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# Investigating the N-shaped EKC in China: An imperious role of energy use and health expenditures

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Since the industrial revolution, the concentration of greenhouse gases (GHGs) has been increasing steadily. It is to be noted that China emitted 27% of the world's GHGs in 2019, making it the world's most significant contributor to climate degradation. The key objectives of this investigation are to ascertain the N-shaped association between CO<sub>2</sub> emissions and economic growth in the presence of energy use and domestic government health expenditures. In addition, the research inspected the role of Belt and Road Initiative through economic globalization in China. This study utilized the autoregressive distributed lag model and found that an N-shaped environmental Kuznets curve exists in China. Furthermore, the study discovered that economic globalization improves ecological excellence in the short run. Nonetheless, energy consumption and health expenditures considerably amplify the intensity of CO<sub>2</sub> emanation in China in the long run. The research suggested that installing green industries through economic globalization can imperatively lessen environmental degradation. Moreover, installing technological firms will be more beneficial in the long run to overcome environmental degradation rather than importing from other countries. The study elaborated momentous causation effects among the study variables through the Granger causality test.

## KEYWORDS

N-shaped EKC, economic growth, energy use, economic globalization, CO<sub>2</sub>, health expenditures, BRI, ARDL

## 1 Introduction

Climate change engenders an increasing threat to survival and human growth, including food scarcity, loss of species, and extreme weather conditions (Wang et al., 2020). Since the industrial revolution, the concentration of greenhouse gases (GHGs) has continued to rise, and the average global temperature has increased by 0.85°C from 1980 to 2012 (Pathak, 2021). Mainly, China emitted 27% of the globe's GHGs in 2019, ranking first in the world (BBC, 2021). Therefore, ecological dilapidation and climate change are among the main debatable and discussed topics in the 21st century. In light of the 2015 Paris Climate Agreement (PCA), countries worldwide are designing their policies to limit global warming below 1.5°C above the pre-industrial level, which requires rapid, far-reaching, and unprecedented changes in all aspects of society. It is to be noted that immediate changes in lifestyles, technology, consumption patterns, and production methods have elevated

environmental problems (Yilanci and Gorus, 2020; Ahmad et al., 2021a; Ahmad et al., 2022; Ekeocha, 2021; Shehzad et al., 2021; Arif et al., 2022). Moreover, it is commonly believed that many countries have prioritized economic development regardless of the consequences, leading to the problems of high fossil fuel energy consumption and environmental pollution (Bertinelli et al., 2012).

In recent decades, China has accredited sudden economic development to the enormous utilization of its resources. This nations have faced structural transformation from agricultural to industrial and service-based economies. Hence, this development is not without cost, and environmental quality is the price. This region is in the initial phase of industrialization, which has incalculably increased the demand of energy. Indeed, electricity consumption in China has almost doubled from 2010 to 2021, i.e., from 4199.9 to 8310 TW h. Moreover, burning up of total energy has been augmented by 2.2% recently in comparison with 2019 (Wong, 2021). The studies of various authors such as Belke et al. (2011) and Tang et al. (2016) reported that energy plays a vital role in boosting economic growth. In addition, Zeraibi et al. (2020) declared that the use of energy directly impacts the economic growth, while indirectly effecting the environmental excellence. Thus, there is an urgent need to develop the most promising economic and energy strategies to accomplish the sustainable development goals (SDGs). Furthermore, Arouri et al. (2012) and Arif et al. (2022) revealed the direct impact of economic growth on environmental degradation. Consequently, the environmental nexus of energy consumption and economic development raise questions about sustainable economic growth, and it becomes indispensable to maintain a balance between economic development, energy use, and ecological sustainability. Numerous studies examined the relationship between economic growth and environmental degradation through the environmental Kuznets curve (EKC) theory introduced by Kuznets (1955), which documented that economic expansion and environmental degradation have a non-linear relationship that can be characterized by an inverted U-shaped curve. As per the EKC theory, an economic boost increases environmental degradation at the initial level but improves environmental excellence after attaining a specific point. Hence, despite significant changes, society will maintain environmental protection, and people will enjoy healthy lives (Stern, 2004; Ahmad et al., 2021b).

