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Effects of air pollution and monetary policy on health expenditure with a sustainable development approach in the European Union

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ABSTRACT

Demographic, social, and economic factors, along with financing arrangements and the organizational structure of the health system, shape a country's health expenditure and its evolution over time. The COVID-19 pandemic had a significant impact on Europe's health expenditure in 2020. This study aims to examine the effects of air pollution and monetary policy on healthcare expenditure in European countries within the framework of sustainable development during the COVID-19 crisis. To achieve this, spatial panel models are used to analyze the 2005–2020 panel data of 27 countries. The results indicate that the average air pollution index negatively affects healthcare expenditure. In contrast, GNI, Broad Money (M3), CPI, and the Death rate positively impact healthcare expenditure. Based on these empirical findings, if EU governments aim to guide the expansion of the healthcare system through a more government-driven monetary policy, they should revise their air pollution regulations accordingly.

Keywords: Air pollution, Monetary policy, Health expenditure, Spatial panel data model.
Article type: Research Article.

INTRODUCTION

Health problems primarily concerning democracy, economic conditions, government capabilities, trade relationships with foreign countries, and the provision of health services are increasingly studied in different societies, particularly in those with a growing elderly population. As countries get richer and richer, global health expenditure increases. Policymakers need not only to know why health expenditures increase, but they should also find out if these increased expenses on health facilities will result in universal coverage and will finally improve people's health (Stepovic 2019). Europe has reduced emissions of various air pollutants in the past decades, followed by improved air quality. However, a reduction in emissions does not always lead to a corresponding decrease in atmospheric concentrations, particularly concerning particulate matter (PM) and ozone, due to the complex relationship between air quality and emissions. Particulate matter is a cumulative expression for a complex, heterogeneous mixture of PM of various sizes and several chemical compositions, mixing different compounds originating from various sources (such as soot particles resulting from incomplete combustion), inorganic salts, etc. Considering the current trends in climate change and related phenomena, an obvious deterioration in air quality is anticipated (European Environment Agency 2020). It is evident that environmental pollution is directly or indirectly linked to most health problems. EEA (2021) indicates that each year, approximately 400,000 premature deaths in Europe are caused by air pollution (PM, ozone, and nitrogen dioxide). In several significantly new studies on air pollution expenditures, the average expenditure of European city occupants is €1,276 per year. EEA's Air Quality in Europe 2020 report shows six Member States exceeded the European Union's limit value for fine particulate matter ($PM_{2.5}$) in 2018: Bulgaria, Croatia, the Czech Republic, Italy, Poland, and Romania. Surprisingly, four European countries- Estonia, Finland, Iceland, and Ireland—had

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fine PM concentrations significantly below the World Health Organization's (WHO) strict guideline values. According to the EEA report, there are considerable gaps between WHO guidelines and EU air quality limits. The European Commission will address these gaps through the Zero Pollution Action Plan. Moreover, exposure to fine particulate matter resulted in approximately 417,000 premature deaths in 41 European countries in 2018, as mentioned in the EEA assessment. Approximately 379,000 of those deaths occurred in the EU-28, of which 54,000 and 19,000 premature deaths were attributed to nitrogen dioxide (NO_2) and ground-level ozone (O_3), respectively. Nearly 5% rebound in global CO_2 emissions was observed in 2021. Based on NASA (2020), volcanoes release the equivalent of approximately 1% of the total amount of CO_2 that human activity emits. Growth rates increased extensively in most countries after the economic crisis in 2008. However, during this period, slow or even negative health expenditure growth was observed across Europe. Between 2013 and 2019, an approximate increase of 3% per year in real terms (adjusted for inflation) in health expenditure was noted, in contrast to 0.7% from 2008 to 2013. Since the COVID-19 crisis is entirely exogenous, it provides a clearer test of how the air pollution index and monetary policy influence EU health expenditures compared to previous crises. It is considered a key factor in determining whether the increased health expenses are due to increased costs of health improvement efforts or pollutant control measures. The main purpose of this research is to analyze the effects of the air pollution index and monetary policy on Health Expenditures with a Sustainable Development approach in the EU with evidence from COVID-19. By creating two important virtual variables, we use structural failures associated with the 2008 financial crisis and the 2020 COVID-19 pandemic crisis. The average main net variable of air pollution, based on the World Health Organization, is the average air pollution index that was used. However, various previous studies have focused on carbon dioxide and greenhouse gases. This study explores the relationship between the European Central Bank's (ECB) monetary policies and healthcare expenditures, an area that has received limited research attention. Few studies have been conducted in this field. The money supply is used as a monetary policy variable, as it is an essential tool. Furthermore, the inflation variable is added to make nominal variables real. A relationship between inflation and the increase in health expenditures is examined. Certain questions are considered in this study:

During the COVID-19 crisis, did the ECB's monetary policy play an effective role in health expenditure?

Does the air pollution index play an effective role in EU health expenditure? (What is the role of environmental protection schemes in reducing health expenditure?).

What is the role of health factors in EU health expenditure, such as the mortality rate and GNI coefficient?

The COVID-19 crisis, unlike the previous crisis, is entirely exogenous. This method of measuring EU health expenditures can provide a clearer test of air pollution indexes and monetary policies. Moreover, it provides researchers with a unique opportunity to explore the effects of monetary policy on health expenditure with a sustainable development approach in the EU. In this study, the data for the time period 2005–2020 is considered, as data until 2020 is available with limited access.

