources in health care. Past spending on public health is negatively associated with health outcomes during pandemics.

2.4. Impact of Education on Health

The importance of education is recognized in all sectors, and the healthcare sector is not an exception. In their research regarding the connection between education and health, the authors of [39] assert that education plays a significant role in better health outcomes through crucial health intervention. Ref. [40] also used data from Vietnam and proved that education is essential to improving public health besides other socioeconomic factors. In the same line, ref. [41] also proved by using OECD data that educated people have better health and life expectancy as compared to uneducated people. A recent study [42] explored this nexus in light of the recent COVID-19 pandemic and concluded that educational programs play an essential role in managing mortality and infections by a coronavirus. This positive relationship between education and public health was also discovered by [43]. However, they find this link through a reduction in air pollution; hence, with education, health improves due to an improved environment.

In light of the previous studies, it seems clear that economic growth, carbon emission, health spending, and education have a significant effect on public health issues. However, according to our limited knowledge, studies regarding the impact of green innovation on public health for the case of Saudi Arabia are still missing from the empirical literature. To cover this gap, this study uses green innovation to examine the empirical relationship between green innovation and health issues. The findings of the study are significant for policy suggestions.

3. Data and Methodology

3.1. Data

The data and source of all the variables are given in Table 1; the public health dependent variable ($HEALTH$) is the incidents of tuberculosis per 100,000 people. There are three independent variables, green innovation (GI), used in the innovation index. A few studies have used different proxies; for example, ref. [44] used environmental-related technology, and ref. [45] used the number of patients registered. In contrast, few studies have calculated the green innovation index as a proxy of green innovation [46]. Due to the non-availability of direct measures of green innovation, studies have used three different methods to calculate green innovation. The first is introduced in [47], which focuses on a single indicator that is derived from a patient. The second method emphasizes a factor analysis method that incorporates innovation output to construct the green technology index [48]. The third method is to use the input and output method and utilize the data envelopment analysis (DEA) to measure the efficiency of green innovation [49]. We adapted the first measure through using the innovation index, instead of patient-related data. We use the simulation method to fill the missing values of the innovation index; for this purpose we adopt the Markov chain Monte Carlo (MCMC) algorithm, as in [50,51]. The second independent variable is sustainable economic development (SED), which is the current gross domestic product in US dollars. Economic growth represents the increase in economic activities that accounts for the positive trend in gross domestic product [52]. However, we divided the gross domestic data into two sets: positive, which reflects the increase in the economy, and negative, which shows the downturn of the economy. For the purpose of analyzing sustainable economic growth, we used the positive trends for further empirical analysis. The third independent variable is carbon emission (CE) which was a proxy for carbon emissions in kilotons (kt). There are two control variables, health spending and education, which are defined as health spending per capita and primary level education respectively, as in [3]. The time period for empirical estimation is 1990 to 2020, with 31 observations for Saudi Arabia. The data of public health, sustainable economic development, carbon emission, health spending, and education were retrieved from World Development Indicators (WDI), whereas the green innovation data are taken from global economy data and reports.

Table 1. Data and sources.

Abbreviation	Variable	Definition	Source
Dependent			
HEALTH	Public health	Incidence of tuberculosis (per 100,000 people)	WDI
Independent			
GI	Green innovation	Innovation index	Global Economy
SED	Sustainable economic development	Current GDP in US $	WDI
CE	Carbon emission	Carbon emission (kt)	WDI
Control			
HS	Health spending	Health spending per capita	WDI
EDU	Education	Primary level education	WDI

Models

The study uses three models for econometric estimations, where model 1 is about green innovation, and includes health spending and education as control variables. Green innovation tends to expand clean and energy-efficient technologies, reducing environmental externalities that directly affect human health. It proposes that greener innovation leads to a reduction in public health problems. The significance of health spending and education, as control variables, is extracted from previous literature studies [33,53,54]. The model is presented below:

Model 1: $HEALTH = f\ (GI,\ HS, EDU)$

Model 2 is about sustainable economic development. There are two distinct views about the relationship between sustainable economic development and health problems. Firstly, an increase in economic growth enables a country to spend more on their health sector, which leads to a decrease in health issues [13,55,56]. Secondly, an increase in economic growth boosts health challenges through the increase in energy consumption, industrialization, and transportation activities [57,58]. Nevertheless, it is important to examine the impact of sustainable economic development on public health in the case of Saudi Arabia. Model 2 incorporates health spending and education as control variables, as given below:

Model 2: $HEALTH = f\ (SED,\ HS, EDU)$

Subsequently, we use carbon emissions as independent variables with two control variables, healthcare spending and education. Carbon is one the dangerous gasses that directly affect human health; it is necessary to study its impact on human health. Mostly, carbon infects the lungs or causes tuberculosis issues [59]. Model 3 is given below:

Model 3: $HEALTH = f\ (CE,\ HS, EDU)$

The descriptive statistics of the studied variables are presented in Table 2, where the mean and standard deviation of public health issues are 3.533 and 0.345, respectively. The minimum and maximum values of health issues are 2.502 and 3.113, respectively. For green innovation, the mean and standard deviation are 9.158 and 0.281, respectively. The minimum and maximum values for green innovation are 8.900 and 9.493, respectively. The mean, standard deviation, minimum, and maximum values of sustainable economic development are 7.991, 0.106, 7.622, and 8.634, respectively. With respect to carbon emission, the mean, standard deviation, minimum, and maximum values are 1.434, 0.303, 1.013, and 1.581, respectively. For health spending by government and education, the mean values are 2.588 and 1.784, respectively. The descriptive statistics present that there seems to be no outlier in the studied variables.

