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The Nexus between CO_2 Emissions and Health Expenditure – Causality Evidence from Selected CEE Countries

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Abstract

Greenhouse gas emissions, primarily carbon dioxide (CO_2), influence climate change and have a significant impact on public health. The relationship is a subject of interest to many researchers. However, the situation of Central and Eastern European (CEE) countries is not sufficiently explored in this context. Thus, this study examines the linkages between CO_2 emissions and health expenditures in 11 CEE countries. The empirical findings obtained using Kónya's bootstrap panel Granger causality test show that CO_2 emissions and health expenditures are related in most CEE countries. Notably, a bidirectional relationship in the bootstrap panel Granger causality test is found for Croatia, Romania, and Slovakia. In contrast, the relationship was revealed to be insignificant in Bulgaria, Lithuania, Poland, and Slovenia. The results are significant and contribute to the existing literature. The findings allow us to issue policy recommendations to intensify efforts to control pollution, particularly CO_2 emissions, especially in Croatia, Romania, and Slovakia, as well as in the countries where at least unidirectional effects from CO_2 emissions to health expenditures were observed (e.g., Estonia, Hungary, and Latvia).

Keywords: causality, CO_2 emissions, health expenditure, Central and Eastern European countries, quality of life

JEL: C20, H51, I10, Q53

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Introduction

Nowadays, one of the most important challenges for many economies is environmental change. These changes influence various aspects of the social and economic situations in many countries, impacting human life and health. One of the most threatening risks to health is environmental degradation, primarily caused by greenhouse gas emissions, particularly CO_2 (Ahmad et al. 2018; Wang et al. 2018).

Our literature review, which covered single countries as well as panels of countries, provided mixed results regarding the causality between CO_2 emissions and health expenditures (see, e.g., Wang et al. 2019a; 2019b; Erdogan, Kirca, and Gedikli 2020; Ganda 2021; Li et al. 2022). However, Central and Eastern European (CEE) countries have yet to be subjected to deeper analysis. Thus, this study aims to investigate the causal relationship between CO_2 emissions and current health expenditures in 11 CEE countries (Bulgaria, Croatia, Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, and Slovenia).

The motivation for this research comes from the importance of environmental issues in the development strategies of many economies. Additionally, the role of health status and social development further influences this motivation. The background of this study is informed by observations of the available data, which indicate that the countries under analysis recently have experienced an increase in health spending and a reduction in CO_2 emissions, as illustrated in Figure 1 and Figure 2.

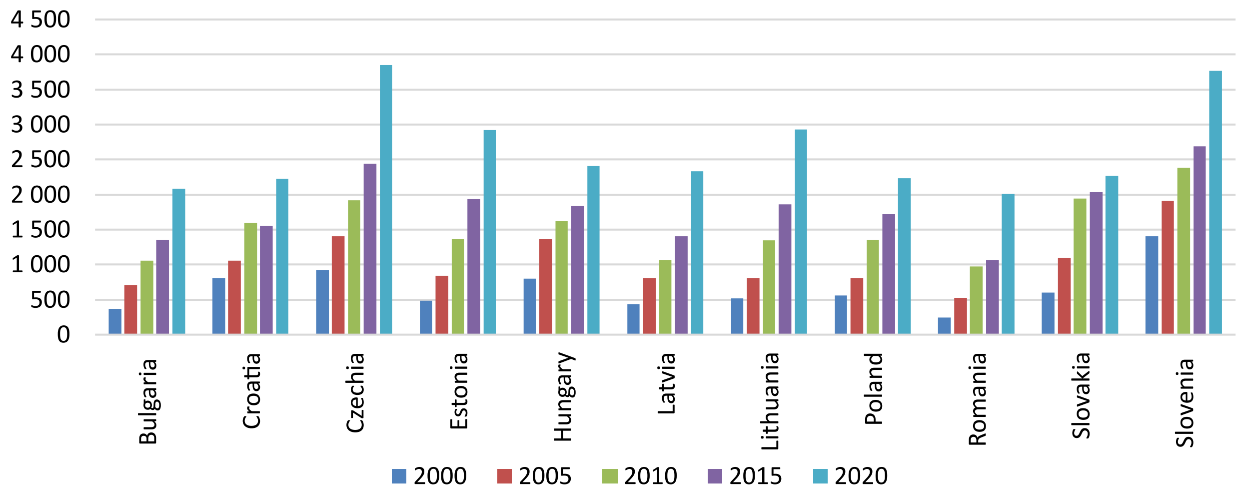

Figure 1. Current health expenditure per capita, PPP (current international $)

Source: own work based on World Bank n.d.

Figure 1 demonstrates that current health expenditures per capita in these 11 CEE countries are relatively similar and show a consistent upward trend over the years. However, there have been notable differences among the countries over time. For instance, Slovenia and Czechia consistently exhibited the highest health expenditures per capita in 2000, 2005, 2015, and 2020. Conversely, Romania and Bulgaria consistently had the lowest expenditures in the same years. Despite these differences, the health expenditures per capita for the remaining countries are generally close to the average for the group.

