Managing health through environmental policies. Analysis for European Union countries

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Abstract

Purpose – Environmental degradation resulting from human activities may adversely affect human health in multiple ways. Until now, policies aimed at mitigating environmental problems such as climate change, environmental pollution and damage to biodiversity have failed to clearly identify and drive the potential benefits of these policies on health. The conducted study assesses and demonstrates how specific environmental policies and instruments influence perceived human health in order to ensure input for a data-driven decision process.

Design/methodology/approach – The study was conducted for the 2004–2020 period in European Union (EU) countries with the use of dynamic panel data modeling. Verification of specific policies' impact on dependent variables allows to indicate this their effectiveness and importance. As a result of the computed dynamic panel data models, it has been confirmed that a number of significant and meaningful relationships between the self-perceived health index and environmental variables can be identified.

Findings – There is a strong positive impact of environmental taxation on the health index, and the strength of this relationship causes effects to be observed in the very short term, even the following year. In addition, the development of renewable energy sources (RES) and the elimination of fossil fuels from the energy mix exert positive, although milder, effects on health. The reduction of ammonia emissions from agriculture and reducing noise pollution are other health-supporting factors that have been shown to be statistically valid. Results allow to identify the most efficient policies in the analyzed area in order to introduce those with the best results or a mix of such measures.

Originality/value – The results of the authors' research clearly indicate the health benefits of measures primarily aimed at improving environmental factors, such as environmental taxes in general. The authors have also discovered an unexpected negative impact of an increase in the share of energy taxes in total taxes on the health index. The presented study opens several possibilities for further investigation, especially in the context of the rapidly changing geopolitical environment and global efforts to respond to environmental and health challenges. The authors believe that the outcome of the authors' study may provide new arguments to policymakers pursuing solutions that are not always easily acceptable by the public.

Keywords Health, Agriculture production, Climate goals, Environmental taxes

Paper type Research paper

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1. Introduction

The global ecological crisis is becoming increasingly complex. Environmental degradation in the form of climate change, environmental pollution and the loss of biodiversity, in combination with limited access to the health care system (further exacerbated by the COVID-19 pandemic), are the crisis' main constituents that pose significant global challenges and require new solutions (Willetts *et al.*, 2022). Ebi *et al.* (2021) assume that "health risks could be prevented through building climate-resilient health systems." Nevertheless, the better the relationships between the factors present in the above-described intertwined system are identified and described, the more effective these solutions will be.

Many believe that hitherto efforts to improve the climate have focused on climate issues, losing sight of the link between climate improvement and population health. It reflects in the fact that even though the main cause of mortality is non-communicable diseases related to diet, there is still no recommendation for the transformation of the food system that combines agrobiodiversity with nutrition (Wagner & Barth, 2012). Other factors independent of diet include, e.g. the transport sector – the second largest greenhouse gas (GHG) emitter in the European Union (EU). McMichael (2011) assumes a link between human health and climate change. Nevertheless, people do not widely acknowledge the risks of this impact, leaving room for further research in this area.

We aimed to identify the impact of different policies and environmental conditions on population health, as measured by a self-assessment of health statistics. The key findings of the study show that climate change is associated with deteriorating human health, which could be mitigated by environmental policies. Furthermore, the notable finding is that a higher proportion of energy taxes within total taxes negatively impacts the health index, which differs from similar research results. The area of environmental policies as well as self-assessment health measures has been a subject of research for many years (Walter & Ugelow, 1979; Bailis, Segall, & Chipperfield, 2003). However, thus far, scholars have not verified in detail the relationships between them. People commonly assume a connection between environmental policies and health but the exact extent of the impact needs detailed verification.

Based on the identified dependencies, the scope of possible solutions may be very wide and concern both general and strategic solutions, as well as at a more detailed level concerning, e.g. planning fiscal solutions that would reduce the negative effects of factors harmful to health. At a later stage, solutions could concern the possibility of linking the stream of the above-mentioned funds with their direct transfer to areas identified as in need of support.

The number of possible interactions between environmental factors and public policy tools requires an attempt to capture the most important relationships to treat them as the basis for the planned solutions.

Simultaneously, the rapid changes in the area under analysis necessitate creating adaptable assumptions that can be easily modified if a change is needed. When implementing long-term solutions, identifying the dependencies that we focused on becomes the foundation for creating a mechanism to review the initial assumptions, considering potential changes in the adopted solutions.

For this purpose, we studied the factors from the areas of taxes (environmental and energy taxes), energy transformation resulting in, among others, a greater use of renewable energy sources (RES), the negative consequences of noise pollution and factors present in agriculture that negatively impact health, such as ammonia emission (which should result in a shift in agriculture toward less resource-intensive production).

Identifying environmental factors and public policy tools aimed at improving both the quality of the climate and the health of the population would certainly help find the relationships between them (Dora, Phillips, & Phillips, 2000; Morris, Beck, Hanlon, &

Robertson, 2006; Postula & Raczkowski, 2020). Morris (2010) indicates the term “ecological public health” in the same context as mentioned above, i.e. positive link between climate and health. After such a link could be demonstrated, it would help in designing solutions responding to the crisis, which is increasingly complex and therefore requires complex responses.

The indicated premises were an inspiration for us in answering how the relative ecological perspective of health risk management can contribute to better protection of health and the environment.

This approach allowed us to define a specific study goal in the form of an assessment of the impact of selected factors representing various policies and environmental conditions on the population’s health as measured by the self-assessment index of health statistics. The main research questions were: What is the impact of environmental threats on human health? What type of negative environmental externalities affect health the most? What is the role of environmental taxes in mitigating environmental factors that affect health? What are the alternative ways of mitigating environmental factors that affect health? The results provide the inputs for three definitive objectives: enhancing the identification of existing dependencies, encouraging policymakers to include health measures in their work and evaluating the impact of such policies on the environment.