3.2. Methodology

3.2.1. KSS Unit Root Test

We use the Kapetanios, Shin and Shell (KSS) unit root test for stationarity in series, presented in [60]. We employee the KSS test, which incorporates adding the index regarding the transfer function, which further accounts the nonlinear adjustment features. Following ESTAR specification shows the KSS:

$$\Delta w_t = \gamma w_{t-1}\left[1 - \exp(-\varsigma w_{t-1}^2)\right] + \varepsilon_t < \ (\varsigma \geq 0) \tag{1}$$

where w_t = demeaned time series of interest, ε_t = i.i.d. error having zero mean constant variance, $\left[1 - \exp(-\varsigma y_{t-1}^2)\right]$ = exponential transition function.

Table 2. Descriptive statistics of studied variables.

Variable	Obs	Mean	Std. Dev.	Min	Max
HEALTH	31	3.533	0.345	2.502	3.113
GI	31	9.158	0.281	8.900	9.493
SED	31	7.991	0.106	7.622	8.634
CE	31	1.434	0.303	1.013	1.581
HS	31	2.588	0.587	1.743	3.180
EDU	31	1.784	0.125	0.926	2.333

In the KSS test, the null hypothesis is given as $H_0 : \varsigma = 0$; in contrast, the alternative hypothesis is $H_1 : \varsigma > 0$.

Autoregressive distributed lagged model (ARDL)

The linear form of models can be represented as follows:

$$lnHEALTH_t = \alpha_0 + \beta_1\, lnGI_t + \beta_2\, lnHS_t + \beta_3 lnEDU_t + \rho_t \tag{2}$$

$$lnHEALTH_t = \alpha_0 + \beta_1\, lnSED_t + \beta_2\, lnHS_t + \beta_3 lnEDU_t + \rho_t \tag{3}$$

$$lnHEALTH_t = \alpha_0 + \beta_1\, lnCE_t + \beta_2\, lnHS_t + \beta_3 lnEDU_t + \rho_t \tag{4}$$

where ln is the natural logarithm, ρ_t represents the error correction term. β_1, β_2, β_3 indicate the long-run elasticity coefficients. The equation encompasses the long-run effects; the cointegration test is easily carried out, as well as short-run data.

The autoregressive distributed lagged (ARDL) form is as follows:

$$\begin{gathered}\Delta lnHEALTH_t = \alpha_0 + \textstyle\sum_{i=1}^{t} \mu_1 \Delta lnHEALTH_{t-i} + \sum_{i=0}^{t} \mu_2 \Delta lnGI_{t-i} + \\ \textstyle\sum_{i=0}^{t} \mu_2 \Delta lnHS_{t-i} + \sum_{i=0}^{t} \mu_3 \Delta lnEDU_{t-i} + \gamma_0 lnHEALTH_{t-1} + \gamma_1 lnGI_{t-1} + \\ \gamma_2 lnHS_{t-1} + \gamma_3 lnEDU_{t-1} + \omega_t\end{gathered} \tag{5}$$

$$\begin{gathered}\Delta lnHEALTH_t = \alpha_0 + \textstyle\sum_{i=1}^{t} \mu_1 \Delta lnHEALTH_{t-i} + \sum_{i=0}^{t} \mu_2 \Delta lnSED_{t-i} + \\ \textstyle\sum_{i=0}^{t} \mu_2 \Delta lnHS_{t-i} + \sum_{i=0}^{t} \mu_3 \Delta lnEDU_{t-i} + \gamma_0 lnHEALTH_{t-1} + \gamma_1 lnSED_{t-1} + \\ \gamma_2 lnHS_{t-1} + \gamma_3 lnEDU_{t-1} + \omega_t\end{gathered} \tag{6}$$

$$\begin{gathered}\Delta lnHEALTH_t = \alpha_0 + \textstyle\sum_{i=1}^{t} \mu_1 \Delta lnHEALTH_{t-i} + \sum_{i=0}^{t} \mu_2 \Delta lnCE_{t-i} + \\ \textstyle\sum_{i=0}^{t} \mu_2 \Delta lnHS_{t-i} + \sum_{i=0}^{t} \mu_3 \Delta lnEDU_{t-i} + \gamma_0 lnHEALTH_{t-1} + \gamma_1 lnCE_{t-1} + \\ \gamma_2 lnHS_{t-1} + \gamma_3 lnEDU_{t-1} + \omega_t\end{gathered} \tag{7}$$

where Δ represents the difference operator, ω_t is the error term for ARDL model, t shows the period that starts from $i = 1$.