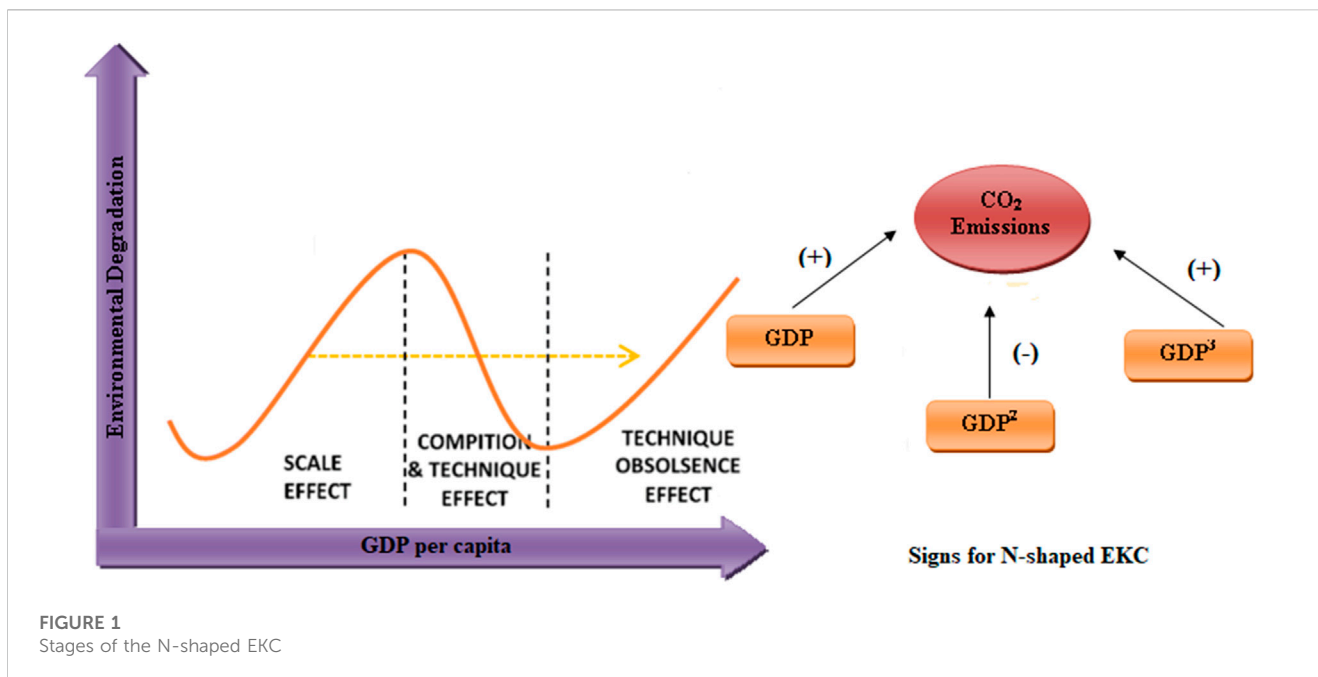
The EKC concept is attributed to three approaches, i.e., scale, component, and the technique effect through which economic growth can affect the environmental excellence in a country (Grossman and Krueger, 1995). In the first stage, a scale effect occurs where natural resources are extracted and valuable resources are put into the manufacturing cycle. When a manufacturing cycle begins, various toxic chemicals are produced, and the by-products of this manufacturing process drastically increase environmental degradation. In order to enhance the economic conditions, the government neglects the destructive aspects of this expansion which, as a result, affects environmental sustainability. At this stage, the use of energy and wages are increasing, and the country's economic system is experiencing constant change; thus, the market framework begins to transform (Stern, 2004). This is the level where compositional impact occurs on environmental management, and the impact of socioeconomic development on environmental sustainability becomes positive. During this progression, additional markets develop, and the industry moves

toward using sustainable technologies (Bagliani et al., 2008). Moreover, this variation upgrades the lifestyle and urges the desire for a healthier society. At this stage, industries adopt clean technologies that augment efficiency without harming environmental sustainability, and the economic system becomes information intensive instead of wealth intensive. At this moment, the government expenditure on innovations and pollutant technology is replaced (Tunç et al., 2009). This whole process is known as the EKC theory. However, some studies have shown that this relationship can sometimes be N shaped (Shehzad et al., 2022) documenting that environmental dilapidation will increase again shortly after the income levels rise above the appropriate level (Figure 1).

Torras and Boyce (1998) proclaimed that the N-shaped EKC occurs when technological transition transpires. The effectiveness of linkage depends on the small scale and extent of the enhanced classification of industries.

Additionally, China has stoutly built the economic relationship to the world through its Belt and Road Initiative (BRI). The BRI aims to improve China's underdeveloped regions, particularly its western regions, and to broaden China's opportunities for cooperation and collaboration with other nations in order to improve connectivity and integration. An integrated logistics layout, a new trade route and fresh trade possibilities, cross-border trade by eliminating cross-border uncertainty, entrepreneurship in developing nations, and this global initiative ultimately increased China's GDP (Akbar et al., 2020; Lee and Shen, 2020; Han et al., 2022). In addition, by increasing cooperation and mutual benefits, deepening relations and connecting diverse nations, and promoting global economic infrastructure, this initiative promotes global economic infrastructure. Likewise, partner nations and Europe's global presence could grow as a result of the BRI, and China and Europe could work together more in markets such as those in West Africa, the Indian Ocean, and Central Asia (Haggai, 2016). It is anticipated that trade between One Belt One Road (OBOR) nations will rise from \$5 billion to \$135 billion (Enderwick, 2018). Accordingly, it is essential to ascertain the environmental concerns of economic globalization. Moreover, recent studies reported that environmental pollution was the major cause of the spread of novel coronavirus (COVID-19) (Bashir et al., 2020; Fattorini and Regoli, 2020; Travaglio et al., 2021). Furthermore, Wu et al. (2020) acknowledged that carbon emissions and COVID-19 cases had a bidirectional impact on each other. Thus, it becomes significant to include domestic government health expenditures in the nexus of economic growth, energy use, economic globalization, and environmental degradation so that constructive strategies can be constructed.

After taking into account the impact of energy use, the primary objectives of this study are to determine the N-shaped association between economic growth and environmental degradation in China. In addition, the investigation examined the connection between environmental degradation in China and BRI (through economic globalization) and domestic government health expenditures. The subsequent reservations of policymakers, academics, researchers, and government officials are dispelled by the study. First, what is the nature of the economic growth, energy use, and ecological dilapidation nexus for the long term era, and does the N-shaped EKC hypothesis exist? Second, can domestic government health



expenditures reduce the level of CO<sub>2</sub> emissions? Third, does economic globalization benefit environmental sustainability? The reason to choose these variables is highly based on the study objectives. This study significantly analyzed the impact of economic growth on the environmental pollution in China through the N-shaped EKC. The sudden economic growth in China has raised many questions relevant to environmental excellence and health level. Hence, exploring the linkage between environmental pollution, health expenditures, and economic growth becomes essential. This study contributes to the literature in three ways. First, this investigation explored the nexus of economic growth, energy use, and environmental degradation through the N-shaped EKC theory. Second, this study evaluated how spending budget in health facilities effects environmental pollution. Third, this study reported the imperious role of the Belt and Road Initiative in terms of environmental excellence in China. As per the author's best knowledge, this is the first examination that evaluates the energy–growth–environmental degradation nexus in a single model. Moreover, it is the first study that measured the impact of the BRI through economic globalization.

The rest of this study is organized as follows. The second section exhibits the recent literature published in environmental economics. The third section discusses the methods applied in this study. The fourth section specifies the results and discussion. Last, the fifth section nominates the conclusion derived from the study's findings.

