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Research Article

What is the role of environmental stress on public health? Asymmetric evidence on carbon emissions, ecological footprint, and load capacity factor

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ABSTRACT

The aim of this paper is to analyze the effects of carbon emission, ecological footprint, which takes into account the demand side of the environment, and load capacity factor, which takes into account both the supply and demand sides of the environment, on health expenditures with conventional and quantile methods. According to the conventional co-integration approach, there is no relationship between the environment and health expenditures. The other side, the findings obtained from the quantile co-integration method, which can give robust results in the presence of tailed distributions and possible endogeneity problems and consider the asymmetric structure in the data set, show the existence of a long-term relationship between the variables. According to the coefficient estimates, while carbon emission and ecological footprint increase health expenditures, the load capacity factor decreases.

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INTRODUCTION

Although a clean environment is indispensable for human health and well-being, environmental problems increase the pressure on human health day by day. For example, air pollution, one of the main environmental problems, has reached unsustainable levels. Today, almost all of the global population (99%) is breathing highly polluted air exceeding the limits in the World Health Organization (WHO) guideline clearly reveals the extent of the danger [1]. When all environmental issues are taken into account, more striking statistics are reached. For example, one in four deaths (13.7 million) in 2016 was caused by environmental risks. In addition, evidence has been presented that environmental degradation causes many health problems such as heart diseases, chronic respiratory diseases, cancer, stroke, infectious diseases, and allergenic diseases [2, 3]. According to WHO, which is a projection for the future, in the 2030–2050 period, in addition to the deaths directly caused by environmental pollution, 250 thousand additional deaths may occur due to reasons such as malnutrition, diarrhea, and heat stress due to climate change [4].

Environmental factors are one of the main determinants of human health after genetic susceptibility. These controllable factors can lead to various health consequences directly or indirectly (Decrease in the supply of food products due to deforestation and desertification, widespread malnutrition, damage to biodiversity, emergence of zoonotic diseases such as COVID-19, dramatic increases in the number of

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disasters caused by environmental degradation, etc.) [5–7]. Governments have great duties in combating health problems caused by environmental problems. For this purpose, governments apply many fiscal policy instruments such as environmental taxes, environmental protection expenditures, and green budget. However, it may not be sufficient in terms of targets to deal with environmental problems only by governments. Because, in the historical process, environmental challenges such as water and air pollution at the local level spread to regional dimensions in the following periods. However, numerous environmental disasters in recent years reveal that environmental pollution has become global [8]. Therefore, there is a need for international cooperation as well as national-scale policies.

International developments in the relationship between environmental problems and health are discussed at many international conferences and summits held by the United Nations (UN), dating back nearly half a century. For example, at the 1972-Stockholm Conference, participants emphasized that clean air, water, shelter, and health needs are indispensable needs and rights for human beings [9]. At the 1992-Rio Conference, "Protection and Promotion of Human Health" was discussed as a separate section and suggestions were presented [10]. The 2000-New York Millennium Summit document emphasized goals such as combating diseases, fighting malaria, ensuring environmental sustainability, etc. [11]. Policies for promoting global public health were discussed at the Millennium Development Goals Summit held in the same city in 2010 [12]. At the 2015-Paris UN Climate Change Conference (Conference of the Parties-21), the right to health, especially environmental problems, was discussed, and countries made commitments for the steps to be taken [13, 14]. Finally, in 2022, at the Stockholm+50 and Sharm El-Sheikh COP27, important decisions were taken for environmental damage to human and planetary health, and the results of the policies produced so far were evaluated [15, 16]. In addition, one of the 17 Sustainable Development Goals (SDGs) determined by the UN has been established as "Ensure healthy lives and promote well-being for all at all ages". According to SDG-3.9, it is targeted to minimize the number of deaths and diseases caused by air, soil, water pollution, and hazardous chemicals by 2030 [17].

Similar to international regulations, some documents in Türkiye include the environment-health relationship. Firstly, according to Article 56 of the 1982 Constitution, "Everyone has the right to live in a healthy and balanced environment. It is the duty of the State and citizens to improve the natural environment, to protect the environmental health, and to prevent environmental pollution." This regulation points to the responsibility of both governments and citizens to tackle environmental problems. Secondly, the effects of declining environmental quality on health are mentioned in many documents by the Ministry of Health, which provides the highest level of service in this field. For example, according to the "National Program and Action Plan for Reducing the Negative Effects of Climate Change on Health" prepared by the Türkiye Public Health Institution, which is part of the Ministry, the number of injuries, illnesses, and deaths caused by weather events such as droughts, heat waves, storms, floods, and fires may increase due to environmental problems that also cover climate change [18]. In the SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis included in the 2019–2023 Strategic Plan, which is a different document prepared by the Ministry, "increasing environmental pollution and global warming" are reported among external threats. In the same document, PESTLE (Political, Economic, Social, Technology, Legal, and Environmental) analysis states that environmental pollution threatens to increase chronic diseases [19].