LITERATURE REVIEW

Health expenditure and air pollution

Europe has reduced emissions of various air pollutants in the past decades, followed by improved air quality (EEA 2020). WHO Air Quality Guidelines (AQG) offer global guidance on thresholds and limits for key air pollutants that pose health risks. Guidelines pertain worldwide to both indoor and outdoor environments predominantly based on expert evaluation of current scientific evidence for: Particulate matter (PM), Sulfur dioxide (SO_2), Ozone (O_3), Nitrogen dioxide (NO_2). A rebound of nearly 5% of global CO_2 emissions is observed in 2021 while approaching the pinnacle in 2018-2019. Despite emitting enormous clouds of particles and gases, volcanoes release the equivalent of approximately 1% of the total amount of CO_2 that human activity does (NASA 2020). It is considered a key factor in finding out whether the increased health expenses are due to the increased costs of taking health improvement efforts or pollutant controlling measures. An updated evaluation of environmental emissions in the EU healthcare sector is essential for legislators to hold the business accountable for protecting public health. Using data from 49 districts in Ontario, Canada, to study the health expenses-environmental variables relationship, Jarret *et al.* (2003) showed that the former per person was more in high-pollution districts, and investing more to enhance the environmental quality could reduce such expenses. In Narayan & Narayan (2008), the authors used 1980-1999 data from eight OECD countries, the panel co-integration test, and emissions of carbon monoxide, nitrogen oxide, and sulfur oxide, as controlling indicators to study the environmental quality effects on health expenses. The sulfur oxide emission proved to have a high and positive effect in addition to income and CO. Using 1995–2012 data of 125 developing countries and the panel co-integration test to analyze the inter-variable relationships, Yahaya *et al.* (2016) studied the environmental quality effects on health-related expenses per person and showed that the former was an effective determining variable. Among different environmental pollutants, CO_2 contributed the most to the increased expenses because it is the highest explanatory variable. Using 1995–2014 data of the Middle East/North Africa (MENA) countries and panel co-integration, and ARDL methods, Khoshnevis Yazdi and Khanalizadeh (2017) studied how health expenses were affected by environmental quality and economic growth reporting that CO_2 emissions had a positive effect on them. Using data from 1966–2009 US states and the panel co-integration and quantile regression methods, Apergis *et al.* (2018) studied the CO_2 emission effects on health expenses per person exhibiting that they were stronger in the regions with quantitatively higher expenses. Per capita CO_2 emissions affect such expenses differently from state to state because inter-variable relationships are not similar in all states. Hence, the effects of the CO_2 emission-reduction policies are felt in various proportions in different states. Hao *et al.* (2018) used 1998-2015 data of thirty Chinese provinces and the GMM (generalized moment method) to analyze the inter-variable relationships and study the effects of environmental pollutants such as sulfur dioxide and soot on the residents' health expenses concluding that they increased the expenses. Using 1994–2017 data from thirteen developing countries and panel co-integration and Granger causality methods to analyze the inter-variables relationships, Usman *et al.* (2019) studied the effects of different economic/non-economic factors and CO_2 emissions on per-person public/private health expenses, reporting, through long term analyses, that CO_2 emissions had positive/negative effects on the public/private health expenses, and identified a one-way CO_2 emission-public/private health expenses causality relationship. Based on 2010-2017 data from 16 South Korean settlements, An & Heshmati (2019) found that pollution increased health expenses significantly when NO_2, NO_3, and PM_{10} levels were elevated. Zaidi & Saidi (2018) used 1990–2015 data from the Sub-Saharan countries, Africa, and VECM Granger and panel ARDL causality tests to analyze inter-variables relations and studied the CO_2 emission-health expenses-economic growth relationship. According to their findings, CO_2 emissions negatively affected health expenses in the long run. CO_2 emissions and health expenses were related in a two-way, and health expenses decreased by 0.066% with a 1% increase in CO_2 emissions.

Health expenditure and monetary policies

Monetary policies play vital roles in improving comprehensive development. More families can save and borrow to be able to pay for healthcare expenses. Otherwise, they may avoid the related services (Blackburn *et al.* 2012). The ECB reviews monetary policy every six weeks to keep inflation at 2%. To achieve price stability in the Eurozone, ECB determines how much to pay to borrow and the interest to be received on savings and conducts open market operations. To mitigate the effect of the COVID-19 pandemic on the Euro area economy and to support all Europeans, the ECB has set up monetary policy and banking supervision measures. The Governing Council of the ECB ensures that all economic sectors should gain from supporting financing conditions to enable support for all its citizens and their families, firms, government, and banks. To promote economic development and assist individuals, businesses, and governments, borrowing costs and interest rates are cut, and lending is raised so that it is less difficult to support expenditure and investment. Other schemes include bonds directly from banks, more funds available that banks can lend to households or businesses, and the purchase of company bonds to increase sources. Given the economic downfall in terms of the pandemic, the Governing Council revised its monetary policy instruments as shown:

1. The Governing Council expects the key ECB interest rates to remain at their present or lower levels until it has seen the inflation outlook robustly converge to a level sufficiently close to, but below 2% within its projection horizon, and such convergence was consistently reflected in underlying inflation dynamics. The interest rate on the main refinancing operations and the interest rates on the marginal lending facility and the deposit facility remain unchanged at 0.00%, 0.25%, and -0.50% respectively.

2. The pandemic emergency purchase program (PEPP) envelope was increased from €500 billion to a total of €1,850 billion by Governing Council, with an increase in net purchases until March 2022 or until the pandemic phase is completed. The reinvestment of principal payments from maturing securities purchased under the PEPP was extended until at least the end of 2023.

3. The third series of targeted longer-term refinancing operations (TLTRO III) period was extended with favorable terms applied by 12 months to June 2022, increasing the total amount that counterparties can borrow, and banks that achieve the new lending performance target will benefit from TLTRO III borrowing conditions.
4. Extending the duration of collateral easing measures to June 2022 will continue to ensure banks benefit from the Eurosystem's liquidity operations and remarkably recalibrated TLTROs.
5. An effective liquidity backstop will be available from the longer-term refinancing operations (PELTROs) in 2021.
6. The ECB's asset purchase program (APP) will continue to receive monthly net asset purchases of €20 billion to reinforce the intended impact of its policy rate increases and to end before interest rate increases are made. The Governing Council expects to maintain favorable liquidity conditions and ample monetary accommodation. It intends to reinvest continuously and the principal payments from maturing securities purchased under APP before the key ECB interest rate increases.
7. An extension of Eurosystem repo for central banks, all temporary swaps, and repo lines with non-euro central banks until March 2022.
8. Continuing performing regular lending operations with full allocation at the prevailing state for as long as essential. Regarding the economic hardship during the pandemic, swap lines have been reactivated and enhanced across several central banks throughout the globe (ECB 2021).

