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# Exploring the link between $CO_2$ emissions, health expenditure, and economic growth in Türkiye: evidence from the ARDL model

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## Abstract

In recent times, the literature has seen considerable growth in research at the intersection of $CO_2$ emission, health expenditure, and economic growth. But looking at the literature, it appears that the relationship between health expenditures, $CO_2$ emissions, and economic growth is unclear. To resolve this uncertainty, this study was conducted with different data, countries, and methods. To this end, the present study analyzed the nexus between $CO_2$ emissions, health expenditure, and economic growth in Türkiye from 1975 to 2020 using the Autoregressive Distributed Lagged (ARDL) model developed by Pesaran et al. (J Appl Econ 16(3):289–326, 2001). The study reveals a connection between $CO_2$ emissions, health spending, and economic development in Türkiye over the long term. It also highlights a short-term correlation among these factors. The study indicates that a 1% increase in economic growth results in a 0.553 and 0.297 rise in $CO_2$ emissions in the short and long term, respectively. That is, it suggests that if economic growth in Türkiye doesn't involve renewable energy, it could negatively affect $CO_2$ emissions both in the short and long term. To address this, substantial efforts are needed to transition to low-carbon technologies like renewable energy and energy efficiency, aiming to reduce emissions and support long-term economic growth. The study further demonstrates that a 1% growth in health expenditure leads to a 0.124% decrease in $CO_2$ emissions over the long term. This implies that Türkiye's health sector could benefit from utilizing more renewable energy or using fossil fuels more efficiently. Additionally, the study warns that long-term population growth could negatively affect $CO_2$ emissions in Türkiye.


**Keywords** $CO_2$ emissions · Health expenditure · Economic growth · ARDL · Long run relation · Türkiye

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## 1 Introduction

In recent years, increasing greenhouse gases have become a global environmental problem that threatens people's ability to breathe freely (Mehmood et al., 2022). Increased greenhouse gas emissions influence precipitation and temperature elevation due to global climate change. Unavoidable climate change poses a grave threat to the long-run survival of people, society, the economy, and the environment (Muntean et al., 2018). The effects of climate change, high greenhouse gas concentrations, and public health effects of global warming are all significantly correlated (Wang et al., 2019a). Respiratory illnesses are caused by air pollutants like $CO_2$ and $SO_2$. Therefore, the public's health suffers as air pollution levels rise (Kayani et al., 2020; Li et al., 2019; Mujtaba & Shahzad, 2021). Burning fossil fuels and deforestation are two examples of human actions that produce $CO_2$, a greenhouse gas, into the atmosphere. A rising body of research indicates a connection between healthcare spending and carbon emissions, despite the fact that the two may not initially appear to be connected. For instance, the manufacture and delivery of medical supplies and medications, as well as the energy requirements of hospitals and other healthcare institutions, all contribute to the emission of $CO_2$. In addition, the growing need for healthcare services, which is being fueled in part by aging populations, might result in increased healthcare costs and, consequently, higher carbon emissions. On the other hand, as a result of the emission of several different air toxins into the atmosphere, increased economic growth, urbanization, and industrialization in both industrialized and developing countries have significantly worsened air quality. Besides, it is known that the deterioration in environmental conditions is associated with economic growth, and worsening in environmental conditions causes heart diseases, cancer, and respiratory diseases. The connection between environmental factors, population health, ecological conservation, public policy, and the price of healthcare services is becoming increasingly significant. While environmental pollution harms human health, it also negatively affects labor productivity (Dağ & Kızılkaya, 2021).