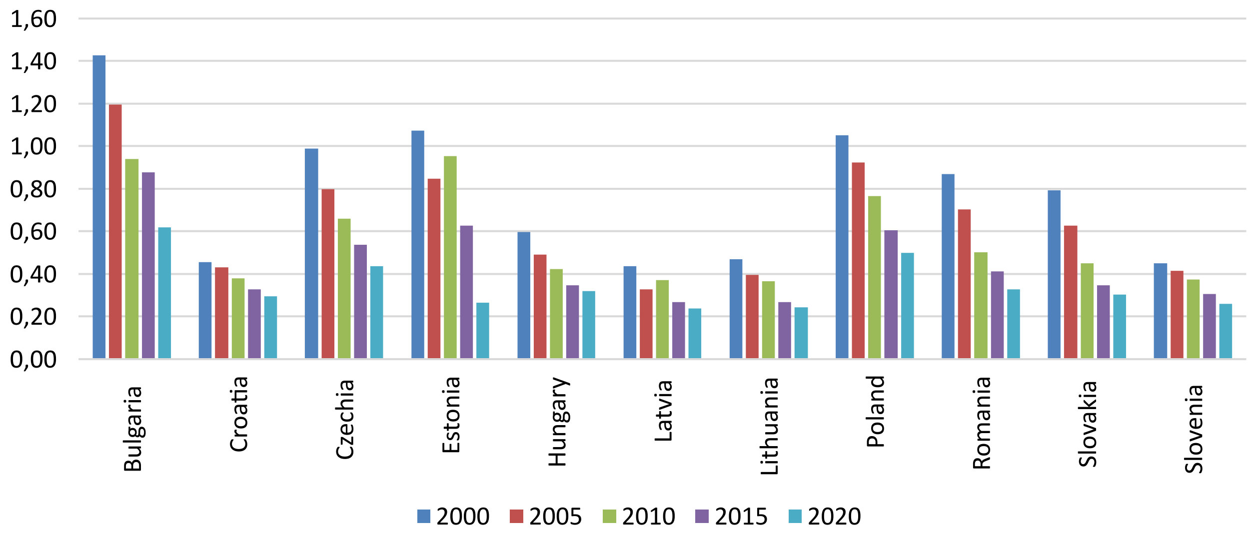

Figure 2. The size of CO_2 emissions (kg per 2015 US$ of GDP) in the analyzed countries

Source: own work based on World Bank n.d.

The group is also very close to each other in terms of CO_2 emissions. As Figure 2 illustrates, CO_2 emissions in these countries have been decreasing since 2000. The countries with the lowest emissions in 2000 were Latvia, Slovenia, and Croatia, although the situation changed slightly in other years, with Latvia, Lithuania, and Slovenia having the lowest CO_2 emissions in 2005, 2010, 2015, and 2020. Among the 11 countries, Bulgaria, Estonia, and Poland had the highest emissions in 2000, 2005, 2010, and 2015. However, by 2020, the ranking had changed slightly, with Bulgaria, Poland, and Czechia having the highest CO_2 emissions. The CO_2 emissions of the other countries are quite close to the group average and similar to each other.

From the literature review presented in Section 2 and considering the data above, it can be assumed that the links between CO_2 emissions and health expenditures may interact simultaneously. CO_2 emissions, as a risk to human health, influence health spending. Conversely, increased awareness of the importance of health status for well-being and economic growth can mitigate environmental degradation.

Considering the above, the main goal of this study is to examine the nexus between health expenditures and CO_2 emission levels in the selected CEE countries. This objective is explored through causality analysis, contributing four substantial insights to the literature. Firstly, this investigation provides new perspectives on the directional impact of health expenditures on CO_2 emissions and vice versa in 11 CEE countries. Secondly, a range of diagnostic tests is employed to validate the results. Thirdly, Kónya's (2006) bootstrap panel Granger causality test is used to explore the causal relationships between the two analyzed variables. Lastly, the study examines the following combined causality effects: (i) from CO_2 emissions to health expenditures and (ii) from health expenditures to CO_2 emissions.

The structure of the paper is as follows. Section 2 provides an extensive literature review, while Section 3 contains information about the data and methodology. The results of the study are presented in Section 4, while Section 5 concludes.

Literature review regarding the relationship between CO_2 emissions and health expenditure

CO_2 emissions are seen as an influential factor in health status. In this context, air pollution has a detrimental impact on public health spending. The link between measures of environmental degradation and public health spending has been examined in a wide range of studies, although the results were mixed. The literature review shows that the relationship between air pollution and health spending is often analyzed within the broader context of causality involving health, environmental degradation, and GDP growth, among others (see, e.g., Mujtaba and Shahzad 2021; Dritsaki and Dritsaki 2023; Vyas, Mehta, and Sharma 2023).

Akbar et al. (2021) used a panel VAR model to analyze the relationship between health expenditure, CO_2 emissions, and the Human Development Index (HDI) in 33 OECD countries, including Latvia, Lithuania, Slovenia, Slovakia, and Poland, from 2006 to 2016. Their methods allowed them to conclude that there is a bidirectional causal relationship between health expenditure and carbon dioxide emissions in OECD countries. This positive relationship indicates that CO_2 emissions significantly increase health expenditures.

Mujtaba and Shahzad (2021) analyzed data from 2002 to 2018 for 28 OECD countries to examine the relationship between environmental (air) pollutants, economic growth, renewable energy, and public health. Their panel VECM model results revealed long-run relationships between these variables. The FMOLS estimates indicated significant and positive effects of CO_2 and nitrous oxide emissions on health expenditure. Similar findings regarding the positive relationship between gas emissions and health spending for countries outside the OECD were highlighted by Chaabouni and Saidi (2017), Khoshnevis Yazdi and Khanalizadeh (2017), Akbar et al. (2021), and Saleem (2022), among others.

Wang et al. (2019a) analyzed the situation in 18 OECD economies over the period 1975–2017. They investigated the relationship between real GDP per capita, real health expenditure per capita, and CO_2 emissions using a bootstrap autoregressive distributed lag (ARDL) cointegration model. The outcomes generally presented mixed results. However, they revealed bidirectional causality between health expenditure and CO_2 emissions specifically for New Zealand and Norway.

In another study, Wang et al. (2019b) analyzed the relationship between a set of variables, including CO_2 emissions and health expenditures, focusing on Pakistan from 1995 to 2017. They employed the autoregressive distributive lag (ARDL) model and found a significant dynamic relationship. Based on their results, they concluded that there is a short-term causal relationship between health expenditure, CO_2 emissions, and economic growth, which also holds in the long run. They identified bidirectional Granger causality between CO_2 emissions and health spending, although, in the short term, causality was found to be unidirectional – from CO_2 emissions to health spending.

Bilgili et al. (2021) examined the nexus between public and private healthcare expenditure, economic growth, and pollution emissions for 36 Asian countries from 1991 to 2017. They explored the environmental Kuznets curve in Asian economies using advanced analyses such as the quantile regression method, FMOLS, and GMM approaches. Their findings indicated that both public and private health expenditures contribute to reducing CO_2 emissions. Notably, the study suggested that private health spending has a larger effect in reducing emissions compared to public health spending.