## 2 Literature review

### 2.1 An N-shaped EKC

The EKC explains the involvement of a state's economic expansion and its related environmental degradation level. It portrays how a country's environmental excellence will progress

if the development level of a nation goes up (Chenghu et al., 2021). Grossman and Krueger (1991) argued that the connection between environmental quality and economic growth was not linear and varied along the development level of an individual nation. In other words, every nation has its own specific EKC based on the use of resources, economic activities, and social background of that country. Various researchers (Ozcan, 2013; Narayan et al., 2016; Arif et al., 2022) reported an inverted U-shaped relationship between economic growth and environmental degradation. However, some researchers reported that an inverted U-shaped relationship does not always exist. Brajer et al. (2008) analyzed the city-wise EKC in China using panel data models. The study stated that an inverted U-shaped and N-shaped EKC exists in China after controlling the health benefits given to the public. The study used SO<sub>2</sub> to nominate the environmental degradation in China. Moreover, Zeraibi et al. (2022) scrutinized the role of broad money supply and government expenditures on environmental degradation in China. The study reported that an inverted U-shaped EKC does not exist in China, though the N-shaped relationship between economic growth and CO<sub>2</sub> emissions was significant. However, Etokakpan et al. (2021) examined the N-shaped EKC in China in the presence of urbanization and natural gas consumption from 1971 to 2018. The study documented that the N-shaped EKC does not exist in China, while confirming that a reversed N-shaped EKC was present. The research reported that natural gas consumption and urbanization directly impact CO<sub>2</sub> emissions. Barış-Tüzemen et al. (2020) investigated the EKC in Turkey after indicating the impact of ICT on CO<sub>2</sub> emissions. The study utilized the data from 1980 to 2017 and employed the autoregressive distributed lag (ARDL) model. The findings revealed that ICT has a positive impact on CO<sub>2</sub> emissions and an inverted significant N-shaped EKC exists in Turkey. However, the study verified these findings through the Quantile regression method and reported that an insignificant inverted N-shaped EKC was evident. Additionally,

Park and Lee, (2011) scrutinized the EKC hypothesis in 16 regions of Korea. The study utilized the panel data of 16 years and employed SO<sub>2</sub>, NO<sub>2</sub>, and CO<sub>2</sub> to nominate the air pollution. The study revealed that each region in Korea has its own specific shape of EKC by using SO<sub>2</sub> and NO<sub>2</sub>. However, the study noted a possible subsistence of the U-shaped and N-shaped EKC. Moreover, using CO<sub>2</sub> emissions, the study found evidence of the U-shaped EKC in most regions across Korea. Moreover, the study mentioned that energy consumption was the highest factor determining the level of environmental degradation in Korea. Rashdan et al. (2021) inspected the EKC hypothesis by using the capture fisheries production (CFP). The research utilized data from 14 nations and employed panel data modeling. The examination discovered the N-shaped affiliation between economic growth and capture fisheries product. Moreover, the study argued that financial development and imports negatively impact the capture fisheries production, while exports positively impact the CFP. Furthermore, Bisset (2022) used the panel data of 41 SSA nations classified into three income classes from 1996 to 2018. The study used the panel data model of SSA states and found that an EKC of the N-shaped exists merely in upper-middle-income groups. The study achieved these findings in the presence of three key governance indicators, i.e., government effectiveness, political and institutional governance, and economic governance.

## 2.2 Nexus between health expenditures and environmental degradation

Khan et al. (2020) examined the ramifications of renewable energy use and health expenditures on CO<sub>2</sub> emissions in BRI countries. The study employed the data from 1995 to 2016 and panel data models, i.e., fully modified ordinary least square (FMOLS) and generalized method of moments (GMM). The study found that renewable energy imperatively reduces CO<sub>2</sub> emanation. However, the study noted that health expenditures and economic expansion significantly diminish the environmental excellence in BRI states. In addition, Gövdeli (2019) examined the nexus among economic growth, health expenditures, and CO<sub>2</sub> emissions in Organization for Economic Co-operation and Development (OECD) nations. The study used secondary data from 1992 to 2014 and applied the panel data models. The study's results exposed that economic growth imperatively surges environmental degradation. The outcomes of the Granger causality model tested by the vector error correction model (VECM) showed momentous causality in a row from CO<sub>2</sub> emissions to health expenditures. Likewise, Ullah et al. (2020) examined the correlations among health expenditures, renewable energy use, trade, and CO<sub>2</sub> emissions for the nation of Pakistan by using annual data from 1998 to 2017. The study made known that trade increases environmental degradation, resulting in a major upsurge in health expenditures. However, the study discovered that renewable energy improves environmental quality, which, as a result, significantly diminishes health expenditures. Also, Chaabouni et al. (2016) analyzed the data from 51 nations from 1995 to 2013. The study used panel data techniques and discovered that health expenditures and CO<sub>2</sub> emissions have a unidirectional causality relationship, whereas

economic growth and health expenditures divulged bidirectional causation.

## 2.3 Environmental degradation and economic globalization nexus

The Belt and Road Initiative of China has strong potential to increase its *per capita* income. Moreover, other developing nations can also benefit its economy through the BRI project of China. You and Lv (2018) investigated the spatial impact of economic globalization on environmental degradation. The study used data from 83 nations through 1985 to 2013 and depicted that CO<sub>2</sub> emissions and economic globalization have a negative relationship. Hence, the study suggested that highly globalized nations have better environmental quality. Additionally, Shahbaz et al. (2017) applied the ARDL model to ascertain the impact of globalization on environmental degradation in China. The study verified that globalization significantly decreases environmental degradation in China; nevertheless, the use of coal significantly upsurges CO<sub>2</sub> emissions. The Granger causality upshots showed that CO<sub>2</sub> emissions appreciably cause globalization. Liu et al. (2020) explored the sway of G7 state's globalization by employing panel data techniques. For this reason, the KOF globalization indicator was utilized. The study documented that globalization and CO<sub>2</sub> emissions have an upturned U-shaped association, which proves the existence of the EKC hypothesis. Moreover, the study stated that economic growth increases environmental pollution while renewable energy helps to reduce it.