Analyzing environmental problems caused by human activities and discussing solutions is essential [20]. Because environmental degradation, which has become both a local and global problem, has consequences for human health, such as many diseases, injuries, and deaths, and also puts pressure on an upward trend in health expenditures (HE). WHO estimates that by 2030, the direct cost of environmental degradation to human health will be between $2 and $4 billion [4]. In this context, researchers prefer the HE indicator, which provides information about the entire health system, in the environment-health literature [21–24]. Empirical studies on the environment-health link shed light on the planning of the upcoming process. Because the analysis of the economic cost of health problems caused by environmental stress is critical in terms of providing concrete information for the environmental policies that governments will design [25].

This paper examines the effects of environmental indicators on HE in Türkiye. The study aims to contribute to the literature in two ways. First, there are two environmental pollution indicators (carbon emission (CO_2) and ecological footprint (EF)) and one environmental quality indicator (load capacity factor (LCF)) representing the environment in the study. In the environmental literature, the more comprehensive EF has become popular in recent years [26–29], while researchers often prefer CO_2 [30]. However, the study on LCF, which measures environmental pollution and environmental supply together, is limited [31–34]. To the best of our knowledge, this study is the first attempt for Türkiye to analyze the effects of EF and LCF indicators on HE. Therefore, the study confirms the empirical consistency of the results by comparing the findings of three different environmental indicators as well as presenting evidence to politicians in terms of new environmental indicators. Secondly, the study offers a methodically different perspective to the environmental-health literature with the Quantile Co-integration Regression (QCR) method proposed by Xiao [35] as well as the conventional method. The quantile co-integration method has many advantages over conventional co-integration methods. Conventional approaches have strict assumptions such as a normal distribution and no endogeneity. However, the QCR test may give resistant results in the presence of a non-normal distribution and possible end-of-endogeny. This method also provides a theoretical basis for examining positive and negative shocks by distinguishing between them.

The rest of the paper is organized as follows: The first section examines, in detail, the literature on environmental indicators and HE. The second section presents information about the dataset, descriptive statistics, and empirical methods in the analysis. The third section discusses the findings regarding conventional and quantile methods. The final section assesses the impact of environmental indicators on HE and provides policy recommendations.

Literature Review

The effects of air pollution on health have been the subject of intense research in the past, and there have been studies linking air pollution and changes in health in the short term and studies that track those exposed to pollution over time [36]. In one of the first studies to empirically address the relationship between environment and HE, Jerrett et al. [37] estimated a two-stage regression model using the 1991–1992 cross-sectional data for 49 counties in the Canadian province of Ontario. After controlling for other variables that may affect HE, it was concluded that HE is also high in counties where total toxic pollution output is high and lower in counties with higher environmental protection expenditures. A large part of the literature on the relationship between environmental pollution/quality and health expenditures in the following periods analyzes the effects of economic, financial, social, institutional, technological, and energy variables on environmental degradation by considering pollution indicators (such as CO_2, EF) and on environmental quality by considering the pollution indicators as the environmental quality variable [38–43]. The findings of these studies differ according to the countries, time period, and especially the method applied.

CO_2 emissions, one of the most important indicators of environmental pollution, negatively affect environmental quality and health, resulting in higher healthcare expenses for both individuals and the public [44]. Therefore, the demand for health services may increase health expenditures. Environmental degradation, on the one hand, may lead to an increase in the share of the environmental protection budget and a decrease in the share that can be allocated to health services. At this point, the results of the health-pollution relationship may change in the short and long term [45]. The analyses generally use one of the environmental pollution indicators such as CO_2 emissions and EF. When it comes to sustainability, CO_2 and EF, which reveal the demand side of the environment, are not enough to explain environmental quality and sustainability [32, 46]. The LCF, which is calculated as dividing the EF by biocapacity, considering both the demand and supply sides of the environment, as proposed by Siche et al. [47], is used in recent studies in terms of environmental quality and sustainability [33, 48–54].

