



Bootstrap ARDL on Health Expenditure, CO₂ Emissions, and GDP Growth Relationship for 18 OECD Countries

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Using annual time-series data over the period 1975–2017, the researcher applied the bootstrap autoregressive-distributed lag (ARDL) cointegration model developed by McNown et al. (1) to examine whether there is a long run relationship among health expenditure, CO₂ emissions, and gross domestic product (GDP) per capita in 18 Organization for Economic Cooperation and Development (OECD) countries. We find cointegration exists in Netherlands when real GDP per capita serves as a dependent variable, in New Zealand when health expenditure is the dependent variable, and in the United States when CO₂ emissions are dependent variables. The main results show evidence of a short run relationship between the three variables. The empirical results support that there is a bidirectional causality between health expenditure and GDP growth for Germany and the United States, between CO₂ emissions and GDP growth for Canada, Germany, and the United States, and between health expenditure and CO₂ emissions for New Zealand and Norway. The results also indicate that there are unidirectional causality in other countries.

Keywords: health expenditure, CO₂ emissions, GDP growth, long run relation, bootstrap ARDL

INTRODUCTION

Climate change caused by increased greenhouse gas emissions not only causes temperature rise but also affects global precipitation. Climate change has become an indisputable fact that poses a serious threat to the sustainable development of human survival, society, economy, and the environment (2). There is an important link between high concentrations of greenhouse gases and climate change that there is the impact of climate change on public health. In recent decades, however, the relationship among economic growth, environment deterioration, and health expenditure has received increasing attention in the literature. Economic growth, environmental degradation, and health care expenditure vary between these relationships—complex and important. Therefore, the negative externalities of low environmental quality due to the impact on human health expenditure are ignored (3).

Health is one of the most important factors to decide the quality of human capital. There are many factors that can affect the health status of the population, such as environmental health, socioeconomic status, economic development, and the environment quality. As environmental

quality deteriorates, the deterioration of global environmental quality poses a serious challenge to healthy living. Particles from the burning of fossil fuels, sulfur dioxide, and CO₂ emissions are a major contributor to global climate change, and this has been a topic of policy makers and a focus of researchers in many different fields of research (4).

Most of the literature in the past examined the pairwise relationship CO₂ emissions, gross domestic product (GDP), and health expenditure. Over the past decade, the first empirical study is based on Grossman and Krueger (5), and a number of researchers have followed the Environmental Kuznets Curve (EKC) between economic growth and environmental quality (6–10). The second pairwise of empirical study shows that many researches have focused on the relationship between health expenditure and GDP (11–13). The majority of previous economists have studied to estimate the health care demand about the size of income elasticity and allocate health care resources. Finally, the third pairwise of empirical study was on the relationship between CO₂ emissions and health expenditure (3, 14, 15). There are many researchers focusing on one-way causation from CO₂ emissions to health expenditure and finding a positive relationship. However, only a limited number of empirical studies have concentrated on two-way causation between CO₂ emissions and health expenditure.

CO₂ emissions from Organization for Economic Cooperation and Development (OECD) countries account for half of global O₂ emissions, yet CO₂ emissions in OECD countries have been reduced since 2001. During this period, the OECD has made huge efforts to reduce CO₂ emission intensity. CO₂ emissions per unit of GDP decreased from 4.9 kg/USD in 2001 to 2.7 kg/USD in 2015. The share of CO₂ emissions in global CO₂ emissions also fell from 54% in 2001 to 38% in 2015 (13). Therefore, it is important to examine CO₂ emissions for health expenditures and economic development in OECD countries.

This article aims to examine the health, CO₂ emissions, and GDP growth nexus for 18 OECD countries by applying a bootstrap autoregressive-distributed lag (ARDL) test proposed by McNown et al. (1). This new method helps identify the occurrence of degenerate cases in ARDL tests. We, for the first time (compared to previous literature in OECD countries), used bootstrap models estimated by the ARDL test for long- and short-run relationships.

The main contribution of our research work to the existing studies is helpful for policy makers of OECD countries in particular and will provide some imperative understanding to other developed countries that include the 18 OECD countries. We used bootstrap ARDL approach for the long-run relationship and Granger causality tests to find directions of the links among the three variables. Therefore, this study aims at filling the gap in the literature by analyzing the health expenditure, CO₂ emissions, and GDP growth using the newly proposed econometric methodology to test.

The study will be separated into five sections. Section Literature presents a review of the literature. The data and methods used are described in section Materials and Methods. Section Results presents the results. Section Discussion has discussions. Section Conclusion concludes the research.

LITERATURE

The purpose of this study was to demonstrate the interaction between CO₂ emissions, health spending, and GDP growth in OECD countries. The pairwise correlation variables between the primary studies will be discussed.

CO₂ Emissions and GDP Growth

Most of the literature in the past concentrate on the relationship between environmental pollution and economic growth. First, the previous study was done to test the validity of the EKC hypothesis, which assumes that the relationship between economic growth and the environment is in the form of an inverted U. Selden and Song (9) used a nation's panel of data and the results confirm the inverted U. This hypothesis, however, was first proposed by Grossman and Krueger (5), where environmental degradation increases proportionally to income, then reaches a certain threshold when income reaches a stable point and then begins to decrease. Holtz-Eakin and Selden (16) examined marginal propensity to emit (MPE) and found that a diminishing MPE carbon dioxide as GDP per capita rises. Some authors (17–20) have reported the existence of the EKC hypothesis. Not all results support the EKC hypothesis. Cole et al. (21) have found evidence against the EKC hypothesis.

Using the cointegration technique of ARDL bound test and Graeger causality, Halicioglu (22) examined the feedback hypothesis between CO₂ emissions and economic expansion for Turkey. Saboori et al. (23) utilized ARDL bound approach to study the causal relationship between GDP growth and CO₂ emissions for Malaysia and found unidirectional causality from GDP growth to CO₂ emissions. Saboori and Sulaiman (24) determined a significant relationship between CO₂ emissions and economic growth that supported the EKC hypothesis in Singapore and Thailand for the long run. Jebli et al. (25) found that two-way causalities existed in the long run between CO₂ emissions and economic growth for 25 OECD countries. Cai et al. used the application of the newly introduced bootstrap ARDL bound test with structural breaks to examine the relationship among clean energy consumption, economic growth, and CO₂ emissions. They found the existence of a long-term and short-term relationship between economic growth and CO₂ emissions for the G7 nations (6).

