CO2 Emissions and Health Expenditures: The Case of EU

Tufan SARITAŞ[1] **Gökhan AKAR**[2]

[1] Assoc. Prof. Dr., Karamanoğlu Mehmetbey University, Faculty of Economics and Administrative Sciences, Department of Economics, tufansaritas@kmu.edu.tr, ORCID: 0000-0003-1728-2377

[2] Assoc. Prof. Dr., Karamanoğlu Mehmetbey University, Faculty of Economics and Administrative Sciences, Department of Economics, gakar@kmu.edu.tr, ORCID: 0000-0001-8401-4052.

Abstract: The link between greenhouse gases and climate change has caused the environment to become more important within the scope of national and global health policies. For this reason, the effects of deterioration in environmental quality on health have been intensively investigated in recent years. One of the important greenhouse gases that harm human health and environmental quality is CO2 emissions. In this context, the effect of carbon emissions on health expenditures in the period of 2001-2019 for 26 EU countries was examined by panel data analysis. In order to empirically test the subject mentioned above, the dependency of health expenditures; An econometric model has been established in which carbon emissions and economic growth are independent variables. In the findings, it was determined that carbon emission and economic growth variables had a positive effect on health expenditures. In other words, as carbon emissions increase, health expenditures increase, and as carbon emissions decrease, health expenditures decrease.

Key Words: CO2 Emissions, Health Expenditures, EU, Panel Data Analysis.

1. INTRODUCTION

The increase in greenhouse gas emissions and global warming due to the consumption of fossil fuels around the world negatively affects the environmental quality. Greenhouse gas emissions are often associated with extreme temperatures and heat waves that cause changes in blood viscosity. This situation accelerates the growth of the climate change problem, which constitutes important health problems in terms of cardiovascular and cerebrovascular diseases among the elderly. However, deterioration in environmental quality such as air, water and soil pollution causes an increase in disease risks and is responsible for many negative effects on health. In addition, these negativities pose a serious threat to healthy life. (Abdullah, 2016; Brunekreef & Holgate, 2002).

Health has an important role in determining the quality of human capital. There are many factors that can affect the health status of individuals, such as socioeconomic development, welfare level and environmental quality. (Wang et al. 2019a). In this context, the impact of anthropogenic emissions on health, such as CO2 emissions associated with the deterioration of environmental quality, has recently attracted great attention. Because these emissions not only harm human health and negatively affect production, but also play a role in increasing health expenditures due to the triggering of diseases (Ahmad et al. 2021). In this context, it is assumed that the general health expenditures of the economy represent the health service demand of a country. Subsequently, a country's health expenditures are linked to GDP, aging population, environmental pollution and energy intensity (Brunekreef & Holgate, 2002). However, the effects of the increase in health expenditures on labor productivity, quality of life and welfare can be multidimensional. In addition, health expenditures have an important position in terms of life expectancy, infant mortality rates and reduction of diseases (Murthy & Okunade, 2009).

The increase in environmental pollution with economic growth around the world obliges countries to develop policies to reduce CO2 emissions. However, there is a process in which especially fast-growing developing countries have to choose between economic growth and environmental sustainability. At the same time, there is increasing pressure from industrialized countries to developing countries to engage in multilateral agreements to reduce industrial emissions (Ahmed et al. 2020). Since the beginning of the 1990s, the relationship between environmental pollution and economic growth has become one of the important empirical relationships tested in the economics literature, with the increasing concerns about climate change and especially global warming as a result of deteriorating environmental quality. The main focus of this literature is to examine the role of economic growth in environmental quality. The theoretical proposition, called the Environmental Kuznets Curve (EKC), is that the environmental environment is deteriorated with high pressure on the environment in the first stage of economic development. However, with the growth of the

economy over time, the pressure on the environment eases and the environmental quality improves (Narayan & Narayan, 2009). In this context, economic growth has an increasing effect on CO2 emissions. In addition, the more intensive use of energy together with the changes in the structure of technology and economy is important in terms of CO2 emissions. Therefore, the CO2 emission function can be defined by growth, health expenditures and energy intensity (Apergis et al. 2020). In this direction, the causal link between environmental quality, economic growth and health expenditures has been examined in the economics literature recently. In this context, while studies on economic growth and environmental quality come to the fore, researchers also show interest in the relationship between health expenditures, economic growth and CO2 emissions (Chaabouni et al. 2016). In this context, the impact of low environmental quality on health expenditures has become a focus for researchers and policy makers in recent years (Alimi et al. 2019).