Although there is a large body of literature on the nexus between CO_2 emissions and HE, there are very few studies on the relationship between HE and EF [22, 24, 31, 55–57]. Yang and Usman [22] analyzes the period 1995–2018 for the 10 countries with the highest HE and finds evidence of a bidirectional causality between the two variables, with EF increasing HE. There are also studies considering CO_2 emissions and EF variables together. For example, Alimi and Ajide [58] examine the nexus among CO_2 emissions, EF, and HE in SSA countries between 1996 and 2016. CO_2 emissions and EF increase the cost of HE, but the impact of CO_2 emissions is greater. Similarly, there are few papers in the literature that analyze the relationship between HE and LCF. Shang et al. [23] examine the link between HE, renewable energy, income, and LCF for ASEAN countries. The long-term effect of renewable energy and HE on the LCF is significant and positive, while income affects the LCF negatively. Adebayo and Samour [59] examine the nexus between fiscal policy and LCF for the BRICS countries between 1990 and 2018 in terms of using the public variable, even without health expenditures. There is a strong link between tax revenues, public expenditures variables, and the LCF. Panel causality findings show a one-way causality from public expenditures and tax revenues to the LCF.

There are two papers in the literature examining the relationship between HE and the environment for Türkiye. According to Demir et al. [60] examines the period from 1975 to 2018 using the NARDL method. According to the findings, positive shocks in CO_2 increase HE. Aydin and Bozatli [61] explore the same period with Fourier Shin and Frequency Domain Causality approaches. The findings indicate that the variables are cointegrated. In addition, the study suggests bidirectional causality between CO_2 and HE. Together with these papers, there are also panel studies covering Türkiye in the literature. From these studies, Chaabouni and Saidi [21], Benli [45] for developed countries, and Demir et al. [60] provide evidence that CO_2 promotes HE. However, Benli [45] for developing countries also provides findings supporting negative effects. Also, Erdogan et al. [62] observed unidirectional causality from CO_2 to HE, while Khan et al. [63] detects bidirectional causality between CO_2 and HE. In summary, the limited number of investigations of the environment-HE connection for Türkiye in the literature and only through CO_2 indicates that new evidence is needed in this area. This study aims to contribute to the gap in the literature by analyzing the effects of CO_2, with a special emphasis on EF and LCF, on HE.

Another striking point in the literature is the use of conventional approaches in most of the studies. Conventional methods are based on some solid assumptions and consider the relationship between variables as a whole. However, the nexus between variables may change over time. The quantile methods can be useful with their features, such as examining relationships that may change over time, giving resistant results against non-normal distributions, and taking into account the possible internality problem. In the literature examining the environment-health link, the use of quantile methods has become widespread in recent years. When the studies using the quantile method are examined, it is seen that some analyze CO_2 emissions [40, 64–66]; and some analyze LCF [48, 54, 67, 68]. Therefore, this study differs significantly from the literature by analyzing the nexus between CO_2 emissions, EF, LCF, and health expenditures for Türkiye with quantile methods.

Table 1. Definition of variables

Variables	Abbreviation	Definition	Data source
Dependent variable			
Health expenditures	HE	Share of health expenditures in GDP (%)	OECD [70]
Independent variable			
Environmental pollution indicators	CO_2	Carbon emission (tonne)	OWID [71]
	EF	Ecological footprint (global hectare)	GFN [72]
Environmental quality indicator	LCF	Load capacity factor (biocapacity/ecological footprint)	

Table 2. Descriptive statistics

							Test of normality	
Variables	Mean	Max.	Min.	SD	S	K	JB	Prob.
HE (%)	3.43	5.49	1.49	1.27	0.14	1.42	4.73	0.090[c]
CO_2 (million tonne)	218.48	430.22	65.42	114.90	0.35	1.86	3.43	0.180
EF (million gha)	164.08	286.20	81.35	60.64	0.35	1.90	3.11	0.210
LCF (%)	0.70	1.07	0.38	0.21	0.14	1.68	3.31	0.190

HE: Health expenditures; EF: Ecological footprint; LCF: Load capacity factor. JB refers to Jarque and Bera [73] normality test. S skewness, K kurtosis, and SD standard deviation. a, b, and c denote the significance level at 1%, 5%, and 10%, respectively. The statistics in the table are calculated with raw data. Descriptive statistics for HE are taken into account for the period 1975–2018.

DATA, MODEL, AND METHODOLOGY

In this section, the data set used in the study, the formulation of the established models, and the econometric methodology related to the methods used in the empirical analysis are explained.