## 2.4 Energy use and environmental degradation

Energy use imperatively boosts the economic growth of a nation (Zeraibi et al., 2020). However, it has also environmental consequences, which cannot be ignored to achieve sustainable development. The investigation by Zhang and Lin (2012) used data from 1995 to 2010 and analyzed the impact of energy consumption on CO<sub>2</sub> emissions at the provincial level of China. The investigation applied the STIRPAT technique and discovered that energy use has a significant nexus with CO<sub>2</sub> emissions and urbanization. Similarly, Wang et al. (2016) explored the nexus among energy consumption, CO<sub>2</sub> emissions, and economic growth. The study made known that a unidirectional causality was moving from energy use to CO<sub>2</sub> emissions; however, the examination also accounted that CO<sub>2</sub> emissions had a momentous effect on energy use. Shafiei and Salim (2014) exposed the role of energy use when utilizing the STIRPAT model for OECD territories. The study compared the impact of renewable and non-renewable energy use on CO<sub>2</sub> emissions and stated that non-renewable energy has a direct impact while renewable energy has an indirect impact on CO<sub>2</sub> emissions. Also, Khan et al. (2019) utilized the time series technique by employing the secondary data from 1971 to 2016. The consequences inspected that energy consumption significantly heightens the level of greenhouse gas emissions in Pakistan. The study also argued that economic globalization, urbanization, and economic growth have

**TABLE 1** Description of the study variables.

Variables	Abbreviation	Proxy	Data source
Carbon dioxide	CO <sub>2</sub>	CO <sub>2</sub> emissions (metric tons <i>per capita</i> )	World Bank
Domestic health expenditures	DHE	Domestic general government health expenditure	World Bank
Per-capita energy consumption	PCEU	Per-capita energy use	Our word in data
Foreign direct investment	FDI	Foreign direct investment, net (BoP, current US\$)	World Bank
Economic growth	GDP	GDP <i>per capita</i> (constant 2015 US\$)	World Bank

**TABLE 2** Unit root testing results.

Variable	Augmented Dickey–Fuller				Phillips–Perron			
	Level		1st difference		Level		1st difference	
	T-statistic	Probability	T-statistic	Probability	T-statistic	Probability	T-statistic	Probability
CO <sub>2</sub>	-2.207886	0.2053	-8.485288	0	-2.103739	0.2439	-9.155442	0
DHE	-2.328715	0.1658	-8.491923	0	-2.153812	0.2248	-8.537211	0
ECG	-2.944677	0.0456	-1.715629	0.4189	-2.127644	0.2346	-3.374587	0.015
PCEU	-0.808193	0.8106	-6.47566	0	4.511428	1	-5.695158	0
GDP	1.00793	0.9964	-2.833326	0.0593	5.532951	1	-2.601576	0.0972
GDP <sup>2</sup>	1.475328	0.9991	-3.435027	0.0544	16.84114	1	-3.408625	0.0579
GDP <sup>3</sup>	3.610094	1	-10.09979	0.0001	29.70435	1	-9.996632	0

Source: The author’s calculation.

**TABLE 3** Results of the bound test.

	Value	Significance (%)	I (0)	I (1)
F-statistic	4.68	10	3.02	3.51
K	6	5	3.62	4.16
		2.5	4.18	4.79
		1	4.94	5.58
Null hypothesis: No level relationship				
Equation: CO <sub>2</sub> = f (DHE, ECG, PECU, GDP, GDP2, GDP3)				

Source: The author’s calculation.

direct association with CO<sub>2</sub> emissions in china. In addition, the study by [Zhang et al. \(2023\)](#) verified that environmental policies imperatively reduced the air pollution. Moreover, [Hou et al. \(2023\)](#) stated that environmental sustainability is highly connected to renewable energy use. However, the study of [Jun et al. \(2020\)](#) argued that trade openness significantly increases the environmental pollution due to more usage of energy in industry. Hence, the abovepresented literature review shows the significance of testing the N-shaped EKC in China. Moreover, it can also be seen that no research has already investigated the N-shaped relationship between CO<sub>2</sub> emissions and economic growth in China after considering the energy use and domestic government health

expenditures. Moreover, no study has evaluated the impact of the BRI through economic globalization in China.

### 3 Data and methodology

#### 3.1 Data

The fundamental purpose of this investigation is to analyze the N-shaped association of economic growth with environmental degradation in China. Second, the study revealed the importance of the OBOR project in China measured through economic globalization for environmental excellence in China. Moreover, the study examined the role of energy use on CO<sub>2</sub> emissions in the presence of the EKC. For the defined aim, the on-hand research used the quarter data from 2000 to 2019. This selected duration is based on the availability of the data. The study converted the annual data into the quarter form using the methodology of [Shehzad et al. \(2019\)](#). To ascertain the N-shaped EKC in China, the study employed GDP, a square form of GDP, and a cubic form of GDP. Particularly, the proxies used in the study are mentioned in [Table 1](#).