It has only lately come up for consideration how health, air quality, and economic growth are related. This literature may be divided into three research areas (Zaidi & Saidi, 2018). The first line concentrated on the connection between environmental preservation and economic expansion, a subject of several studies since 1960. Despite different findings from research on the relationship between the environment and economic growth, there is a widespread understanding that economic growth leads to environmental deterioration (Arouri et al., 2012; Dinda, 2004; Iwata et al., 2010; Jalil & Mahmud, 2009; Liu et al., 2019; Lotfalipour et al., 2010; Marrero, 2010; Mujtaba & Jena, 2021; Musibau et al., 2021; Pao & Tsai, 2010; Soytas et al., 2007; Wang et al., 2011). It has been discovered that $CO_2$ emissions and economic development have a complicated connection. Economic activity frequently results in higher energy consumption and industrial production; hence $CO_2$ emissions have generally been linked to economic expansion. According to some studies, when countries advance and become wealthy, they may also increase their investments in clean energy and energy efficiency, which can reduce emissions.

The relationship between environment and health expenditure is the subject of the second line (Burnett et al., 1998). Air pollution from carbon dioxide ($CO_2$), nitrogen oxides (NOX), sulfur dioxide ($SO_2$), and methane ($CH_4$) is blamed for environmental damage. Health and environmental issues have recently been discussed (Zaidi & Saidi, 2018). Research on the relationship between health and the environment is necessary due to the increase in infectious diseases brought on by air pollution and high temperatures (Béral-Guyonnet, 1996). Many ecosystems and the creatures that inhabit them are affected by climate change, but it also has an effect on human health.

The third line indicates how health and economic growth are related (Akram et al., 2008; Baltagi & Moscone, 2010; Bloom & Canning, 2003a, 2003b; Erçelik, 2018; Gerdtham & Löthgren, 2002; Lucian, et al., 2009; Murthy & Okunade, 2016; Rivera & Currais, 2003; Wang, 2011). Health is one of the most crucial components of human capital. People are more motivated and productive when they are in good physical and mental health, which helps with both their academic and professional lives. Because of this, this condition can help countries' economies flourish by improving the effectiveness of their people resources.

The literature, continuous economic growth and increases in health expenditures are linked to $CO_2$ emissions, but this relationship is complex and uncertain. To clarify this complex and uncertain relationship, this study is addressed with different data, countries, and methods. Therefore, the motivation of the current study is to contribute to the literature by observing the impact of health expenditure and economic growth on $CO_2$ emissions through the autoregressive-distributed lag (ARDL) test in Türkiye for the period 1975–2020. The major contribution of our research to the field is to be useful to decision makers in other developing countries, especially Türkiye, and to provide important information on reducing $CO_2$ emissions for developing countries such as Türkiye.

The paper is divided into five sections. An overview of the literature is given in Sect. 2. In Sect. 3, the data and techniques are explained. The results and comments are presented in Sect. 4, and the research is concluded in Sect. 5.

## 2 Literature review

The purpose of this study is to demonstrate the potential connection, if exists, between GDP growth, $CO_2$ emissions, and health expenditures in Türkiye. We'll focus on the pairwise correlation variables between the key researches. The literature review is organized into three sections: literature on $CO_2$ emissions and GDP growth, literature on $CO_2$ emissions and health expenditure, and literature on health expenditure and GDP growth.

### 2.1 The nexus between $CO_2$ emissions and economic growth

In recent decades, there has been a lot of discussion over the relationship between economic growth and $CO_2$ emissions. The Environmental Kuznets Curve (EKC) theory is investigated using several sorts of econometric techniques for various economies (Cai et al., 2018). Income and environmental pollution appear to have an inverted U-shape connection. Numerous investigations back up the EKC concept. The initial empirical analysis was based on Grossman and Krueger's work, and many scholars have examined the Environmental Kuznets Curve (EKC), which connects economic development to environmental quality. Gökmenoğlu and Taspinar (2016) examined the presence of the environmental Kuznets curve (EKC) hypothesis in Türkiye for the period 1974–2010 using carbon dioxide emissions and GDP growth with ARLD bound test and Toda-Yamamo causality. They find evidence for the EKC theory for $CO_2$ emissions in Türkiye. Similar to this, Apergis and Payne (2010) found that during the years 1992 to 2004, the panel vector error correction model demonstrated that the EKC hypothesis was true when looking at the relationship between $CO_2$ and GDP for eleven countries. Along the same lines, Ahmed and Long (2012), Kanjilal and Ghosh (2013), Bouznit and Pablo-Romero (2016), Shahbaz et al. (2013), Pata (2018), Suki et al. (2020), and He and Lin (2019) each discovered the presence of EKC. On the contrary, several researchers, such as Richmond and Kaufmann (2006), Begum et al. (2015), Pontarollo and Muñoz (2020), Mikayilov et al. (2018), Zhou et al. (2019), Robalino-López et al. (2015) did not find the presence of EKC hypothesis.