The article is structured in a traditional, regular manner. After a comprehensive literature review and depiction of numerous studies regarding the discussed factors and measures, we will present a research part. The qualitative research was based on the literature studies and the quantitative research used data from European sources in a study based on statistical methods. Next, we will present a detailed discussion and conclusions.

2. Background: literature review

There is a strong correlation between the condition of the natural environment and human health. A healthy life is determined by environmental quality. There are several ways in which human activities impact the natural environment: by generating water, air and noise pollution, degrading soil and devastating biodiversity and wildlife. A healthy life is indispensable and critical to sustainable development. To reflect the importance of human health and well-being, their promotion became one of the Sustainable Development Goals established by the UN (2015) and countries pursue it in the context of the 2030 Agenda.

Improvement of human health is closely intertwined with other components of sustainable development, such as the protection of the natural environment. Efforts aimed at reducing environmental health threats should help achieve sustained health benefits and improve environmental protection (Corvalán, Kjellström, & Smith, 1999). Therefore, we decided to concentrate on the nexus of human health and various environmental aspects having a potential impact on our health. This research area has grown in importance as some recent studies urge to redefine environmental policies (Yirong, 2022).

Environmental taxation constitutes one of many tools that can help us achieve environmental and climate objectives. In the EU context, environmental taxation and more specifically energy tax, is becoming an increasingly important issue, as the European Green Deal aims to align energy taxation with its climate objectives. As noted by the European Court of Auditors (2022), this goal is particularly challenging as attractive carbon prices and non-deterrent energy taxes on fossil fuels result in higher costs of low-carbon technologies, delaying the green transformation. The European Climate Law set a 55% GHG emission minimum net reduction target for 2030 and the EU has committed itself to become climate-neutral by 2050 (European Commission). Environmental taxes are also a revenue-generating tool. However, as Williams (2016) demonstrated, the selection of adequate solutions is crucial. While we may identify carbon tax, a variation of the energy tax indicated above, as cost-effective concerning GHG reduction, the tax credits on renewable energy production and investments result in limited environmental effects.

Nevertheless, when discussing energy tax, other tangible benefits of such environmental taxes are identifiable. Paultrel (2008) has shown the positive effect of environmental taxes on life expectancy through the former reducing pollution and as a result positively affecting public health. By targeting environmental taxes well, policymakers wish to influence consumers' choices through price incentives aimed at directing them towards accessible and more sustainable products and services, making environmentally harmful goods more expensive and, as a result, less attractive. Simultaneously, higher environmental taxes make the production process more expansive, thus incentivizing producers to search for more environmentally friendly technological solutions (Kosonen, 2012). Finally, Dogan, Chishti, Alavijeh, and Tzeremes (2022) showed that environmental taxes effectively reduce pollutant emissions and Li, Zhongguo, Du, Feng, and Zuo (2021) indicated the advantage of such a solution over a pollution discharge fee policy. In this respect, some doubts may arise regarding the impact of such taxation policies on competitiveness and economic growth. For example, Zhu, Qian, Jiang, and Mbroh (2020) found that a carbon tax negatively impacts economies, leading in particular to a slowdown in economic growth (Tu, Liu, Jin, Wei, & Kong, 2022).

Although as Wang, Zhu, Wang, Hu, and Nkana (2022) as well as Dechezleprêtre and Sato (2017) argue, environmental taxes positively impact economic growth and companies' limited, low-scale and short-term competitiveness. Furthermore, Dechezleprêtre and Sato (2018) indicated that the identified adverse effect is limited to high energy consumption production, which constitutes rather a small fraction of traditional industry sectors.

Scholars note that especially in enterprises operating in industries that strongly pollute the environment, ecological taxes increase production costs (Liao & Wang, 2022). This is because environmental taxes force changes related to energy saving, emission reduction and innovative technologies, which lead to an increase in production costs, involving a certain amount of capital over time and reducing the profitability of enterprises (Rassier & Earnhart, 2010). Since environmental taxes entail investments in pollution control, this leads to capital commitments that cannot be allocated to direct production growth. From this perspective, environmental regulations will likely hamper productivity growth. Gray and Shadbegian (2003) confirmed it as they found a link between higher operating costs related to pollution reduction and lower productivity in the pulp and paper industry.

However, this is a temporary effect and in the long run, environmental taxes positively impact companies' economic benefits (Yi, Wei, & Fu, 2021; Landa Rivera, Reynès, Bellocq, & Grazi, 2016; Takeda & Arimura, 2021). In other words, even if environmental taxes increase some of the company's operating costs in the short term, they will be offset in the long term by a range of benefits brought by technological progress. Research confirms that environmental taxes positively impact production costs in the long term (Yamazaki, 2022; Zárate-Marco & Vallés-Giménez, 2015; Beladi, Chen, Chu, Hu, & Lai, 2021), financing (Zhu, Bu, Jin, & Mbroh, 2020) and the amount of tax liabilities (Cadoret, Galli, & Padovano, 2020).

Noise is the second largest environmental health risk in Europe. The burden of environmental noise has been calculated for Europe since 2011 when the World Health Organization (WHO) Regional Office for Europe, together with the European Commission and its Joint Research Center, presented a study showing the healthy years of life lost due to environmental noise in Western European countries (WHO, JRC, 2011). Researchers quantified the burden of disease from environmental noise concerning cardiovascular disease, cognitive impairment in children, sleep disturbance, tinnitus and annoyance. Studies, such as a 15-year follow-up in Switzerland, unequivocally confirm a significant association between noise pollution and cardiovascular diseases (Vienneau *et al.*, 2022) In conclusion, at least one million healthy years of life are lost every year from traffic-related environmental noise in western Europe.