Data Set

Three different models are established in the study, and the share of health expenditures in GDP is used as the dependent variable in all models. On the other hand, the explanatory variables CO_2, EF, and LCF are included in the models to represent the environment. Explanatory variables in the first two models, namely CO_2 (Model 1) and EF (Model 2), reflect environmental pollution, while the explanatory variable LCF in the third model reflects environmental quality. CO_2 is one of the most frequently used pollution indicators in the literature, providing information on environmental degradation. EF, another pollution indicator, has attracted attention in recent years. EF, including carbon footprint, consists of six components (carbon, forest products, agriculture, pasture, fisheries, and residential areas) and provides more information about environmental pollution when compared to CO_2 [69]. The LCF variable in Model 3, developed by Siche et al. [47], differs from the other two variables because it is an environmental quality indicator. The LCF value obtained by dividing the biocapacity, which reflects the supply side of the environment, by the EF, which reflects the demand side of the environment, indicates environmental sustainability if it is 1 and above. Values below 1 indicate that there is an ecological deficit, that is, environmental degradation is more dominant [46]. Therefore, analyses focused only on environmental pollution may present incomplete or misleading findings because they neglect the environmental supply. From this point of view, this study investigates more holistic evidence about the environment by comparing the findings on environmental pollution variables with the findings in the LCF model.

Due to data availability, the sampling periods taken into account in the models differ. In this framework, while the 1975–2020 period is considered in the model established for the CO_2 variable, the 1975–2018 period is examined in the models established for the ecological footprint and LCF variables. Annual data is used as the data frequency. Due to the scale differences in the variables, the data are used in logarithmic form. The definition and source information of the data are shown in detail in Table 1. Analyses were carried out with the GAUSS-21 program.[1]

Table 2 lists descriptive statistics for the variables. The results of the Jarque and Bera [73] test show that health expenditures have a non-normal distribution, while other variables have a normal distribution. Positive skewness values in the series indicate the presence of a right-tailed distribution, and negative values indicate the presence of a left-tailed distribution. The presence of a platykurtic distribution is indicated by a kurtosis value less than 3, that is, an extremely negative kurtosis, and leptokurtic distribution, i.e. an extremely positive kurtosis, is indicated by a value greater than 3. In light of this information, it is seen that the skewness values for all variables are greater than zero. In this context, there is a right-tailed structure in

The unit root tests were conducted with TSPDLIB developed by Nazlioglu [83].