Ganda (2021) analyzed the situation in five BRICS countries from 2000 to 2017, focusing on CO_2 emission determinants. The study utilized two regression models: one based on aggregated health expenditure and another based on disaggregated health expenditure. The Dumitrescu–Hurlin panel Granger causality test was employed to analyze causality. The results revealed bidirectional causality between CO_2 emissions and health expenditure, with more detailed insights provided for three disaggregated categories of health spending: current, private, and domestic. However, the study found that the nexus between external health expenditure and CO_2 emissions was insignificant.

Apergis, Bhattacharya, and Hadhri (2020) presented interesting findings in their study analyzing a group of 178 countries from 1995 to 2017. The countries were categorized into four income groups: low, low-middle, upper-middle, and high-income. The study examined the long-run dynamics between environmental pollution and health spending, alongside income levels and health expenditures. Overall, the study found positive estimated elasticities for the relationship between CO_2 emissions and health spending. Specifically, a 1% increase in CO_2 emissions was associated with a 2.5% increase in health spending across the full sample. Upon disaggregation, the highest elasticity was observed in low-income countries at 2.9%. High-income countries also exhibited a high elasticity at 2.6%, while upper-middle-income countries had a slightly lower elasticity at 2.3%. The lowest elasticity was found in low-middle-income countries, which stood at 1.2%. These results highlight similarities between low-income and high-income countries in terms of their response to CO_2 emissions impacting health spending.

Yahaya et al. (2016) applied panel cointegration analysis to investigate the situation across a panel of 125 developing countries from 1995 to 2012. The study focused on the relationship between health expenditure per capita and a set of explanatory variables, including environmental quality. The authors identified a long-run relationship between per capita health expenditure and all explanatory variables. Specifically, they highlighted the significant explanatory effect of CO_2 emissions. Their findings indicated that both long-run and short-run outcomes confirm the increasing impact of air pollutants on per capita health expenditure over time.

Dritsaki and Dritsaki (2023) utilized data from G7 countries spanning the period 2000–2018 to examine the relationship between per capita healthcare expenditures, per capita CO_2 emissions, and per capita gross domestic product (GDP). Employing Dumitrescu and Hurlin's causality test, they identified a unilateral causality from per capita greenhouse gas emissions towards per capita health expenditure across all G7 countries. They concluded that CO_2 emissions significantly affect health expenditures in the most advanced economies, namely Canada, Germany, France, the United Kingdom, Italy, Japan, and the United States.

Ullah et al. (2019) analyzed the nexus between trade liberalization, CO_2 emissions, population growth, industrial production, and healthcare expenditures in China from 1990 to 2017.

The causality test indicated a unidirectional link between CO_2 emissions and health spending, specifically showing causality from CO_2 emissions to health spending. This suggests that emissions tend to increase healthcare expenditures. Additionally, Ecevit et al. (2023) examined the effects of globalization, economic growth, greenhouse gas emissions, and population aging on health expenditures using data from 12 emerging market economies between 2000 and 2018. Their empirical analysis included causality tests, revealing a bidirectional causality between carbon emissions and health expenditure.

Some empirical evidence suggests nonsignificant or negative correlations between CO_2 emissions and health spending variables (Yahaya et al. 2016; Alimi, Ajide, and Isola 2020; Erdogan, Kirca, and Gedikli 2020). For instance, Erdogan, Kirca, and Gedikli (2020) used a panel causality test to investigate the relationship between CO_2 emissions and health-related expenditure in five BRICS countries and Türkiye from 2000 to 2016. The study found that the relationship between healthcare expenditure and CO_2 emissions was not statistically significant in the analyzed countries, except for China. Specifically, in China, they identified a one-way positive causal relationship between health expenditures and CO_2 emissions.

Li et al. (2022) provided analyses for four BRICS countries using data from 2000 to 2019 to examine the correlation between health expenditures, CO_2 emissions, and GDP fluctuations. The study utilized autoregressive distributed lag (ARDL) models. The causality analysis yielded mixed results. In Brazil, in the short term, CO_2 emissions were found to have a one-way impact on health expenditure, while in China, health expenditure had a one-way impact on CO_2 emissions. In India, a two-way causal relationship between CO_2 emissions and health expenditure was identified.

Zaidi and Saidi (2018) revealed a negative correlation while investigating the interaction among environmental pollution, health expenditure, and economic development in sub-Saharan African countries from 1990 to 2015. They evaluated the effects of environmental pollution (CO_2 emissions and nitrous oxide emissions) on health expenditure and economic growth across these countries. The results indicated a negative long-run relationship between CO_2 emissions and nitrous oxide emissions with health spending, covering both public and private expenditures. The estimated elasticities showed that a 1% increase in CO_2 emissions would decrease health spending by 0.066%, while a 1% increase in nitrous oxide emissions caused a more substantial decrease of 0.577% in health expenditure. The effect was particularly pronounced in the case of CO_2 emissions. Causality analysis revealed a bidirectional relationship between health spending and CO_2 emissions. The main conclusion drawn was that, in the long run, carbon dioxide emissions were negatively associated with health expenditures.

Alimi, Ajide, and Isola (2020) analyzed the causal relationship between environmental quality (measured by CO_2 emissions per capita in metric tonnes) and healthcare expenditure in 15 ECOWAS (Economic Community of West African States) countries over the period 1995–2014. The dependent variable, health expenditure, was analyzed in three specifications: national healthcare expenditure, public healthcare expenditure, and private healthcare expenditure. The methods employed revealed a significant positive impact of carbon emissions on public and national healthcare expenditure. However, the relationship between environmental pollution and private healthcare expenditure was found to be insignificant.

Data and methodology

The literature extensively demonstrates a causal relationship between CO_2 emissions and health expenditure, confirmed by numerous studies. In contrast to the existing research, this study investigates the causal link between CO_2 emissions and health expenditures across 11 Central and Eastern European countries that are members of the European Union. To achieve this objective, an econometric analysis was conducted using the bootstrap panel Granger causality test. This section provides a detailed description of the data, followed by an explanation of the methodology used. Finally, empirical findings derived from the analysis are presented and discussed.