### 2.2 The nexus between $CO_2$ emissions and health expenditure

The second part focuses on $CO_2$ emission and health expenditures. Less research has been done on the connection between $CO_2$ emissions and health expenditures (Wang et al., 2019a). $CO_2$ emissions are regarded as a significant factor in the environmental issue, of their increased detrimental effects on public health. Using the ARDL bound test, Khoshnevis Yazdi and Khanalizadeh (2017) examine how environmental quality ($CO_2$ and $PM_{10}$) affects health expenditures in the Middle East and North Africa (MENA) area countries during the years 1995 to 2014. They demonstrate that a co-integrated panel of health expenditure, $CO_2$ emissions, and $PM_{10}$ emissions exists. Long-run elasticities indicate that $CO_2$ and $PM_{10}$ emissions have statistically significant positive impacts on health expenditures. Using the panel co-integration approach, When Narayan and Narayan (2008) investigated how environmental quality affected per capita health spending, they found that carbon monoxide emissions had a favorable impact on it in the short run. Long-run results demonstrate that sulfur oxide emissions, together with carbon monoxide emissions, have a statistically significant positive impact on healthcare expenditures. Similarly, Ullah et al. (2020), Wang et al. (2019b), and Blázquez-Fernández et al. (2019) found a positive effect of $CO_2$ on health expenditures. On the contrary, Boachie et al. (2014) find that health expenditure and $CO_2$ emissions in Ghana between 1970 and 2008 have a negative association. While investigating the impact of $CO_2$ and health expenditures, results discovered by Zaidi and Saidi (2018) indicate that increased $CO_2$ emissions negatively affect health expenditures in long run. Additionally, Bilgili et al. (2021) investigated the relationship between environmental pollution, economic growth, and public and private healthcare spending in 36 Asian countries. Spending on both private and public health can lower $CO_2$ emissions, according to the quantile regression results for the panel data. According to the study, improved environmental quality in Asian countries is a direct result of increased spending on healthcare services.

### 2.3 The nexus between health expenditure and GDP growth

The third part contains studies that look at the connection between GDP growth and health expenditures. The empirical study's third pairing shows that a variety of research techniques have been employed to look at the connection between GDP growth and health spending. Previous economists concentrated on methods for estimating healthcare demand and distributing resources according to income elasticity (Apergis et al., 2018; Wang et al., 2019a).

Wang et al. (2019a) evaluated the relationship between health expenditure and GDP using data from 1975 to 2017 using the ARDL technique and Granger causality application. They found a bidirectional causation for GDP growth in Germany and the United States. Similar research by Nasiru and Usman (2012) and Mehmood et al. (2014) shows a two-way association between health expenditures and economic growth. Using dynamic simultaneous equation models, Ghorashi and Rad (2017)looked at the correlation between health spending and GDP growth in Iran from 1972 to 2012. They found a one-way causal relationship between GDP growth and health spending. Using data from 1995 to 2005 for a sample of 13 MEAN countries, Mehrara et al. (2012) evaluated the stationarity and co-integration between health spending and GDP. They found that the unit root tests indicate that the two variables are not stationary. Despite this, the findings indicate a connection between GDP and health spending. They found that the proportion of health spending to GDP decreases as GDP rises. This suggests that healthcare is essential in MEAN countries. In a similar vein, Baltagi and Moscone (2010) investigated the relationship between health expenditure and GDP growth in a sample of 20 OECD countries. Because of the low coefficient of elasticity involved, the study's findings, which covered the years 1971–2004, show that spending on health is more of a need than a luxury. According to Wang (2011), more health spending has a long-term positive influence on GDP growth. Wang (2011) looked studied the relationship between health spending and GDP growth in 31 countries, including in the years 1986–2007. In contrast, Zaidi and Saidi (2018) showed through modeling the long run and short run using the estimating approach ARDL that economic growth has a favorable impact on health expenses. Gerdtham and Löthgren (2002) discovered that for 12 of the OECD conutries, health expenditure and GDP growth are co-integrated in their study of the co-integration between health spending and GDP growth in the 25 OECD countries from 1960 to 1997. Similar to this, Tang (2011) found that from 1970 to 2009, Malaysia's GDP and health spending were co-integrated.