#### 3.2 Methodology

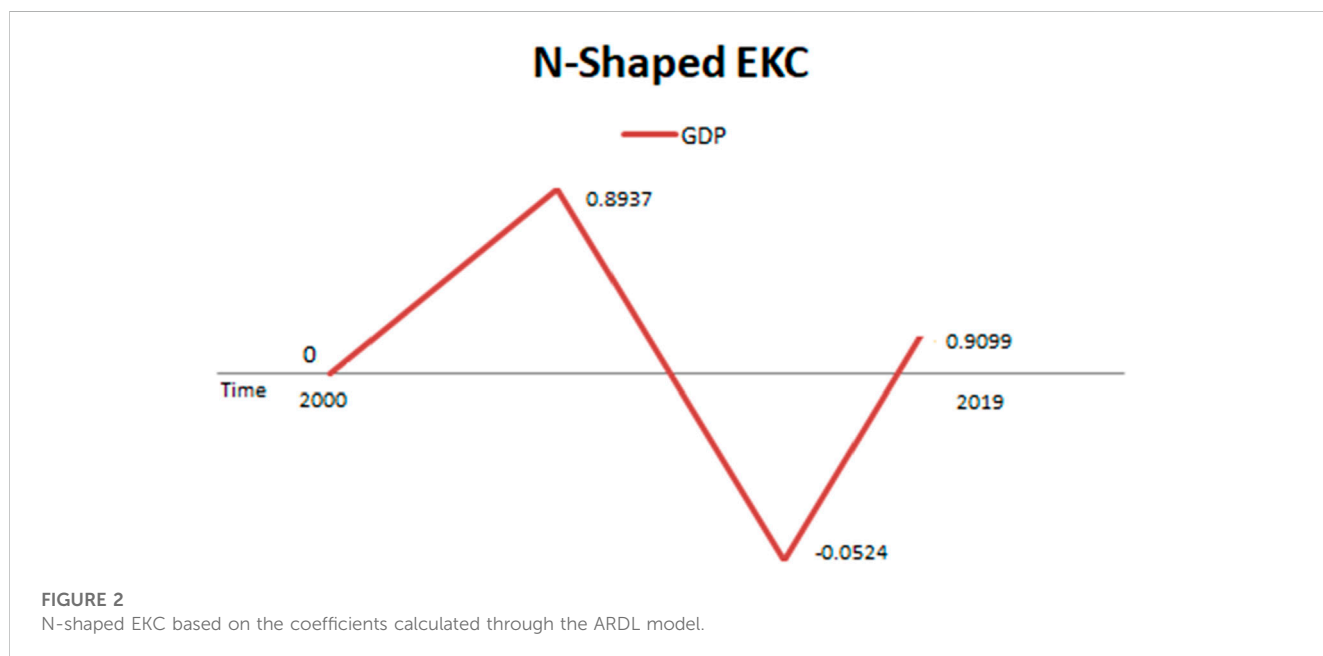
Our model defines the functional equation as follows:



TABLE 4 Long-run and short-run dynamics of the study variables.

Variable	Coefficient	Std. error	t-statistic	Probability
<b>Long run</b>				
DHE	0.8665***	0.0602	14.3831	0.0000
ECG	-0.0116	0.0128	-0.9063	0.3681
PECU	0.3504***	0.0614	5.7008	0.0000
GDP	0.8937***	0.0636	14.0401	0.0000
GDP2	-0.0524***	0.0154	-3.3999	0.0012
GDP3	0.9099***	0.0357	25.4252	0.0000
C	-0.0521*	0.0279	-1.8670	0.0664
<b>Short run</b>				
D (CO <sub>2</sub> (-1))	0.6095***	0.0579	10.5153	0.0000
D (DHE)	-0.0032**	0.0014	-2.6231	0.0108
ECG	0.0057***	0.0014	3.9469	0.0002
D (GDP)	0.0047***	0.0005	9.0409	0.0000
D (GDP2)	-0.0115	0.0077	-1.4896	0.1411
D (GDP3)	0.8741***	0.0607	14.3960	0.0000
ECT <sub>t-1</sub>	-0.0408**	0.0167	-2.447891	0.0171
R-squared	0.9635	Adjusted R-squared		0.9529
		Durbin-Watson		2.1936

Source: The author's calculation. Here, \*, \*\*, and \*\*\* represent the 10%, 5%, and 1% level of significance, respectively.



$$CO_2 = f(DHE, ECG, PCEU, GDP, GDP^2, GDP^3) \quad (1)$$

Here, CO<sub>2</sub> nominates the CO<sub>2</sub> emissions used to evaluate the environmental degradation in China. Moreover, DHE, ECG, and

PCEU indicate the domestic general government health expenditures, economic globalization, and *per capita* energy use, respectively. In addition, GDP, GDP<sup>2</sup>, and GDP<sup>3</sup> symbolize the economic growth, square of economic growth,

**TABLE 5 Robustness testing through the CCR model.**

Variable	Coefficient	Std. error	t-statistic	Probability
DHE	4.040814***	0.60913	6.633749	0
PCEU	1.083647	0.748235	1.448271	0.152
ECG	0.014536***	0.004943	2.940355	0.0045
GDP	1.173376***	0.049949	23.49172	0
GDP2	-1.49831*	0.78535	-1.90783	0.06080
GDP3	1.686764***	0.580404	2.906190	0.004900
C	-0.25970**	0.12716	-2.04239	0.04510

Source: The author's calculation. Here, \*, \*\*, and \*\*\* represent the 10%, 5%, and 1% level of significance, respectively.

**TABLE 6 Outcomes of the stability testing.**

Breusch–Godfrey serial correlation LM test			
F-statistic	0.165181	Probability	0.8481
Obs*R-squared	0.3586	Prob. chi-square (1)	0.8359
Breusch–Godfrey heteroskedasticity test			
F-statistic	0.792877	Probability	0.5021
Obs*R-squared	2.43343	Prob. chi-square (2)	0.4874

Source: The author's calculation.

and cubic form of economic growth, respectively, to evaluate the N-shaped EKC in China. We utilized the autoregressive distributed lag model to estimate the study factors' long- and short-run dynamics (Pesaran et al., 2001). We employed the ARDL model for the following reasons: ARDL is the best fit for a small dataset. Additionally, this approach does not bound the data to be stationary at the same level of integration, i.e., I (0) or I (1), and can be applied to mixed co-integrated data. Furthermore, the ARDL model diagnoses the behavior of the dependent variable in terms of its own and prior values of the independent factor (Cherni and Essaber Jouini, 2017; Shehzad et al., 2020). The ARDL co-integration model based on a bound testing approach can be written as follows:

$$\begin{aligned} \Delta CO_{2t} = & \omega_0 + \omega_1 (CO_2)_{t-1} + \omega_2 (DHE)_{t-1} + \omega_3 (ECG)_{t-1} \\ & + \omega_4 (PCEU)_{t-1} + \omega_5 (GDP)_{t-1} + \omega_6 (GDP^2)_{t-1} \\ & + \omega_7 (GDP^3)_{t-1} + \sum_{j=0}^p \varphi_1 (CO_2)_{t-i} + \sum_{j=0}^p \varphi_2 (DHE)_{t-j} \\ & + \sum_{j=0}^p \varphi_3 (ECG)_{t-k} + \sum_{j=0}^p \varphi_4 (PCEU)_{t-l} + \sum_{j=0}^p \varphi_5 (GDP)_{t-m} \\ & + \sum_{j=0}^p \varphi_6 (GDP^2)_{t-n} + \sum_{j=0}^p \varphi_7 (GDP^3)_{t-o} + \mu_t \end{aligned}$$