3.2.2. Nonlinear ARDL

This study applied the nonlinear ARDL approach which accounts for the asymmetric results, proposed by [61]. The nonlinear ARDL estimation provides comprehensive results, as compared to ARDL. In contrast to ARDL, the nonlinear ARDL approach divides the series into two components, positive shock and negative shock, and examines the impact of both on dependent variables [62,63]. In accordance with nonlinear ARDL, this study uses positive and negative changes in green innovation, sustainable economic development, carbon emission, health spending, and education that are decomposed into additional sets of series, as in [64]. The simple way to present this is as follows:

$$V_{it} = \varphi_0 + \varnothing^+ IV_t^+ + \varnothing^- IV_t^- + \varepsilon_{it} \text{ and } \Delta IV_t = v_t$$

where V_{jt} and IV_t are the scalar I(1). V_{jt} is the return of i at time t and is divided into positive and negative shocks. IV_t^+ and IV_t^- represent positive and negative shocks in the IV (independent variable). ε_{it} and v_t are the random distribution terms. The modified form of the series is given in the equations below.

$$\begin{cases} POS(GI)_t = \sum_{i=1}^{t} lnGI_i^+ = \sum_{i=1}^{t} MAX(\Delta lnGI_i, 0) \\ NEG(GI)_t = \sum_{i=1}^{t} lnGI_i^- = \sum_{i=1}^{t} MIN(\Delta lnGI_i, 0) \end{cases} \quad (8)$$

$$\begin{cases} POS(SED)_t = \sum_{i=1}^{t} lnSED_i^+ = \sum_{i=1}^{t} MAX(\Delta lnSED_i, 0) \\ NEG(SED)_t = \sum_{i=1}^{t} lnSED_i^- = \sum_{i=1}^{t} MIN(\Delta lnSED_i, 0) \end{cases} \quad (9)$$

$$\begin{cases} POS(CE)_t = \sum_{i=1}^{t} lnCE_i^+ = \sum_{i=1}^{t} MAX(\Delta lnCE_i, 0) \\ NEG(CE)_t = \sum_{i=1}^{t} lnCE_i^- = \sum_{i=1}^{t} MIN(\Delta lnCE_i, 0) \end{cases} \quad (10)$$

We decompose the GI, SED, and CE into positive and negative shocks, where $POS(GI)$ and $NEG(GI)$ are the positive and negative shocks in green innovation. $POS(SED)$ and $NEG(SED)$ are the positive and negative shocks in sustainable economic development. Similarly, $POS(CE)$ and $NEG(CE)$ reflect the positive and negative shocks in carbon emission. $MAX(\Delta lnGI_i, 0)$ and $MIN(\Delta lnGI_i, 0)$ are the maximum and minimum absolute values of green innovation. Similar notations are used for $MAX(\Delta lnSED_i, 0)$, $MIN(\Delta lnSED_i, 0)$, $MAX(\Delta lnCE_i, 0)$, and $MIN(\Delta lnCE_i, 0)$. Now, the above equations can be rewritten by incorporating the negative and positive shocks. The nonlinear ARDL equations for the studied models are as follows:

$$\begin{gathered} \Delta lnHEALTH_t = \alpha_0 + \\ \sum_{i=1}^{t} \mu_1 \Delta lnHEALTH_{t-i} + \sum_{i=0}^{t} \mu_2^+ \Delta lnPOS(GI)_{t-i} + \sum_{i=0}^{t} \mu_2^- \Delta lnNEG(GI)_{t-i} + \gamma_0 lnHEALTH_{t-1} + \\ \gamma_1^+ lnPOS(GI)_{t-1} + \gamma_1^- lnNEG(GI)_{t-1} + \omega_t \end{gathered} \quad (11)$$

$$\begin{gathered} \Delta lnHEALTH_t = \alpha_0 + \\ \sum_{i=1}^{t} \mu_1 \Delta lnHEALTH_{t-i} + \sum_{i=0}^{t} \mu_2^+ \Delta lnPOS(SED)_{t-i} + \sum_{i=0}^{t} \mu_2^- \Delta lnNEG(SED)_{t-i} + \gamma_0 lnHEALTH_{t-1} + \\ \gamma_1^+ lnPOS(SED)_{t-1} + \gamma_1^- lnNEG(SED)_{t-1} + \omega_t \end{gathered} \quad (12)$$

$$\begin{gathered} \Delta lnHEALTH_t = \alpha_0 + \\ \sum_{i=1}^{t} \mu_1 \Delta lnHEALTH_{t-i} + \sum_{i=0}^{t} \mu_2^+ \Delta lnPOS(CE)_{t-i} + \sum_{i=0}^{t} \mu_2^- \Delta lnNEG(CE)_{t-i} + \gamma_0 lnHEALTH_{t-1} + \\ \gamma_1^+ lnPOS(CE)_{t-1} + \gamma_1^- lnNEG(CE)_{t-1} + \omega_t \end{gathered} \quad (13)$$

where μ_1 and μ_2 are the elasticity coefficients for short-run estimations, γ_0 and γ_1 reflect the elasticity coefficients of long-run estimations. POS and NEG represent the positive and negative shocks of each variable, which is used for asymmetric analysis and is derived from the Wald test. $HEALTH_t$ is public health issues, GI is green innovation, SED reflects sustainable economic development, CE is carbon emission.