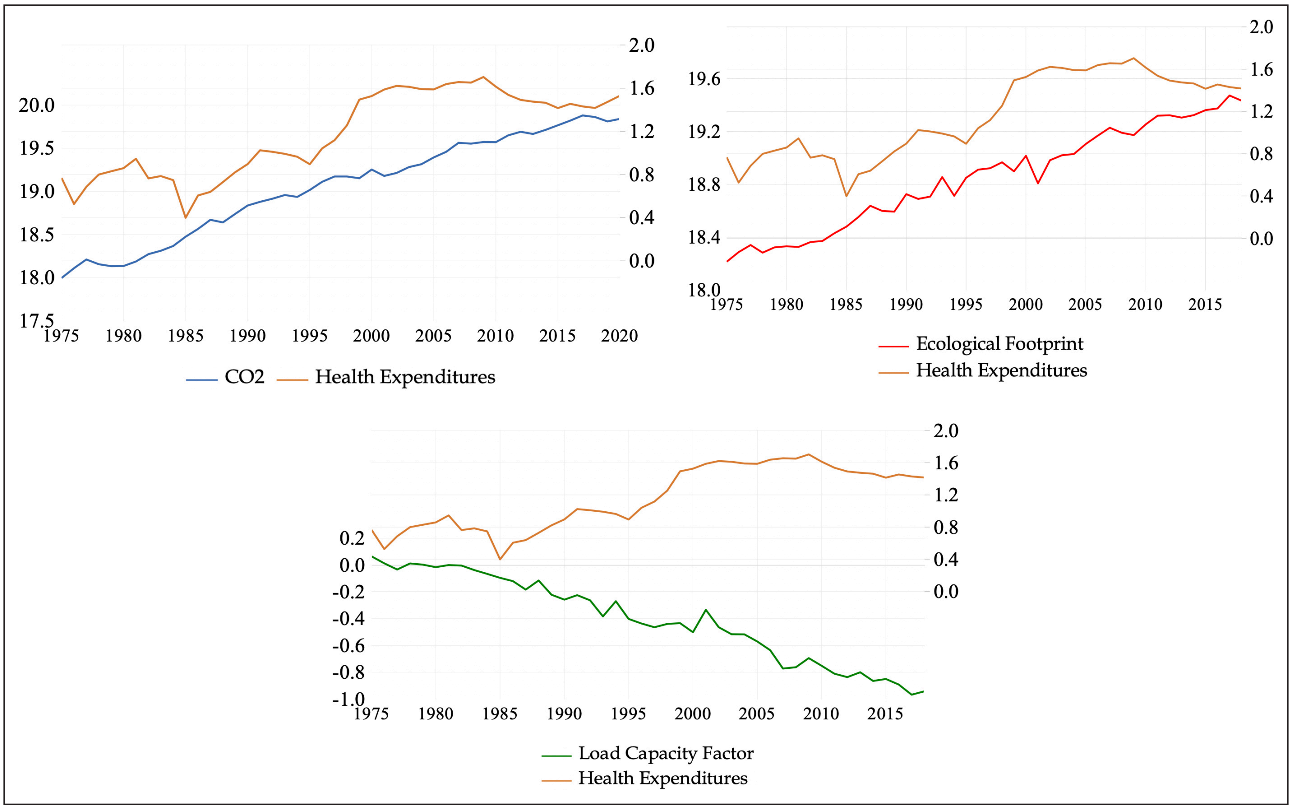

Figure 1. Time-based coherence of health expenditures and environmental indicators.

the distribution of variables. Kurtosis values are less than 3 for all variables. These statistics show the existence of a platykurtic distribution, which expresses negative extreme kurtosis in the variables.

When the development of statistics regarding the variables in Table 2 is examined, it is seen that HE has an average 3.4% share of GDP. HE, which was below the level of 3% until the second half of the 1990s, increased to levels of 4–5%, especially in the post-2000 period. In the same period, the EF increased by more than 250%, from 81 million to 286 million global hectares. On the other hand, the increase in biocapacity was limited to approximately 25%. Therefore, Türkiye has been experiencing a growing ecological deficit since the 1980s. This resulted in a dramatic decrease in the LCF. The LCF value, which permanently decreased below 1 in the post-1980 period, has decreased below the level of 0.4 in recent years, revealing that the ecological balance is unsustainable. Finally, the CO_2 indicator increased from 65 million tonnes to 430 million tonnes in the related period, increasing by approximately 560%. This statistic reveals strikingly the extent of environmental degradation in Türkiye.

Figure 1 shows the change in HE and environmental indicators over time. Accordingly, it is seen that health expenditures and environmental indicators act in harmony with each other. Although the relationship seems to break from time to time, it is slowly getting back into balance. The ruptures occurring at various periods show that the long-term relationship may change in the process. This situation causes a possible co-integration to change over time. At this point, it is important to use methods that allow the regression coefficient to change over time, such as the quantile approach, in order to better explain the data set.

Model

Increasing environmental pollution potentially causes increased HE, putting increasing pressure on government budgets [74]. Jerrett et al. [37] conducted a discussion on the link between environmental government policies and controlling costs in the health system. For this reason, it is important to examine the relationship between health expenditures and environmental pollution.

In this study, the relationship between HE and environmental pollution is examined in Türkiye. There are many variables that explain environmental pollution. In this context, three environmental indicators that are prominent and frequently used in explaining environmental pollution in the relevant literature are taken into consideration. The fact that EF includes CO_2 and LCF is a ratio of EF causes the problem of multicollinearity. For this reason, the relationship of each indicator with health expenditures is examined separately.

The specifications for the established models are as shown in Equations 1, 2, and 3:

Model 1: $lnHE_t = \alpha_1 + \beta_1\, lnCO2_t + \varepsilon_{1t}$ (1)

Model 2: $lnHE_t = \alpha_2 + \beta_2\, lnEF_t + \varepsilon_{2t}$ (2)

Model 3: $lnHE_t = \alpha_3 + \beta_3\, lnLCF_t + \varepsilon_{3t}$ (3)

where α is the constant term, β_1, β_2 and β_3 are the regression parameters, ln is the operation of the logarithm, t is the time dimension, and ε_t is the error term.

Table 3. Unit root and co-integration analysis results

	ADF (1979)				EG (1987)		
	Level		First diffence				
Variables	Statistic	Prob.	Statistic	Prob.	Model	Statistic	Prob.
$lnHE_t$	-1.051(0)	0.726	-6.977(0)[a]	0.000	$lnSH_t$&$lnCO2_t$	-2.050(0)	0.508
$lnCO2_t$	-1.581(0)	0.484	-6.273(0)[a]	0.000	$lnSH_t$&$lnEA_t$	-2.085(0)	0.491
$lnEF_t$	-0.024(2)	0.951	-7.384(1)[a]	0.000	$lnSH_t$&$lnYKF_t$	-1.895(0)	0.587
$lnLCF_t$	0.727(2)	0.991	-7.347(1)[a]	0.000			

HE: Health expenditures; EF: Ecological footprint; LCF: Load capacity factor. The maximum lag length is set to 2 due to the use of annual data. The t-statistics criteria was used to determine the appropriate number of lags. The values in brackets give the appropriate lag length.