Clark and Paunovic (2018a, b) showed the link between noise exposure and impaired children's cognitive ability. They demonstrated that aircraft noise negatively impacts kids' reading and long-term memory. Scholars also connected aircraft noise exposure with a higher risk of depression (Hegewald *et al.*, 2020).

We can analyze another aspect of noise exposure by looking at the vulnerability of different communities depending on their socioeconomic status, which researchers identified as one of the factors that can be affiliated with an individual's vulnerability to noise exposure (EEA, 2019b). The above assumption is embedded in the more general narrative, indicating that communities with lower socioeconomic status face environmental risks more frequently. Evans and Kantrowitz (2002) showed that income is often essential to environmental quality, especially when comparing less-wealthy individuals to the more privileged ones. Braubach and Fairburn (2010) concluded that social position, particularly the low-income parts of society, face higher exposure to environmental risks where they live. These risks include noise exposure, but also dampness, chemical contamination and poor sanitation.

Dreger, Schüle, Hilz, and Bolte (2019) conducted a systemic analysis of the available evidence and concluded that although the findings were mixed, less-wealthy people are more exposed to higher environmental noise. Hoffmann, Robra, and Swart (2003) presented similar findings. They analyzed the relationship between socioeconomic status and noise pollution in residential areas in Germany. The results indicated that people with lower socioeconomic status suffered more from noise pollution in their environments.

However, noise exposure is a very localized phenomenon and is not always automatically linked with socioeconomic status. For example, a study conducted in London (Tonne *et al.*, 2018) indicated that the differences in road traffic noise exposure were marginal. This may be because wealthier people choose to live in the city center and other prestigious locations, which results in greater noise exposure (Havard, Reich, Bean, & Chaix, 2011; Tonne *et al.*, 2018). The results of the EEA's project (2018) did not show systemic variances between urban and rural areas. This may be potentially explained by the high concentration of dwellings close to roads with heavy traffic, while noisy urban environments can be perceived as desirable places to live.

The energy transformation constitutes one of the cornerstones of the sustainable development concept and is a key element of the world's efforts to reduce GHG emissions. RES are the best alternatives to fossil-fuel-based energy generation, as they generate much less GHG emissions. The benefits of using RES are multiple. They help mitigate climate change, the key challenge of humanity. Moreover, RES reduce dependency on fossil fuels, an element of crucial importance in the context of recent geopolitical events, such as the Russian invasion of Ukraine. However, renewable energy can also help improve public health by relocating emissions away from fossil-fueled electricity generation (Buonocore *et al.*, 2016; Karaaslan & Çamkaya, 2022). This happens as a consequence of the reduction of CO_2 and air pollutant (such as $PM_{2.5}$) emissions from fossil-fuel-based installations, which results in better air quality (Gschwind *et al.*, 2015; Halkos & Gkampoura, 2020; Koengkan, Fuinhas, & Silva, 2021; Tong *et al.*, 2021). Trever *et al.* (2012) also confirm that GHG emissions resulting from the production of electricity from fossil fuels have the greatest impact on human health, while nuclear and renewable technologies have a significantly smaller impact.

However, the literature indicates that the impact of climate change on health (Campbell-Lendrum & Woodruff, 2007; Portier *et al.*, 2010) shows the worst impact in societies characterized by limited resources, little technology and inadequate infrastructure. Scholars expect that the acceleration of global warming will be associated with an increase in malnutrition and diseases such as malaria, mainly affecting poor countries (Akachi, Goodman, & Parker, 2009; Dell, Jones, & Olken, 2012).

Transport and power generation are the two sectors contributing the most to climate change and the increasing epidemiological risks (Pablo-Romero, Román, & Yñiguez, 2016; Aminzadegan, Shahriari, Mehranfar, & Abramović, 2022).

The benefits of reducing GHG emissions can be important. Markandya *et al.* (2009) conducted a study to evaluate the evolution of particle air pollutant emissions resulting from GHG mitigation measures and the consequent effects on health in the EU, China and India. The results show that modifications in the production of electricity would reduce $PM_{2.5}$ emissions and their associated deaths. Moreover, the health benefits greatly counterbalance the costs of GHG mitigation, particularly in India, where pollution is significant and the mitigation's costs are small, suggesting clear health benefits of the decarbonization of electricity production.

Therefore, reducing GHG emissions is beneficial from a health perspective, but it could also bring economic gains. NCA4 (2018) estimated that reducing GHG could generate hundreds of billions of dollars annually by 2,100 and result in intangible health benefits.

The research also verified the adverse impact of agriculture on human health. Ammonia emissions caused by agriculture are a crucial source of air pollution. Himics *et al.* (2022) showed that plant-based (flexitarian) diets would reduce ammonia emissions by 33% in the EU and significantly reduce premature death rates. Eshel (2021) states that animal-based foods (especially beef) emit the largest share of GHG and are responsible for the greatest share of air pollution mortality. Giannakis, Kushta, Bruggeman, and Lelieveld (2019) conclude that in Europe, ammonia emissions strongly contribute to $PM_{2.5}$ pollution and the associated premature human mortality. They propose ways to reduce the NH3 emissions in agriculture, such as by using low-nitrogen feed, low-emission animal housing, covered manure storage and finally applying urea fertilizer. Ma *et al.* (2021) assume that ammonia (NH3) emissions from agriculture generate substantial health damage. Giannakis, Kushta, & Bruggeman suggest that technological change and trade structure adjustments are necessary to reduce NH3 emissions. Shen *et al.* (2020) found that a combination of climate-adaptive agricultural management practices can improve crop production, air quality and ecosystem health. Based on a literature review, some authors declare that organic farming is one way to improve air quality and reduce NH3 emissions. Our research confirms that organic farming positively influences human health at an early stage. However, an in-depth analysis shows this factor loses significance.