Health expenditure, GNI, inflation, and death rate

In "Public Financing of Health Expenditures, insurance, and Health Outcomes" by Berger and Messer (2002), various health production models estimated using 1960–1962 data across the 20 OECD countries were used to evaluate the effects of public funding of insurance coverage, health expenses, and other factors. Death rates depended on a combination of health care costs and insurance coverage. However, as the proportion of health expenditures borne by the public grew, death rates rose. A reduction of death rates was indicated with an increase in inpatient, and ambulatory insurance coverage costs. Previous studies showed similar mortality rates on the effects of GDP, health expenditures, and age. Overall death rates are remarkably related to education levels, fat consumption, alcohol use, tobacco use, and female labor force participation. There are signnumbert changes in specifications, and samples show that elevated public financing results in increased death rates. Therefore, while countries augment their health expenses, more publicly financed expenses should be avoided. The elevates in the share of health expenditures are associated with increased mortality rates. For instance, a higher proportion of old-age persons is associated with a higher share of health expenditures and COVID-19 mortality. A short paper studies whether the positive correlation between COVID-19 death rates in Europe and the share of healthcare expenditures holds for COVID-19 mortality and provides a positive answer (Khan *et al.* 2020). According to Fernandes (2020), the global pandemic of COVID-19 has increased the mortality rate, and beyond that, a severe diminish is seen in the global economy in terms of the decrease in production, consumption, unemployment, and decrease in quality of life, increases in the mortality rates are in direct relationship with the elevates in the share of healthcare expenditures. This is consistent with Berger & Messer (2002), but inconsistent with Novignon *et al.* (2012) and Rahman *et al.* (2018). The quality of health care received is preserved via the ways to mitigate the increasing costs that the government and the private sector are discovering despite the magnificent importance of healthcare enterprises.

Virtually most of the healthcare cost inflation since recent years is considered notable for:
1. General inflation;
2. Conduct of remuneration costs during inflation;
3. Corresponding labor strength of the industries;
4. Specific patterns in which labor productivity changes.

The effectiveness of health expenses via the regulation or controls planned to affect the pattern of changes in health care prices remains counterproductive towards cost-effectiveness as per the study. Furthermore, the study analyse implies that changes in patterns of actual consumption of healthcare products and respective services should rely on the probable impact on OFE (Opportunities for Employment) increase in costs by businesses, public schemes and by government on employees' medical protection (Virts & Wilson 1984). Increases in GNI per capita reduce illness and mortality rates, leading to an increase in the elderly population. However, the trend varies positively across the world; improvements are faster in some countries and slower in others (Jalal & Khan 2015).

EU sustainable development policy, healthcare, COVID-19

Ensuring that health and well-being are promoted at all ages is necessary for sustainable development (EEA 2020). As human health and environmental integrity are intertwined, a continuous pandemic threat can highlight some vulnerabilities and weaknesses of the ecosystem and society and the difficulty countries face in dealing with unforeseen emergencies. Before the pandemic, major progress was made in improving millions of people's health. Remarkable strides were made to increase life expectancy and reduce mother and child mortality rates. However, the pandemic decreased life expectancy and augmented poverty and unemployment rates in many countries. COVID-19 case fatalities in a cross-section of European countries and the positive correlation among health share expenditures is puzzling. COVID‑19 contributed, directly and indirectly, to a 16% increase in the expected number of deaths in 2020 and the first half of 2021 across the OECD countries. Life expectancy fell in 24 out of 30 countries, and the mental health effect of the pandemic has been huge. The pandemic has also led to a sharp increase in health spending across the OECD. Coupled with reductions in economic activity, the average health spending to GDP ratio jumped from 8.8% in 2019 to 9.7% in 2020 (COVID 2021). Furthermore, preliminary data shows that the EU greenhouse gas (GHG) emissions diminished by 10% from 2019 to 2020 (EEA 2020). On the other hand, Warnings have been already issued of a few swift rebounds in world energy demand and the GHG emissions post COVID-19 (Ibrahim *et al.* 2021; Tollefson 2021). The COVID-19 pandemic was negatively affecting the European Union's progress towards achieving the 2030 Agenda, and Sustainable Development Goals (SDGs), a 2021 Eurostat report has found. For the first time since the adoption of the SDGs in 2015, the average SDG Index score of the EU declined. In this regard, Fig. 1 shows the SDG index score in the period 2000–2020 (Europe Sustainable Development Report 2021).

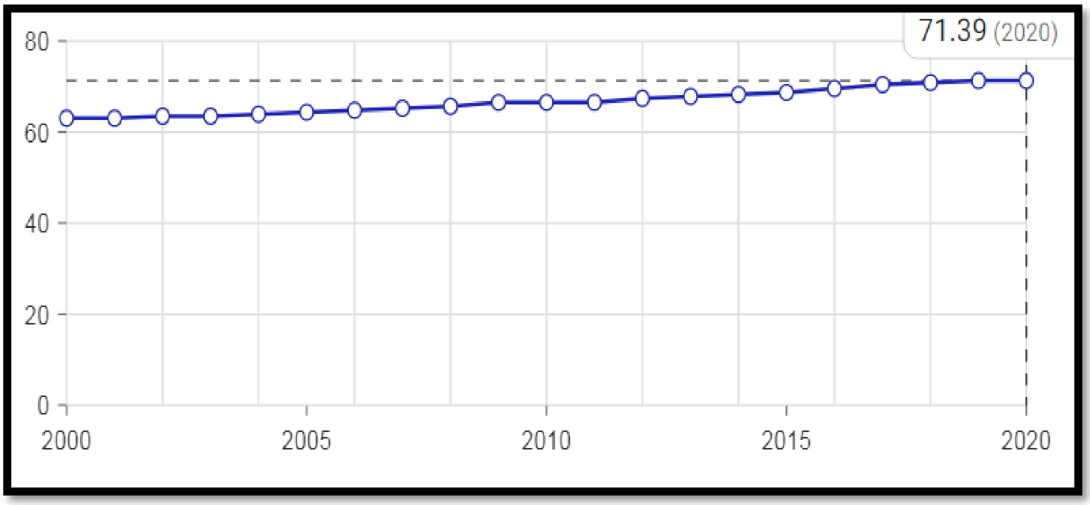

Fig. 1. SDG Index Score (2000–2020).