Here,  $\omega_1, \omega_2, \omega_3, \omega_4, \omega_5, \omega_6,$  and  $\omega_7$  signify the short-term coefficients, while  $\omega_0$  measures the constant term. Likewise,  $\varphi_1 - \varphi_7$  symbolize the long-term parameters. Furthermore,  $\Delta$  and  $\mu_t$  define the first difference and the error terms, respectively. The ARDL model utilized the F-bound test approach to observe the long-term co-integration in the study variables. Consequently,

this approach is based on two limits. First, we define the upper-bound limit, and second, we describe the lower-bound limit. Thus, if the calculated F-bound analysis coefficient is less than the lower limit, then it means there is no long-run co-integration. Moreover, an F-bound value greater than the upper limits indicates significant long-run co-integration in the data. Nonetheless, if the F-bound weights lie between the upper and lower bounds, the results are inconsequential (Pesaran et al., 2001). The ARDL-based error correction term can be specified as follows:

$$\begin{aligned} \Delta CO_{2t} = & \omega_0 + \omega_1 (CO_2)_{t-1} + \omega_2 (DHE)_{t-1} + \omega_3 (ECG)_{t-1} \\ & + \omega_4 (PCEU)_{t-1} + \omega_5 (GDP)_{t-1} + \omega_6 (GDP^2)_{t-1} \\ & + \omega_7 (GDP^3)_{t-1} + \gamma_1 ECT_{t-1} + \mu_t \end{aligned}$$

Here,  $ECT_{t-1}$  nominates the error correction term, which measures the adjustment speed of the dependent variable to gain an equilibrium level. The study engaged the Breusch–Godfrey serial correlation heteroskedasticity in the model. Furthermore, the cumulative sum of recursive residuals (CUSUM) and its square (CUSUMSQ) techniques are utilized to measure the stability of the ARDL model. At last, the study applied the canonical integration regression technique for robustness testing of the long-run results of the ARDL model.

## 4 Results and discussion

### 4.1 Unit root evaluation and co-integration analysis

This investigation has employed the Phillips–Perron (PP) and Augmented Dickey–Fuller (ADF) test (Dickey, D. and Fuller, W., 1979) to ascertain the stationary level of the study factors. The findings of these tests are given in Table 2, which state that complete elements are stationary at the 1st difference level. However, ECG is also stationary at the level, which specified that the stationary order of the study elements is mixed, and the ARDL approach is best to deal with this kind of data. This study used the bound test approach based on the F-test to evaluate the long-run co-integration in the data. The upshots of the bound test are exhibited in Table 3, which shows that the null hypothesis of no co-integration has been rejected