3. Theoretical foundation of the study and research gap

The problems presented above come from many areas and occur in many complex relationships, which makes it difficult to develop tools that effectively reduce the negative phenomena. The literature refers to policies in which people take actions and assess their effects in terms of assumed goals, based on measuring specific factors and these policies are extraordinarily complex. Table 1 presents examples of studies referring to seven different policies.

Based on the literature review, we can state a link between the environment and health (Lauriola *et al.*, 2020). However, there is still a research gap in this field. Dravik *et al.* (2022) indicate the need to support "a better understanding of the causes, interlinkages, and impacts of environmental stressors on health and the environment." The primary question concerns the relationship between the health system and public policies (environmental, research, etc.). Reed *et al.* (2021) consider ways to reimagine health services and policy research. Based on a Canadian case study, they explain how environmental sustainability must be embedded into health services and policy research. Few studies have been conducted to assess the link between environmental policies and health, especially the efficiency of environmental policies. Davies and Mazumder (2003) analyze (also based on a Canadian case study)

Author	Scope	Results	Region	Period
Graham and White (2016)	Interconnection of public health and environmental sustainability	Conditions for health are being undermined by rapid environmental change	High-income countries	n/a Review paper
Aunan *et al.* (2004)	GHG mitigation reduces damage to human health	Evaluation of CO2 reduction policy and local health benefits	Shanxi, China	2004
Dantas *et al.* (2017)	Cross-sectoral outcome assessment of local government cost-effectiveness in the fields of health and environment	Larger (and better) investments in the environment can also enhance performance in health	Sao Paulo, Brazil	2007–2011
Stead and Stead (2008)	Institutional dimension of integrating transport, environment, and health policies	Policy integration, in relation to transport, health and environment is increasingly recognized	Worldwide	n/a
Coomes *et al.* (2022)	Health benefits of clean air and climate policies	Transportation sector strategies to reduce carbon emissions had the potential to provide substantial air quality-related health	New York, USA	Model until 2032
Woodward *et al.* (2022)	Investigate the positive and negative impacts of climate policies on population health in China	Restricting emissions brings gains to public health – mainly in the controls on coal burning	China	1995–2018
Watts *et al.*(2015)	Map the impacts of climate change, and policy responses to ensure the highest standards of health for populations worldwide	Tackling climate change could be the greatest global health opportunity of the 21st century	Worldwide	2015

Source(s): Authors' own elaboration

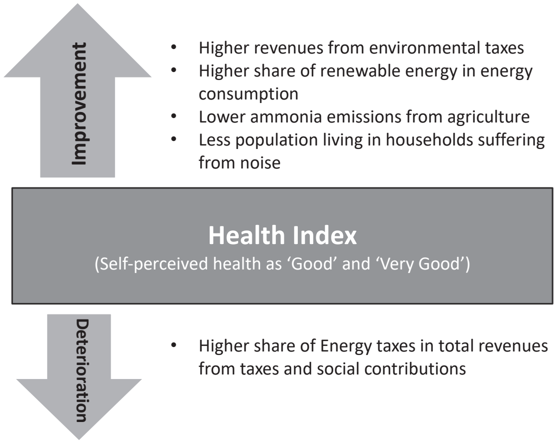
Table 1. Examples of studies referring to seven different policies

developing effective policies (health and environmental) and the role of government in sustaining clean, safe drinking water sources. Bilotta, Milner, and Boyd (2014) analyze the role of systematic reviews in health and informing environmental policies. Barnidge *et al.* (2012) consider "types of environmental and policy interventions to promote physical activity or healthy eating." According to our best knowledge, there is no comprehensive study analyzing the interdependencies between health and environmental policies, and our paper covers this research gap.

4. Methods and modeling results

In the following theoretical and qualitative discussion, we evaluated the influence of different environmental policies and conditions on population health, as measured by self-perceived health statistics, to quantify their impact (see Figure 1).

We collected the data for all EU member countries and Norway for the period 2004–2020. We excluded the United Kingdom and Croatia from the panel due to their limited data availability in this field. In the case of Croatia, there was no relevant data available in Eurostat before 2010, and in the case of the UK, there was no data available after 2018. We focused on the EU countries, because the EU has a relatively common regulatory framework compared to other regional clusters of countries. This allows for more sound cross-country analyses and the formulation of better-tailored recommendations. The EU countries are also the most



Source(s): Own elaboration

Figure 1. Analyzed variables and dependencies

advanced ones in shaping common policy tools in the environmental area. We extracted all data from the Eurostat database to secure its integrity and comparability.

We selected the variables in Table 2 for the subsequent modeling as a result of the discussion presented in the previous section. Moreover, as we attempted to identify long-term relationships between population health and several environmental variables in this article, the availability of long-term data constituted an additional consideration for variable choice. The selected variables represent vast aspects of environmental policies and factors, including noise pollution.