Methodology

The link between HE and the environment (CO_2, EF, and LCF) can be analyzed with the co-integration approach. Co-integration tests differ in terms of their assumptions. Traditional co-integration tests (For example, Engle and Granger (EG) [75]) are based on the assumption of a Gaussian distribution. However, Koenker and Xiao [76] show that in the presence of heavy-tailed distributions, conventional tests have weak power properties. In addition, traditional methods assume that there is no endogeneity problem in the model. However, models established for examining the relationship between economic variables may face the problem of endogeneity. This situation may cause deviations in the estimates [77].

Xiao [35] developed the QCR test, which can examine the asymmetric structure in the data set in detail and is resistant to the endogeneity problem. QCR testing extends the traditional co-integration model to a more general class of models that allow β to change over time. This test allows the relationship between variables to be analyzed by dividing them into quantiles. Syed et al. [78] state that the relationship between economic variables changes in different quantiles. In this regard, it offers a theoretical framework to explore the impact of positive and negative shocks by dissecting the asymmetric structure in the dataset into quantiles. In this context, methods that yield results on the basis of quantiles are useful in order to examine the asymmetric structure in detail.

The initial model in the QCR test is given by Equation 4.

$$y_t=\alpha+\beta X_t+\varepsilon_t \qquad (4)$$

The expanded version of Equation 4 by allowing β to change over time is shown in Equation 5:

$$y_t=\alpha+\beta_t X_t+\varepsilon_t \qquad (5)$$

where ε_t shows the errors for each quantile is expressed with $F_\varepsilon(\cdot)$. In accordance with the methodology of Xiao [35], the τ th conditional quantile of y_t is given by Equation 6.

$$Q_{i_t}(\tau|X_t) = \alpha(\tau) + \beta(\tau)X_t + \sum_{j=-K}^{K} \gamma_j(\tau)\cdot X_{t-j} + F_\varepsilon^{-1}(\tau) \qquad (6)$$

where $\beta(\tau)$ is the co-integration coefficient, which is different for each quantile. K denotes the leads of ΔX_t, and $-K$ denotes the lags. To overcome the problem of endogeneity, leads and lags are included in the model. In order to determine the existence of the co-integration, the γ_n statistics are calculated. The formulation for the γ_n statistic is as shown in Equation 7:

$$\gamma_n = \frac{1}{\omega_\psi^* \sqrt{n}} \sum_{j=1}^{K} \psi_\tau(\varepsilon_{j\tau}) \qquad (7)$$

where ω_ψ^* denotes the long-run variance of $\psi_\tau(\varepsilon_{j\tau})$. $\varepsilon_{j\tau}$ is the errors obtained from quantile co-integration regression. The H_0 (null) hypothesis reveals that there is co-integration between variables, and H_A (alternative) hypothesis reveals that there is no co-integration between variables. If the γ_n statistic is greater than the critical values of t-table, H_0 hypothesis is rejected, and it is decided that there is no co-integration.

FINDINGS

In the empirical analysis, firstly, whether the series contains a unit root or not is examined with the Augmented Dickey and Fuller (ADF) [79] test. Table 3 shows that the series contain unit roots at levels but become stationary when the first difference is taken (I(1)). Co-integration analysis is used to examine the relationship between non-stationary series. At this point, firstly, the effects of environmental indicators on HE is examined with the traditional co-integration test in order to make a comparison.

According to the EG co-integration test results, the null hypothesis that there is no co-integration in all models cannot be rejected. In other words, there is no relationship between HE and environmental indicators in Türkiye.

Then, the co-integration relationship between the series is examined with the QCR test, which allows to observe the time-varying co-integration, examines the effects of positive and negative shocks in detail, and gives a resistant estimate in the case of a non-normal distribution and possible endogeneity problems. The results are listed in Table 4.