Health Expenditures and GDP Growth

The second part focuses on health expenditures and GDP growth. Much of the previous research has focused on estimating the impact of health care income elasticity on scale, except for distribution of health care resources.

Gerdtham and Löthgren test the cointegration between health expenditure and GDP in the 25 OECD nations for the period 1960–1997. The outcomes revealed that health expenditure and GDP are cointegrated for the 12 OECD nations (26). Baltagi and Moscone (27) also considered OECD countries using a panel of data to reconsider the long-run relationship between health care expenditure and income for the period 1971–2004. Their findings suggest that health care, a necessity, is in elastic demand.

Wang applied the quantile panel-type analysis to determine the causality between health expenditure and economic growth from 1986 to 2007. The findings indicated that the estimation of quantile regression of the effect of health expenditure growth on economic growth is different (28). Albuiescu et al. utilized health care spending for six EU member countries for the time period 1972–2013. The findings indicated that no significant convergence occurred with regard to the ratio of health care expenditure to GDP (29). Erçelik and Murthy and Okunade used ARDL to estimate the relationship between health expenditure and economic growth (30, 31).

Health Expenditures and CO₂ Emissions

The third research strand on the issue that has limited literature regarding the relationship between CO₂ emissions and health expenditure discusses the relationship between environmental pollution (carbon emissions) and health expenditure.

Yazdi et al. (3) applied the ARDL approach to investigate carbon monoxide and sulfur oxide that have a positive relationship on health expenditures. Beatty and Shimshack used a cohort analysis to study relationships between carbon monoxide exposure and children's health outcome. They find that the increase in carbon monoxide resulted in positive and significant increases in children's health treatment (32). Boachie et al. in Ghana utilized health care expenditure for the time period 1970–2008. The finding revealed that a negative relationship exists between health care expenditure and CO₂ emissions (14). According to the result presented in the study by Chaabouni et al. and Chaabouni and Saidi found that the low-income group countries have unidirectional causality from CO₂ emissions to health expenditure (33, 34). Lu et al. (15) verified a negative effect of CO₂ emissions and other pollutants on human health in 30 Chinese provinces.

Only a few studies have focused on the relationship among health expenditures, CO₂ emissions, and economic growth. Chaabouni et al., Chaabouni and Saidi, and Chaabouni and Abdnnadher provide evidence of causality among health expenditures, CO₂ emissions, and economic growth (33–35). Zaidi and Saidi showed a one-way causal relationship from health expenditure to GDP and a two-way causal relationship between health expenditure and CO₂ emissions in sub-Saharan African countries (36). Ghorashi and Rad applied dynamic simultaneous equation model to investigate health expenditures, CO₂ emissions, and economic growth in Iran. The empirical findings supported the presence of two-way causality flowing among CO₂ emissions and economic growth and one-way causality from health expenditure to economic growth (37). Wang (28) used the ARDL model for the time period 1995–2017 to examine the dynamic linkages among CO₂ emissions, health expenditures, and economic growth in Pakistan. The results of their empirical study show a long-run relationship among the three variables and a two-way relationship of causality between health expenditure and CO₂ emissions and between health expenditure and economic growth, as well as a one-way causal relationship from CO₂ emissions to health expenditure.

MATERIALS AND METHODS

This study covers 18 OECD countries between 1975 and 2017. The 18 OECD countries selected for this study are Australia, Austria, Belgium, Canada, Denmark, Finland, Germany, Ireland, Japan, Netherland, New Zealand, Norway, Portugal, Spain, Sweden, Turkey, the United Kingdom, and the United States. Real GDP per capita (GDP) are obtained from the World Development Indicators, World Bank. Per capita real health expenditure (HE) in U.S. PPP dollars older came from OECD Statistics. CO₂ emissions (CO₂) data are retrieved from The BP Statistical Review of World Energy (available at: <http://www.bp.com/>). All variables are transformed into natural logarithm form.

Research Framework

The ARDL model is as follows:

$$y_t = c + \sum_{i=1}^k \alpha_i y_{t-i} + \sum_{j=0}^k \beta_j x_{t-j} + \sum_{j=0}^k \gamma_j z_{t-j} + \sum_{h=0}^p \lambda_j S_{t,j} + \mu_t \quad (1)$$

i and j are the indicators of the lag period, $i = 1, 2, \dots, k$; $j = 0, 1, \dots, k$; $h = 0, 1, \dots, p$. t represent time $t = 1, 2, \dots, T$. The y_t in the equation is the explanatory variable, x_t and z_t are the explanatory variables, and the variable $S_{t,j}$ is a dummy variable. The parameters α_i , β_i , and γ_i are the coefficients of the lag of y_i , x_i , and γ_i . The error term is μ_t , and Equation (2) can be rewritten and expanded into the following equation:

$$\Delta y_t = c + \sum_{i=1}^{k-1} a_{1,i} \Delta y_{t-i} + \sum_{j=1}^{k-1} a_{2,i} \Delta x_{t-i} + \sum_{j=1}^{k-1} a_{3,i} \Delta z_{t-i} + \sum_{h=1}^p b_j D_{t,j} + b_1 y_{t-1} + b_2 x_{t-1} + b_3 z_{t-1} + \varepsilon_t \quad (2)$$

where $b_1 = -1 + \sum_{i=1}^k \alpha_i$, $b_2 = \sum_{i=0}^k \beta_i$, $b_3 = \sum_{i=0}^k \gamma_i$ and other parameters are the function values of the original parameters in Equation (1).

