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HEALTH EFFECTS OF AIR POLLUTION- THE CASE OF GERMANY (1990-2019)

HAVA KİRLİLİĞİNİN SAĞLIK ETKİLERİ- ALMANYA ÖRNEĞİ (1990-2019)

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ABSTRACT

Objective: In recent years, air pollution, which threatens individual and public health, has become an important problem with industry and unplanned urbanization. This research aims to reveal the health effects of air pollution.

Methods: Time series analysis was used in the study. Accordingly, the stationarity of the series was tested with single and double-break unit root tests. Short- and long-term cointegration relationship has been revealed by the ARDL estimation method. The future effects of the shocks were calculated with the Error Correction Method. Information was given about the direction of the relationship with the Granger causality test.

Results: The effects of carbon emission on disability-adjusted life years, the crude death rate, respiratory system-related deaths, and per capita health expenditures variables between 1990 and 2019 in Germany were examined. Accordingly, a bidirectional relationship was found between carbon emission and the burden of disease, carbon emission and crude death rate, carbon emission and deaths due to respiratory diseases, and a unidirectional relationship between carbon emissions and per capita health expenditures.

Conclusion: Carbon emission, which is an environmental pollutant, has significant effects on health indicators. It has been concluded that air pollution is an important cause of health expenditures, years spent with diseases, death and crude death rates due to respiratory diseases. Therefore, countries must adopt sustainable environmental policies and meet their needs from renewable energy sources.

Keywords: Burden of Disease, Carbon Emissions, Health Expenditures.

ÖZET

Amaç: Son yıllarda birey ve toplum sağlığını tehdit eden hava kirliliği, sanayi ve çarpık kentleşme ile birlikte önemli bir sorun haline gelmiştir. Bu araştırma, hava kirliliğinin sağlık üzerindeki etkilerini ortaya çıkarmayı amaçlamaktadır

Gereç ve Yöntem: Araştırmada zaman serisi analizi kullanılmıştır. Buna göre serilerin durağanlığı tek ve çift kırılmalı birim kök testleri ile test edilmiştir. ARDL tahmin yöntemi ile kısa ve uzun dönemli eş-bütünleşme ilişkisi ortaya konulmuştur. Şokların gelecekteki etkileri Hata Düzeltme Yöntemi ile hesaplanmıştır. Granger nedensellik testi ile ilişkinin yönü hakkında bilgi verilmiştir.

Bulgular: Almanya'da, 1990 ile 2019 yılları arasında, karbon emisyonunun engelliliğe ayarlanmış yaşam yılı, kaba ölüm hızı, solunum sistemine bağlı ölümler ve kişi başına sağlık harcamaları değişkenleri üzerindeki etkileri incelenmiştir. Buna göre, karbon emisyonu ile hastalık yükü, karbon emisyonu ile kaba ölüm hızı, karbon emisyonu ile solunum yolu hastalıklarına bağlı ölümler arasında çift yönlü, karbon emisyonu ile kişi başına sağlık harcamaları arasında tek yönlü bir ilişki bulunmuştur.

Sonuç: Çevresel bir kirletici olan karbon emisyonunun sağlık göstergeleri üzerinde önemli etkisi bulunmaktadır. Hava kirliliğinin sağlık harcamaları, hastalıkla geçirilen yıllar, solunum yolu hastalıklarına bağlı ölüm ve kaba ölüm oranlarının önemli bir nedeni olduğu sonucuna varılmıştır. Bu yüzden ülkeler, sürdürülebilir çevre politikaları benimsemeli ve ihtiyaçlarını yenilenebilir enerji kaynaklarından karşılamalıdır.

Anahtar Kelimeler: Hastalık Yükü, Karbon Emisyonu, Sağlık Harcamaları.

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INTRODUCTION

Along with industrialization, the natural environment is polluted significantly due to rapid population growth, overuse and destruction of resources, gases released into the atmosphere due to the thinning of the ozone layer, destruction of forest and agricultural areas, and pollution of the sea and freshwater resources (Batı, 2014) (Manisalidis et al., 2020) One of the most critical environmental pollutants is the release of carbon emissions. Carbon emission negatively affects both the ecological order and the life cycle (Karamıklı & Şaşmaz Mahmut Ünsal, 2021; Özbay & Pehlivan, 2021) This destructive effect, which occurs because carbon emissions cause environmental destruction, causes an increase in disease burden, death rates and health expenditures in various ways (Keyifli & Recepoğlu, 2020). As a result of the literature review, carbon emissions cause various chronic diseases, accelerating health expenditures (Sancar & Atay Polat, 2021). According to WHO (World Health Organization) reports, it has been concluded that living in an unhealthy environment causes death and disability, as well as an increase in the burden of disease on a global scale (WHO: World Health Organization, 2009). A time series analysis was used to understand better the adverse effects of environmental pollutants on human health. The environmental destruction that has occurred due to the unnecessary intervention of humans in natüre significantly impacts individual and public health.