Subsequent tables present the characteristics of the data used. Table 3 shows the key descriptive statistics. Table 4 shows the correlations between variables. The majority of the

Table 2. Variables used in modeling

Variable	Variable abbreviation used in models	Description	Eurostat dataset
Good & very good health (dependent variable)	hvg_g (dependent variable)	Self-perceived health as "Good" and "Very Good" (% of responses in total population)	hlth_silc_10
Environmental taxes	taxenvg	Total environmental taxes (revenues as % of GDP)	env_ac_tax
Energy taxes	taxenp	Energy taxes (as % of total revenues from taxes and social contributions)	env_ac_tax
Renewable energy	Reen	Share of renewable energy in gross final energy consumption (in %)	sdg_07_40
Organic farming	orfarm	Area under organic farming (% of utilized agricultural area)	sdg_02_40
Ammonia emissions from agriculture	amagr	Ammonia emissions from agriculture (kilograms per hectare)	sdg_02_60
Households suffering from noise	homno	Population living in households considering that they suffer from noise (% of total population)	sdg_11_20

Source(s): Authors' own elaboration

Variable	Mean	Median	Minimum	Maximum
hvg_g	66.45	68.60	35.10	84.40
taxenvg	2.60	2.53	1.21	4.99
taxenp	5.41	5.08	2.76	9.82
orfarm	6.64	5.70	0.00	26.64
amagr	27.98	19.60	6.20	179.00
reen	19.25	15.69	0.10	77.36
homno	18.47	17.80	7.70	50.20

Variable	Std. Dev	Coeff. of variation	Skewness	Ex. Kurtosis
hvg_g	10.34	0.16	−0.70	−0.33
taxenvg	0.60	0.23	0.78	0.92
taxenp	1.58	0.29	0.65	−0.25
orfarm	5.13	0.77	1.21	1.32
amagr	26.40	0.94	3.04	11.47
reen	14.70	0.76	1.48	2.34
homno	6.16	0.33	0.79	1.12

Variable	5% perc	95% perc	IQ range	Missing obs
hvg_g	46.07	78.77	14.48	27*
taxenvg	1.76	3.80	0.76	0
taxenp	3.30	8.65	2.33	0
orfarm	0.50	17.40	6.11	0
amagr	7.50	73.34	19.25	27**
reen	2.86	52.22	16.61	0
homno	9.80	29.70	9.00	0

Note(s): * no data for 2020
** no data for 2004
Source(s): Authors' own elaboration

Table 3.
Descriptive statistics for variables used in modeling

hvg_g	Taxenvg	Taxenp	Orfarm	Amagr	reen	Homno	
1.000	0.092	−0.423	−0.136	0.376	−0.052	0.057	hvg_g
	1.000	0.381	0.010	0.212	0.012	0.014	taxenvg
		1.000	−0.014	−0.249	−0.113	−0.140	taxenp
			1.000	−0.341	0.478	−0.290	orfarm
				1.000	−0.377	0.401	amagr
					1.000	−0.389	reen
						1.000	homno

Note(s): 5% critical value (two-tailed) = 0.0915 for $n = 459$
Source(s): Authors' own elaboration

Table 4.
Correlation matrix

correlation coefficients are statistically significant but do not exceed 0.50 in absolute terms, which preliminary indicates the existence of some meaningful relationships but with a limited threat of collinearity.

Before modeling, we performed several procedures to prepare the data for further analysis, such as panel data organization, structuring of the variables and analysis of collinearity. Initially, we constructed a fully balanced panel with individual missing data substituted by proxy data calculated as a geometric mean of the neighboring observations.

This adjusting procedure regarded very rare cases (less than 0.1% of all records). Using this approach was important since our panel consisted of a relatively short time series. Thus, any missing data would require a full year of observations to be removed, which would negatively impact the credibility of the entire modeling. Next, we calculated the first differences for all variables to eliminate variable stationarity and to remove endogeneity from the panel (Anderson & Hsiao, 1982). We used the Levin-Lin-Chu test for panel augmented Dickey–Fuller (ADF) (Levin, Lin, & Chu, 2002). We checked the time lags equal to 0 and 1. Table 5 presents the results.

Next, we calculated the variance inflation factors to check for collinearity between the differenced variables through the iterative regression process. As shown in Table 6, we did not detect collinearity, which also contains the data of variance inflation factors for the final shape of the modeled variables presented in Table 7.

Modeling this class of data may encounter several obstacles. Standard panel data approaches using pooled ordinary least squares (OLS), fixed effects and random effects may be insufficient to rule out such problems as autocorrelation of errors, heteroscedasticity of

Variable	Coefficient	t-student	z-score	
with zero lag				
d_hvg_g	−1.2063	−23.428	−18.4091	[0.0000]
d_taxenvg	−0.96777	−19.405	−13.9374	[0.0000]
d_taxenp	−0.99177	−19.639	−13.6416	[0.0000]
d_orfarm	−0.88398	−18.796	−13.1725	[0.0000]
d_amagr	−1.1070	−22.334	−17.3406	[0.0000]
d_reen	−1.1083	−20.541	−14.1856	[0.0000]
d_homno	−1.1469	−27.908	−22.9362	[0.0000]
with one lag				
d_hvg_g	−1.3311	−16.468	−7.26452	[0.0000]
d_taxenvg	−0.96777	−19.405	−13.9374	[0.0000]
d_taxenp	−1.0395	−14.466	−5.26736	[0.0000]
d_orfarm	−1.0107	−15.751	−7.5138	[0.0000]
d_amagr	−1.2126	−17.253	−8.97393	[0.0000]
d_reen	−1.0461	−13.460	−3.14087	[0.0000]
d_homno	−1.4059	−19.600	−8.6244	[0.0000]

Note(s): H0: Panels contain unit roots
Source(s): Authors' own elaboration

Table 5.
Results of non-stationarity testing – Levin-Lin-Chu tests for panel ADF

For the initial panel		For the panel with lagged data used in model 1*	
d_taxenvg	2.598	d_taxenvg_1	2.382
d_taxenp	2.648	d_taxenp_1	2.445
d_orfarm	1.009	d_orfarm	1.007
d_amagr	1.013	d_amagr	1.023
d_reen	1.037	d_reen_1	1.036
d_homno	1.032	d_homno	1.040