4. Results

4.1. Preliminary analysis

The current study examines the multicollinearity in the model, by using the Variance Inflation Factor (VIF). The outcomes of the VIF are documented in Table 3, which presents values between 1 and 10. The VIF confirms that there is no evidence of multicollinearity in the studied model.

Firstly, we check the presence of a structural break in the data, as shown in Table 4. The null hypothesis of the Quandt–Andrew test presents the non-existence of a structural break [65,66]. The results of the Quandt–Andrew test fail to reject the null hypothesis, indicating that the data of the studied period have no break point.

Table 3. Variance inflation factor (VIF).

Model 1	Model 1	Model 2	Model 3
GI	7.40		
SED		9.03	
CE			8.77
HS	4.38	4.51	5.00
EDU	6.65	6.54	6.92
Mean VIF	6.14	6.78	6.90

Table 4. Structural break test.

Quandt–Andrews Structural Break Test	Maximum LR	Expected LR	Average LR
F-Statistics	136.027	141.762	94.860

Note: Null hypothesis for Quandt–Andrews test is "no breakpoint". As the results of maximum LR, expected LR, and average LR are insignificant, the null hypothesis is accepted.

The study uses the KSS unit root test to check the existence of stationarity in series of studied variables, as shown in Table 5. The outcomes of the unit root test, at level, confirm the non-stationarity in public health, sustainable economic development, carbon emission, and education. Green innovation and health spending have indicated the presence of stationarity at level. At first difference, all the studied variables are stationary. The mixed evidence of stationarity, at level and first difference, motivates one to use the bond cointegration test. However, it is worth mentioning that ARDL bond cointegration test is suitable for examining the long-run persistence of all models. The findings of bond cointegration are presented in Table 6, which shows the presence of cointegration in model 1, model 2, and model 3. The outcome of cointegration confirms the presence of a long-run relationship between the independent and dependent variable. These results lead us to employ the autoregressive distributed lagged model (ARDL) for long-run and short-run empirical estimations. As WRDL estimations are unable to account for the asymmetric impact of independent variables, we apply the nonlinear ARDL estimations that give the results of negative and positive shocks, separately.

Table 5. KSS unit root test.

	Level		Diff	
Variable	***p*-Value**		***p*-Value**	
HEALTH	0.711	IS	0.000 ***	Sig
GI	0.021 **	Sig	0.001 ***	Sig
SED	0.893	IS	0.000 ***	Sig
CE	0.997	IS	0.000 ***	Sig
HS	0.002 ***	Sig	0.041 **	Sig
EDU	1.756	IS	0.069 *	Sig

Notes: ***, **, and * represent the level of significance at 1%, 5%, and 10%, respectively.

4.2. Empirical Estimations

Long-Run Estimation

The data of nonlinear ARDL are presented in Table 7, which is composed of two parts: (i) long-run estimation, (ii) short-run estimation. The long-run estimations confirmed that lagging health issues are significant and positively related with current public health issues, indicating that higher public health issues lead towards higher public health issues. The coefficients of green innovation are negative, for positive and negative shocks. The results of green innovation indicate the importance of green innovation in controlling public health issues in Saudi Arabia. The positive shock magnitude is higher than the negative shock, as the coefficient value of positive shock is −0.026 and negative shock is −0.013. Focusing on sustainable economic development, the positive shock coefficient is significant and positive, indicating that higher economic growth triggers public health issues. Similarly, a negative shock in sustainable economic development increases public health issues. The carbon emission coefficients are significant and positive in positive and negative shocks, indicating that carbon emission is one of the main causes of public health problems. However, the positive shock magnitude is higher than the negative shock.

Table 6. ARDL bounds cointegration Test.

ARDL Bounds Cointegration Test	F-stat	CI
$HEALTH = f\ (GI,\ HS, EDU)$	6.482	Exist
$HEALTH = f\ (SED,\ HS, EDU)$	8.339	Exist
$HEALTH = f\ (CE,\ HS, EDU)$	5.971	Exist
Lower-bound critical value at 1%		4.29
Upper-bound critical value at 1%		5.61
Lower-bound critical value at 5%		3.23
Upper-bound critical value at 5%		4.35
Lower-bound critical value at 10%		2.72
Upper-bound critical value at 10%		3.77

Table 7. Nonlinear ARDL estimation.