## 3 Material and methods

### 3.1 Data

The study uses GDP per capita (GDP) (constant 2015 US$), health expenditure (HE) (US$ per capita), and population (Pop) (total) as independent variables, with $CO_2$ emissions ($CO_2$) (metric tons per capita) as a dependent variable. The natural logarithm form is applied to all variables. To ensure that the data were distributed regularly, this was done (Rjoub et al., 2021; Kirikkaleli et al., 2021). The variables, research abbreviations, and measurement methods are listed in Table 1. Additionally, Table 2 displays the variables' descriptive statistics.

### 3.2 Modeling and methodological framework

This study aims to investigate the relationship between health expenditures, $CO_2$ emissions, and economic growth using data for Türkiye from 1975 to 2020. By drawing on the methodologies of Zaidi and Saidi (2018), Apergis et al. (2018), Karaaslan and Çamkaya (2022), Wang et al. (2019a), and Wang et al. (2019b), In order to evaluate the dynamic link between $CO_2$, GDP, HE, and POP in Türkiye, this study creates a framework. The fundamental model is expressed as follows:

$$CO_{2t} = f\left(HE_t, GPD_t, POP_t\right) \tag{1}$$

The natural logarithms of the variables were employed to remove multicollinearity between the variables, resulting in the natural logarithmic transformation of Eq. 1 described above.

**Table 1** Variables

| Variable names | Abbre-viations | Measurement Proxies | Sources |
|---|---|---|---|
| Carbon dioxide emissions | $CO_2$ | $CO_2$ emissions in metric tons per capita | International Energy Agency |
| Health expenditure | HE | US$ per capita | OECD |
| Gross domestic product per capita | GDP | GDP per capita in constant 2015 US$ | World Development Indicators |
| Population | Pop | Total population | World Development Indicators |

$$lnCO_{2t} = \alpha + \beta_1 lnHE_t + \beta_2 lnGDP_t + \beta_3 lnPOP_t + \varepsilon_t \quad (2)$$

In Eq. (2), where $t$ stands for the years from 1975 to 2020, $CO_2$ for $CO_2$ emissions, *HE* for health expenses, *GDP* for gross domestic product per person, *POP* for the population, $\beta$ for coefficient and $\varepsilon$ for the error term.

### 3.3 Unit root test

Before checking for the existence of a co-integration relationship between the variables, the integration levels of the series should be defined. The augmented Dickey-Fuller (ADF) (1979) and Phillips-Perron (PP) (1988) unit root tests were used to ascertain the levels of integration of the variables in this investigation. The alternative hypothesis in these tests is that there is no unit root, which would imply that the series is stationary. According to the null hypothesis in these tests, there is a unit root, which suggests that the series is not stationary. The results of the unit root test are shown in Table 3.

None of the variables in the ADF and PP unit root tests are level stationary, except for POP. However, when the first difference between the variables is considered, they are all stationary. This illustrates that the variables' order of integration is a mixture of I (1) and I (0). These outcomes enable the use of the ARDL limit test.