The aim of this study is to examine the effect of CO2 emissions on health expenditures for 26 EU countries by panel data analysis method. In this context, a single model is presented to determine the effects of CO2 on health expenditures. Within this scope, the study contributes to the existing literature as follows. The findings obtained in the study may be useful for policy makers in terms of designing and evaluating legislation in the context of environmental quality and health expenditures. Secondly, the data used for the variables contribute to this area, which is limited in terms of series and sample. The remaining sections of this study is structured as follows; Chapter 2 presents a literature review on the model. Chapter 3 provides information about the data and method. Chapter 4 describes the results of the empirical analysis and includes evaluation.

2. LITERATURE REVIEW

There is an important link between the intensity of greenhouse gas emissions and climate change and the impact of climate change on public health. In this context, there has been an increasing interest in the relationship between economic growth, environmental degradation and health expenditures in the literature in recent years. Because the destruction of global environmental quality is seen as a serious threat to healthy life (Wang et al. 2019a). For this reason, the increase in health expenditures since the 1960s has worried the whole world. Many studies have addressed the increase in health expenditures and investigated which variables can be affected to reduce costs (Chaabouni & Abednnadher, 2014). However, many studies have empirically investigated the factor determinants of health expenditures by considering both income and non-income variables (Khandelwal, 2015; Ghorashi & Rad, 2017; Metu et al.2017; Afolayan & Aderemi, 2019; Badulescu et al.2019; Barkat et al.2019; Blázquez-Fernández et al. 2019; Moosa & Pham, 2019; Usman et al.2019; Şahin & Durmuş, 2019; Wang et al.2019b; Shahzad et al. 2020; Ibukun & Osinubi, 2020; Bilgili et al.2021;). In this regard, Chaabouni et al. (2016) examined the causal relationship between CO2 emissions, health expenditures and economic growth using the GMM method. As a result of the study, they determined that there is a bidirectional causality between CO2 emissions and economic growth, and between health expenditures and economic growth. In addition, they found a unidirectional causal relationship from CO2 emissions to health expenditures, except for low-income countries. On the other hand, Khoshnevis Yazdi & Khanalizadeh (2017) examined the role of economic growth and environmental quality in determining health expenditures for MENA countries, using the ARDL method for the period 1995-2014. As a result of the study, they found that CO2-PM10 emissions have a positive effect on health expenditures in the long term. Similarly, as a result of VECM Granger causality analysis conducted by Body (2019) for the 1992-2014 period and for 26 selected OECD countries, it was determined that economic growth is the cause of health expenditures and CO2 emissions, and CO2 emissions are the cause of health expenditures. In addition, the study found unidirectional causality running from economic growth and CO2 emissions to health expenditures for the long term. In addition, Dumrul (2019) found that environmental pollution and economic growth increase health expenditures in his study using the 2000-2014 period data for ASEAN-5 countries. Wang et al. (2019a) analyzed the relationship between health expenditures, CO2 and GDP in a sample of 18 OECD countries for the period 1975-2017 using the ARDL method. As a result of the study, they found bidirectional causality between health expenditures and CO2 emissions for New Zealand and Norway, CO2 emissions and GDP for the USA, Germany and Canada, and between health expenditures and GDP for Germany and the USA. Li et al. (2022), examined the relationship between health expenditures, CO2 emissions and economic growth with the ARDL method for BRICS countries with the help of data for the period of 2000-2019. In the study, they found a cointegration relationship between health expenditures, CO2 emissions and economic growth

for Brazil and China in the long term. They also found that while there is a negative causal relationship between CO2 emissions and health expenditures for India in the short term, the relationship between CO2 emissions, health expenditures or economic growth in other countries is unidirectional.