Long Run	Model 1	Model 2	Model 3
$HEALTH_{t-1}$	1.103 **	1.011 ***	0.930 ***
GI^{+}_{t-1}	−0.026 **		
GI^{-}_{t-1}	−0.013 *		
SED^{+}_{t-1}		0.485 **	
SED^{-}_{t-1}		−1.022 *	
CE^{+}_{t-1}			2.117 ***
CE^{-}_{t-1}			0.665 **
HS^{+}_{t-1}	−1.850 ***	−0.403 ***	−1.260 ***
HS^{-}_{t-1}	−1.932 **	−0.674 **	−0.238 *
EDU^{+}_{t-1}	−0.645 **	−0.419 ***	−1.343 **
EDU^{-}_{t-1}	−0.019 *	−0.012 *	−0.103 *
Short-run			
$\Delta\ GI^{+}_{t-1}$	−0.010 *		
$\Delta\ GI^{-}_{t-1}$	−0.816		
$\Delta\ SED^{+}_{t-1}$		1.658	
$\Delta\ SED^{-}_{t-1}$		2.190	
$\Delta\ CE^{+}_{t-1}$			1.379 **
$\Delta\ CE^{-}_{t-1}$			0.220
$\Delta\ HS^{+}_{t-1}$	−0.271 ***	−0.801 **	−1.032 **
$\Delta\ HS^{-}_{t-1}$	−0.125 *	−0.745 *	−0.051 *
$\Delta\ EDU^{+}_{t-1}$	1.032	0.432	1.371
$\Delta\ EDU^{-}_{t-1}$	2.673	1.090	2.473
Constant	12.375 **	9.672 **	6.494 ***

Notes: ***, **, and * represent the level of significance at 1%, 5%, and 10%, respectively.

Long-run estimations of positive and negative shocks in health spending are significant and negative. The results of government health spending confirm that higher health spending leads to a reduction in public health issues, whereas a decrease in government health spending increases public health issues. Turning to education, the positive shock in education is significant and negative, indicating that higher education tends to reduce public health issues. The negative shock coefficient is significant and negative, at one percent level of significant.

Short-Run Estimation

The second section of Table 7 concerns short-run estimations. The green innovation coefficient is significant and negative for positive shock, indicating that higher green innovation tends to reduce public health issues. The value of the coefficient is −0.010, significant at 10 percent, which suggest a weak relationship between green innovation and public health issues in the short run. In contrast, the negative shock coefficient in green innovation is insignificant in short-run estimation. Similarly, the coefficients of positive and negative shocks in sustainable economic development are insignificant, indicating that economic growth is not responsible for health issues in the short run. The positive shock in carbon emission is significant and negative, whereas the negative shock in carbon emission is insignificant. The carbon emission results indicate that carbon emission is one of the key factors in public health issues in Saudi Arabia. The health spending data show significant coefficients for positive and negative shocks. All the models produce significant and negative coefficients for positive shocks in health spending, which suggests that public health issues can be minimized by enhancing the Saudi government's health expenditure. A negative shock in health spending leads to significant and negative coefficients, indicating that public health issues will increase by decreasing health spending in a short period of time. Surprisingly, the coefficient of education is insignificant, for positive and negative shocks.

Diagnostics

Table 8 presents the asymmetric and diagnostics of all models. In model 1, the long-run positive shock coefficient in green innovation has a significant and negative value, indicating that higher green innovation tends to reduce public health issues. Positive and negative shocks in health spending have significant and negative coefficients, which suggests that public health issues can be controlled by increasing the Saudi government's health spending. Similar results are found for education, where the coefficients are significant and negative. The long-run asymmetric results are significant for green innovation, health spending, and education, which indicates that there exists a long-run asymmetric relationship between independent variables and public health, whereas for short-run asymmetric estimation, health spending is significant.

For model 2, positive and negative shocks in sustainable economic growth have positive and negative coefficients, respectively. Health spending and education have negative coefficients for positive and negative shocks, indicating that higher health spending and education are important for minimizing health issues. Long-run asymmetry confirms the significance of sustainable economic growth, health spending, and education. In short-run asymmetry, sustainable economic growth and education are insignificant, whereas health spending has a significant coefficient.

Data of model 3 have confirmed the positive and significant coefficient for positive and negative shocks in carbon emission, indicating that carbon emission is one of the major reasons for public health issues. The positive and negative shocks in health spending and education have significant and negative coefficients. All the three variables, in model 3, affirm the asymmetry in the long run, whereas health spending is the only variable that confirms the short-run asymmetric affect.

In summary, all the three models validate the significance of green innovation, health spending and education with respect to controlling public health issues. Furthermore, to minimize public health challenges, sustainable economic growth and carbon emission need to be countered by using renewable sources of energy in energy mix, industry, and transportation. All the diagnostics report the persistence of model 1, model 2, and model 3.

4.3. Post Vision 2030 Estimations

Table 9 presents the results after the introduction of Saudi Vision 2030. It is evident that positive shocks in green innovation are significant and negative, indicating that an increase in green innovation helps to reduce public health issues. The value of the coefficient is

−0.107, so if green innovation is enhanced by 1%, public health issues decline by 0.107%. This coefficient is high compared to the results before Vision 2030, suggesting that the goals and policies outlined in Vision 2030 regarding sustainable energy and the latest environmentally friendly medical equipment positively impact public health. Moreover, negative shocks in green innovation are no longer an issue for public health because the coefficient is insignificant. It can be said that the introduction of Vision 2030 not only enhanced the benefits of green innovation but also reduced the negative impact of the downward movement in green innovation.