COVID-19 demonstrated the urgency to scale up strategic and smart investments in areas relevant to human development, which will be decisive to achieve Sustainable Development Goals (Coccia 2021). The increase in efficiency along with advanced technology caused a reduction in the dispersion of environmental pollutants, along with GDP growth and a consequent increase in government tax revenue (Ghasemi *et al.* 2020). More innovative ways to finance human development and a possible role for the European Fund for Sustainable Development (EFSD) could be further explored. In the context of the response to COVID-19, the EIB has engaged with the Bill and Melinda Gates Foundation on health projects, with contributions from the European Fund for Sustainable Development (EIB 2020). According to Ghasemi *et al.* (2020), the increase in efficiency along with technological advances caused a reduction in the dispersion of environmental pollutants along with the GDP growth and a consequent increase in government tax revenue.

MATERIALS AND METHODS

Spatial panel-data models

Firstly, a standard linear panel data model devoid of spatial effects was estimated. The formulation of a standard linear regression model (SLM) is as follow (Baum 2006):

$$y_{it} = x'_{it}\beta + u_i + \varepsilon_{it} \qquad (\mathbf{1})$$

where y is the explained variable, i denotes the individuals, it constitutes the regions (N = 27), t is the dimension of the time series, i.e., from 2005 to 2020, x'_{it} is the $1 \times k$ vector of observations of the explanatory variables and β is the $1 \times k$ vector of undetermined coefficients, u_i is an individual effect that cannot be directly observed and quantified and ε_{it} is a disturbance term that varies with the individual and time. If u_i is related to x_{it}, the panel data model is a fixed-effects model; otherwise, it is a random-effects model (Fotheringham & Rogerson 2008). Spatial panel data models include the spatial auto-regression model (SAR), spatial error model (SEM), spatial autocorrelation model (SAC), and spatial Durbin model (SDM). These models consider the spatial effects based on the SLM and they are estimated using the maximum likelihood principle.
Hence, its formula can be expressed as follow:

$$y_{it} = \rho \sum_{j=1}^{N} w_{ij} y_{jt} + \acute{\beta} X_{it} + e_{it} \qquad (\mathbf{2})$$

where X_{it} is a k × 1 vector of each specifically observed regressor on the i^{th} cross-section unit at time t (i = 1,..., N and t = 1,..., T), e_{it} is the error term, w_{ij} is the generic element of a non-negative N × N matrix W (called spatial weights matrix where rows and columns relate to the cross-section observations), and w_{it} is the i - j potential interaction strength (Anselin 2002, 2013). Any two local i - j distances can be shown as follows Case (1991), Case *et al.*(1993) and Baicker (2005):

$$\begin{aligned} Y &= (1-\rho w)^{-1} X\beta + (1-\rho w)^{-1}\varepsilon \\ &= \sum_{r=1}^{k} (1-\rho W)^{-1} \beta_r X_r + (1-\rho W)^{-1}\varepsilon \\ &= \sum_{r=1}^{k} S_r(W) X_r + (1-\rho w)^{-1}\varepsilon \qquad (\mathbf{3}) \end{aligned}$$

With $Y=\begin{pmatrix} Y_1 \\ Y_2 \\ \cdot \\ \vdots \\ Y_n \end{pmatrix}$, $X=\begin{pmatrix} X_1 \\ X_2 \\ \cdot \\ \vdots \\ X_n \end{pmatrix}$, and $S_r(W) = \begin{pmatrix} S_r(W)_{11} S_r(W)_{12.} \ldots . & S_r(W)_{11} \\ S_r(W)_{21} \;\; S_r(W)_{22} & S_r(W)_{11} \\ \vdots \qquad \vdots \qquad \cdot & \vdots \\ S_r(W)_{n1} \, S_r(W)_{1n.} \ldots & S_r(W)_{nn} \end{pmatrix} \qquad (\mathbf{4})$

Anselin (2002) believes that using weights based on proximity (geographical distance) ensures their exogenocity to the model (not ensured when the basis is more general distance metrics; Kelejian & Prucha 1999). The row-standardization of the weighting matrix to enable the sum of weights to equal 1 for each row is a common practice and guarantees that all the weights vary in a 0-1 range and the weighting process can be considered as the mean of the neighboring values. However, the resulting matrix may not be symmetric and entail considerable estimation calculation complexities (Manski 1993). In model (1), ρ measures how expenses in one area relate to those in the neighboring ones depending on the explanatory variables' vector. Such simultaneous models as Eq. (1) that try to find the agent's choices interdependence result in a misidentification i.e., not being able to find the difference between behavioral and contextual factors, which is generally a reflection problem. Therefore, a vital spatial coefficient might be a sign of expenditure choices endogeneity or effects of contextual characteristics and common policies on expenditure decisions made by some local authorities. Inter-local governments' interactions are not the only reasons for a specific model in expenditure choices, such observable features as the political party or location too can share unobservable features that would result in the correlation of the regression disturbances. Here, there is good conformity with some existing difficult-to-measure environmental risks, such as air and acoustic pollution, which can be identified by considering that errors are generated by a spatial process. Reviewing many practical spatial econometric articles has led us to suppose that our regression model's error term follows a spatial autoregressive (SAR) process:

$$y_{it} = \acute{\beta} X_{it} + e_{it}\,, \qquad (5)$$

$$e_{it} = \lambda \sum_{j=1}^{N} w_{ij} e_{jt} + \varepsilon_{it}\,, \qquad (6)$$