### 3.4 The ARDL approach

The autoregressive distributed lag (ARDL) model, first introduced by Shin and Pesaran (1999) and developed by Pesaran et al. (2001), addresses single cointegration. The ARDL method has the benefit of allowing I(0) and I(1) variables in a set without requiring that they all be I(1) variables. The ARDL approach has been employed in most research, including the current study, because of its convenience. As a result, this method has been used to determine the series' long-term connection. Equation (2) can be rewritten as an ARDL formula as the model with intercept in Eq. (3) as follows:

$$\begin{aligned} \Delta lnCO_{2t} = & \alpha_0 + \sum_{i=1}^{p} \beta_1 \Delta lnCO_{2t-i} + \sum_{i=0}^{q} \beta_2 \Delta lnHE_{t-i} \\ & + \sum_{i=0}^{q} \beta_3 \Delta lnGDP_{t-i} + \sum_{i=0}^{q} \beta_4 lnPOP_{t-i} \\ & + \beta_5 lnCO_{2t-i} + \beta_6 lnHE_{t-i} + \beta_7 lnGDP_{t-i} + \beta_8 lnPOP_{t-i} + \varepsilon_t \end{aligned} \quad (3)$$

**Table 2** Descriptive statistics

| | $CO_2$ | HE | GDP | POP |
|---|---|---|---|---|
| Mean | 0.990722 | 5.633030 | 8.762019 | 17.91242 |
| Median | 1.029619 | 5.644243 | 8.711704 | 17.93873 |
| Maximum | 1.547563 | 7.173735 | 9.398680 | 18.24794 |
| Minimum | 0.405465 | 3.632494 | 8.265423 | 17.49620 |
| Std. Dev | 0.349238 | 1.097871 | 0.356285 | 0.223416 |
| Skewness | − 0.123614 | − 0.149357 | 0.352397 | − 0.246275 |
| Kurtosis | 1.758543 | 1.624075 | 1.909852 | 1.909445 |
| Jarque–Bera | 3.071147 | 3.799600 | 3.229888 | 2.744503 |
| Probability | 0.215332 | 0.149599 | 0.198902 | 0.253535 |
| Sum | 45.57321 | 259.1194 | 403.0529 | 823.9715 |
| Sum Sq. Dev | 5.488523 | 54.23947 | 5.712255 | 2.246169 |
| Observations | 46 | 46 | 46 | 46 |

The Bounds test is used to examine whether the variables have a long-term relationship. The alternative hypothesis ($H_1$: $\beta_5 \neq \beta_6 \neq \beta_7 \neq \beta_8$) contradicts the null hypothesis ($H_0$: $\beta_5 = \beta_6 = \beta_7 = \beta_8$), which implies that there is no cointegration. The null hypothesis will be rejected if the estimated F statistic is greater than the upper bound critical value I (1) for the number of explanatory variables (k) proposed by Pesaran et al. The null hypothesis cannot be proved if the F statistic is lower than the lower bound critical value I (0). The F statistic indicates uncertainty regarding cointegration when it is between I (0) and I (1). Alternative critical values I (0) and I (1), which are more suitable than those of small sample sizes, were proposed by Narayan. The optimal lag values $p$ and $q$ in Eqs. (3) and (4) are determined by model selection criteria such as Akaike (AIC) or Schwarz (SIC). Optimal $p$ and $q$ are implied by the model's minimal AIC or SIC. Additionally, the residuals of the model cannot have serial correlation. The model with the highest R-squared value or the smallest information criterion is the one that has the best estimation. Last but not least, the following equation estimates the short-run estimation of the ARDL model, also referred to as the error-correction model:

$$\begin{aligned}\Delta lnCO_{2t} =& \alpha_0 + \sum_{i=1}^{p}\beta_1 \Delta lnCO_{2t-i} + \sum_{i=0}^{q}\beta_2 \Delta lnHE_{t-i} \\ &+ \sum_{i=0}^{q}\beta_3 \Delta lnGDP_{t-i} + \sum_{i=0}^{q}\beta_4 \Delta lnPOP_{t-i} \\ &+ \beta_5 lnCO_{2t-i} + \beta_6 lnHE_{t-i} + \beta_7 lnGDP_{t-i} + \beta_8 lnPOP_{t-i} + \lambda ECM_{t-1} + \varepsilon_t\end{aligned} \tag{4}$$

The speed of adjustment parameter, also known as the coefficient of the error-correction term ($ECM_{t-1}$) $\lambda$ in Eq. (4), determines how quickly the series achieves long-run equilibrium. The model is put through diagnostic tests to ensure its suitability, including tests for serial correlation, normalcy, functional form, and heteroscedasticity. Brown et al. used stability tests such as the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) to determine whether the coefficients on the graphical representations were stable.