Table 1. Data description

Variables	Description	Period	Data type	Source
CO_2	CO_2 emissions (kg per 2015 US$ of GDP)	2000–2020	Panel Data	World Bank n.d.
HE	Current health expenditure per capita, PPP (current international $)			

Source: own work.

As Table 1 shows, the analysis utilized two distinct variables: CO_2 (CO_2 emissions, kg per 2015 US$ of GDP) and HE (current health expenditure per capita, PPP, current international $). The panel data utilized in this study was sourced from the World Bank (n.d.) and covers the period 2000–2020. The study focuses on 11 CEE countries that are members of the European Union: Bulgaria, Croatia, Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, and Slovenia. The period of the study was determined by data availability, and all variables underwent logarithmic transformations for our econometric analysis.

It is hypothesized that the causality relationship between CO_2 emissions and health expenditure may vary across countries that exhibit similar levels of development in these variables. Therefore, an empirical examination was conducted using the bootstrap panel Granger causality test, which offers country-specific causality test results. This approach allows for a nuanced analysis of how CO_2 emissions and current health expenditures per capita interact within different country contexts.

In the empirical part of this study, a panel data model was constructed to forecast the causality relationship between the variables. The model can be formulated as:

$$\mathrm{CO}_{2\mathrm{it}} = \alpha_{1\mathrm{i}} + \alpha_{2\mathrm{i}}\mathrm{HE}_{\mathrm{it}} + \mathrm{u}_{\mathrm{it}}, \tag{1}$$

where: i stands for the countries (i = 1, 2, …, 11), t denotes time period (t = 2000, …, 2020), α_{1i} is the constant term, and α_{2i} is the parameter of health expenditure that expresses the effect of CO_2 emissions. The panel data model used in this current study is based on Kónya's (2006) bootstrap panel Granger causality test.

There are several compelling reasons to choose this method for our empirical analysis. First and foremost, it eliminates the need for pre-tests. Many panel causality tests require preliminary investigations into stationarity and the presence of cointegration among variables. However, our chosen method bypasses these initial requirements. Another significant advantage is its ability to accommodate cross-sectional dependence, making its assumptions more realistic for our study context. Lastly, the method incorporates panel heterogeneity, allowing us to derive specific results for each country in the panel (Kar, Nazlıoğlu, and Ağır 2011, p. 688). This feature enables comparative analysis across countries, enhancing the depth of our findings.

The analysis using Kónya's bootstrap panel Granger causality test involves two important stages. The first stage involves assessing the validity of cross-sectional dependence and panel heterogeneity conditions for the entire panel. Pesaran (2004) notes that cross-sectional dependence refers to the correlation among cross-sections. In the second stage, the panel Granger causality relationship between variables should be estimated for each country using the Seemingly Unrelated Regression Equation (SURE) method developed by Zellner (1962).

Pesaran (2004) also addresses Breusch and Pagan's (1980) contributions with proposed Lagrange Multiplier (CD_{LM1}) test statistics:

$$CD_{LM1} = T\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}^{2}. \tag{2}$$

As shown in Equation (2), the Lagrange Multiplier (LM_1) test statistic provides the asymptotic chi-square distribution with N(N – 1)/2 degrees of freedom. In this equation $\hat{\rho}_{ij}$ represents the sample estimate of the pairwise correlation of the residuals. The null hypothesis (H_0) states that there is no cross-sectional dependence, while the alternative hypothesis $\left(H_1\right)$ asserts there is cross-sectional dependence for at least one pair. The hypotheses may be written for this test as follows:

$H_0:\ \text{cov}\left(u_{it},\ u_{kt}\right) = 0$ for all t and $i \neq t$,

$H_1:\ \text{cov}\left(u_{it},\ u_{kt}\right) \neq 0$ for at least one pair of $i \neq t$.

The CD_{LM1} test statistic is generally used when $T \rightarrow \infty$ and N remains constant. However, when N is large, the CD_{LM1} statistics may be limited. For this reason, Pesaran (2004) proposes the following CD_{LM2} test statistics:

$$CD_{LM2} = \sqrt{\frac{1}{N\left(N-1\right)}}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}(T\hat{\rho}_{ij}^{2} - 1). \tag{3}$$

According to Pesaran (2004), CD_{LM2} is suitable for testing the hypothesis of cross dependence even when both N and T are large ($T \rightarrow \infty$ and $N \rightarrow \infty$) (T > N). Additionally, Pesaran (2004) also introduced the following simpler alternative CD test statistic:

$$CD = \sqrt{\frac{2T}{N\left(N-1\right)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}\right). \tag{4}$$

The CD test statistic applies in cases where N (the number of cross-sections) is high and T (the number of periods) is relatively low. It relies on pairwise correlation coefficients rather than their squares, as in the CD_{LM1} statistic. However, when there are concerns regarding the significance levels of groups, these two test statistics may not suffice to reject the null hypothesis. To address this, Pesaran, Ullah, and Yamagata (2008) proposed an alternative test:

$$CD_{LMadj} = \sqrt{\left(\frac{2T}{N(N-1)}\right)} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij} \frac{(T-k)\hat{\rho}_{ij}^{2} - \mu_{Tij}}{\sqrt{\nu_{Tij}^{2}}}. \tag{5}$$

The CD_{LMadj} test statistic is called the bias-adjusted LM statistic with asymptotic standard normal distribution for the cases where both T→∞ and N→∞. In this case, μ_{Tij} and ν_{Tij}^{2} refer to the mean and the variance of (T – k) $\hat{\rho}_{ij}^{2}$, respectively.