McNown et al. showed the bootstrap method to the ARDL tests of cointegration and proposed a cointegration that requires rejecting the F -test (denoted as F') $H_0: b_1 = b_2 = b_3 = 0$ and the other F -test (denoted as F'') $H_0: b_2 = b_3 = 0$; t -test on the lagged dependent variable $H_0: a_1 = 0$ (28). They showed that two degenerate situations can arise. Situation 1 occurs when F' and t are significant but F'' is not significant. In this situation, the joint significance of the error correction terms is due solely to the lag of the dependent variable. Thus, the explanatory variables are not part of the long-run cointegrating relation. The other situation, degenerate situation 2, occurs when F' and F'' are significant but t is not significant. McNown et al. added a test on the lagged independent variables (F -test denoted as F''') to complement the existing F' and t -tests for cointegration as proposed by Pesaran et al. (1, 38).

McNown et al. showed that the bootstrap ARDL test has better size and power properties than the asymptotic test in the ARDL bound test. After testing the long-term relationships, we concluded that short-run causal relationship will be determined

by standard Granger causality tests if there is no cointegration relationship among y , x and z . We used the Granger causality test for x and z , which should include the lagged difference on x or z , and we tested $a_{2,j} = 0$ or $a_{3,j} = 0$ in Equation (2). However, if there is cointegration between the dependent variable and the independent variable, they will form a fixed linear combination. In this case, the short-term relationship test should include the hysteresis difference of x or z and the hysteresis level of x or z , that is, test $a_{2,j}$ and b_2 or $a_{3,j}$ and b_3 .

RESULTS

The ARDL bound test allows the variables with different orders of integration [I(0) or I(1), not for I(2)] (29). The Augmented Dickey–Fuller (ADF), Kwiatkowski–Phillips–Schmidt–Shin (KPSS), and Zivot–Andrews (ZA) unit root tests were employed to test the integration level (39–41). We found that all series have a unit root at 5% level of significance, but all variables are stationary in the first differences when AD, KPSS, and ZA tests are used. To conserve space, the unit root test results are not shown here.

Bootstrap ARDL Test (Long Run) With Structural Breaks

Table 1 provides the results of the Bootstrap ARDL tests. This study uses the two F -test (F_c' and F_c'') and one T -test (t_c) as critical values for determining the long-run forcing variable found in McNown et al. We believe that only several estimated equations are able to reject the null hypothesis of the t -test and both F -tests simultaneously. We could only find cointegrated evidence for Netherlands when GDP serves as the dependent variable, for New Zealand when health expenditure is the dependent variable, and for the United States when CO₂ emission is the dependent variable. Degenerated case 2 also occurs for Finland, where both the F' -test and F'' -test are statistically significant but not the t -test. Besides, we believe that no cointegration can be revealed by bootstrap ARDL test among the GDP, health expenditures, and CO₂ emissions for Australia, Austria, Belgium, Canada, Denmark, Germany, Ireland, Japan, Norway, Portugal, Spain, Sweden, Turkey, and the United Kingdom. Although not many countries show a long-run relationship between GDP, health expenditures, and CO₂ emissions, however, some causality patterns are identified in the short run.

Short-Run Granger Causality Test

Based on the results from ARDL cointegration test, we test the causality among the variables for 18 OECD countries by standard Granger causality test to indicate the casual relationship among health expenditure, GDP growth, and CO₂ emissions. From **Table 2**, we can see that a feedback exists between health expenditure and GDP, between health expenditure and CO₂ emissions, and between CO₂ emissions and GDP.

We find a two-way Granger causality running between health expenditure and GDP for Germany and the United States. This finding supports the past empirical studies (42–44). The

results from Granger causality tests indicate the existence of bidirectional causality between health expenditure and CO₂ emissions for New Zealand and Norway. Studies look at the causal relationship between health expenditures and GDP growth that, in most of these countries, have bidirectional causality (35). We report the causal link between CO₂ emissions and GDP growth for Canada, Germany, and the United States by employing a bootstrap ARDL approach. In the short running analysis, many studies also find evidence to support the two-way Granger causality between CO₂ emissions and GDP growth (28, 37, 45, 46).

There was unidirectional causality running from GDP to health expenditures for Belgium, Denmark, Finland, New Zealand, Sweden, Portugal, and Spain. The short-run relationship Granger causality was found from health expenditure to CO₂ emissions for Austria, Belgium, Sweden, and the United Kingdom, and from CO₂ emissions to health expenditures in Germany, Ireland, Japan, Netherlands, and the United States, and these countries exhibit only unidirectional causality. In the short run, it is unidirectional causality. Granger causality tests indicate that CO₂ emissions Granger causes GDP in Finland and Netherlands, and GDP Granger causes CO₂ emissions in Australia, Denmark, Japan, Spain, Sweden, and the United Kingdom.

DISCUSSION

The overall results revealed that there is no long-run relationships in the 18 OECD countries. There is no long-run relationship among health expenditures, CO₂ emissions, and GDP growth that we support Atay and Ergun that we get the same result in Turkey (40). Wang et al. found a long-run relationship among CO₂ emissions, health expenditure, and GDP in Pakistan (47). The researchers examined health expenditure, environmental pollution (CO₂ emissions; nitrous oxide emissions), and GDP growth and indicated the long-run relationship among them in the sub-Saharan African countries (36). We only report a long-run relationship among health expenditure, CO₂ emissions, and GDP growth in Netherlands, New Zealand, and the United States. There is important available that examined the link between health expenditure, CO₂ emissions, and GDP growth in Netherlands, New Zealand and the United States.

Furthermore, we also estimated the Granger causality based on the ARDL model. The short-run relationship among the three variables, the coefficient value for CO₂ emissions, reports a positive and significant effect with health expenditures in Ireland, Netherlands, United States, New Zealand, and Norway that means CO₂ emissions increase health expenditures. The important policy is that the government actively limits carbon emissions because environmental pollution will increase health expenditures. The coefficient for GDP growth is showing the positive and significant effect between GDP and health expenditures, which shows that in the short run, the increasing level of GDP increases health expenditures. GDP growth sacrifices health factors because economic development may

TABLE 1 | Cointegration results: health expenditures (HE), CO2 emissions (CO₂), and gross domestic product (GDP) growth.