where ε_{it} (i = 1,..., N and t = 1,..., T) are zero mean/variance σ2 , ε random errors and λ is a scalar quantity. Moscone & Knapp (2005) believe, based on a former mental health expense cross-sectional exploratory analysis, that observable features may not be revealed by the expenditure's high geographical heterogeneity. If this unobserved variability is not appropriately included in the model, the result may be wrong spatial correlation conclusions (McMillen 2003). Hence, this paper's empirical analyses are based on the findings of a random-effects model that includes a spatial error correlation, some common factors, and spatially lagged dependent variables as follows (Hsiao 2007):

$$y_{it} = \rho \sum_{j=1}^{N} w_{ij} y_{jt} + \acute{\beta} X_{it} + e_{it} \qquad (7)$$

$$e_{it} = \mu_i + \varepsilon_{it}\,, \qquad (8)$$

where ε_{it} is already defined, and μi is the i[th] the municipality-associated random-effect the specification of which spatial error correlation is (Baltagi *et al.* 2003):

$$y_{it} = \acute{\beta} X_{it} + e_{it}\,, \qquad (9)$$

$$e_{it} = \mu_i + v_{it}\,, \qquad (10)$$

$$v_{it} = \lambda \sum_{j=1}^{N} w_{ij} v_{jt} + \varepsilon_{it} \qquad (11)$$

where the used notation is as above.

A general model with both individual and time effects (Lee & Yu 2010).

$$y_{it} = \alpha + \tau y_{it-1} + \rho \sum_{j=1}^{n} W_{ij}\, y_{jt} + \sum_{k=1}^{k} X_{itk}\, \beta_k + \sum_{k=1}^{k} \sum_{j=1}^{n} W_{ij} X_{jtk} \theta_k + \mu_{it} + \vartheta_{it} \qquad (12)$$

i= 1. … .n t= 1. … .T

The relationships among the previously stated spatial panel models are illustrated in Fig. 2. First, we examine the SLM estimated using ordinary least squares. We start with this model as it is the simplest and most common. Although it is a non-spatial effects model, it is frequently used as a diagnostic tool for model specification and serves as a benchmark for comparisons with spatial models.

The total health expenditure function has the following form:

$$HCE_{it} = \alpha HCE_{it-1} + \beta_1 \boldsymbol{Ln}\, Air + \beta_2 \boldsymbol{ln}\, M3 + \beta_3 \boldsymbol{ln}\, GNI + \beta_4 CPI + \beta_5 Death + covid19 + \varepsilon_{it} \qquad (13)$$

$$\varepsilon_{it} = Virtual\ financial\ crisis\ 2008 \qquad (14)$$

Constructing the model, selecting variables, and determining data sources

The WHO, European Environment Agency, and WDI were the sources that provided the data for the present paper. The panel consists of 27 reporting countries (N = 27). The considered period for which the yearly data are available (T = 14) is 2005-2020, and the EU countries are listed in Table 1.

Table 2 presents the summary statistics of the variables used in this study. Our sample consists of 432 observations from the EU (The list of all 27 European Union countries indicated in "Appendix A").

A statistical summary of all variables is presented in Table 2. The Death variable has the highest mean value, while Broad Money (M3) has the lowest average. The largest median value is (91313) for the Death variable, while the lowest median value is (1.7314) for CPI. The variance of the Death variable (4.69×10^{10}) is the highest, followed by that of Health Care Expenditure (HCE), which is (2,000,049). The minimum value of HCE is (542.401), while those for Air, CPI, M3, Death, and GNI are (9.153), (-4.478), (1.570), (3010), and (3.957), respectively. The maximum value of HCE is (6730.942), while those for Air, CPI, M3, Death, and GNI are

(9.331), (15.402), (2.203), (985572), and (4.922), respectively. The sum of the Death variable is the highest (7.17 × 10^7), while its maximum value is (985572). The kurtosis of CPI is the highest (9.967297), while HCE has the lowest kurtosis (2.154263). Death (10415.6) has the highest standard error, while the average Air Pollution Index (0.002082) has the lowest value.

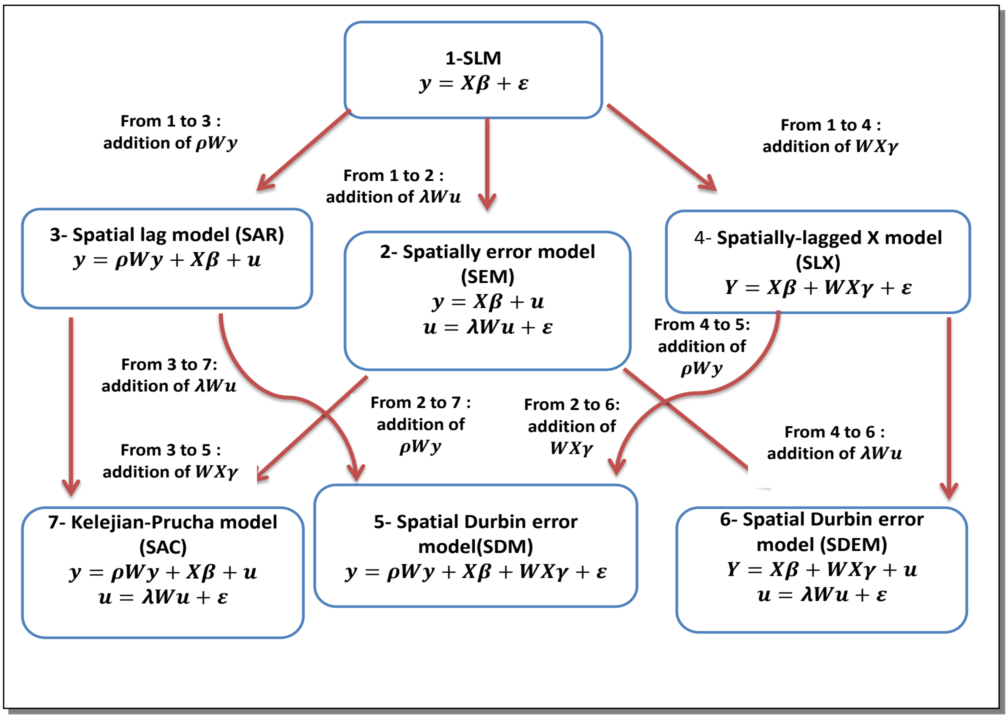

Fig. 2. Relationships among spatial panel models (Golgher &Voss 2016).