In this study, the research aims to reveal the catastrophic effect of air pollution (environmental destruction) on human health. In this context, variables such as carbon emission, the burden of disease, per capita health expenditure, crude death and death due to respiratory diseases were taken as the basis.

In the study, the health indicators of Germany between 1990-2019 were examined using the data of Stats Oecd. This study used time series analysis to reveal time-based changes in the long term. This method consists of several processes. First, the stationarity level was determined with unit root tests, and the long-term causality relationship was investigated with the ARDL estimation method. Then, the Granger causality test examined the effect of shocks with the Error Correction Model and the direction of the relationship between the variables. According to the existing studies in the literature, this research is important in revealing the health effects of environmental factors in Germany, which has an important position in terms of industry in the world and motivating industrialized countries to use sustainable/renewable energy sources.

MATERIALS AND METHODS

The study determines how air pollution affects causes of death, the burden of disease and health expenditures. The research provides information on whether air pollution and health effects are related and the direction of causality. In the study, 30 observations between 1990-2019 were used by using time series. The data used in the study were made following the Declaration of Helsinki Data on air pollution and health indicators for Germany were obtained from the OECD data pool (stats.oecd.org/). To reveal the health effects of environmental pollution, these indicators are coded as CO_2, DALY, ALLD, RESPD and EXP, abbreviated and detailed (Table 1).

Table 1. Information on Variables Used in the Research

Variable Code	Statements	Source data
CO_2	Carbon Emission	OECD Data
DALY	Disability Adjusted Life Years (Per 1000 People)	OECD Data
ALLD	Crude Mortality Rate (Per 100,000 People)	OECD Data
RESPD	Respiratory System-Related Deaths (Per 100,000 Persons)	OECD Data
EXP	Health Expenditures Per Capita, US Dollars	OECD Data

The carbon emission (CO_2) variable was determined based on air pollution resulting from industrialization and urbanization, excluding CO_2 produced naturally from green areas such as forests

Econometric Method

The research tested stationarity using Zivot-Andrews with one break and Lee-Strazicich unit root tests with two breaks. Zivot and Andrews (1992) criticized Perron's (1989) extrinsic breakpoint assumption and proposed a new unit root test (Tıraşoğlu Yıldırım, 2014).

Zivot and Andrews's test determines the breakout periods internally. The values calculated in this test are greater than the critical table value, indicating that the series is stationary; that is, the H0 hypothesis is rejected against the alternative hypothesis, there is a structural break, and it does not contain a unit root. The alternative hypothesis shows the stationary process of the trend series allowing a breakout (Zivot & Andrews, 1992) Lee and Strazicich's (2003) unit root test, which takes two breaks into account, tests the trended stationarity of the series. If the H0 hypothesis is rejected, it is decided that the series is stationary without breaking. If the H0 hypothesis is accepted, the existence of a unit root with a structural break is determined (Lee & Strazicich, 2003) After testing the stationarity of the series, the lag lengths are calculated. Information criteria such as AIC, SBC, FPE and HQ have been found suitable, and the lag length that gives the smallest critical value is the most appropriate lag value for the model (Akıncı et al., 2020). In the next step of the research, the ARDL bounds test was applied to determine the short- and long-term cointegration relationship. This test gives reliable results with small samples.

The essential feature of the ARDL model is that it is stationary at the same level and allows for level and first-level stationarity (Ecevit & Çetin, 2022) If the F statistical value in this limit test is less than the lower limit value, the H0 hypothesis is accepted; if the series is not cointegrated, if it is greater than the upper limit value, it shows that there is cointegration. If the F statistical value is between the lower and upper limit values, there is no clear judgment about the cointegration status (Gangopadhyay et al., 2023) In the presence of cointegration, it is stated with the Vector Error Correction Model (VECM) how much of the shocks that occur in the short term will disappear in the long term (Andrei & Andrei, 2015). After determining the effect of shocks, the Granger causality test is one of the most used methods to fully understand the relationship between variables in econometric analyses. This test gives information about the direction of the correlation between the variables (Turgut et al., 2021).