Country	DV IV	Dummy variables	F'	F' _C	t	t _C	F''	F'' _C	Result
Australia (1)	HE GDP,CO ₂	D83, D93, D99, D12	2.223	3.826	-2.142	-2.787	3.330	3.439	Non-cointegration
	GDP HE, CO ₂	D83, D05	-2.483	4.548	-2.606	-3.109	2.203	5.984	Non-cointegration
	CO ₂ GDP, HE	D81, D87, D94, D04	2.554	3.081	-1.246	-2.341	1.425	3.674	Non-cointegration
Austria (1)	HE GDP,CO ₂	D87, D93, D04	0.628	2.509	-0.895	-1.249	0.588	2.787	Non-cointegration
	GDP HE, CO ₂	D90, D04	3.388	3.767	-2.921	-2.434	3.535	4.072	Non-cointegration
	CO ₂ GDP, HE	D95	2.899	4.249	-1.981	-3.100	4.001	5.605	Non-cointegration
Belgium (2)	HE GDP,CO ₂	D81, D90, D99, D08	1.498	2.874	-0.164	-1.751	1.899	3.164	Non-cointegration
	GDP HE,CO ₂	D90, D04	3.060	3.473	-2.982	-2.453	3.302	4.168	Non-cointegration
	CO ₂ GDP, HE	D82, D90, D96, D11	0.664	3.569	-0.454	-2.404	0.341	4.368	Non-cointegration
Canada (2)	HE GDP,CO ₂	D85, D91, D98, D06	1.267	3.151	-1.443	-2.300	1.373	3.654	Non-cointegration
	GDP HE,CO ₂	D04	1.821	4.763	-2.301	-3.157	2.432	6.149	Non-cointegration
	CO ₂ GDP, HE	D88, D97	1.892	3.256	-1.340	-2.338	2.706	3.603	Non-cointegration
Denmark (1)	HE GDP,CO ₂	D93, D01, D07	2.001	2.714	0.731	-1.839	2.226	2.919	Non-cointegration
	GDP HE,CO ₂	D90, D04	3.744	4.467	-3.300	-3.042	4.850	5.121	Non-cointegration
	CO ₂ GDP, HE	D09	2.101	4.459	-1.982	-3.008	3.150	5.189	Non-cointegration
Finland (2)	HE GDP,CO ₂	D81, D90, D03, D09	0.661	2.987	0.137	-2.174	0.985	3.488	Non-cointegration
	GDP HE,CO ₂	D87, D03	3.032	3.288	-2.372	-2.238	4.549	3.471	Non-cointegration
	CO ₂ GDP, HE	D94, D12	2.086	4.336	0.284	-2.958	2.944	5.487	Non-cointegration
Germany (3)	HE GDP,CO ₂	D84, D99, D08	2.052	2.786	-2.308	-1.402	2.434	2.973	Non-cointegration
	GDP HE,CO ₂	D87, D04	2.198	2.906	-2.374	-1.739	2.016	2.921	Non-cointegration
	CO ₂ GDP, HE	D82, D92, D99, D07	2.528	3.044	-2.349	-2.019	3.480	3.232	Non-cointegration
Ireland (1)	HE GDP,CO ₂	D95, D03, D09	2.644	4.269	-1.118	-2.719	3.517	5.372	Non-cointegration
	GDP HE,CO ₂	D90, D96, D04	3.803	4.897	-3.108	-3.339	5.632	6.194	Non-cointegration
	CO ₂ GDP, HE	D86, D96, D02, D11	0.292	3.867	-0.129	-2.493	0.188	4.672	Non-cointegration
Japan (3)	HE GDP,CO ₂	D83, D92, D00, D10	1.349	2.735	-0.674	-1.631	1.237	2.802	Non-cointegration
	GDP HE,CO ₂	D81, D87, D93, D08	0.999	3.763	0.146	-2.259	0.451	3.625	Non-cointegration
	CO ₂ GDP, HE	D90, D96	2.243	4.986	-2.071	-3.329	3.339	6.571	Non-cointegration
Netherland (1)	HE GDP,CO ₂	D81, D88, D99, D06	1.678	3.028	-0.338	-2.068	1.588	3.287	Non-cointegration
	GDP HE,CO ₂	D90, D04	7.207	4.846	-4.605	-3.339	9.427	5.490	Cointegration
	CO ₂ GDP, HE	D91	0.632	3.593	-0.756	-2.478	0.617	4.229	Non-cointegration
New Zealand (2)	HE GDP,CO ₂	D81, D97, D05	5.012	4.096	-3.024	-2.733	7.260	5.226	Cointegration
	GDP HE,CO ₂	D82, D04	4.741	4.859	-3.258	-3.119	6.492	5.663	Non-cointegration
	CO ₂ GDP, HE	D84, D90, D01	1.829	3.117	1.015	-2.054	2.044	3.176	Non-cointegration
Norway (1)	HE GDP,CO ₂	D86, D94, D02	0.566	2.631	-0.803	-1.410	0.284	2.799	Non-cointegration
	GDP HE,CO ₂	D90, D03	2.195	3.717	-2.537	-2.694	2.261	3.718	Non-cointegration
	CO ₂ GDP, HE	D94	1.840	4.406	-2.046	-3.143	2.038	5.393	Non-cointegration
Portugal (1)	HE GDP,CO ₂	D83, D00	2.703	3.824	-1.128	-2.766	2.043	3.992	Non-cointegration
	GDP HE,CO ₂	D82, D04	2.612	5.095	-1.839	-3.453	0.200	5.401	Non-cointegration
	CO ₂ GDP, HE	D81, D89, D95, D10	1.844	3.040	-2.139	-2.305	0.855	3.406	Non-cointegration
Spain (1)	HE GDP,CO ₂	D03	1.210	3.976	-0.123	-2.774	1.743	4.613	Non-cointegration
	GDP HE,CO ₂	D81, D87, D04	2.651	4.876	-2.562	-3.307	0.915	5.901	Non-cointegration
	CO ₂ GDP, HE	D89, D97	0.249	4.127	-0.740	-2.880	0.018	4.998	Non-cointegration
Sweden (1)	HE GDP,CO ₂	D86, D00, D06, D12	0.556	3.516	-0.896	-2.209	0.807	3.425	Non-cointegration
	GDP HE,CO ₂	D82, D04	1.642	3.991	-2.216	-2.680	1.284	4.377	Non-cointegration
	CO ₂ GDP, HE	D81, D09	2.972	4.267	-1.989	-2.917	2.536	5.422	Non-cointegration
Turkey (1)	HE GDP,CO ₂	D85, D94, D00	1.705	3.198	-1.821	-1.878	1.584	3.484	Non-cointegration
	GDP HE,CO ₂	D84, D94, D00	2.177	3.922	-0.517	-1.187	0.718	4.817	Non-cointegration
	CO ₂ GDP, HE	D85, D95, D06, D12	0.622	2.759	0.039	-2.045	0.729	3.199	Non-cointegration
United Kingdom (2)	HE GDP,CO ₂	D92, D02, D12	1.449	3.079	-1.085	-1.904	1.569	3.306	Non-cointegration
	GDP HE,CO ₂	D88, D97, D03	2.512	4.279	-2.607	-2.978	3.286	5.391	Non-cointegration
	CO ₂ GDP, HE	D81, D09	0.801	4.059	-0.741	-2.619	1.065	5.365	Non-cointegration
United States (4)	HE GDP,CO ₂	D83, D91, D02	2.134	5.569	-1.253	-3.145	1.148	7.243	Non-cointegration
	GDP HE,CO ₂	D85, D96, D04	2.851	5.131	-2.617	-2.642	4.150	6.265	Non-cointegration
	CO ₂ GDP, HE	D88, D94, D00, D09	4.599	3.787	-2.267	-2.064	6.838	4.441	Cointegration