**Table 3** Unit root results

| *Variables* | Augmented Dickey-Fuller (ADF) | | | | Phillips-Perron (PP) | | | |
|---|---|---|---|---|---|---|---|---|
| | *Level* | | *First Difference* | | *Level* | | *First Difference* | |
| | t-stat | *p*-value | t-stat | *p*-value | t-stat | *p*-value | t-stat | *p*-value |
| *Health Expenditure (LnHE)* | −1.134 | 0.693 | −8.454*** | 0.000 | −1.215 | 0.659 | −8.235*** | 0.000 |
| *$CO_2$ Emission ($LnCO_2$)* | −0.934 | 0.768 | −7.907*** | 0.000 | −1.091 | 0.711 | −10.260*** | 0.000 |
| *Economic Growth (LnGDP)* | 0.458 | 0.983 | −6.635*** | 0.000 | 0.527 | 0.9859 | −6.635*** | 0.000 |
| *Population (LnPop)* | −3.702*** | 0.007 | – | – | −5.595*** | 0.000 | – | – |

*** indicates the significance levels of 1%

## 4 The empirical results

This study's main aim is to give empirical evidence of how health expenditure and economic growth affect $CO_2$ emissions. The study first uses the co-integration of bound test to analyze the data set, then long-run and short-run estimate findings, and lastly the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) test results are described.

We ran a bounds test using the following model specifications: unrestricted intercept and no trend (case III) based on the estimated ARDL model (4,6,4,6). Table 4 shows the estimated F test as well as the equivalent Narayan (2005) critical values for the lower and upper boundaries. According to the F computed values when compared to critical values, the null hypothesis of no cointegration is firmly rejected. This demonstrates that in Türkiye, there is a long-run link between $CO_2$, health spending, economic growth, and population.

Table 5 displays the long-run and short-run estimate findings. All of the coefficients (long-run estimates) are significant. Economic growth has a statistically significant positive effect on $CO_2$ emissions. Economic growth of 1% increased $CO_2$ emissions by 0.297. Previous research are supported by our empirical results (Ahmed & Long, 2012; Bouznit & Pablo-Romero, 2016; He & Lin, 2019; Kanjilal & Ghosh, 2013; Pata, 2018; Shahbaz et al., 2013; Suki et al. 2020)). These findings are consistent with Türkiye's growth trends because the manufacturing industry and transportation services are two essential areas that drive economic growth in Türkiye. The

**Table 4** Co-integration results of Bound testing

| Model | | k | F-statistics | Decision | Lower bound | Upper bound |
|---|---|---|---|---|---|---|
| ARDL(4,6,4,6) | | 3 | 8.930 | Yes | I(0) | I(1) |
| | 10% significance | | | | 2.893 | 3.983 |
| | 5% significance | | | | 3.535 | 4.733 |
| | 1% significance | | | | 4.983 | 6.423 |

Narayan (2005) provided the critical value constraints for lower I(0) and higher I(1). The following are the critical values for the boundaries test: Case III: unrestricted intercept and no trend (k = 3); the optimal lag duration is chosen automatically based on SC