In the literature, there are studies that examine the relationship between CO2 emissions, economic growth and health expenditures in a specific country sample. Abdullah et al. (2016) examined the effects of environmental quality for the short and long term using the ARDL estimation method, using annual data from Malaysia for the period 1970-2014. As a result of the study, they found a long-term relationship between GDP, CO2, Mortality Rate, Fertility Rate, Nitrogen Dioxide, Sulfur Dioxide and health expenditures. Ecevit & Çetin (2016) examined the effects of economic growth and environmental pollution on health, using data from the period of 1996-2011 in the sample for Turkey. In the study in which infant mortality data were used for the health quality variable, Johansen-Juselius and Phillips-Ouliaris analyzed the variables with the help of cointegration method and Granger causality test. As a result of the study, they found a long-term relationship between the variables. Also, they found that carbon emissions positively affect infant mortality and there is a bidirectional Granger causality relationship between carbon emissions and infant mortality rate. At the same time, Polat & Ergun (2018) analyzed the variables with Gregory-Hansen cointegration and Toda Yamamoto causality methods using the data of 1980-2016 for Turkey. As a result of the study, they found that there is no long-term relationship between health expenditures, economic growth and CO2 emissions. They also found unidirectional causality running from health expenditures to economic growth and CO2 emissions, and from economic growth to CO2 emissions. For China and India. Atuahene et al. (2020) examined the effects of economic growth and CO2 emissions on health expenditures by using the Generalized Moments Method (GMM) estimation method of the data for the period 1960-2019. As a result of the study, they found that there is a significant relationship between the variables and that CO2 emissions have a positive effect on health expenditures.

Variables such as urbanization and renewable energy consumption, which are some other determinants of health expenditures along with CO2 emissions, have been taken into account in the literature. Apergis et al. (2018a) examined the relationship between health expenditures and per capita carbon dioxide (CO2) emissions, per capita real gross domestic product (GDP), renewable energy consumption using panel data analysis method, using data from 1995-2011 for 42 Sub-Saharan African countries. In the study, they concluded that there is a relationship between the variables in the long run. They also found unidirectional causality from real GDP to CO2 emissions, renewable energy consumption and health expenditures, and bidirectional causality between renewable energy consumption and CO2 emissions in the short term. However, in the study, they found bidirectional causality between health expenditures and CO2 emissions for the long term. On the other hand, Xiu et al. (2022) in their study using fully modified ordinary least square (FMOLS), dynamic ordinary least square (DOLS) and canonical cointegrating regression (CCR) analysis method with the help of data from the period 2000:Q1-2018:Q4 in the Chinese sample. They concluded that economic growth, urbanization and CO2 emissions increase health expenditures. In this context, while there is a relatively large literature on the determinants of health expenditures, studies that only examine the relationship between environmental quality indicators and health expenditures are still limited (Apergis et al. 2018b). Within this scope, Alimi et al. (2019) investigated the causal relationship between environmental quality and health expenditures in 15 ECOWAS countries using pooled OLS, fixed effects and system GMM methods, with the help of data from 1995-2014. In the study, they concluded that carbon emissions have a statistically significant effect on public health expenditures. Also, they found that there is no relationship between environmental pollution and private health expenditures in the study. Apergis et al. (2018b) analyzed the short- and long-term effects of carbon dioxide (CO2) emissions on health expenditures in the US states using the quantile regression method for the period 1966-2009. Accordingly, they concluded that the impact of CO2 emissions on health services is stronger for states with higher health expenditures. Similarly, Apergis et al. (2020), using the data of the period 1995-2017, examined the relationship between health expenditures and environmental pollution for 178 countries within the scope of four different income groups with panel data analysis method. In the study, they found that the increase in CO2 emissions in four different income groups increases health expenditures.