Table 8. Asymmetry and model diagnostics.

	Long Run (+)	**Long Run (-)**	**Long-Run Asymmetry (*p*-Value) W_{LR}**	**Short-Run Asymmetric (*p*-Value) W_{SR}**
$HEALTH = f\ (GI,\ HS, EDU)$				
GI	−0.191 **	−0.294 *	0.081 *	0.662
HS	−1.520 ***	−0.873 **	0.014 **	0.021 **
EDU	−0.085 *	−0.126 *	0.063 *	0.238
Cointegration				3.102
Heteroskedasticity				0.372
Ramsey test				0.698
J-B test				0.027
$HEALTH = f\ (SED,\ HS, EDU)$				
SED	0.068 *	−0.035 **	0.015 **	0.914
HS	−0.873 **	−0.704 **	0.002 ***	0.097 *
EDU	−0.044 *	−0.005 *	0.089 *	0.530
Cointegration				1.311
Heteroskedasticity				0.513
Ramsey test				0.647
J-B test				0.038
$HEALTH = f\ (CE,\ HS, EDU)$				
CE	0.041 ***	0.022 **	0.001 ***	0.574
HS	−0.726 ***	−0.432 **	0.000 ***	0.083 *
EDU	−0.029 **	−0.365 *	0.047 **	0.257
Cointegration				2.714
Heteroskedasticity				0.673
Ramsey test				0.753
J-B test				0.029

Notes: ***, **, and * represent the level of significance at 1%, 5%, and 10%, respectively.

In Model 2, sustainable economic development is added to the equation, and the results show that positive shocks in sustainable economic development increase health issues, whereas negative shocks reduce these issues. The coefficient of positive shocks is 0.042, which is lower than the coefficient of negative shocks, which is −0.738. These results suggest that even after the implementation of policies and guidelines of Vision 2030, economic growth is still impacting public health negatively. The reason could be that the Saudi economy is still not fully diversified, and the primary energy source is fossil fuels, which emit harmful gases and hence damage health [30]. The main goals of Vision 2030 are sustainable economic growth and the reduction of environmental-related health issues. However, Saudi Arabia is still far behind in achieving this goal.

In Model 3, carbon emission is added, and results suggest that negative and positive carbon emission shocks increase public health issues. The coefficient of positive shocks is higher than negative shocks, and a 1% increase in carbon emissions enhances public health issues by 1.001%. At the same time, a 1% reduction in carbon emissions enhances public health issues by 0.326%. These coefficients are lower as compared to the pre-Vision 2030 results. Hence, it can be said that Saudi Arabia is making some improvements in reducing the harmful effects of carbon emissions. However, fossil fuels are still the country's primary energy source, which increases health issues through high carbon emissions.

Table 9. Nonlinear ARDL estimation (post Vision 2030).

Long Run	Model 1	Model 2	Model 3
$HEALTH_{t-1}$	0.051 *	0.914 ***	1.202 ***
$GI^{+}{}_{t-1}$	−0.107 **		
$GI^{-}{}_{t-1}$	−0.181		
$SED^{+}{}_{t-1}$		0.042 **	
$SED^{-}{}_{t-1}$		−0.738 *	
$CE^{+}{}_{t-1}$			1.001 ***
$CE^{-}{}_{t-1}$			0.326 **
$HS^{+}{}_{t-1}$	−1.005 ***	−1.706 ***	−1.655 ***
$HS^{-}{}_{t-1}$	−0.270 **	−0.191 **	−0.120 **
$EDU^{+}{}_{t-1}$	−0.344 **	−0.679 ***	−0.094 **
$EDU^{-}{}_{t-1}$	−0.591 *	−0.021 *	−0.362 *
Short-run			
$\Delta\ GI^{+}{}_{t-1}$	−0.493 **		
$\Delta\ GI^{-}{}_{t-1}$	−0.686		
$\Delta\ SED^{+}{}_{t-1}$		0.222	
$\Delta\ SED^{-}{}_{t-1}$		0.930	
$\Delta\ CE^{+}{}_{t-1}$			0.374 **
$\Delta\ CE^{-}{}_{t-1}$			0.765
$\Delta\ HS^{+}{}_{t-1}$	−0.118 ***	−0.085 **	−0.079 **
$\Delta\ HS^{-}{}_{t-1}$	−0.003 *	−0.006 *	−0.003 *
$\Delta\ EDU^{+}{}_{t-1}$	0.348	0.225	1.001
$\Delta\ EDU^{-}{}_{t-1}$	0.236	1.090	0.742
Constant	8.050 **	7.021 **	3.634 ***

Notes: ***, **, and * represent the level of significance at 1%, 5% and, 10%, respectively.

Now we turn our attention toward health spending and education. It is evident that after Vision 2030, negative and positive shocks in health spending reduce public health issues because, in all models, coefficients are negative and significant. Greater private sector involvement in the economy is one of Vision 2030′s goals, especially regarding healthcare. There is a clear trend toward privatization, with the National Transformation Programs' (NTPs) declared goal of raising private healthcare spending from 25% to 35% of overall spending. According to projections, this will result in a rise in income from 3 billion SAR to 4 billion SAR. The Health Ministry also intends to invest more than 23 billion SAR in new projects over the next five years [67]. The Saudi government can control public health issues through these efforts and other initiatives.