Note(s): *Variance Inflation Factors for Model 1, which is presented in Table 7 below
Values > 10 may indicate collinearity
Source(s): Authors' own elaboration

Table 6.
Variance inflation factors (a verification of collinearity)

Group variable: Country				Number of obs = 324		
Number of instruments = 84				Number of groups = 27		
Wald $\chi^2(7)$ = 43.04***				Obs per group: = 12		
Robust	Coef	Std. Err	z	$p>\lvert z\rvert$	(95% conf. Interval)	
d_hvg_g_1	−0.1600814	0.0655673	−2.44	0.015**	−0.288591	−0.0315717
d_taxenvg_1	1.335799	0.6973308	1.92	0.055*	−0.0309442	2.702543
d_taxenp_1	−0.6701967	0.345301	−1.94	0.052*	−1.346974	0.0065808
d_reen_1	0.2492477	0.1224292	2.04	0.042**	0.009291	0.4892045
d_orfarm	0.1307251	0.1525647	0.86	0.392	−0.1682962	0.4297465
d_amagr	−0.0824425	0.028103	−2.93	0.003***	−0.1375235	−0.0273616
d_homno	−0.2372829	0.1008363	−2.35	0.019**	−0.4349184	−0.0396473

Note(s): Prefix "d_" denotes a first difference; suffix "_1" denotes a lagged variable (t−1)
"*" denotes 10% significance level, "**" denotes 5% significance level, "***" denotes 1% significance level
Arellano-Bond test for AR(1) in first differences: z = −3.94 Pr > z = 0.000
Arellano-Bond test for AR(2) in first differences: z = −1.41 Pr > z = 0.158
Sargan test of overid. restrictions: $\chi^2(77)$ = 114.95 Prob > χ^2 = 0.003
Hansen test of overid. restrictions: $\chi^2(77)$ = 19.69 Prob > χ^2 = 1.000
Difference-in-Hansen tests of exogeneity of instrument subsets
Hansen test excluding group: $\chi^2(71)$ = 19.44 Prob > χ^2 = 1.000
Difference (null H = exogenous): $\chi^2(6)$ = 0.25 Prob > χ^2 = 1.000
Source(s): Authors' own elaboration

Table 7. Model 1 – results of dynamic panel data modeling and relevant tests; one-step difference GMM; dependent variable: d_hvg_g

errors' variance and variables' endogeneity. Although the standard panel data model confirmed the lack of autocorrelation of errors, it indicated potential problems with heteroscedasticity. The model's tests also implied the rejection of the fixed effects and random effect specifications for the panel in favor of a pooled OLS approach.

Moreover, testing for correlation between the dependent variable (d_hvg_g) and its lagged form (d_hvg_g_1) showed that the d_hvg_g variable was characterized with an autoregressive behavior: corr(d_hvg_g, d_hvg_g_1) = −0.1834. Moreover, we rejected the null hypothesis of no correlation (t(376) = −3.618 with p = 0.0003). This indicated that a dynamic panel model would be the most proper choice for model specification. However, this would still require to deal with heteroscedasticity and endogeneity.

This indicates the application of the generalized method of moments (GMM) in this specific case. This approach is particularly useful if, among others, the dependent variable shows autoregressive behavior, the panel analyzed consists of fewer periods than groups (in our case – countries), which typically produces a non-normal distribution of residuals, heteroscedasticity emerges, a linear relationship is tested and the independent variables may not be strictly exogenous (see Roodman, 2009). The initial solution to such issues involves using the GMM modeling procedure of Arellano and Bond (1991), based on the first differences of variables and errors. However, a model may still be prone to endogeneity problems. Consequently, an application of robust standard errors is required (using, for example, the xtabond2 modeling package). As shown by (Roodman, 2009), such a procedure eliminates heteroscedasticity and autocorrelation within individuals and it allowed us to confirm the exogeneity of instruments with the usage of the difference-in-Hansen tests. Thus, we used a dynamic panel model estimated with the different GMM approach for data modeling in this research. Subsequent paragraphs of this section present more details on the modeling procedure, including the relevant test results.

The dynamic panel model, which we ultimately used in this research, has the following general form:

$$y_{it} = \sum_{j=1}^{p} \propto_j y_{i,t-j} + x_{it}\beta_1 + w_{it}\beta_2 + v_i + u_{it}\, i = 1, \ldots, N\, t = 1, \ldots, T_i \tag{1}$$

in which:

(1) *yit* –dependent variable, namely % of people perceiving their health status as good or very good – see Table 2;

(2) $\propto_j$ – p coefficients for *y*;

(3) x_{it} – a 1 *x* k_1 vector of strictly exogenous variables – see Table 2 showing the set of exogenous variables;

(4) β_1 – a k_1 *x* 1 vector of coefficients for *x*;

(5) w_{it} – a 1 *x* k_2 vector of predetermined and endogenous variables;

(6) β_2 – a k_2 *x* 1 vector of coefficients for *w*;

(7) v_i – panel-level effects – time-invariant error term (which may be correlated with the covariates) and

(8) u_{it} – time-dependent error term, which is independent and identically distributed over the whole sample with variance σ_u^2.

It is assumed that v_i and u_{it} are mutually independent as well. We used the earlier lag period *y* as an instrumental variable. Equation (1) shows a simplified dynamic panel without lagged independent variables. Both the *x* and *w* variables could be lagged, and their lagged periods may have differed from the *y* variable.

In general, the lagged dependent variables are correlated with the unobserved panel-level effects. This may produce inconsistent estimators when using the standard estimation procedure. Even though the fixed effects would be removed due to the use of first differences (Δ), the lagged dependent variable would remain endogenous, since the $y_{i,t-1}$ term in $\Delta y_{i,t-1} = y_{i,t-1} - y_{i,t-2}$ may have been correlated with the $u_{i,t-1}$ in $\Delta u_{i,t} = u_{i,t} - u_{i,t-1}$. Similarly, any variables in *x* that are not strictly exogenous may also become endogenous due to their relationship with $u_{i,t-1}$.