There are many studies in the literature that focus on unidirectional causality from CO2 emissions to health expenditures and find a positive relationship. For example, Erden & Turan Koyuncu (2014) in their study using the data for the period of 1980-2012 for

Turkey, concluded that according to the Granger causality test, economic development causes an increase in CO2 emissions, and as a result, CO2 emissions cause an increase in health expenditures. As a result of the study by Yahaya et al. (2016), in which they examined the period of 1995-2012 for 125 developing countries with panel data analysis method, they found that CO2 emissions have a significant power among the explanatory variables of per capita health expenditure. At the same time, in the study conducted by Chaabouni & Saidi (2017), they examined the relationship between CO2, GDP growth and health expenditures by using Dynamic simultaneous-equations models and generalized method of moments (GMM) analysis methods for 51 countries with the help of data for the period 1995-2013. As a result of the study, they found a bidirectional causality between CO2 emissions and GDP per capita for all income groups, and between health expenditures and economic growth. Furthermore, they found a one-way causality relationship from CO2 emissions to health expenditures for country groups other than the low-income country group. On the other hand, Ozmen et al. (2019) analyzed the relationship between health expenditures and carbon emissions for G7 countries using bootstrap panel causality test and data for the period 1991-2014. As a result of the study, they found a bidirectional causality for Canada and Italy, and a unidirectional causality from carbon emissions to health expenditures for Japan and the USA. Ergün & Polat (2019) found that the increase in CO2 emissions caused by fossil energy sources has a positive effect on health expenditures in upper-middle and low-middle income countries, according to the results of the Panel ARDL analysis, in their study using data for the period of 1995-2014 for 119 countries. They also found that CO2 emissions from the industrial sector positively affect health expenditures for high-income countries. Ullah et al (2019) concluded that CO2 emissions increase health expenditures in their study using data from Pakistan for the period 1998-2017. However, only a limited number of empirical studies have focused on the bidirectional relationship between CO2 emissions and health expenditures. In the study by Zaidi & Saidi (2018), they examined the relationship between CO2 emissions, economic growth and health expenditures with the Panel ARDL approach, using data from 1990-2015 for Sub-Saharan African countries. As a result of the study, they found that economic growth has a positive effect on health expenditures and CO2 emissions have a negative effect on health expenditures in the long term. In addition, they found a bidirectional relationship between CO2 emissions and health expenditures according to the VECM Granger causality test results. Erdogan et al. (2019) determined a long-term cointegration relationship between CO2 emissions and health indicators in their study for Turkey with the help of data for the period 1971-2016. Keyifli & Recepoğlu (2020) determined a bidirectional causality relationship between health expenditures and CO2 emissions using the Bootstrap panel Granger causality test with the help of annual data for the E7 countries for the period 2000-2016. Also, Ahmad et al. (2021), in their study for 27 provinces of China, found that there is a bilateral link between the increase in health expenditures and CO2 emissions. Although the findings obtained from the studies differ due to various reasons such as the measurement of variables and data coverage, it has been concluded that CO2 emissions and health expenditures can affect each other.

3. DATA AND METHODOLOGY

In this study, the effect of carbon emissions on health expenditures in the period 2001-2019 for 26 EU countries was examined by panel data analysis. The EU Countries studied are; Germany, Austria, Belgium, Bulgaria, CzechRepublic, Denmark, Estonia, Finland, France, Cyprus, Croatia, Netherland, Ireland, Spain, Sweden, Italy, Lithuania, Latvia, Luxembourg, Hungary, Poland, Portugal, Romania, Slovak Rebublic, Slovenia, Greece. Malta was not included in the study due to lack of data. Information about the series is shown below

Table 1. Data and Sources

VariableCode	Variable Name	Source
HEA	Current health expenditure per capita (current US$)	World Bank
CO2	Million tonnes of carbondioxide	British Petrol
GDP	GDP (constant 2015 US$)	World Bank

Logarithmic transformation was applied to all series. The “Currenthealthexpenditurepercapita (current US$)” series (HEA) was used to represent health expenditures, the “Million tonnes of carbondioxide” series (CO2) to represent carbon emissions, and the “GDP (constant 2015 US$)” series (GDP) to represent economic growth. HEA

and GDP series, from the World Bank; The CO2 series was obtained from British Petroleum. Summary statistics for the series are shown in the table below.