**Table 5** Long-run and Short-run estimation results

| Variables | | Coefficient | Std. Error | t-Statistic | Prob |
|---|---|---|---|---|---|
| **Long-Run** | | | | | |
| *lnGDP* | | 0.297*** | 0.101 | 2.931 | 0.006 |
| *lnHE* | | −0.124** | 0.053 | −2.336 | 0.026 |
| *lnPop* | | 1.523*** | 0.244 | 6.239 | 0.000 |
| **Short-Run** | | | | | |
| **Variables** | | | | | |
| *C* | | −23.452*** | 3.737 | −6.276 | 0.000 |
| *D(lnGDP)* | | 0.553*** | 0.124 | 4.474 | 0.000 |
| *D(lnHE)* | | 0.037 | 0.050 | 0.753 | 0.457 |
| *D(lnHE (-1))* | | 0.161*** | 0.049 | 3.310 | 0.002 |
| *D(lnPop)* | | −5.880 | 5.361 | −1.097 | 0.281 |
| *D(lnPop (-1))* | | −12.909 | 11.392 | −1.133 | 0.266 |
| *D(lnPop) (-2))* | | 34.213*** | 11.739 | 2.914 | 0.007 |
| *D(lnPop) (-3))* | | −27.933*** | 6.470 | −4.317 | 0.000 |
| *ECM(-1)* | | −0.839*** | 0.134 | −6.269 | 0.000 |
| **Diagnostic tests** | | | | | |
| $R^2$ | 0.993 | | | | |
| Adjusted-$R^2$ | 0.990 | | | | |
| F-statistic | 405.041 (0.000) | | | | |
| DW | 1.952 | | | | |
| Jarque–Bera | 0.519 (0.771) | | | | |
| $x^2BPG$ | 0.617 (0.799) | | | | |
| $x^2LM$ | 0.051 (0.950) | | | | |
| $x^2Reset$ | 0.511 (0.480 | | | | |

Indicates the probability value in parentheses. ***, ** show that the variable are significant at the 1% and 5% levels

energy used in the manufacturing industry and transportation services in Türkiye is mostly nonrenewable (natural gas, hard coal, coke, oil, lignite, and similar). This arrangement assures that $CO_2$ emissions will rise in tandem with growth. In other words, it contributes to more pollution. What matters here is that renewable energy sources are prioritized over nonrenewable energy sources. Environmental pollution will be decreased as a result, as will steady growth.

In contrast, health investment boosts public awareness of pollution and reduces carbon emissions. Because the variable HE has a negative coefficient, $CO_2$ decreases by 0.124% for every 1% rise in HE. The results are explained in terms of the decreased influence of increased health-care costs on pollution. Contrary to Narayan and Narayan (2008), Ullah et al. (2020), Wang et al. (2019b), and Blázquez-Fernández et al. (2019), these results are in line with those of Boachie et al. (2014), Apergis et al. (2018), Bilgili et al. (2021), and Karaaslan and Çamkaya (2022). These results, our long-run elasticity estimates demonstrate that a rise in health care spending relative to GDP lowers $CO_2$ emissions. This is most likely because the health-care industry uses more renewable energy (like solar energy) and/or is more efficient at using fossil fuels than the other economic sectors. Population growth and health expenses are linked, therefore as the population rises, more energy is spent, increasing pollution. Our findings corroborate Türkiye's position. For every 1% increase in POP, $CO_2$ rises by 1.523%.