The modeling procedure follows the approach of Arellano and Bond (1991) using a GMM estimator to estimate $\propto_1, \ldots, \propto_p, \beta_1, \beta_2$. The moment conditions are formed from the first-differenced errors from Eq. (1) and instruments. The first differences of the *x* are applied as standard instruments:

$$\Delta y_{it} = \gamma \Delta y_{it-1} + \beta' \Delta X_{it} + \Delta u_{it} \tag{2}$$

in which, specifically:

(1) X – vector of first differences of the exogenous variables; shown in Table 2,

γ, β – represent the set of estimation coefficients,

Δ– denotes the first difference,

(2) and the remaining parameters and variables defined as in Eq. (1).

We applied the xtabond2 STATA function in the modeling using the GMM estimation. We conducted the calculations with the STATA 16.1 package. Moreover, we conducted some supporting calculations with Gretl ver. 1.9.90. Table 7 shows the outcome of the dynamic panel modeling. In order not to inflate the number of instruments, we simplified the model to contain only a single representation of each variable – either lagged (*t*−*1*) or non-lagged, whichever was more significant. This procedure produced meaningful results, as shown in Table 7. The value of the coefficient for d_hvg_g_1 < |1| safeguarded the model's dynamic stability.

The results obtained in Model 1 indicated several significant relationships between the analyzed phenomena. The Wald test provided satisfactory results. The subsequent Arellano-Bond tests showed an adequate choice of *t*−*1* lag for the dependent variable – the test for AR(1) in the first differences yielded z = −3.94 (Pr > z = 0.00) along with the test for AR(2) in the first differences which yielded z = −1.41 (Pr > z = 0.158), thus rejecting errors autocorrelation. Applying robust standard errors in the one-step GMM (computed with the use of xtabond2) eliminated both heteroscedasticity and autocorrelation within individuals (Roodman, 2009, p. 123). The difference-in-Hansen tests also confirmed the validity and exogeneity of the subset of instruments, which overrode the partially conflicting message from the Sargan–Hansen tests of overidentifying restrictions.

However, the Hansen tests produced a "perfect" statistic of 1.00. This could be potentially worrying as the number of instruments in Model 1 is relatively large and well above the number of groups. Such a situation with instrument proliferation may overfit endogenous variables. To verify if this was the case, we estimated the model with a limited number of instruments. We used the "collapse" parameter with the xtabond2 functions, which creates one instrument for each variable and lag distance, instead of each variable, period and lag distance – see (Roodman, 2009).

Table 8 shows these results (Model 2). They confirm the findings from Model 1 except for the "energy taxes" variable. The signs of all the coefficients remain the same as in Model 1. All the Arellano–Bond tests, difference-in-Hansen tests and the tests for over-identification of restrictions as well as the Wald test produced satisfactory results, confirming the appropriate form of Model 2.

Both models confirmed several significant and meaningful relationships between the self-perceived health index and environmental variables. Namely, there is a strong positive link between environmental taxation and the health index. Likewise, the development of RES and the elimination of fossil fuels from the energy mix exert further positive effects on health.

Group variable: Country | Number of obs = 324
Number of instruments = 18 | Number of groups = 27
Wald $\chi^2(7)$ = 46.47*** | Obs per group: = 12

Robust	Coef	Std. Err	z	p>|z|	(95% conf. Interval)	
d_hvg_g_1	−0.1268201	0.0643736	−1.97	0.049**	−0.2529901	−0.0006501
d_taxenvg_1	1.198019	0.6507239	1.84	0.066*	−0.0773763	2.473415
d_taxenp_1	−0.4025534	0.3533117	−1.14	0.255	−1.095032	0.2899248
d_reen_1	0.2842993	0.1403517	2.03	0.043**	0.0092149	0.5593837
d_orfarm	0.1866586	0.1553204	1.20	0.229	−0.1177637	0.491081
d_amagr	−0.1087108	0.0242032	−4.49	0.000***	−0.1561482	−0.0612734
d_homno	−0.2233539	0.0977834	−2.28	0.022**	−0.4150058	−0.031702

Note(s): Prefix "d_" denotes a first difference; suffix "_1" denotes a lagged variable (t−1)
"*" denotes 10% significance level, "**" denotes 5% significance level, "***" denotes 1% significance level
Arellano-Bond test for AR(1) in first differences: z = −3.80 Pr > z = 0.000
Arellano-Bond test for AR(2) in first differences: z = −1.11 Pr > z = 0.269
Sargan test of overid. restrictions: $\chi^2(11)$ = 13.91 Prob > χ^2 = 0.238
Hansen test of overid. restrictions: $\chi^2(11)$ = 13.30 Prob > χ^2 = 0.274
Difference-in-Hansen tests of exogeneity of instrument subsets
Hansen test excluding group: $\chi^2(5)$ = 4.07 Prob > χ^2 = 0.540
Difference (null H = exogenous): $\chi^2(6)$ = 9.24 Prob > χ^2 = 0.161
Source(s): Authors' own elaboration

Table 8. Model 2 – results of dynamic panel data modeling with limited number of instrumental variables; one-step difference GMM; dependent variable: d_hvg_g

Reducing ammonia emissions from agriculture and noise pollution are other statistically valid health-supporting factors. The development of organic farming has a positive effect on health, but this factor was statistically insignificant. The subsequent section describes these results in more detail.