As previously mentioned, in Kònya's bootstrap panel Granger causality test method, another consideration after identifying cross-sectional dependence is controlling for slope homogeneity (or panel heterogeneity). For this purpose, the method proposed by Swamy (1970) is often preferred, but it can only be applied when T is greater than N (T > N). To extend Swamy's method to larger panels, Pesaran and Yamagata (2008) developed another test, which is shown in the following equation:

$$\tilde{S} = \sum_{i=1}^{N} \left(\hat{\beta}_{i} - \hat{\beta}_{WFE}\right)' \frac{x_i' M_{\tau} x_i}{\tilde{\sigma}_{i}^{2}} \left(\hat{\beta}_{i} - \hat{\beta}_{WFE}\right), \tag{6}$$

where: $\hat{\beta}_{I}$ represents the pooled OLS estimator, $\hat{\beta}_{WFE}$ denotes the weighted and fixed effect pooled estimator, M_{τ}, is the identity matrix, and $\tilde{\sigma}_{I}^{2}$ indicates the estimator of σ_{I}^{2}. Pesaran and Yamagata (2008) also introduced a standardized version of this test statistic, expressed as follows:

$$\tilde{\Delta} = \sqrt{N}\left(\frac{N^{-1}\tilde{S} - k}{\sqrt{2k}}\right). \tag{7}$$

Based on Equation (7), when $\sqrt{N}/T \rightarrow \infty$, the null hypothesis ($H_0: \beta_i = \beta$; for all i,) tests the assumption that "slope coefficients are homogeneous when $(N,T) \rightarrow \infty$" against the alternative hypothesis ($H_1: \beta_i = \beta_{j;}$ for $i \neq j$), which posits that "slope coefficients are heterogeneous". Additionally, In the meantime, Pesaran and Yamagata (2008) proposed a bias-adjusted test statistic, denoted as $\tilde{\Delta}_{adj}$, to use in smaller samples. The adjusted test statistic is shown in Equation (8) as follows:

$$\tilde{\Delta}_{adj} = \sqrt{N}\left(\frac{N^{-1}\tilde{S} - E(\tilde{z}_{it})}{\sqrt{var(\tilde{z}_{it})}}\right). \tag{8}$$

As noted by Kar, Nazlıoğlu, and Ağır (2011), once the cross-section dependence and slope homogeneity tests have been conducted and the required conditions are satisfied, the panel Granger causality relationship between variables should be examined. The Wald test statistics and bootstrap critical values are determined using the SURE method developed by Zellner (1962).

Kónya (2006) presented the following two sets of Equations (9) and (10) based on the SURE method:

$$Y_{N,t} = \alpha_{1,N} + \sum_{j=1}^{ly_N} \beta_{1,N,j} Y_{N,t-j} + \sum_{j=1}^{lx_N} \gamma_{1,N,j} X_{N,t-j} + \varepsilon_{1,N,t} \tag{9}$$

and

$$X_{N,t} = \alpha_{2,N} + \sum_{j=1}^{lx_N} \beta_{2,N,j} Y_{N,t-j} + \sum_{j=1}^{ly_N} \gamma_{2,N,j} X_{N,t-j} + \varepsilon_{2,N,t}. \tag{10}$$

In the context of this study's data, in Equations (9) and (10), Y represents CO_2 emissions, X represents health expenditure, t denotes the period, and N indicates the number of countries. Parameters α, β, and γ denote common factors, and ε signifies the disturbance. The outcome of this test will yield four possible causal relationships:

- A unidirectional Granger causality relationship from CO_2 to HE ($\gamma_{1,i} = 0$ and $\beta_{2,i} \neq 0$ for each i),
- A unidirectional Granger causality relationship from HE to CO_2 ($\gamma_{1,i} \neq 0$ and $\beta_{2,i} = 0$ for each i),
- A bidirectional Granger causality relationship between CO_2 and HE (if $\gamma_{1,i} \neq 0$ and $\beta_{2,i} \neq 0$ for each i),
- No Granger causality relationship between CO_2 and HE (if $\gamma_{1,i} = 0$ and $\beta_{2,i} = 0$ for each i).

Empirical findings

The diagnostic tests begin with an examination of cross-sectional dependence. Since T > N in this study, it is necessary to focus on the results of CD_{LM1}, CD_{LM2}, and CD_{LMadj} test statistics when assessing the results of cross-sectional dependence. Tables 2 and 3 show the results of these test statistics.

Table 2. Cross-sectional dependence test results (based on model)

		CD_{LM1}	CD_{LM2}	CD	CD_{LMadj}
Model	Statistics	198.475***	13.680***	1.007	1.155
	Probability	0.000	0.000	0.157	0.876

Note: *** denotes significance at the 0.01 level.

Source: own work.

As shown in Table 2, the null hypothesis, which states there is no cross-sectional dependence for the forecast panel model, was rejected based on the results of the CD_{LM1} and CD_{LM2} test statistics. This finding indicates the presence of cross-sectional dependence within the established panel model and suggests its suitability for the bootstrap panel Granger causality test method.

Table 3. Cross-sectional dependence test results (based on variables)

		CD_{LM1}	CD_{LM2}	CD	CD_{LMadj}
CO_2	Statistics	91.072***	3.439***	– 2.122**	1.595*
	Probability	0.002	0.000	0.017	0.055
HE	Statistics	74.414**	1.851**	– 1.483*	3.131***
	Probability	0.042	0.032	0.069	0.001

Note: ***, **, and * denote significance at the 0.01, 0.05 and 0.10 levels, respectively.

Source: own work.

The findings presented in Table 3 are significant as they reject the null hypothesis of no cross-sectional dependence for CO_2 and health expenditure (HE) at the series level. The consistent results of the CD_{LM1}, CD_{LM2}, and CD_{LMadj} test statistics affirm the suitability of the series for the test method and provide insights into the presence of cross-sectional dependence within the series. These results are crucial as they indicate that shocks in CO_2 and HE in the CEE countries also affect other countries. Table 4 presents the results of the slope homogeneity tests alongside the cross-sectional dependence tests.

Table 4. Slope homogeneity test results

		$\tilde{\Delta}$	$\tilde{\Delta}_{adj}$
Model	Statistics	2.141**	2.304**
	Probability	0.016	0.011

Note: ** denotes significance at the 0.05 level.

Source: own work.