As far as education is concerned, the coefficients of positive and negative shocks are negative and significant. This means education is a major factor in reducing health issues in Saudi Arabia. Education can affect public health from different angles. The income level and occupation of educated people are usually high, enabling them to avail themselves of high-quality health facilities and improve their health. Moreover, a high income can be used to consume healthy and nutritious food, which is essential for health [68,69]. Education can also improve problem-solving skills and cognitive abilities, through which negative health aspects, including stress, can be well handled. Moreover, education can improve environment quality by using renewable energy, which is essential for reducing environment-related health issues [70].

The second section of Table 9 presents short-run estimations. In the short run, positive shocks in green innovation reduce health issues by 0.493%, but negative shocks have no impact on health-related issues. Moreover, sustainable economic development is not related to public health issues in the short run. As far as carbon emissions are concerned, only positive shocks increase health issues by 0.374%. However, health spending significantly reduces public health issues in the short run as well. Hence, it can be said that, besides other measures taken in Vision 2030 to improve public health, investment in this sector proved to be the best short-term and long-term solution. In the case of education, it has no impact on public health in the short run because to get the full benefits of education, some time is needed where people can complete their higher education, which can contribute to positive health outcomes.

Diagnostics

Table 10 presents the results of asymmetric and model diagnosis for post-Vision 2030. In model 1, the long-run coefficient of positive shocks in green innovation is significant, with a value of −1.031. This value is high compared to pre-Vision 2030 data; hence, it can be said that the role of green innovation in reducing public health issues is enhanced through Vision 2030. In the long run, positive and negative shocks in health spending have significant and negative coefficients. Moreover, these coefficients are higher than the coefficients of pre-Vision 2030 data due to the Saudi government's commitment to increasing spending in the health sector to promote public health [71]. Likewise, the positive and negative shocks in education also have negative and significant coefficients. The strategic reforms and increased spending in the education sector help the kingdom improve people's learning outcomes and cognitive ability [72], which is essential for attaining better health facilities and diet. The long- and short-run asymmetric results show significant positive coefficients for green innovation, health spending, and education. Hence, long-run and short-run asymmetric effects are present between green innovation, health spending, education, and public health.

Table 10. Asymmetric and model diagnostics (post Vision 2030).

	Long Run (+)	**Long Run (-)**	**Long-Run Asymmetry (*p*-Value) W_{LR}**	**Short-Run Asymmetric (*p*-Value) W_{SR}**
$HEALTH = f\ (GI,\ HS, EDU)$				
GI	−1.031 **	−0.106	0.011 **	0.094 *
HS	−2.756 ***	−1.430 *	0.020 **	0.002 ***
EDU	−0.943 **	−0.781 *	0.071 *	0.088 *
Cointegration				1.422
Heteroskedasticity				0.771
Ramsey test				0.853
J-B test				0.009
$HEALTH = f\ (SED,\ HS, EDU)$				
SED	0.012 **	−0.065 **	0.041 **	0.030 *
HS	−1.337 **	−1.421 **	0.003 ***	0.071 *
EDU	−1.132 *	−2.002 *	0.002 *	0.988
Cointegration				3.543
Heteroskedasticity				0.767
Ramsey test				0.281
J-B test				0.002
$HEALTH = f\ (CE,\ HS, EDU)$				
CE	0.130 ***	1.262 **	0.002 ***	0.709
HS	−1.651 ***	−0.204 **	0.001 ***	0.051 *
EDU	−1.894 **	−0.398 *	0.007 ***	0.437
Cointegration				3.330
Heteroskedasticity				0.462
Ramsey test				0.655
J-B test				0.006

Notes: ***, **, * represent the level of significance at 1%, 5%, and 10%, respectively.

Model 2 shows that positive, sustainable economic development significantly and positively impacts public health issues. At the same time, negative shocks have a significant negative coefficient. This suggests that Saudi Arabia is not getting the full benefits of economic restructuring, and economic growth is still a significant issue for public health, where economic restructuring refers to transforming the industrial and urban models by introducing advanced and energy-efficient technologies that help to increase energy efficiency and reduce environmental gasses. As a result, this decrease in environmental gasses leads to a decrease in public health issues. The positive and negative shocks in health spending and education significantly and negatively impact public health issues. Hence, it can be said that health spending and education are essential for improving public health. The long- and short-run asymmetric results show a significant and positive asymmetric relationship between sustainable economic development, health spending, and public health. However, education only has a long-run positive asymmetric effect on health.