First, the existence of a co-integration between the variables is examined on a model basis. When the γ_n statistics of the models in Table 4 are examined, the null hypothesis that there is a co-integration relationship for all models cannot be rejected. In other words, according to the results of the QCR test, contrary to the EG test, it

Table 4. Quantile co-integration analysis results

	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Independent variables									
$lnCO2_t$									
$\hat{\beta}_{(\tau)}$	0.351[a]	0.481[a]	0.488[a]	0.491[a]	0.528[a]	0.609[a]	0.664[a]	0.611[a]	0.583[a]
SD	0.132	0.101	0.098	0.102	0.098	0.110	0.105	0.095	0.090
t-stat.	2.658	4.744	4.961	4.817	5.390	5.554	6.349	6.407	6.488
$lnEF_t$									
$\hat{\beta}_{(\tau)}$	1.059[a]	0.906[a]	0.916[a]	0.843[a]	0.828[a]	0.873[a]	1.068[a]	0.963[a]	0.945[a]
SD	0.162	0.159	0.180	0.175	0.174	0.166	0.152	0.130	0.132
t-stat.	6.556	5.714	5.094	4.817	4.757	5.271	7.047	7.433	7.141
lnLCFt									
$\hat{\beta}_{(\tau)}$	-1.157[a]	-0.947[a]	-0.999[a]	-0.971[a]	-1.054[a]	-1.116[a]	-1.172[a]	-1.273[a]	-1.275[a]
SD	0.186	0.174	0.164	0.168	0.180	0.192	0.196	0.200	0.223
t-stat.	-6.224	-5.442	-6.082	-5.772	-5.849	-5.811	-5.968	-6.374	-5.726
	Test stat. (γ_n)	Prob.	%1	%5	%10				
Models									
$lnHE_t$&$lnCO2_t$	0.935	0.936	1.79	1.60	1.52				
$lnHE_t$&$lnEF_t$	0.986	0.939	1.93	1.66	1.60				
$lnHE_t$&$lnLCF_t$	1.248	0.386	1.89	1.60	1.51				

HE: Health expenditures; EF: Ecological footprint; LCF: Load capacity factor. Where the γ_n statistic is used to examine the existence of a co-integration, 0.1, …, 0.9 represent quantiles. SD represents a standard deviation. 1,645, 1,960, and 2,578 are t-table values expressing significance at 10%, 5%, and 1%, respectively. The probability values for the γ_n statistics were generated with 1,000 replications.

is determined that health expenditures ($lnSH_t$) and environmental indicators move together in the long term in Türkiye.

After the determination of the co-integration relationship, long-term coefficient estimates are made in order to determine the size and direction of the relationship. One of the most important advantages of quantile approaches is that they allow us to analyze this relationship on a quantile basis. In this context, coefficient estimates for each quantile are listed in Table 4. First of all, when the signs of the coefficients are examined, it is seen that the increases in CO_2 and EF in all quantiles increase the HE, while the increase in the LCF decreases the HE (Fig. 2). These results are in line with expectations. As the threat to human health from environmental pollution increases day by day, it plays a triggering role in health services and, thus, in HE. On the other hand, the decreasing effect of the LCF, namely the increase in environmental quality, on HE as a result of positive effects on human health supports the findings of CO_2 and EF on HE. When the coefficient sizes are examined in general, while CO_2 increases HE by 0.35% in negative shocks, this effect doubles when the direction of the shock changes. The coefficients of extreme negative and positive shocks in the EF are greater compared to the middle quantiles. Finally, there is no significant difference in the coefficient sizes for positive and negative shocks for the LCF, and the effect of the LCF on HE is higher for extreme positive shocks.

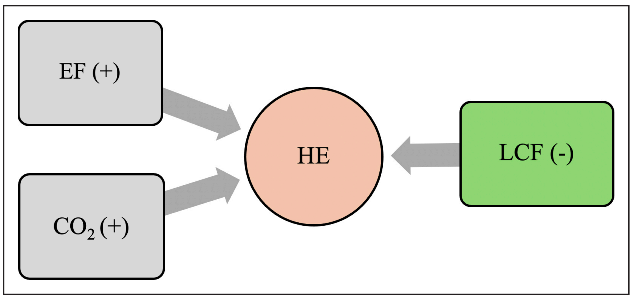

Figure 2. QCR test based coefficient signs of environmental indicators.

RESULTS AND DISCUSSION

The response to the question of how the environment affects HE in Türkiye differs on the basis of empirical approaches. According to the analysis results, the conventional co-integration (EG) test results reveal that there is no long-term relationship in the models. However, the models are cointegrated according to the QCR quantile co-integration method, which can better explain the data structure and give resistant estimates in cases of a non-normal distribution and possible endogeneity problem. This result supports the studies of Aydin and Bozatli [61], who discovered the co-integration between different environmental indicators and HE. The coefficient estimates of the method on the basis of quantiles show that the CO_2 and EF variables affect HE positively. In the literature, Demir et al. [60] studies reached similar findings. On the other hand, coefficient estimates provide evidence that the LCF variable negatively affects EH. When the findings of the three models are compared, the effects of environmental indicators on EH are consistent. The finding that environmental pollution increases HE and environmental quality decreases HE supports the expectations in the literature.