The Granger causality test is tested on the H0 hypothesis. Accordingly, in the H0 hypothesis, the assumption that X, Y is not a Granger cause is tested. If the H0 hypothesis is rejected, X is the Granger cause of Y. If the H0 hypothesis is not denied, X is not the Granger cause of Y (Hood et al., 2008). Though there were breaks in different years in the parameters discussed between 1990-2019, it is compromised that the series is stationary at this level.

RESULTS

Table 2. Zivot-Andrews Unit Root Test Outcomes

Variables	TB_1	Level	Likelihood Value	Outcome	First Level	Likelihood Value	Outcome
CO_2	2006	-7.801	0.000	I (0)	-1.739	0.094	I (1)
DALY	2001	-8.855	0.000	I (0)	4.509	0,000	I (1)
ALLD	1992	-4.061	0,010	I (0)	3.669	0.000	I (1)
RESPD	1998	-5.460	0.000	I (0)	1.227	0.232	I (1)
EXP	2008	7.343	0.000	I (0)	-0.448	0.659	I (1)

Note: It indicates stationarity at the 5% Critical value level.

Breaks occurred in the CO_2, DALY, ALLD, RESPD and EXP variables in 2006, 2001, 1992, 1998 and 2008, respectively, and it is seen that the series became stationary at the level (Table 2).

Table 3. Lee-Strazich Unit Root Test Outcomes

Variables	$TB_{1,2}$	Critical Value	Test Statistics	Likelihood Value	Outcome
CO_2	1992	-2.545	-4.354	0.000	**I (0)**
	2006		-6.653	0.000	
DALY	1998	-3.472	-10.654	0.000	**I (0)**
	2013		-4.789	0.000	
ALLD	1997	-9.738	-3.664	0.001	**I (0)**
	2010		2.848	0.008	
RESPD	1995	-6.776	-5.355	0.000	**I (0)**
	2007		-2.833	0.009	
EXP	2001	-3.168	7.305	0.000	**I (0)**
	2012		5.363	0.000	

It indicates stationarity at the 5% Critical value level.

After testing the stationarity with the Zivot-Andrews Unit Root test, the test was tested with the Lee-Strazicich Unit Root Test with two breaks. According to this test, it has been proven that all variables used in the research are stationary at the level (Table 3).

Table 4. ARDL (1 1 3 3 3) Model Estimation Outcomes

F_İstatistiği (4.449)		
Significance level	**Lower Limit I (0)**	**Upper Limit I (1)**
%1	2.45	3.52
%5	2.86	4.01
%10	3.74	5.06

The ARDL estimation results are smaller than the lower I (0) and upper I (1) threshold F statistical value (4,449) calculated at the 1% and 5% critical levels. The H0 hypothesis was rejected. As a result, a long-term cointegration relationship was accepted (Table 4).

Table 5. Error Correction Model Implementation

Error Correction	D(CO_2)	D(DALY)	D(ALLD)	D(RESPD)	D(EXP)
Error Correction Coefficients	1	-20120.81	468.80	-1884.15	-1.714
Standard Error	.	4557.83	144.51	1674.51	4.129
Likelihood Value	.	0.000	0.001	0.261	0.678
It is calculated at a 95% confidence interval.					

Approximately 20 (20120/1000=20.12) of the short-term deviations in the independent variable disappear each year. The resulting deviations are 1/|ECM|=1/|20.12| It will reach long-run equilibrium after about 0.049 periods. In other words, approximately 20% of the difference between the current value and the long-term value in DALY disappears every year (Table 5).

Table 6. Granger Causality Test Outcomes

H_0 (Granger is not the cause)	Chi2	Likelihood	Decision
Carbon Emission (CO_2) =//=> Burden of Diseases (DALY)	29.997	0.000	H_0 Rejected
Burden of Diseases (DALY) =//=> Carbon Emission (CO_2)	25.974	0.000	H_0 Rejected
Crude Mortality Rate (ALLD) =//=> Carbon Emission (CO_2)	39.025	0.000	H_0 Rejected
Carbon Emission (CO_2) =//=> Crude Mortality Rate (ALLD)	16.451	0.000	H_0 Rejected
Deaths Due to Respiratory Diseases (RESPD) =//=> Carbon Emission (CO_2)	24.807	0.000	H_0 Rejected
Carbon Emission (CO_2) =//=> Deaths Due to Respiratory Diseases (RESPD)	22.056	0.000	H_0 Rejected
Carbon Emission (CO_2) =//=> Health Expenditures per Person (EXP)	45.415	0.000	H_0 Rejected
The relationship between CO_2 and other variables has been searched.			