Table 1. The definition of variables.

Type	Name	Definition
Dependent	HCE	Health expenditure indicators, this dataset provides internationally comparable data on current health expenditure (i.e. final consumption expenditure on health care goods and services) by health care functions, providers and financing schemes.
Independent	M3	Broad money (M3), an index adjusted seasonally based on 2015=100, includes an upto-2 years-agreed maturity currency deposits, an upto-3 months-notice redeemable deposits and upto-2 years repurchase agreements, money market fund shares/units and debt securities.
	GNI	GNI per capita, PPP (purchasing power parity) (current international $) calculates the total income earned by a nation's people and businesses, including investment income, regardless of where it was earned. It also covers money received from abroad such as foreign investment and economic development aid.
	AIR	Average Air Pollution Index. This dataset contains : Carbon dioxide (CO_2), Carbon monoxide (CO), Greenhouse gas (GHG), Nitrogen oxides (NOx), Sulphur oxides (SOx) and particulate matter (PM).
	CPI	Consumer Price Inflation, (annual %) is measured by the consumer price index and reflects the percent annual cost change to the average consumer's basket of goods and services, which can be fixed or changed at specified time intervals.
	Death	Total mortality rates (Average of men and women)
	D_1	Virtual variable, 2008
	COVID-19	Virtual variable, 2020. Structural failure due to the COVID 19

RESULTS

The results of the panel unit root tests

To examine the stationarity of changes in HCE and other variables, Tables 3 and 4 present the results of the panel unit root tests.

Table 2. Descriptive statistics.

Stats	HCE	Ln (Air)	CPI	Ln (M3)	DEATH	Ln (GNI)
Mean	2956.777	9.271728	1.966828	1.926913	165935.9*	4.487913
Median	2662.936	9.266645	1.731484	1.941754	91313*	4.499825
Variance	2000049	0.001873	4.261421	0.023198	4.69×10^{10}*	0.035359
Max	6730.942	9.331266	15.40232	2.203911	985572*	4.922674
Min	542.401	9.153719	-4.478103	1.570037	3010*	3.957607
Sum	1277328	4005.386	849.6697	832.4263	7.17×10^{7}*	1938.778
Kurtosis	2.154263	4.221964	9.967297*	2.278069	6.063036	3.096953
Se (Mean)	68.04222	0.002082	.0993197	0.007328	10415.6*	0.009047
Observations	432	432	432	432	432	432

Table 3. The Panel Unit Root Test

Variables	Statistics	*p*-value	Test results
HCE	-4.6266	0.0456	I (0)
Air	0.8675	1.0000	I (1)*
GNI	-1.9192	0.3700	I (1)*
Death	-9.431	0.0000	I (0)
CPI	-11.799	0.0000	I (0)
M3	6.3258	1.0000	I (1)*

I (1) *: The series contains a unit root and * indicate elimination of instability using the logarithmic form of variables.
I (0): The series is stationary.

Table 4. Levin-Lin-Chu unit root test with one difference.

Variables	Statistics	*p*-value	Test results
lnGNI	-5.6167	0.0000	I (0)
lnAir	-11.4051	0.0000	I (0)
LnM3	-3.7316	0.0264	I (0)

Levin–Lin–Chu test with panel-specific means, but no time trend requires that the number of periods grows more quickly than the number of panels, so the ratio of panels to time periods tends to zero. The null hypothesis is that the series contains a unit root; the alternative is that the series is stationary. As the output indicates, The Levin-Lin-Chu unit root test is done to examine the variables' stationary. In general, variables with a *p*-value less than 0.05 are stable, whereas variables with a *p*-value greater than 0.05 are not stable (Rahimzadeh & Ebrahim 2021). Based on the Levin-Lin-Chu test results (Table 3), we reject the null hypothesis and conclude that HCE, Death, and CPI are stationary based on the *p*-value of less than 0.05, according to the Levin-Lin-Chu test (Table 4), the variables AIR, M3 and GNI became stable with one difference. Therefore, the variables can be used to estimate the model without concern over erroneous inferences about the extent of the relationship among the variables. The place of propagation of spatial effects is derived from the dependent variable.

Results of the spatial panel autocorrelation test

As shown in Table 5, there are different types of positive spatial autocorrelation. The Moran's test is used to detect spatial autocorrelation. Rejection of the null hypothesis indicates the presence of spatial autocorrelation. Furthermore, the Moran's test statistic is estimated at 3.79 (*p*-value = 0.0005). Thus, the null hypothesis is rejected, confirming the presence of significant positive spatial effects among countries in terms of health expenditure.

Results of the spatial panel models

According to Table 6, the SDM model with random effects shows that the Air Pollution Index has a significantly negative effect on healthcare expenditure in the studied countries. Specifically, a 1% increase in the Air Pollution Index results in an approximately (-5306.721%) decline in healthcare expenditure. Healthcare expenditure is influenced positively and significantly by GNI per capita. By elevating the ratio of Gross national income/population, the demand for healthcare services increases. Consequently, the healthcare expenditure is increased, so that a 1% elevation in the GNI will upraise the healthcare expenditure by (3279.64%).

Table 5. Spatial panel autocorrelation tests.

Specification Test	Statistics	*p*-value
GLOBAL Moran MI	0.29	0.000
GLOBAL Geary GC	0.39	0.000
Moran MI Error Test	3.79	0.0005
LM Error (Burridge)	32.07	0.000
LM Error (Robust)	64.67	0.000

Healthcare expenditure is influenced positively and significantly by inflation. As the inflation, healthcare expenditure is increased. Hence, a 1% elevation in inflation will increase the healthcare expenditure by (23.64%). Broad money (M3) has positively and significantly correlated to total healthcare expenditure. A 1% elevation in the broad money is associated with increased health care expenditure per capita (1434.98%). The death rate has positively and significantly correlated to health care expenditure. A 1% elevation in the Death rate is associated with increased healthcare expenditure per capita (0.002046%).