The results of the slope homogeneity test indicate that the panel causality relationship between CO_2 and health expenditure (HE) may vary across countries. This is because the null hypothesis, which assumes homogeneity of slope coefficients, was rejected at the 5% significance level for the panel model. These results, along with the findings from the cross-sectional dependence test, which are prerequisites for Kónya's (2006) bootstrap panel Granger causality test, align as expected. With these conditions met, the bootstrap panel Granger causality relationship between CO_2 and HE was examined, and the findings are presented in Tables 5 and 6.

According to these tables, the null hypothesis suggesting no causality relationship from CO_2 to health expenditure (HE) is rejected, revealing a unidirectional causality from CO_2 to HE in Estonia, Hungary, and Latvia. This finding suggests that reductions in CO_2 emissions could positively impact health expenditures in these three countries, as changes in CO_2 emissions appear to influence health expenditures. Conversely, the null hypothesis indicating no causality relationship from HE to CO_2 is rejected, showing a unidirectional causality from HE to CO_2 in Czechia.

Table 5. Bootstrap panel Granger causality test results ($H_0 : CO_2 \nrightarrow HE$)

Countries	Wald statistics [EC]	Bootstrap critical values		
		1%	5%	10%
Bulgaria	8.850	41.786	24.296	17.592
Croatia	**4.454*** **[0.090]**	**15.092**	**6.097**	**4.119**
Czechia	10.374	49.485	28.050	20.800
Estonia	**7.288*** **[0.079]**	**17.558**	**8.667**	**6.528**
Hungary	**9.340**** **[0.049]**	**20.624**	**9.020**	**5.933**
Latvia	**24.931***** **[0.006]**	**15.619**	**9.171**	**6.603**
Lithuania	42.881	229.895	147.611	122.518
Poland	3.671	19.709	10.875	7.879
Romania	**6.672*** **[0.093]**	**19.587**	**9.399**	**6.314**
Slovakia	**4.537*** **[0.080]**	**9.953**	**5.537**	**3.793**
Slovenia	84.925	152.271	109.511	91.615

Note: ***, **, and * denote significance at the 0.01, 0.05 and 0.10 levels, respectively. Statistically significant estimates are bolded. [EC] = Estimated coefficients. Critical values obtained from 10,000 replications.

Source: own work.

Table 6. Bootstrap panel Granger causality test results ($H_0 : HE \nrightarrow CO_2$)

Countries	Wald statistics [EC]	Bootstrap critical values		
		1%	5%	10%
Bulgaria	11.598	53.555	29.935	20.923
Croatia	**20.953*** **[0.058]**	**42.982**	**22.285**	**16.206**
Czechia	**16.466**** **[0.046]**	**29.915**	**16.091**	**10.783**
Estonia	17.384	49.569	32.453	23.628
Hungary	8.388	38.913	21.646	15.774
Latvia	9.963	40.242	19.910	13.312
Lithuania	34.243	173.633	131.000	110.622
Poland	6.571	40.196	18.101	12.478
Romania	**32.722**** **[0.031]**	**46.040**	**27.212**	**18.944**

Countries	Wald statistics [EC]	Bootstrap critical values		
		1%	5%	10%
Slovakia	**24.898**** **[0.046]**	**39.401**	**22.844**	**15.407**
Slovenia	24.623	202.096	129.856	100.848

Note: ***, **, and * denote significance at the 0.01, 0.05 and 0.10 levels, respectively. Statistically significant estimates are in bold. [EC] = Estimated coefficients. Critical values obtained from 10,000 replications.

Source: own work.

Unlike the other countries, the relationship direction between CO_2 and HE in Czechia is reversed, indicating that health expenditures have a decisive effect on CO_2 emissions in this country. Furthermore, a bidirectional causality relationship between CO_2 and HE has been identified in Croatia, Romania, and Slovakia, where CO_2 emissions and health expenditures mutually influence each other, with both variables acting as cause and effect. These empirical findings are summarized in Figure 3.

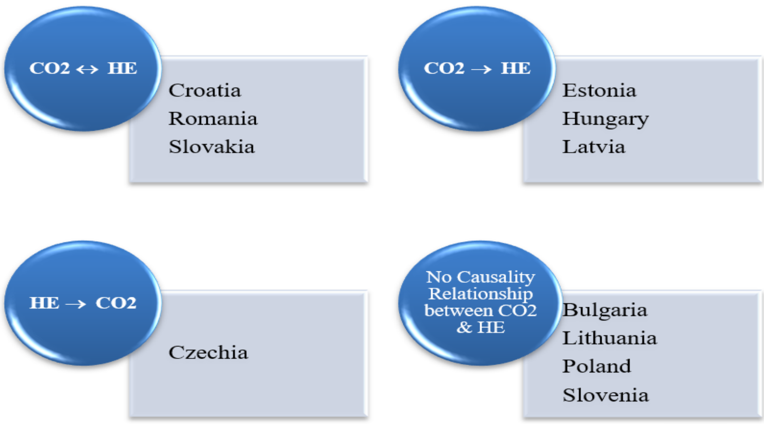

Figure 3. Causality between variables

Source: own work.

Based on these findings, the role and significance of health expenditures should be carefully considered when governments formulate policies aimed at reducing emissions. In contrast, no causal relationship was observed between CO_2 emissions and health expenditures in Bulgaria, Lithuania, Poland, or Slovenia. The unique situation in these four countries, which differ from those of the others, warrants detailed discussion in future research.

Conclusions

The rise in health expenditures and improvements in life expectancy have prompted countries to increase their healthcare budgets. This trend has been particularly pronounced in many countries following the COVID-19 pandemic, including those in Central and Eastern Europe. According to Jakovljevic, Vukovic, and Fontanesi (2015), South and Eastern European economies have shown strong performance in terms of life expectancy and health outcomes. Despite occasional setbacks in health outcomes, these countries have maintained a long-term growth trajectory in health expenditures. CEE countries have also been active in implementing various strategies to enhance healthcare spending, similar to other developing and emerging economies. For instance, Nica et al. (2023) reported that Poland has increased the budget allocated to the National Health Fund and introduced tax incentives for healthcare professionals to bolster health expenditures. In Romania, efforts have focused on improving healthcare efficiency through the introduction of a new payment system for healthcare providers. Meanwhile, Bulgaria has expanded its healthcare network by increasing the number of doctors and constructing new hospitals in remote areas. It would also be advantageous to align these advancements in health expenditures with efforts to address climate change and the rise in greenhouse gas emissions.