The parentheses is optimal lag order based on Akaike Information Criterion (AIC). D84 means a dummy variable for the year 1984; other years are 0. F' is the F-statistics for the coefficients of HE_{t-1}, GDP_{t-1} and CO_{2,t-1}; t_{dep} is the t-statistics for the dependent variable, and F'' is the F-statistics for the independent variable. F'_C, t_C and F''_C are the critical values at the 10% significance level, generated from the bootstrap program. Bold value represents Cointegration results.

TABLE 2 | Granger causality results: health expenditures, CO₂ emissions, and gross domestic product (GDP) growth.

Country	Variables	HE equation	GDP equation	CO ₂ equation
		<i>F</i> -statics, (<i>p</i> -value) (Sign)	<i>F</i> -statics, (<i>p</i> -value) (Sign)	<i>F</i> -statics, (<i>p</i> -value) (Sign)
Australia	Health expenditures	–	1.032 (0.310) (+)	–0.603 (0.537) (–)
	GDP	0.015 (0.988) (+)	–	–2.089 (0.000) ** (–)
	CO ₂	–0.780 (0.441) (–)	0.409 (0.685) (+)	–
Austria	health expenditures	–	0.209 (0.836) (+)	1.843 (0.074)* (+)
	GDP	–1.325 (0.195) (–)	–	–0.434 (0.667) (–)
	CO ₂	0.540 (0.593) (+)	1.170 (0.251) (+)	–
Belgium	Health expenditures	–	0.059 (0.943) (–)	2.011 (0.154) (–)
	GDP	3.819 (0.035)** (+)	–	4.235 (0.025)** (–)
	CO ₂	0.696 (0.508) (+)	2.258 (0.123) (+)	–
Canada	Health expenditures	–	1.791 (0.185) (+)	2.372 (0.111) (+)
	GDP	0.791 (0.464) (–)	–	19.80 (0.000)*** (+)
	CO ₂	1.032 (0.370) (+)	3.325 (0.05)** (+)	–
Denmark	Health expenditures	–	0.235 (0.816) (+)	1.227 (0.229) (+)
	GDP	2.079 (0.046)** (+)	–	1.825 (0.077)* (+)
	CO ₂	–1.427 (0.593) (–)	–1.501 (0.136) (–)	–
Finland	Health expenditures	–	1.108 (0.344) (–)	1.332 (0.280) (+)
	GDP	3.348 (0.050)** (+)	–	1.117 (0.342) (+)
	CO ₂	1.039 (0.368) (+)	2.563 (0.095)* (+)	–
Germany	Health expenditures	–	6.889 (0.001)*** (–)	1.771 (0.182) (+)
	GDP	4.454 (0.013)** (–)	–	3.996 (0.020)** (–)
	CO ₂	1.268 (0.295) (–)	4.894 (0.008)*** (+)	–
Ireland	Health expenditures	–	–0.151 (0.881) (–)	0.396 (0.695) (+)
	GDP	–0.789 (0.195) (–)	–	–0.374 (0.711) (–)
	CO ₂	2.120 (0.042)** (+)	1.020 (0.315) (+)	–
Japan	Health expenditures	–	0.501 (0.685) (–)	1.579 (0.221) (–)
	GDP	0.492 (0.691) (+)	–	7.589 (0.001) *** (+)
	CO ₂	0.540 (0.793) (–)	0.498 (0.687) (–)	–
Netherland	Health expenditures	–	2.296 (0.117) (+)	–0.657 (0.516) (–)
	GDP	–0.061 (0.952) (–)	–	0.783 (0.439) (+)
	CO ₂	2.828 (0.008)*** (+)	4.464 (0.019) ** (+)	–
New Zealand	Health expenditures	–	1.321 (0.283) (+)	2.637 (0.089)* (–)
	GDP	2.307 (0.099)* (+)	–	0.394 (0.678) (+)
	CO ₂	5.622 (0.004)*** (+)	0.386 (0.683) (+)	–
Norway	Health expenditures	–	–0.467 (0.644) (–)	2.095 (0.044) ** (+)
	GDP	–1.648 (0.109) (–)	–	0.789 (0.436) (+)
	CO ₂	2.989 (0.005)*** (+)	0.347 (0.731) (+)	–
Portugal	Health expenditures	–	0.082 (0.935) (+)	1.237 (0.226) (+)
	GDP	5.028 (0.000) *** (+)	–	–0.679 (0.502) (–)
	CO ₂	–1.483 (0.148) (–)	1.007(0.321) (+)	–
Spain	Health expenditures	–	1.416 (0.259) (+)	1.087 (0.351) (+)
	GDP	3.657 (0.039)** (+)	–	3.070 (0.062)* (+)
	CO ₂	1.167 (0.326)(+)	2.240 (0.126) (+)	–
Sweden	Health expenditures	–	2.296 (0.117) (–)	2.507 (0.099) * (–)
	GDP	9.274 (0.000)*** (+)	–	0.363 (0.699) (–)
	CO ₂	1.013 (0.379) (–)	0.739 (0.487) (+)	–
Turkey	Health expenditures	–	1.291 (0.206) (+)	0.574 (0.570) (+)
	GDP	1.634 (0.112) (+)	–	0.133 (0.895) (+)
	CO ₂	–0.510 (0.6714) (–)	0.232 (0.818) (+)	–
United Kingdom	Health expenditures	–	1.604 (0.219) (–)	3.855 (0.033)** (–)
	GDP	1.192 (0.319) (–)	–	3.116 (0.060)* (–)
	CO ₂	0.502 (0.611) (+)	0.726 (0.493) (+)	–
United States	Health expenditures	–	4.591 (0.009) *** (+)	0.685 (0.612) (–)
	GDP	5.388 (0.005)*** (–)	–	2.604 (0.071) * (–)
	CO ₂	5.533 (0.004)*** (+)	3.644 (0.022) ** (–)	–