Table 6. Results of spatial panel models.

Variable	SDM with spatial fixed- effects					
	Coef.	Std. Err.	Z	*p* > I	95% Conf.	Interval
LnAir	-10180.38	2718.252	-3.75	0	-15508.06	-4852.708
CPI	25.7197	10.07818	2.55	0.011	5.966839	45.47257
LnM3	949.8774	434.6933	2.19	0.029	97.89422	1801.861
Death	0.002858	0.0008563	3.34	0.001	0.0011796	0.0045363
lnGNI	3236.106	339.4936	9.53	0	2570.711	3901.502
D1	-342.9306	151.0689	-2.27	0.023	-639.0202	-46.84099
COVID-19	-320.4992	290.8457	-1.1	0.27	-890.5464	249.548
Spatial rho	0.2272714	0.0477745	4.76	0	0.1336351	0.3209078
Variance sigma2_e	57315.4	3932.408	14.58	0	49608.02	65022.78

Variable	SDM with random- effects**					
y	Coef.	Std. Err.	Z	P> |z|	95% Conf.	Interval
lnAir	-5306.721	1377.236	-3.85	0	-8006.055	-2607.387
CPI	23.63942	10.35807	2.28	0.022	3.337984	43.94085
LnM3	1434.978	355.892	4.03	0	737.4427	2132.514
Death	0.0020457	0.0006407	3.19	0.001	0.0007899	0.0033014
lnGNI	3279.636	343.6037	9.54	0	2606.185	3953.087
D1	-185.4444	138.6469	-1.34	0.181	-457.1873	86.29849
COVID-19	133.5025	203.645	0.66	0.512	-265.6343	532.6393
_cons	35281.68	13062.64	2.7	0.007	9679.37	60883.99
rho	0.2577496	0.0477199	5.4	0	1642204	0.3512788
lgt_theta	-2.687407	0.1644048	-16.35	0	-3.009634	-2.36518
sigma2_	61886.01	4385.629	14.11	0	53290.33	70481.68

Note: ** indicate the SDM model has been accepted. The result of spatial autoregression model (SAR) is presented in "Appendix B".

The results of the Wald test for model selection

Based on the results of Table 7, the *p*-value (prob) is less than 5%, i.e., the null hypothesis based on the SAR model is rejected, and as a result, the SDM model was accepted.

Table 7. The Wald test to determine the most appropriate model between the SDM and SAR models.

Specification Test	Statistics	*p*-value
Wald	37.06	0.000

Results of the Hausman test

Table 8 presents the results of the Hausman test, which distinguishes between fixed-effects and random-effects models in panel data. Under the null hypothesis (H_0), the random-effects (RE) model is preferred due to its higher efficiency. However, if the null hypothesis is rejected, the fixed-effects (FE) model is preferred.

Table 8. The Hausman test.

Specification Test	Statistics	*p*-value
Hausman	4.55	0.9712

If the error term in the random-effects model is correlated with the independent variables, the estimates will be inconsistent, making the fixed-effects model the preferred choice. The individual-specific component in the random-effects model might be correlated with the independent variables in the presence of omitted variables, to which the fixed-effects model is robust.

H_0: The appropriate model is random-effects. There is no correlation between the error term and the independent variables in the panel data model. $COV(\alpha_I, x_{it}) = 0$

H_1: The appropriate model is Fixed-effects. The correlation between the error term, and independent variables in the panel data model is statistically significant. $COV(\alpha_I, x_{it}) \neq 0$

Since the p-value is greater than (0.05), we fail to reject the null hypothesis (H_0). Therefore, it is concluded that the random-effects model is more appropriate than the fixed-effects model, and the research model should be specified as an SDM with random effects. The random-effects model provides efficient and consistent estimates.