It is stated in the model that CO_2 has significant effects on health indicators (Figure 1). While there is a bidirectional relationship between Carbon Emission and Burden of Disease, Carbon Emission and Crude Mortality, Carbon Emission and Respiratory Disease-Related Deaths, It was concluded that there is a one-way causality relationship between Carbon Emission and Per Capita Health Expenditures (Table 6).

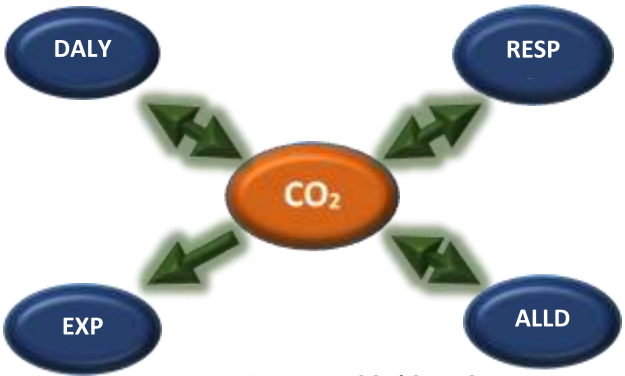

Figure 1. Model of the study

DISCUSSION

This study reveals the effect of carbon emission emissions on health expenditures, the burden of disease, and causes of death due to disease burden by using time series analysis. According to the findings, it has been determined that air pollution has a significant effect on the determinants of health. It has been concluded that carbon emission is a fundamental cause of per capita health expenditures, disease burden, crude death and death rate due to respiratory tract diseases. As a result of the literature review, there is a causal relationship between health expenditures, economic growth and carbon emissions. Such a situation is thought to increase the health expenditures of environmental pollutants (Atay Polat & Ergün, 2018). Similar results were obtained in the study conducted by Dumrul (2019). Environmental pollution has been found to increase health expenditures in the long term (Dumrul, 2019). The research by Jacobson (2008) emphasized that the increase in carbon emissions increases the death rates worldwide (Jacobson, 2008). In the study based on an Asian country, it was determined that carbon emission positively affects total health expenditure (Nasreen, 2021). According to research on EU member states, carbon emissions affect health expenditures in the short and long term (Badulescu et al., 2019). Environmental pollution, energy consumption, and economic growth in ASEAN countries have increased health expenditures (Haseeb et al., 2019). It has been determined that carbon emissions cause health expenditures in sub-Saharan African countries (Zaidi & Saidi, 2018). Similar results were obtained in the study based on the Middle East and North Africa region. It has been concluded that carbon emissions positively affect health expenditures (Yazdi & Khanalizadeh, 2017). As a result, in the long run, it can be thought that environmental pollutants cause various health problems, which also constitute an expense item. It was concluded that there is a weak relationship between death rates and carbon emissions (Anenberg et al., 2019). A long-term cointegration relationship was found between carbon emissions and health indicators. In addition, the increase in carbon emissions has decreased life expectancy from birth. Reducing carbon emissions and increasing renewable energy sources are vital for a sustainable environment (Erdoğan et al., 2019). Environmental pollutions is a significant cause of death in Central Asia (Anenberg et al., 2011). A study conducted in India concluded that carbon emissions are the primary cause of infant mortality (Avik Sinha, 2014). In Africa, carbon emissions increase infant mortality, while electricity consumption reduces infant mortality (Olubiyi, 2020). It is claimed that carbon emissions constitute the critical cause of death indicators, which are important determinants of health indicators. According to other research, carbon emissions are the most important cause of mortality. It has also been reported that carbon emissions cause an increase in chronic patients such as cancer. Creating a sustainable environment is vitally important (Rasoulinezhad et al., 2020). To the World Health Organization (WHO), carbon emissions at the global level are the most crucial cause of the disease burden. This situation has led to excessive consumption of resources at both the government and individual levels (Campbell-Lendrum & Prüss-Ustün, 2019).

CONCLUSION

As a result, about 20 of the short-term deviations disappear each year. The resulting deviations will reach the long-run equilibrium after approximately 0.049 periods. According to the different significant results, it has been proven that there is a bidirectional causality relationship between carbon emission and the burden of disease, carbon emission and crude death rate, carbon emission and deaths due to respiratory diseases, and a unidirectional causality relationship between carbon emissions and per capita health expenditures.

Carbon emissions have a significant impact on health indicators. Since air pollution is a definitive cause of health expenditures, years spent with diseases, death due to respiratory diseases, as well as crude death rates, it is thought that countries' adopting sustainable environmental policies and investing in renewable energy sources can make a significant contribution to the health of future generations.

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