The asterisks ***, **, and * denote the significance at the 1, 5, and 10% levels, respectively. Additionally, the parentheses are *p*-value and sign for the coefficients. The case of non-cointegration and its causality test involved only lagged differenced variables. Bold value represents Granger causality results.

cause environmental pollution, and low-quality human capital forms more health losses. However, there do exist negative relations with short-run relationship running from GDP growth to health expenditures for a number of countries, including Germany and the United States. This may be the reason of the negative link between GDP and health expenditure for the case of Germany and the United States because human capital and institutional quality are in good condition. When growth increases, people's investment in physical exercise reduces the expenditure for health.

There are negative relations with short-run relationship from health expenditures to GDP growth for Germany but positive relations for the United States. Increasing health expenditures is associated with low productivity of human being because health creates disturbance for the economic growth (48). Health expenditures cannot lead to social security, efficient resource allocation, and better economies of scale in Germany (37). The human capital stock is positive and statistically significantly affects GDP growth in the United States (34). CO₂ emissions have a positive and significant relation to GDP growth in Finland, Netherlands, Canada, and Germany. These countries have a high intensity of CO₂ emissions due to the use of fossil fuels and rapid GDP growth. However, energy consumption and CO₂ emissions do not increase the GDP growth of the United States but have a negative effect.

This study has found that health expenditure has a significant and positive effect on CO₂ emissions at the level of 5% in Austria and Norway. In addition, CO₂ emissions are negatively and significantly affected by health expenditures in Belgium, Sweden, the United Kingdom, and New Zealand. There are two effects on health expenditures that affect carbon emissions. The effect of health expenditures is related to population growth, thus as long as population increases, the rise in energy consumption results in greater environment pollution (33). On the other hand, health expenditures increase people's awareness of pollution and reduce carbon emissions. The first effect is significantly larger than the second effect in Austria and Norway and vice versa in Belgium, the United Kingdom, and New Zealand. In addition, GDP has a positive and significant effect on CO₂ emissions in Canada, Denmark, Japan, and Spain but a negative effect on CO₂ emissions in the United Kingdom, Australia, Germany, and the United States.

CONCLUSIONS

This study contributes to the literature in the dynamic relationship among CO₂ emissions, health care expenditure, and GDP growth for the 18 OECD countries over the period of 1975–2017. We investigate the bidirectional causal relationship between health expenditure and GDP and between CO₂ emissions and GDP and between health expenditure and CO₂ emissions for the three ARDL models. The results show that the bootstrap ARDL analysis is useful in evaluating the effects of different socioeconomic scenarios in the context of different positions for health expenditure and environment policy in OECD countries.

Our study results showed that there is cointegration existing in Netherlands when real GDP per capita serves as the dependent variable, in New Zealand when health expenditure is the dependent variable, and in the United States when CO₂ emission is the dependent variable. The short-run relationship exists in a unidirectional causality relationship from CO₂ emissions to health expenditure for Germany, Ireland, Japan, Netherlands, and the United States and from health expenditure to CO₂ emissions for Austria, Belgium, Sweden, and the United Kingdom. There is a bidirectional causality relationship between health expenditure and CO₂ emissions in New Zealand and Norway. This empirical result supports previous researches (33, 34, 47). There is a unidirectional causality relationship from GDP to health expenditure for Belgium, Denmark, Finland, New Zealand, Sweden, Portugal, and Spain. There is a bidirectional causality relationship between GDP and health expenditure for Germany and the United States (42–44). It is unidirectional causality from CO₂ emissions to GDP for Finland and Netherlands, and GDP Granger causes CO₂ emissions for Australia, Belgium, Denmark, Japan, Spain, and the United Kingdom. Our study results showed the bidirectional causality relationship between Canada, Germany, and the United States (28, 37).