Table 2. Summary Statistics About Data

Variable	Obs	Mean	Std. Dev.	Min.	Max.
GDP	468	0.022	0.035	-0.161	0.225
HEA	468	0.064	0.112	-0.204	0.396
CO2	494	4.106	1.244	1.979	6.770

Since the research covers the period 2001-2019 for 26 EU countries, panel data analysis was preferred as the analysis method. Before the panel data analysis, Pesaran CIPS (Pesaran, 2007) unit root test was used in order to detect the possible panel unit root problem in the series. Then, the F test was applied to determine possible unit and/or time effects in the panel data set. As is known, if the probability value of the F test for unit effects is statistically significant at the 5% level, it is decided that unit effect panel models are appropriate in the panel data set. Similarly, if the probability value of the F test for time effects is statistically significant at the 5% level, it is understood that time effect panel models can be used in the panel data set. However, if it is determined that there are both unit effects and time effects in the F test findings, it is recommended to prefer two-way panel data models (Yerdelen Tatoğlu, 2018, 168-171). As it can be seen in the analysis results section, since both unit effects and time effects were found in the study, the in-group estimation method was preferred from the two-way panel data models (ibid. 145).

Hausman test (Hausman, 1978) was used to choose between fixed effects and random effects in the panel data model. As it is known, if the value of this test is significant at the 5% level, fixed effects are assumed, and if it is insignificant at the 5% level, random effects are assumed to be validAgain, as can be seen in the analysis results section, since fixed effects are valid for the model, the model was estimated by in-group estimation method under the assumption of fixed effects.

Since fixed effects are valid in the model, ModifiedWald Test (Greene, 2000) was used to detect possible heteroscedasticity problem, and Baltagi-Wu test (Baltagi & Wu, 1999) and Durbin-Watson (Bharagava et al., 1982) tests were used to detect possible autocorrelation problems. Again, since the fixed effects are valid in the model, the Driscoll-Kray (Driscoll & Kray, 1998) resistive estimator was preferred to solve the heteroscedasticity and autocorrelation problems in the model.

In the study, an econometric model was established in which health expenditures (HEA) are the dependent variables and carbon emissions (CO2) and economic growth (GDP) are the independent variables. In the analysis results; It is expected that carbon emission (CO2) and economic growth (GDP) variables will positively affect the health expenditures variable (HEA). The econometric form of the model is as follows:

$$HEA_{it} = \beta_0 + \beta_1 CO2 + \beta_2 GDP + \varepsilon_{it} \quad (1)$$

In the study, firstly, the results of the analysis will be given. After that, econometric findings will be interpreted and evaluated in the conclusion part.

4. EMPIRICAL ANALYSIS RESULTS

In the study, firstly, the possible unit root test problem in the series was tried to be determined with the help of unit root test. In the table below, the findings of the Peseran CIPS unit root test are given. In the unit root test results, it is understood that there is a unit root problem in I(0) in the HEA and GDP series. When the related series are taken as the first difference, it is seen that they become stationary in I(1). The CO2 series was found to be stationary in I(0).

Table 3.Pesaran CIPS UnitRoot Test Results

Variable	Model	Test Stat.	Critical Values		
			%10	%5	%1
HEA	Constant	-1.323	-2.110	-2.200	-2.380
	ConstantLinear Tr.	-1.988	-2.630	-2.720	-2.880
ΔHEA	Constant	-3.347	-2.110	-2.200	-2.380
	ConstantLinear Tr.	-3.412	-2.630	-2.720	-2.880
GDP	Constant	-1.676	-2.110	-2.200	-2.380
	ConstantLinear Tr.	-2.377	-2.630	-2.720	-2.880
ΔGDP	Constant	-2.940	-2.110	-2.200	-2.380
	ConstantLinear Tr.	-2.960	-2.630	-2.720	-2.880
CO2	Constant	-2.212	-2.110	-2.200	-2.380
	ConstantLinear Tr.	-2.994	-2.630	-2.720	-2.880

Possible unit and/or time effects on the model were tried to be determined by using the F test. As can be seen in the table below, where the F test findings are reported, it is understood that there are both unit and time effects in the econometric model used in the study, therefore, two-way models should be preferred. Because the F test probability value is significant at the 5% level for both unit and time effects.