In Model 3, positive and negative shocks in carbon emissions show significant and positive coefficients, suggesting that carbon emissions increase health issues. The increased amount of carbon in the atmosphere is dangerous because it results in many lung and respiratory diseases. Moreover, many skin-related issues are the outcome of a polluted atmosphere. Positive and negative long-run shocks in health spending have negative and significant coefficients. Moreover, long-run positive and negative shocks in education have negative and significant coefficients, which means health spending and education are essential to reducing public health issues. Long-run asymmetric results suggest that all independent variables have a long-run positive asymmetric effect on public health. However, only health spending has a long-run positive asymmetric effect on public health.

4.4. Discussion

The finding that there are significant and positive impacts of lagging health issues is consistent with [2,3,73]. There are multiple justifications for this relation, such as (i) a failure to discover significant factors that cause public health issues, (ii) a lack of knowledge with respect to handling the main causes, etc. There are multiple justifications for linking the significant and negative impact of green innovation on public health with public health issues. such as the following: green innovation produces energy-efficient and environmentally friendly products which on the one hand reduces energy consumption and on the other hand minimizes environmental externalities. Higher nonrenewable energy consumption and more greenhouse gasses are harmful for public health; a reduction in nonrenewable energy consumption and pollutant gasses reduces public health issues. Despite this, the impact of green innovation in terms of reducing public health issues is lower, which indicates that green innovation, in Saudi Arabia, is not mature enough to fix health issues [51].

With regard to sustainable economic growth, positive and negative shocks have adverse impacts on public health issues. The findings suggest that growing economies are more concerned with industrialization and improving transportation, instead of public health issues. To maintain the pace of industrialization, they require nonrenewable energy, which increases greenhouse gas emissions [74–76]. These gasses have a significant effect on the general public; as a result, the countries face public health challenges [2]. Emphasizing the significance of carbon emissions, positive shocks in carbon emission increase health issues and negative shocks in carbon emission reduce health issues. As a greenhouse gas, carbon in particular is one of the dangerous gasses that directly affect human health [2,77,78]; we confirm the adverse impact of carbon emissions on public health.

Positive shocks in health spending reduce public health issues, whereas negative shocks in health spending increase public health issues. Improvements in the health sector provide health facilities in each district, which increases public access to hospitals [79,80]. The Saudi government spends 5.7 percent of its gross domestic product on health expenditure, around 1300 USD per person (World Development Indicators). By spending more on the health sector, the Saudi government can reduce public health issues. Our findings concerning education can be justified through different channels, such as (i) higher education enables the general public to be aware of healthy diets, which reduces health challenges [81,82]; (ii) higher education produces innovative minds that focus on research and development and innovation, which produces green and clean products [76,83]. Such green and clean technologies reduce energy consumption and pollutant gasses. Consequently, with the reduction in pollutant gasses, public health issues will decrease.

5. Conclusions

This study examines the impact of green innovation, sustainable economic development, and carbon emission on public health issues in Saudi Arabia. The nonlinear ARDL approach is used for econometric estimations over the period 1990–2020. The study contributes to the existing literature by incorporating green innovation into the health model for Saudi Arabia. Green innovations motivate the community to adopt green products and energy-efficient tools and devices that improve environment quality; as a result, public health problems show a declining trend. However, it is important to consider whether green innovation is mature enough to counter the health challenges. Health spending of the government and education are included as control variables in the studied models.

The data of nonlinear ARDL confirm the significance of green innovation; the increase in green innovation helps to control public health issues. The surge in green innovation leads towards energy-efficient and clean technology that uses less energy compared to traditional products. Similarly, green technology in transportation reduces fossil fuel consumption. This reduction in energy consumption is helpful for improving on environmental degradation processes. As a result, this reduction in carbon emission has positive effects on public health. This finding is confirmed in all three models, as the coefficients of positive shocks are significant and negative. Health spending and education also had similar results with long-run data. In the short run, green innovation and health spending play a role in reducing health issues, where the impact of government health spending is higher. Sustainable economic development and carbon emissions are the main public health considerations in Saudi Arabia.

The results of the study have a number of policy implications for policy makers: (i) the government needs to allocate a large budget for research and development for educational institutions and industrial sectors. This will help scientists and entrepreneurs to innovate and produce green equipment, appliances, etc., that consume less energy and mitigate environmental externalities. As a result, health issues will be controlled. (ii) The government must increase its spending on health infrastructure and its outreach. It must introduce health insurance policies for the public and build more hospitals in remote areas to increase public access to hospitals. (iii) It is urgent to provide education regarding health challenges, environment, energy utilization, etc., which help to reduce nonrenewable energy consumption and replace non-green appliances with green appliances. (iv) Strict laws need to be imposed regarding carbon emissions, such as a carbon tax on industries. Nonrenewable energy sources should be replaced with renewable energy sources. Renewable energy vehicles should be introduced, instead of traditional cars.

Like other studies, this study also has some limitations, such as non-availability of data for longer periods and high frequency data. Data for other health determinants are not easily available. For future directions, researchers could generate a health index and use that as a dependent variable. Moreover, future studies could focus on other GCC or Arab countries in either a single country analysis or a multiple-country analysis. Additionally, researchers could carry out a detailed analysis of oil-exporting and oil-importing countries, as a panel analysis. Most importantly, upcoming research should use the time varying concept to provide details of variables across time.

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