The most important policy of these OECD countries is to limit CO₂ emissions. In addition, these countries should adopt measures and policies to protect the quality of the environment to reduce the occurrence of health diseases. Environmental quality as a contributing factor to increased health spending has been proven. Our results demonstrate a significant increase in health spending on CO₂ emissions in Ireland, Netherlands, the United States, New Zealand, and Norway. In some countries, health factors are sacrificed because of GDP growth because economic development may cause environmental pollution and low-quality human capital will cause more health losses. For some economies, however, including Germany and the United States, Granger causality does have a negative correlation from GDP to health spending. This may be the reason for the negative relations between GDP and health expenditure in Germany and the United States, as institutional quality and human capital are in good condition. When growth increases, people's investment in physical exercise reduces health spending. Therefore, environmental degradation is becoming a contemporary issue, and we urgently need to reexamine health and environmental policies so that GDP growth should not increase at the expense of public health or the environment. Due to the consumption of fossil fuels by OECD countries, industrial and household natural resources contribute significantly to CO₂ emissions. It seems that policy makers should study the need for investment to promote technology transfer to protect environment quality.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

AUTHOR CONTRIBUTIONS

C-MW designed the research, performed the experiments, and wrote the paper. H-PH collected the data. FL analyzed the results. C-FW edited the paper.

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REFERENCES

- McNown R, Sam CY, Goh SK. Bootstrapping the autoregressive distributed lag test for cointegration. *Appl Econ*. (2018) 50:1509–21. doi: 10.1080/00036846.2017.1366643
- Muntean M, Guizzardi D, Schaaf E, Crippa M, Solazzo E, Olivier J, et al. *Fossil CO2 Emissions of All World Countries*. Luxembourg: Publications Office of the European Union (2018).
- Yazdi S, Zahra T, Nikos M. Public healthcare expenditure and environmental quality in Iran. In: *Recent Advances in Applied Economics*. (2014). Available Online at: <http://www.wseas.us/e-library/conferences/2014/Lisbon/AEBD/AEBD-17.pdf> (accessed January 12, 2018).
- Bank AD. *ADB Annual Report 2012*. Asian Development Bank (2013) Available online at: <https://www.adb.org/documents/adb-annual-report-2012> (accessed October 6, 2019).
- Grossman GM, Krueger AB. Economic growth and the environment. *Q J Econ*. (1995) 110:353–77. doi: 10.2307/2118443
- Cai Y, Sam CY, Chang T. Nexus between clean energy consumption, economic growth and CO2 emissions. *J Clean Prod*. (2018) 182:1001–11. doi: 10.1016/j.jclepro.2018.02.035
- List JA, Gallet CA. The environmental Kuznets curve: does one size fit all? *Ecol Econ*. (1999) 31:409–23. doi: 10.1016/S0921-8009(99)00064-6
- Pata UK. Renewable energy consumption, urbanization, financial development, income and CO2 emissions in Turkey: testing EKC hypothesis with structural breaks. *J Clean Prod*. (2018) 187:770–9. doi: 10.1016/j.jclepro.2018.03.236
- Selden TM, Song D. Environmental quality and development: is there a Kuznets curve for air pollution emissions? *J Environ Econ Manag*. (1994) 27:147–62. doi: 10.1006/jeem.1994.1031
- Stern DI, Common MS. Is there an environmental Kuznets curve for sulfur? *J Environ Econ Manag*. (2001) 41:162–78. doi: 10.1006/jeem.2000.1132
- Chen W-Y. Health progress and economic growth in the USA: the continuous wavelet analysis. *Empir Econ*. (2016) 50:831–55. doi: 10.1007/s00181-015-0955-6
- Fogel RW. New sources and new techniques for the study of secular trends in nutritional status, health, mortality, and the process of aging. *Hist Methods J Quant Interdiscip Hist*. (1993) 26:5–43. doi: 10.3386/h0026
- Liu Y-H, Chang W-S, Chen W-Y. Health progress and economic growth in the United States: the mixed frequency VAR analyses. *Qual Quant*. (2019) 53:1895–911. doi: 10.1007/s11135-019-00847-z
- Boachie MK, Mensah IO, Sobiesuo P, Immurana M, Iddrisu A-A, Kyei-Brobby I. Determinants of public health expenditure in Ghana: a cointegration analysis. *J Behav Econ Finance Entrep Acc Transp*. (2014) 2:35–40. doi: 10.12691/jbe-2-2-1
- Lu Z-N, Chen H, Hao Y, Wang J, Song X, Mok TM. The dynamic relationship between environmental pollution, economic development and public health: evidence from China. *J Clean Prod*. (2017) 166:134–47. doi: 10.1016/j.jclepro.2017.08.010
- Holtz-Eakin D, Selden TM. Stoking the fires? CO2 emissions and economic growth. *J Public Econ*. (1995) 57:85–101. doi: 10.1016/0047-2727(94)01449-X
- Akbostanci E, Türtüt-Aşik S, Tuğç GI. The relationship between income and environment in Turkey: is there an environmental Kuznets curve? *Energy Policy*. (2009) 37:861–7. doi: 10.1016/j.enpol.2008.09.088
- Bimonte S. Information access, income distribution, and the Environmental Kuznets Curve. *Ecol Econ*. (2002) 41:145–56. doi: 10.1016/S0921-8009(02)00022-8
- Lise W. Decomposition of CO2 emissions over 1980–2003 in Turkey. *Energy Policy*. (2006) 34:1841–52. doi: 10.1016/j.enpol.2004.12.021
- Fodha M, Zaghoud O. Economic growth and pollutant emissions in Tunisia: an empirical analysis of the environmental Kuznets curve. *Energy Policy*. (2010) 38:1150–6. doi: 10.1016/j.enpol.2009.11.002
- Cole MA, Rayner AJ, Bates JM. The environmental Kuznets curve: an empirical analysis. *Environ Dev Econ*. (1997) 2:401–16. doi: 10.1017/S1355770X97000211
- Halicioglu F. An econometric study of CO2 emissions, energy consumption, income and foreign trade in Turkey. *Energy Policy*. (2009) 37:1156–64. doi: 10.1016/j.enpol.2008.11.012
- Saboori B, Sulaiman J, Mohd S. Economic growth and CO2 emissions in Malaysia: a cointegration analysis of the environmental Kuznets curve. *Energy Policy*. (2012) 51:184–91. doi: 10.1016/j.enpol.2012.08.065
- Saboori B, Sulaiman J. CO2 emissions, energy consumption and economic growth in Association of Southeast Asian Nations (ASEAN) countries: a cointegration approach. *Energy*. (2013) 55:813–22. doi: 10.1016/j.energy.2013.04.038
- Jebli MB, Youssef SB, Ozturk I. Testing environmental Kuznets curve hypothesis: the role of renewable and non-renewable energy consumption and trade in OECD countries. *Ecol Indic*. (2016) 60:824–31. doi: 10.1016/j.ecolind.2015.08.031
- Gerdtham U-G, Löthgren M. New panel results on cointegration of international health expenditure and GDP. *Appl Econ*. (2002) 34:1679–86. doi: 10.1080/00036840110116397
- Baltagi BH, Moscone F. Health care expenditure and income in the OECD reconsidered: evidence from panel data. *Econ Model*. (2010) 27:804–11. doi: 10.1016/j.econmod.2009.12.001
- Wang K-M. Health care expenditure and economic growth: quantile panel-type analysis. *Econ Model*. (2011) 28:1536–49. doi: 10.1016/j.econmod.2011.02.008
- Albulescu CT, Oros C, Tiwari AK. Is there any convergence in health expenditures across EU countries? *Econ Bull*. (2017) 37:2095–101. Retrieved from: <https://ideas.repec.org/a/eb/ebull/eb-17-00577.html>
- Ercelik G. The relationship between health expenditure and economic growth in Turkey from 1980 to 2015. *J Polit Econ Manag*. (2018) 1:1–8. Retrieved from: <https://dergipark.org.tr/tr/pub/jopem/issue/36356/369537>
- Murthy VN, Okunade AA. Determinants of US health expenditure: Evidence from autoregressive distributed lag (ARDL) approach to cointegration. *Econ Model*. (2016) 59:67–73. doi: 10.1016/j.econmod.2016.07.001
- Beatty TK, Shimshack JP. Air pollution and children's respiratory health: a cohort analysis. *J Environ Econ Manag*. (2014) 67:39–57. doi: 10.1016/j.jeem.2013.10.002
- Chaabouni S, Zghidi N, Mbarek MB. On the causal dynamics between CO2 emissions, health expenditures and economic growth. *Sustain Cities Soc*. (2016) 22:184–91. doi: 10.1016/j.scs.2016.02.001
- Chaabouni S, Saidi K. The dynamic links between carbon dioxide (CO2) emissions, health spending and GDP growth: a case study for 51 countries. *Environ Res*. (2017) 158:137–44. doi: 10.1016/j.envres.2017.05.041
- Chaabouni S, Abednadh C. The determinants of health expenditures in Tunisia: an ARDL bounds testing approach. *Int J Inf Syst Serv Sect*. (2014) 6:60–72. doi: 10.4018/ijiss.2014100104
- Zaidi S, Saidi K. Environmental pollution, health expenditure and economic growth in the Sub-Saharan Africa countries: Panel ARDL approach. *Sustain Cities Soc*. (2018) 41:833–40. doi: 10.1016/j.scs.2018.04.034
- Ghorashi N, Rad AA. CO2 emissions, health expenditures and economic growth in Iran: application of dynamic simultaneous equation models. *JCHR*. (2017) 6:109–16. Retrieved from: <https://pdfs.semanticscholar.org/4df6/4a73ad03b0605efcb216e95789c52645b9f3.pdf>