Table 4. F Test Results for Determining Unit and Time Effects

Effect	Coef. (Prob.)
Unit	5.63 (0.000)
Time	84.93 (0.000)
Suitable Model	Bilateral Model

The panel data analysis findings related to the model in the study are reported in the table below. In the "Uncorrected Model" column, the results of the model estimated by the intragroup estimation method are shown. Hereunder; It is understood that the CO2 series representing carbon emissions, with a coefficient of 0.070, statistically at the 5% significance level, and the GDP series representing economic growth at the 0.675 coefficient and 1% significance level, positively affecting the HEA series representing health expenditures. In other words, in terms of the subject we discussed, an increase in carbon emissions increases health expenditures, and a decrease in carbon emissions reduces health expenditures.

Table 5. Panel Estimation Results

	DependentVariables: HEA	
	Uncorrected Model	**Corrected Model**
CO2	0.070 (0.033)*	0.452 (0.001)*
GDP	0.675 (0.000)*	1.071 (0.000)*
C	-	-1.817 (0.001)*
Hausman Test Stat. (Prob.)	124.930 (0.000)*	-

Model	FixedEffect	-
R-Squared	-	0.34
ModifiedWald Test	51.520 (0.002)*	-
Durbin-Watson Stat.	1.723	-
Baltagi-Wu LBI Stat.	1.770	-

**Note: Values in parantheses are probility values, others are coefficients*

The fact that the probability value of the ModifiedWald test for the model is statistically significant at the 1% level indicates that there is a heteroscedasticity problem in the model. In addition; The fact that the values of Durbin-Watson and Baltagi-Wu tests are less than 2 means that there is an autocorrelation problem in the model. For the solution of related statistical problems, the Driscoll-Kraay resistive estimator, which can be used in fixed-effect panel models, is used and the findings are reported in the "Corrected Model" column. According to this; It is understood that the CO2 series representing carbon emissions, with a coefficient of 0.452, statistically at 1% significance level, and the GDP series representing economic growth at the 1% significance level with a coefficient of 1.071 positively affects the HEA series representing health expenditures. In other words, if we express it in terms of the subject we discussed, similar to the results in the "Uncorrected Model" column, it has been observed that an increase in carbon emissions increases health expenditures, and a decrease in carbon emissions reduces health expenditures.

5. CONCLUSION AND DISCUSSION

In this study, the effect of carbon emissions on health expenditures in the period 2001-2019 for 26 EU countries was examined by panel data analysis. Studied EU countries are; Germany, Austria, Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Finland, France, Cyprus, Croatia, Netherland, Ireland, Spain, Sweden, Italy, Lithuania, Latvia, Luxembourg, Hungary, Poland, Portugal, Romania, Slovak Rebublic, Slovenia and Greece. Malta was not included in the study due to lack of data.

In the study, an econometric model was established in which health expenditures (HEA) are the dependent variables and carbon emissions (CO2) and economic growth (GDP) are the independent variables. In the results of the model estimated by the in-group estimation method, the CO2 series representing carbon emissions, with a coefficient of 0.070, was at the 5% significance level and the GDP series representing the economic growth was at the 1% significance level with a coefficient of 0.675, It is understood that the HEA series, which represents health expenditures, has a positive effect.

In the resistant estimator findings used to solve the heteroscedasticity and autocorrelation problem in the model; It is understood that the CO2 series representing carbon emissions, with a coefficient of 0.452, statistically at 1% significance level, and the GDP series representing economic growth at the 1% significance level with a coefficient of 1.071 positively affects the HEA series representing health expenditures. Therefore, if we express it in terms of the subject we discussed, an increase in carbon emissions increases health expenditures, and a decrease in carbon emissions reduces health expenditures.

The findings of this research will contribute as an effective policy tool to maximize both environmental quality and health gains in relation to CO2 emissions and health expenditures. In addition, according to the results of the analysis, it is important for EU countries to adopt measures and policies related to environmental quality in order to reduce diseases and control air pollution, since CO2 emissions are a factor contributing to the increase in health expenditures. However, countries need to examine investment projects to promote environmental quality and increase renewable energy sources with carbon-free technology transfer to reduce environmental degradation. For this reason, policies and programs that will contribute to the increase in average life expectancy in a sustainable perspective for EU countries should be encouraged. In addition, including other determinants of health expenditures in the model for future research on the subject will contribute to the expansion of the literature.

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