DISCUSSION

The results indicate that the Air Pollution Index significantly negatively affects healthcare expenditures in the studied countries. Hence, this study suggests that to reduce the adverse impact on a society facing constant pandemic threats, nations have to enact public policies designed to increase spending in the health sector and reduce the main sources of air pollution to improve the health of the population in the context of complete environmental sustainability. This finding is evaluated in light of the following considerations. During the review phase, we carefully analyzed two failure factors that substantially influenced the outcomes. During the massive crisis in 2008, air pollution decreased significantly. However, from 2013 to 2019, an approximate increase of 3% per year in real terms (adjusted for inflation) in health expenditure was noted, in contrast to 0.7% between 2008 and 2013. During the COVID-19 pandemic, air pollution decreased significantly due to lockdowns and curfews, while health expenditures increased. Secondly, the focus of our research was the levels of health expenditures, which include the total costs of treatment, so increases in the cost of these health issues may not be caused directly by air pollution. Finally, the pollution index we used contains information on several air contaminants. Therefore, our estimation results may be larger and vary from most individual pollution estimates. Similar findings were reported by Zaidi and Saidi (2018), Shen *et al.* (2021), Coccia (2020, 2021), and Sabat *et al.* (2020). Our result was inconsistent with the results of Yang & Zhang (2018). The increase in the share of health expenditures is associated with an elevation in the death rate. Based on the Situation Report on World Health and Epidemics, a higher proportion of elderly individuals is associated with a higher share of health expenditures and higher COVID-19 mortality. This result is consistent with Berger &Messer (2002), Fernandes (2020), and Khan *et al.* (2020). However, it is inconsistent with the research findings of Novignon *et al.* (2012), Rahman *et al.* (2018), and Coccia (2021). This study found a positive and significant correlation between Broad Money (M3) and total healthcare expenditures. Monetary policies play vital roles in improving comprehensive development following the outbreak of the COVID-19 pandemic. The increase in money growth has broadened concerns about the inflationary effect of COVID-19 and the government's responses to it, as evidenced by an increase in inflation expectations and the uncertainty of the inflation outlook (Arnold 2022). More families can save and borrow to pay for healthcare expenses; otherwise, they may avoid related services. Moreover, this can also be referred to as mitigating the impact of the COVID-19 pandemic on the Eurozone economy and supporting all Europeans. The ECB has set up monetary policy and banking supervision measures. The Governing Council of the ECB ensures that all sectors of the economy benefit from supportive financing conditions to enable assistance for all citizens, families, firms, governments, and banks. To support economic growth and assist citizens, firms, and governments, borrowing costs and interest rates are lowered, and lending is increased, making it easier to support expenditure and investment. Other schemes have also been implemented, such as purchasing bonds directly from banks, making more funds available for banks to lend to households or businesses, and acquiring company bonds to increase financial sources. This outcome is consistent with Musgrove (1996), Blackburn *et al.* (2012), and Chireshe & Ocran (2020). Furthermore, the increase in GNI has a positive impact on healthcare expenditures. Each group of countries, depending on per capita income, has healthcare costs. Almost all EU member states are classified as high-income nations. This result is consistent with the findings of Vezhnovets *et al.* (2021). According to their research, GNI per capita has a greater impact on HCE in high-income groups than low-income groups. The increase in GNI per capita does not affect other financial indicators in these groups of countries. This means that in these groups, only government expenditures depend on GNI per capita. In contrast, in the group of low-income countries, it was found that an elevation in GNI per capita leads to a decrease in the share of healthcare expenditures. The increase in inflation has a positive impact on healthcare expenditures. The literature shows that studies mostly focus on examining the relationship between health expenditures and revenue (Baltagi & Moscone 2010; Sghari & Hammami 2013; Caporale *et al.* 2018). Although it is known that revenue is not the only variable influencing health expenditures, the inflation rate is another factor that may affect healthcare costs (Russell 1975; Newhouse 1977; Hartwig & Sturm 2014). This result is consistent with Virts & Wilson (1984) and Turgut *et al.* (2017). However, it is inconsistent with Taşkaya & Demirkıran (2016), who found no relationship between GDP per capita, the inflation rate, and health expenditure as a share of GDP. The inflation rate only affected GDP.

CONCLUSION

There is extensive literature on the determinants of health expenditure. This paper examines the effects of air pollution and monetary policy on health expenditure within the framework of sustainable development for EU member countries, using panel data based on spatial panel models with spatial autocorrelation tests, including the Wald and Hausman tests, for the period 2005-2020. Empirical evidence indicates that the average air pollution index negatively affects health expenditure. Additionally, GNI, broad money (M3), CPI, and the Death rate benefit health expenditures in EU member states. The findings of this research will unquestionably serve as significant policy instruments to optimize the environmental and health advantages broadly associated with economic development and growth. The COVID-19 pandemic highlighted the urgency of strategic and smart investments in human development. To mitigate the negative impact on societies facing constant pandemic threats, nations must implement public policies that increase health sector spending and address primary sources of air pollution, ensuring public health within a framework of environmental sustainability. Applying better expense control strategies and focusing on primary and intensive care are essential policy priorities for healthcare systems in these countries.

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APPENDICES

Appendix A

Table A. The names of countries.

Austria [AUT]	**France [FRA]**	**Malta [MLT]**
Belgium [BEL]	Germany [DEU]	Netherlands [NLD]
Bulgaria [BGR]	Greece [GRC]	Poland [POL]
Croatia [HRV]	Hungary [HUN]	Portugal [PRT]
Cyprus [CYP]	Ireland [IRL]	Romania [ROU]
Czech Republic [CZE]	Italy [ITA]	Slovak Republic [SVK]
Denmark [DNK]	Latvia [LVA]	Slovenia [SVN]
Estonia [EST]	Lithuania [LTU]	Spain [ESP]
Finland [FIN]	Luxembourg [LUX]	Sweden [SWE]

Appendix B

Table B. Spatial panel models.

Variable				**SAR with spatial fixed-effects**			
	y	Coef.	Std. Err.	Z	P> |z|	[95% Conf.	Interval]
Main	lnAir	-4800.583	1443.278	-3.33	0.001	-7629.355	-1971.81
	CPI	42.48285	9.336815	4.55	0.000	24.18303	60.78267
	LnM3	1225.78	315.2695	3.89	0.000	607.8631	1843.697
	Death	.0031039	.0009438	3.29	0.001	.0012541	.0049538
	lnGNI	1781.209	316.5303	5.63	0.000	1160.821	2401.597
	D1	-145.7371	60.57412	-2.41	0.016	-264.4602	-27.01403
	Covid	-203.0347	132.9471	-1.53	0.127	-463.6061	57.53675
Spatial	rho	.1390654	.040239	3.46	0.001	.0601984	.2179324
Variance	sigma2_e	73891.52	5038.2	14.67	0.000	64016.83	83766.21

Variable				**SAR with random-effects**			
	y	Coef.	Std. Err.	Z	P> 1zl	[95% Conf.	Interval]
Main	lnAir	-4630.335	1489.016	-3.11	0.002	-7548.753	-1711.916
	CPI	41.76764	9.60551	4.35	0.000	22.94119	60.5941
	LnM3	1188.136	318.1789	3.73	0.000	564.5169	1811.755
	Death	.0018905	.0006958	2.72	0.007	.0005267	.0032543
	lnGNI	1892.303	317.9338	5.95	0.000	1269.164	2515.442
	D1	-144.3455	62.38421	-2.31	0.021	-266.6163	-22.07471
	Covid	-169.9313	136.9496	-1.24	0.215	-438.3476	98.48496
	_cons	34416.98	14171.55	2.43	0.015	6641.253	62192.7
Spatial	rho	.1578747	.0399396	3.95	0.000	.0795945	.2361549
Variance	lgt_theta	-2.60943	.1578836	-16.53	0.000	-2.918876	-2.299983
	sigma2_e	79012.89	5572.37	14.18	0.000	68091.25	89934.53

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