38. Pesaran MH, Shin Y, Smith RJ. Bounds testing approaches to the analysis of level relationships. *J Appl Econom.* (2001) 16:289–326. doi: 10.1002/jae.616
39. Dickey DA, Fuller WA. Likelihood ratio statistics for autoregressive time series with a unit root. *Econom J Econom Soc.* (1981) 1057–2. doi: 10.2307/1912517
40. Kwiatkowski D, Phillips PC, Schmidt P, Shin Y. Testing the null hypothesis of stationarity against the alternative of a unit root: how sure are we that economic time series have a unit root? *J Econom.* (1992) 54:159–78. doi: 10.1016/0304-4076(92)90104-Y
41. Zivot E, Andrews DWK. Further evidence on the great crash, the oil-price shock, and the unit-root hypothesis. *J Bus Econ Stat.* (2002) 20:25–44. doi: 10.1198/073500102753410372
42. Amiri A, Ventelou B. Granger causality between total expenditure on health and GDP in OECD: Evidence from the Toda–Yamamoto approach. *Econ Lett.* (2012) 116:541–4. doi: 10.1016/j.econlet.2012.04.040
43. Elmi ZM, Sadeghi S. Health care expenditures and economic growth in developing countries: panel co-integration and causality. *Middle-East J Sci Res.* (2012) 12:88–91. doi: 10.5829/idosi.mejsr.2012.12.1.64196
44. Mladenović I, Milovančević M, Mladenović SS, Marjanović V, Petković B. Analyzing and management of health care expenditure and gross domestic product (GDP) growth rate by adaptive neuro-fuzzy technique. *Comput Hum Behav.* (2016) 64:524–30. doi: 10.1016/j.chb.2016.07.052
45. Ghosh S. Examining carbon emissions economic growth nexus for India: a multivariate cointegration approach. *Energy Policy.* (2010) 38:3008–14. doi: 10.1016/j.enpol.2010.01.040
46. Cherni A, Jouini SE. An ARDL approach to the CO2 emissions, renewable energy and economic growth nexus: Tunisian evidence. *Int J Hydrog Energy.* (2017) 42:29056–66. doi: 10.1016/j.ijhydene.2017.08.072
47. Wang Z, Asghar MM, Zaidi SAH, Wang B. Dynamic linkages among CO2 emissions, health expenditures, and economic growth: empirical evidence from Pakistan. *Environ Sci Pollut Res.* (2019) 26:15285–99. doi: 10.1007/s11356-019-04876-x
48. Bedir S. Healthcare expenditure and economic growth in developing countries. *Adv Econ Bus.* (2016) 4:76–86. doi: 10.13189/aeb.2016.040202

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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