This paper analyzed the relationship between CO_2 emissions and current health expenditures in 11 CEE countries from 2000 to 2020 using Kónya's (2006) bootstrap panel Granger causality test method. The study yielded varied but important results. Consistent with the findings, Croatia, Romania, and Slovakia exhibited a bidirectional causal relationship between CO_2 emissions and health expenditures, while Estonia, Hungary, and Latvia showed a unidirectional effect of CO_2 emissions on health expenditures. In Czechia, the direction was reversed, with health expenditures influencing CO_2 emissions. The findings suggest that environmental degradation, specifically through carbon dioxide emissions, significantly impacts health expenditures in half of the countries studied. Therefore, a key policy recommendation is to prioritize measures to reduce CO_2 emissions in these economies. Conversely, Bulgaria, Lithuania, Poland, and Slovenia showed insignificant relationships between CO_2 emissions and health expenditures. Further research is recommended to explore the underlying reasons for these findings in greater depth.

Beyond the specific results, the study underscores the importance of reevaluating health and environmental policies in CEE countries. The analysis presented in this study is very important both in terms of showing the current situation of the 11 CEE countries in terms of CO_2 emissions and health expenditures and in terms of understanding how the variables influence each other (which varies by country). The findings are valuable and may stimulate further academic discussion. The economic costs of environmental degradation on public health, overall health outcomes, national well-being, and economic growth warrant heightened attention from policymakers. Thus, there is a pressing need for policies aimed at environmental protection and the reduction of greenhouse gas emissions.

References

Ahmad, M., Ur Rahman, Z., Hong, L., Khan, S., Khan, Z., Naeem Khan, M. (2018), *Impact of Environmental Quality Variables and Socio-Economic Factors on Human Health: Empirical Evidence from China*, "Pollution", 4 (4), pp. 571–579, https://doi.org/10.22059/poll.2018.252214.391

Akbar, M., Hussain, A., Akbar, A., Ullah, I. (2021), *The dynamic association between healthcare spending, CO_2 emissions, and human development index in OECD countries: Evidence from panel VAR model*, "Environment, Development and Sustainability", 23, pp. 10470–10489, https://doi.org/10.1007/s10668-020-01066-5

Alimi, O.Y., Ajide, K.B., Isola, W.A. (2020), *Environmental quality and health expenditure in ECOWAS*, "Environment, Development and Sustainability", 22 (6), pp. 5105–5127, https://doi.org/10.1007/s10668-019-00416-2

Apergis, N., Bhattacharya, M., Hadhri, W. (2020), *Health care expenditure and environmental pollution: A cross-country comparison across different income groups*, "Environmental Science and Pollution Research", 27 (8), pp. 8142–8156, https://doi.org/10.1007/s11356-019-07457-0

Bilgili, F., Kuşkaya, S., Khan, M., Awan, A., Türker, O. (2021), *The roles of economic growth and health expenditure on CO_2 emissions in selected Asian countries: A quantile regression model approach*, "Environmental Science and Pollution Research", 28, pp. 44949–44972, https://doi.org/10.1007/s11356-021-13639-6

Breusch, T.S., Pagan, A.R. (1980), *The Lagrange Multiplier Test and its Applications to Model Specification in Econometrics*, "The Review of Economic Studies", 47 (1), pp. 239–253, https://doi.org/10.2307/2297111

Chaabouni, S., Saidi, K. (2017), *The dynamic links between carbon dioxide (CO_2) emissions, health spending and GDP growth: A case study for 51 countries*, "Environmental Research", 158, pp. 137–144, https://doi.org/10.1016/j.envres.2017.05.041

Dritsaki, M., Dritsaki, C. (2023), *The Relationship Between Health Expenditure, CO_2 Emissions, and Economic Growth in G7: Evidence from Heterogeneous Panel Data*, "Journal of the Knowledge Economy", 15, pp. 1–26, https://doi.org/10.1007/s13132-023-01349-y

Ecevit, E., Cetin, M., Kocak, E., Dogan, R., Yildiz, O. (2023), *Greenhouse gas emissions, economic globalization, and health expenditures nexus: does population aging matter in emerging market economies?*, "Environmental Science and Pollution Research", 30 (11), pp. 29961–29975, https://doi.org/10.1007/s11356-022-24274-0

Erdogan, S., Kirca, M., Gedikli, A. (2020), *Is There a Relationship between CO_2 Emissions and Health Expenditures? Evidence from BRICS-T Countries*, "Business and Economics Research Journal", 11 (2), pp. 293–305, https://doi.org/10.20409/berj.2019.231

Ganda, F. (2021), *The impact of health expenditure on environmental quality: the case of BRICS*, "Development Studies Research", 8 (1), pp. 199–217, https://doi.org/10.1080/21665095.2021.1955720

Jakovljevic, M.B., Vukovic, M., Fontanesi, J. (2016), *Life expectancy and health expenditure evolution in Eastern Europe – DiD and DEA analysis*, "Expert Review of Pharmacoeconomics & Outcomes Research", 16 (4), pp. 537–546, https://doi.org/10.1586/14737167.2016.1125293

Kar, M., Nazlıoğlu, S., Ağır, H. (2011), *Financial development and economic growth nexus in the MENA countries: Bootstrap panel granger causality analysis*, "Economic Modelling", 28 (1–2), pp. 685–693, https://doi.org/10.1016/j.econmod.2010.05.015

Khoshnevis Yazdi, S., Khanalizadeh, B. (2017), *Air pollution, economic growth and health care expenditure*, "Economic Research-Ekonomska Istraživanja", 30 (1), pp. 1181–1190, https://doi.org/10.1080/1331677X.2017.1314823

Kónya, L. (2006), *Exports and growth: Granger causality analysis on OECD countries with a panel data approach*, "Economic Modelling", 23 (6), pp. 978–992, https://doi.org/10.1016/j.econmod.2006.04.008