When the overall coefficient (0.5 quantile) results are examined, EF negatively affects HE 63.7% more than CO_2. Based on the average of the analysis period, the carbon footprint in EF represents 50.7% [69]. The fact that these two ratios are close to each other strengthens the reliability of the analysis's results. In addition, the coefficients for LCF, which provides the most comprehensive information about the environment among the models, are larger compared to other indicators. Considering biocapacity in the LCF model transforms the degrading effect of the environment on HE into a curative effect.

The study finally analyzes the quantile-based results for all models. Accordingly, the coefficients for CO_2 increase from negative shocks to positive shocks. This demonstrates the positive pressure of increases in CO_2 on HE. On the other hand, EF increases HE more in extremely large negative and positive shocks. Environmental pollution increases EH in positive shocks, which is in line with the expectations in the literature. However, the repulsive effect of negative shocks in EF on HE is a surprising finding. The reason for this result can be explained with the help of Figure 1. Accordingly, during the 2001 and 2008 economic crisis periods, human-induced EF declined due to the decrease in production and demand. However, in the same periods, instead of a decrease in HE, the course of increase continues. In times of crisis, the assumption that social stress is higher and the need for healthcare services increases may partly explain the increases in HE. Findings for LCF in the third model are similar to those for EF in terms of quantile-based coefficient change. In addition, LCF coefficient values are higher than those of CO_2 and EF. Therefore, the increase in environmental quality provides benefits beyond compensating for the increase in HE caused by environmental pollution. In positive shocks of LCF, the reducing effect of environmental quality on HE increases its severity.

CONCLUSION

The paper explores the effect of environmental indicators on HE with conventional and quantile co-integration methods. For this purpose, three models are created in the study. In the first two models, CO_2 and EF variables represent environmental pollution. In the third model, LCF, which has become popular recently and measures environmental quality, is preferred. Incorporating environmental supply over biocapacity into the calculation as well as environmental pollution, LCF provides holistic evidence and new perspectives on the effects of the environment on HE. Analyzing three environmental models in the study allows for comparison of findings and evaluation of consistency.

Among the empirical findings, firstly, the EG test finds no relationship between environmental indicators and HE, while the QCR test discovers different levels of relationship in the models. The quantile approach offers evidence through three models that, on the one hand, environmental degradation (CO_2 and EF models) encourages HE and, on the other hand, environmental improvement (LCF model) minimizes the need for HE. In addition, it confirms the existence of an asymmetric structure by revealing that the coefficients of the models change in negative and positive shocks.

Findings from all models indicate that for sustainable HE, governments should both combat environmental degradation and develop policies to increase environmental supply, namely biocapacity. In this context, some policy recommendations that will improve environmental quality and reduce HE can be listed as follows: Firstly, the share of renewable energy sources should be increased by minimizing fossil fuel consumption. As of 2019, the share of renewable energy consumption in Türkiye is only 14.1% of the total [80]. An increase in this rate will also contribute to the reduction of CO_2, which is the most important cause of environmental pollution. Secondly, public transportation should be encouraged instead of personal transportation vehicles, whose number is increasing day by day, especially in metropolitan cities. While the number of motor land vehicles in Türkiye was approximately 786 thousand in 1975, it increased approximately 32 times and reached 26.4 million in 2022 [81]. During the same period, the population increased by only 111% [82]. Therefore, new policies based on a sustainable environment, especially taxation, are needed for motor vehicles emitting CO_2. Third, governments should strive to spread healthy lifestyles among the population. Individuals should be encouraged to walk and eat healthy instead of using vehicles when appropriate. The policies governments develop in response to these three recommendations, in accordance with WHO, can prevent 7 million premature deaths globally each year [3]. Fourthly, environmentally friendly production should be encouraged by taxes and subsidy instruments in sectors that directly concern human health, especially agriculture. On the other hand, the prohibition of sectors with more environmental damage or the implementation of deterrent policies will improve the environment and human health. Finally, legislative arrangements should be made to prevent biocapacity resources such as rivers, lakes, seas, forests, and grasslands, which are known as common goods in the fiscal literature, from being damaged or destroyed due to excessive consumption. Because only reducing pollution is not enough for a sustainable environment, environmental supply sources need to be developed.

For further studies, researchers may prefer new and inclusive environmental indicators such as LCF and up-to-date empirical methods that take into account the characteristics of the data structure.

DATA AVAILABILITY STATEMENT

The author confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

USE OF AI FOR WRITING ASSISTANCE

Not declared.

ETHICS

There are no ethical issues with the publication of this manuscript.

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