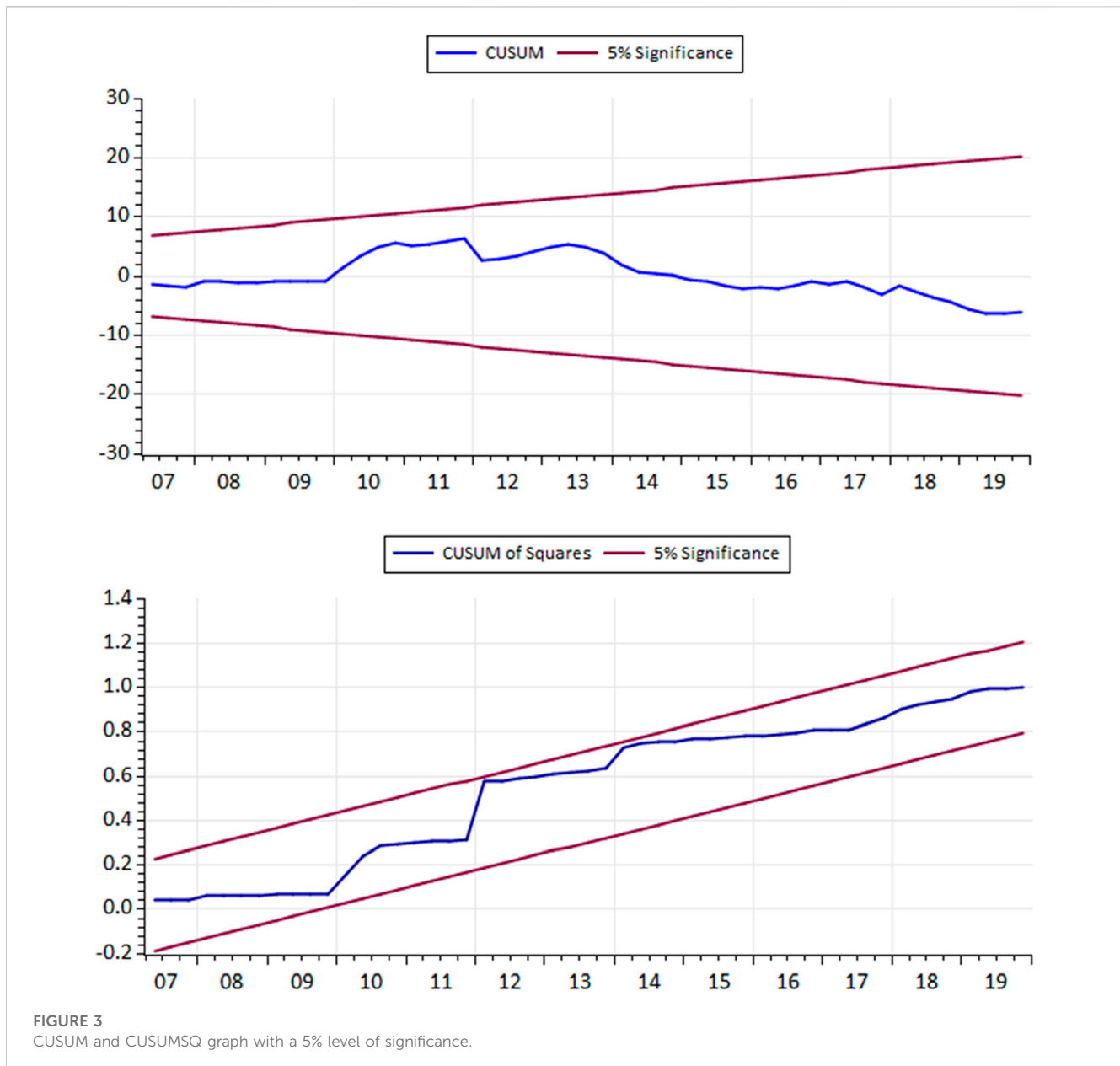


FIGURE 3  
CUSUM and CUSUMSQ graph with a 5% level of significance.

at a 5% significance level. Hence, the ARDL model can be utilized to examine the long- and short-run dynamics.

## 4.2 Long- and short-run dynamics

Table 4 displays the long-run and short-run dynamics among the study variables. The study demonstrated that one unit increase in GDP significantly increases the CO<sub>2</sub> emissions by 0.89 units implying that GDP positively effects the environmental degradation in China. However, after achieving the threshold level, the square of GDP (GDP<sup>2</sup>) revealed that one unit increase in GDP<sup>2</sup> lessens the CO<sub>2</sub> emission. Moreover, again, when GDP exceeds the threshold level, it increases environmental degradation as one unit increase in GDP<sup>3</sup> upsurges the CO<sub>2</sub> emissions by 0.909 units. Thus, as per the concept of Narayan and Narayan (2010), these findings demonstrated that there

is a long-term N-shaped relationship between economic growth and environmental degradation in China (see Figure 2). Additionally, in the short run, economic growth variables (GDP, GDP<sup>2</sup>, and GDP<sup>3</sup>) do not reveal a significant N-shape association with CO<sub>2</sub> emissions. Brajer et al. (2008) analyzed the city-wise data of China and documented that both an inverted U-shaped and N-shaped relationship exist between GHGs and economic growth in China. The study used SO<sub>2</sub> as a proxy for GHGs. Moreover, the study by Liu et al. (2021) also verified the existence of the EKC hypothesis in China in the presence of agricultural development. However, these findings do not match those of Etokakpan et al. (2021). In addition, the findings expressed that one unit increase in domestic general government health expenditures considerably improves the CO<sub>2</sub> emanation for the long period. Nevertheless, for the short-term era, DHE indicated a harmful and noteworthy influence on China's CO<sub>2</sub> emissions. These findings documented that action



TABLE 7 A causality analysis.

Null hypothesis	F-statistic	Probability
DHE does not Granger cause CO <sub>2</sub>	2.9496*	0.0592
CO <sub>2</sub> does not Granger cause DHE	4.51366**	0.0145
ECG does not Granger cause CO <sub>2</sub>	0.24309	0.7849
CO <sub>2</sub> does not Granger cause ECG	1.17734	0.3144
PCEU does not Granger cause CO <sub>2</sub>	5.02178***	0.0093
CO <sub>2</sub> does not Granger cause PCEU	1.60887	0.2077
GDP does not Granger cause CO <sub>2</sub>	0.14892	0.8619
CO <sub>2</sub> does not Granger cause GDP	0.51094	0.6023
GDP <sup>2</sup> does not Granger cause CO <sub>2</sub>	0.0513	0.9575
CO <sub>2</sub> does not Granger cause GDP <sup>2</sup>	2.91867*	0.0609
GDP <sup>3</sup> does not Granger cause CO <sub>2</sub>	0.04276	0.9582
CO <sub>2</sub> does not Granger cause GDP <sup>3</sup>	9.37838***	0.0003

Source: The author's calculation. Here, \*, \*\*, and \*\*\* represent the 10%, 5%, and 1% level of significance, respectively.

taken by the general government to improve health conditions also improves the environmental quality and discourages carbon dioxide emissions in China. These findings matched with the study of Chaabouni et al. (2016), Zeeshan (2021), and Bilgili et al. (2021).

This analysis inspected the effects of economic globalization on CO<sub>2</sub> emissions, which showed a negative but insignificant liaison with CO<sub>2</sub> emissions in the long run. Nonetheless, in the short run, it confirmed the positive association with CO<sub>2</sub> emissions. These findings imply that increasing the economic affiliation of China with other countries needs strict policies and strategies that can immensely control the import of polluted goods and services. These results are harmonized with the study of Ahmad M. et al. (2021). The results of PCEU stated that enlarging the energy consumption puts a significant burden on the environmental quality in China. Zhang and Lin (2012) and Wang et al. (2016) also explored the impact of energy consumption on CO<sub>2</sub> emissions in the presence of urbanization and economic growth and documented its imperious role for environmental degradation. The error correction term (ECT<sub>t-1</sub>) specified a negative indication with a value of -0.040 at a significance of a 1% level, implying that divergence occurred in the equilibrium of CO<sub>2</sub> emissions because of the independent elements engaged in the study will be accurate with the velocity of 4% in a quarter. Furthermore, the model signified that 96.3% of changes in CO<sub>2</sub> emissions are due to the study variables and 95.2% are because of significant factors among them. The Durbin-Watson value is 2.193, entailing that model is free from serial correlation.