Li, F., Chang, T., Wang, M.C., Zhou, J. (2022), *The relationship between health expenditure, CO_2 emissions, and economic growth in the BRICS countries – based on the Fourier ARDL model*, "Environmental Science and Pollution Research", 29, pp. 1–20, https://doi.org/10.1007/s11356-021-17900-w

Mujtaba, G., Shahzad, S.J.H. (2021), *Air pollutants, economic growth and public health: implications for sustainable development in OECD countries*, "Environmental Science and Pollution Research", 28, pp. 12686–12698, https://doi.org/10.1007/s11356-020-11212-1

Nica, E., Poliakova, A., Popescu, G.H., Valaskova, K., Burcea, S.G., Constantin, A.L.D. (2023), *The impact of financial development, health expenditure, CO_2 emissions, institutional quality, and energy mix on life expectancy in Eastern Europe: CS-ARDL and quantile regression Approaches*, "Heliyon", 9 (11), e21084, https://doi.org/10.1016/j.heliyon.2023.e21084

Pesaran, M.H. (2004), *General Diagnostic Tests for Cross Section Dependence in Panels*, "University of Cambridge Working Papers in Economics", 0435, https://doi.org/10.2139/ssrn.572504

Pesaran, M.H., Yamagata, T. (2008), *Testing slope homogeneity in large panels*, "Journal of Econometrics", 142 (1), pp. 50–93, https://doi.org/10.1016/j.jeconom.2007.05.010

Pesaran, M.H., Ullah, A., Yamagata, T. (2008), *A bias-adjusted LM test of error cross-section independence*, "Econometrics Journal", 11 (1), pp. 105–127, https://doi.org/10.1111/j.1368-423X.2007.00227.x

Saleem, H., Khan, M.B., Shabbir, M.S., Khan, G.Y., Usman, M. (2022), *Nexus between non-renewable energy production, CO_2 emissions, and healthcare spending in OECD economies*, "Environmental Science and Pollution Research", 29 (31), pp. 47286–47297, https://doi.org/10.1007/s11356-021-18131-9

Swamy, P.A. (1970), *Efficient Inference in a Random Coefficient Regression Model*, "Econometrica", 38 (2), pp. 311–323, https://doi.org/10.2307/1913012

Ullah, I., Ali, S., Shah, M.H., Yasim, F., Rehman, A., Al-Ghazali, B.M. (2019), *Linkages between Trade, CO_2 Emissions and Healthcare Spending in China*, "International Journal Environmental Research and Public Health", 16 (21), 4298, https://doi.org/10.3390/ijerph16214298

Vyas, V., Mehta, K., Sharma, R. (2023), *The nexus between toxic-air pollution, health expenditure, and economic growth: An empirical study using ARDL*, "International Review of Economics & Finance", 84 (C), pp. 154–166, https://doi.org/10.1016/j.iref.2022.11.017

Wang, B., Wang, X., Guo, D., Zhang, B., Wang, Z. (2018), *Analysis of factors influencing residents' habitual energy-saving behaviour based on NAM and TPB models: Egoism or altruism?*, "Energy Policy", 116, pp. 68–77, https://doi.org/10.1016/j.enpol.2018.01.055

Wang, C.M., Hsueh, H.P., Li, F., Wu, C.F. (2019a), *Bootstrap ARDL on Health Expenditure, CO_2 Emissions, and GDP Growth Relationship for 18 OECD Countries*, "Frontiers in Public Health", 7, 324, https://doi.org/10.3389/fpubh.2019.00324

Wang, Z., Asghar, M.M., Zaidi, S.A.H., Wang, B. (2019b), *Dynamic linkages among CO_2 emissions, health expenditures, and economic growth: Empirical evidence from Pakistan*, "Environmental Science and Pollution Research", 26, pp. 15285–15299, https://doi.org/10.1007/s11356-019-04876-x

World Bank (n.d.), *World Development Indicators*, https://datatopics.worldbank.org/world-development-indicators/ (accessed: 26.04.2024).

Yahaya, A., Nor, N.M., Habibullah, M.S., Ghani, J.A., Noor, Z.M. (2016), *How relevant is environmental quality to per capita health expenditures? Empirical evidence from panel of developing countries*, "SpringerPlus", 5, 925, https://doi.org/10.1186/s40064-016-2505-x

Zaidi, S., Saidi, K. (2018), *Environmental pollution, health expenditure and economic growth in the Sub-Saharan Africa countries: Panel ARDL approach*, "Sustainable Cities and Society", 41, pp. 833–840, https://doi.org/10.1016/j.scs.2018.04.034

Zellner, A. (1962), *An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias*, "Journal of The American Statistical Association", 57 (298), pp. 348–368, https://doi.org/10.1080/01621459.1962.10480664

Związek między emisją CO_2 a wydatkami na zdrowie – analiza krajów Europy Środkowo-Wschodniej

Emisje gazów cieplarnianych (głównie dwutlenku węgla – CO_2) wpływają na zmiany klimatyczne, co oddziałuje na zdrowie publiczne. Celem artykułu jest zbadanie powiązań między emisją CO_2 a wydatkami na zdrowie w 11 krajach Europy Środkowo-Wschodniej (CEE) z wykorzystaniem wariantu testu przyczynowości Grangera, opracowanego przez Kónya. Próba czasowa obejmuje dane roczne od 2000 do 2020 roku. Badania empiryczne dostarczają zróżnicowanych wyników. Dwukierunkową zależność stwierdzono w przypadku Chorwacji, Rumunii i Słowacji, podczas gdy na przykład w Bułgarii, na Litwie, w Polsce i Słowenii powiązanie było nieistotne. Zalecenia polityczne obejmują podjęcie wysiłków w zakresie kontroli zanieczyszczeń, w szczególności emisji CO_2 w Chorwacji, Rumunii, Słowacji, jak również w Estonii, na Węgrzech i Łotwie, a więc w krajach, gdzie oszacowano przynajmniej jednokierunkowy wpływ emisji CO_2 na wydatki na zdrowie.

Słowa kluczowe: przyczynowość, emisja CO_2, wydatki na zdrowie, kraje Europy Środkowo-Wschodniej, jakość życia