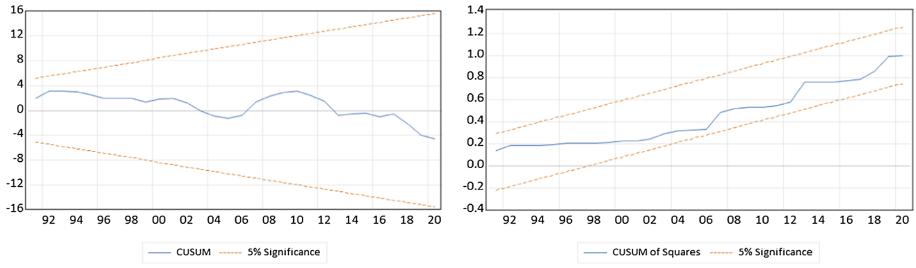


**Fig. 1** CUSUM and CUSUM of square

The short-run GDP connection, like the long-run relationship, increased $CO_2$ emissions by 0.553% (Table 5). In contrast to the long-term connection, HE increased $CO_2$ emissions by 0.037% in the short run. Furthermore, Table 5 reveals that short-term population increase is unrelated to emissions. The equilibrium correction mechanism (ECM) is a statistical model used to investigate the connection between two or more non-stationary variables that tend to trend over time. The error correction term in the ECM model is the difference between the current value of the dependent variable and its equilibrium level. The error correction term's coefficient reflects the rate at which the dependent variable adjusts to departures from its long-run equilibrium. In other words, it measures the pace at which a shock or disturbance causes the dependent variable to converge to its equilibrium level. The error correction term coefficient is an essential parameter in the ECM model because it gives vital information about the dynamics of the relationship between the variables being researched. A high coefficient value implies that the dependent variable quickly adapts to departures from equilibrium, whereas a low coefficient value indicates that the adjustment process is longer. The coefficient of the error correction term is negative and statistically significant, as predicted (Table 5). When $CO_2$ emissions are far from their equilibrium level, they adapt by around 84% within the first year. After complete convergence, it takes around $1/0.839 = 1.19$ years to reach the equilibrium level.

Diagnostic testing on ARDL models are critical for verifying the correctness and dependability of the results. The diagnostic test results are also provided at the bottom of Table 5. As a result of these findings, the model exhibits no autocorrelation or heteroskedasticity issues and a normal distribution with no model setup error. CUSUM and CUSUMSQ tests were also done to determine whether there is a structural break in the series, as illustrated in Fig. 1.

According to the CUSUM and CUSUMSQ test findings, the statistics are between the critical boundaries (5% significance level), indicating that the coefficients are stable during the research time; that is, the results may be understood to mean that the estimated parameters are stable throughout the research period.

## 5 Conclusion

This study examined the short- and long-run links between health expenditures, $CO_2$ emissions, and economic growth in Türkiye from 1975 to 2020. The data were examined using the Autoregressive Distributed Lagged (ARDL) cointegration methodology developed by Pesaran et al. (2001). The investigation uncovers a number of interesting conclusions. First, there is evidence in Türkiye of a long-run co-integrating connection between $CO_2$ emissions, economic growth, healthy expenditure, and population expansion. Second, just as in the long run, a relationship was discovered between these factors in the short term. In the long and short term, each 1% rise in economic growth increased $CO_2$ emissions by 0.297 and 0.553, respectively, from 1975 to 2020. According to the study, economic growth may have a negative impact on $CO_2$ emissions in Türkiye in the long and short run if it cannot be done with renewable energy. Balancing economic growth with $CO_2$ emissions reductions is thus a daunting problem that needs a comprehensive and coordinated strategy. This policy proposal highlights the need to implement sustainable practices to foster economic growth while mitigating the negative consequences of climate change. We can pave the road for a greener and more prosperous future by establishing emission reduction goals, supporting renewable energy sources, enhancing energy efficiency, switching to low-carbon transportation, putting carbon price systems into place, and encouraging international collaboration. Besides, governments, corporations, and people all need to understand how urgent it is to combat climate change and accept their roles as contributors to sustainable development. In order to create a sustainable balance between economic growth and environmental preservation, this proposal highlights the need for creative solutions, technology improvements, and behavioral adjustments. However, the success of these policies relies on practical implementation, continuous monitoring, and adaptive measures. To ensure that policies remain in line with developing scientific understanding, technological improvements, and shifting economic environments, regular analyses and reviews are required.

In order to address the health hazards and difficulties brought on by high emissions of carbon dioxide, health expenditure is crucial. Spending more on healthcare systems has the potential to increase public health efforts, disease prevention and control, and access to medical treatment. These initiatives are essential for reducing the damaging impacts on human health brought on by pollution and environmental deterioration brought on by $CO_2$ emissions. Societies can better address the health effects of climate change and advance sustainable development by investing in healthcare infrastructure, research, and education. It demonstrates that the link between health expenditures and $CO_2$ emissions reflects this condition, i.e., in the long run, $CO_2$ decreases by 0.124% for every 1% rise in health expenditure, but this conclusion has little importance in the short run. Furthermore, the study suggests that population growth in Türkiye may have a detrimental long-term impact on $CO_2$ emissions.

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## Declarations

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