The study also applied the canonical co-integrating regression (CCR) model for the robustness of the ARDL upshots. Table 5 illustrates the findings of the CCR model, which also confirms the existence of the N-shaped EKC in China. Hence, it discloses that the results generated through the ARDL model are correct and reliable. However, CCR showed an insignificant impact of PCEU.

### 4.3 Discussion and suggestions

In the analysis, we found that GDP has an encouraging effect on environmental degradation. However, GDP<sup>2</sup> designated a negative effect on environmental degradation, which documented that achieving a specific level of economic growth helps improve environmental quality. However, the excess of economic growth again degrades the environmental quality in China as GDP<sup>3</sup> represents a positive connection with CO<sub>2</sub> emissions. Consequently, it verifies the existence of an N-shaped EKC in China (see Figure 2). In addition, this investigation demonstrated that an increase in energy consumption adversely affects environmental quality and human health. Various studies such as those by Belke et al. (2011); Tang et al. (2016); and Ren et al. (2022) also confirmed that the increase in energy consumption boosts the economic activities and *per capita* income. In this situation, the study suggested that the government should focus on sustainable development through the installation of the green industry with the help of economic globalization. Moreover, the government should import the green technologies, improving the production process and discouraging pollutant technology use. Moreover, domestic investment in advanced technologies can also boost the final products' energy efficiency and effectiveness, enhancing environmental excellence. Short-term CO<sub>2</sub> emissions were also negatively impacted by domestic general government health expenditures. As a result, the government ought to spend more money on activities that boost health and directly discourage rising CO<sub>2</sub> emissions. In order to build institutes that improve health facilities and can advance environmental excellence, the government ought to make it easier for foreign companies to construct such facilities by providing tax breaks and duties.

## 4.4 Constancy assessment of the ARDL approach

Table 6 explains the findings of heteroskedasticity and serial correlation evaluation. The outcomes showed that the ARDL approach implemented in this investigation is unoccupied from heteroskedasticity and serial correlation. Moreover, CUSUM and CUSUMSQ lines are also under the limit of a 5% level of significance, meaning that the model is stable and consistent (Figure 3).

## 4.5 Causality evaluation

Table 7 shows the causality test results, which declare that DHE and CO<sub>2</sub> emissions have a bidirectional causation relationship with each other. It entails that a policy focusing the domestic general health expenditures will also impact the environmental excellence in China and *vice versa*. Moreover, the causality findings of economic growth made known that a remarkable causality effect is moving from CO<sub>2</sub> emissions to GDP<sup>2</sup> and GDP<sup>3</sup>, confirming that environmental excellence has a strong bond with economic growth and strategies regarding to control CO<sub>2</sub> emissions can improve economic activities. The examination carried out by Esso and Keho (2016) used the panel causality model and showed that a reverse causality was running from GDP to CO<sub>2</sub> emissions in several countries of Africa, although the study reported that GDP Granger caused the level of carbon emission in Nigeria. The outcomes of our causality test for economic growth are also in line with the study of Gorus and Aydin (2019). Furthermore, a unidirectional causality attachment of PCEU was documented in the examination, which corroborates that the use of energy causes the CO<sub>2</sub> emission augmentation. Mirza and Kanwal (2017) also employed the Granger causality model and highlighted that energy use and CO<sub>2</sub> emissions have a bi-variate causality affiliation. On the other hand, Nain et al. (2017) argued that the nature of causality affiliation between energy use and CO<sub>2</sub> emissions varies for different sectors.

## 5 Conclusion and policy implications

### 5.1 Summary

This study's critical objective is to analyze the N-shaped EKC in China in the presence of domestic general government health expenditures. Moreover, the investigators evaluated the role of OBOR by using the proxy variable of economic globalization on environmental degradation in China. Moreover, the investigation ascertained the impact of energy use on CO<sub>2</sub> emissions. The study utilized the quarter data from 2000 to 2019 and employed the autoregressive distributed lag model. Moreover, for the robustness of the findings, the study engaged the CCR model.

### 5.2 Key findings

The findings of the ARDL model discovered that an N-shaped relationship exists between economic growth and CO<sub>2</sub> emissions in China. Moreover, domestic general government health expenditures illustrated a negative impact on CO<sub>2</sub> emissions in the short run.

However, in the long run, it showed a constructive bonding with CO<sub>2</sub> emissions. Also, energy usage illustrated a direct impact on CO<sub>2</sub> emissions. The results of the CCR model also confirm the N-shaped EKC in China. Hence, these results successfully answered the queries mentioned in Introduction.

### 5.3 Policy implications

The investigation revealed that amplification in the energy usage heightens the environmental degradation in China. In addition, the study established that China's economic intensification and CO<sub>2</sub> discharge have an N-shaped association, implying that excess economic growth considerably discourages environmental excellence. Therefore, the study suggested that the Chinese government should promote the green industry through economic globalization in order to achieve sustainable development. In a similar vein, the Chinese government must encourage nations along the One Belt One Road to invest in and set up technological businesses that can clean the manufacturing process and improve environmental excellence. Green energy use, which directly reduces environmental degradation, should also be encouraged. The study found that health-promoting activities reduce carbon dioxide emissions. Hence, the Chinese government should increase the health budget and collaborate internationally to improve health-related activities in the country. This study also defines some limitations to achieving these outcomes; i.e., first, the data used in the study are from 2000 to 2019. Second, CO<sub>2</sub> emission is utilized to nominate the environmental deprivation. Furthermore, future studies can be conducted by including carbon and ecological footprints to represent the environmental deprivation. Furthermore, urbanization, financial development, environmental innovations, financial globalization, overall globalization, and ICT can be included in the model to verify these findings.

### Data availability statement

The data used in the study is online available at <https://data.worldbank.org/>.

### Author contributions

MN, MS, and KS: Conceptualization, methodology, software, formal analysis, investigation, resources, writing—original draft, and writing—review and editing. SZ: Supervision and funding.

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### Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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