5. Discussion

The conducted research showed several meaningful relationships between self-perceived health and the environmental variables selected for the analysis. Among other things, studies have shown that an important element that positively affects self-perceived health is the level of environmental taxes in relation to gross domestic product (GDP). The obtained results indicate that a subsequent increase in the self-perceived health index followed an increase in the share of environmental taxes in GDP in the previous year. This may result from several causes. First, increasing the taxation scale of activities that lead to climate pollution forces the introduction of pro-ecological actions on a larger scale, and the society experiences their effects already in the following year. Kosonen (2012), Paultrel (2008), Postula and Raczkowski (2020) and Li *et al.* (2021) reached similar conclusions. Furthermore, Faccioli *et al.* (2022) assume that "a combined carbon and health tax policy maximizes benefits in terms of both environmental and health outcomes." Another reason that may have influenced the result was the behavioral impact of government activities related to climate issues and the implementation of tax measures connected to enforcing the "polluter pays" principle, a fundamental environmental concept in the EU. Given the reinforcement of these activities, study participants were more inclined to rate their health assessment as higher and the study findings support it. The European Commission indicates a similar factor in its reports (2022), recognizing that the intention to change human behavior to positively impact health has not always been an important aspect during the initial design of many energy taxes, but it is now gaining in importance rapidly, since the impact of environmental taxes on these areas of human life is significant. People are becoming increasingly aware of their carbon footprint and can choose to reduce their energy consumption through a variety of energy-efficient solutions. Reducing emissions decreases health risks and medical costs for the individual and everyone around them, hence the effect is positive (Chatterjee, Halim, & Mozumder, 2022). Furthermore, the analysis showed (only in Model 1) that the increase in the share of energy taxes in total taxes negatively impacts the health index, which may raise some additional questions as to why, since environmental taxes in relation to GDP have a positive effect in general. This could be surprising since, for example, a study by Hassan *et al.* (2021) presenting the impact of these taxes on physical investment, human capital and environmental innovation found that energy taxes negatively impact polluting emissions. In turn, this should translate into health indicators. Energy taxes are also intended to prevent air pollution, which is one of the deadliest pollution sources. According to a report by *the European Heart Journal* (Lelieveld *et al.*, 2019, quoted in Schlanger, 2019), an average inhabitant of Europe loses two years of life as a result of the health effects of breathing polluted air. There is a large amount of research in medical science providing evidence of the negative impact of PM pollution on human health (Brunekreef & Forsberg, 2005; Kim, Kabir, & Kabir, 2015; Marcelli, Hampai, Cibin, & Maggi, 2012). However, we have not identified a positive relationship between the growing share of energy taxes in total taxes and good health. Therefore, the effect can only be studied in the long term and is also influenced by the wealth of the particular society.

However, after a detailed analysis, we can conclude that an increase in the level of energy taxes in the general tax pool shows that there are increasing problems with air quality in the given country and this negatively impacts the citizens' health, which translates into the need for increasing pollution fees. Moreover, it is also generally accepted that energy taxes are regressive (e.g. Metcalf, 2009; Rausch, Metcalf, & Reilly, 2011; Williams, Gordon, Burtraw, Carbone, & Morgenstern, 2015), which means that the more vulnerable parts of society feel their economic impact more than the wealthier parts. Consequently, raising the cost of fuels and energy-intensive goods through additional taxation implies a greater percentage reduction in overall consumption of poorer households (Pizer & Sexton, 2019), as these goods often include relatively large shares of low-income household budgets, which, in turn, can contribute to a reduction in disposable income for other expenses such as health. Therefore, it is quite unexpected that our research found the impact of energy taxes on health to be insignificant.

The research has shown that the share of renewable energy in the gross final energy consumption by sector (%) index has a significant positive impact on citizens' health measured by self-perceived health in the following period. The literature is scarce in studies on such direct correlations, which indicates the relevance and uniqueness of the results of the research presented in the article. The obtained results indicate that from the point of view of the analysis of factors affecting health, direct actions that assist the energy transformation through the introduction of RES are effective facilitators of health policies (Mo, Jiang, Wang, Shao, & Wang, 2022).

Bearing in mind that agriculture has a huge impact on climate change; for example, through GHG emissions and the level of water pollution resulting from the use of artificial fertilizers and that it is responsible for huge water intake for irrigation, scholars analyzed also the impact of one of the indicators from this area on health. Our research results confirmed the findings of several studies related to air pollution caused by agriculture and its impact on human health, such as Domingo *et al.* (2021). Giannadaki, Giannakis, Pozzer, and Lelieveld (2018), Cohen *et al.* (2017) and Domínguez *et al.* (2016) reached similar conclusions in their research.

A significant factor influencing the health of society is noise, which impacts both the quality of life and bodily function (Moudon, 2009). Our research confirmed that noise pollution is a crucial environmental health risk in Europe (see WHO, 2011) and as such, authorities cannot ignore it in policy design. The health impacts of noise lead to direct adverse auditory effects such as hearing loss and tinnitus. However, long-term exposure to noise affects us the most (WHO, 2018). Such long-term exposure results in non-auditory effects, including psychological and physiological suffering and even an unbalance in the body's homeostasis and an increased allostatic load (Basner *et al.*, 2014). These, in turn, result in annoyance, sleep deprivation, cardiovascular and metabolic effects and cognitive impairment in children (WHO, 2018). For small groups in the population, the subsequent changes may lead to clinical symptoms, such as insomnia and cardiovascular problems (EEA, 2019a).

Our research results show that when the share of the population living in noisy households increases by one unit, the self-perceived health index decreases by 0.2 units, assuming other variables remain constant. This indicates a significant negative impact. Based on research, Clark and Paunovic (2018a, b) and Clark, Crumpler, and Notley (2020) agree with this assessment.

We can interpret the statistical insignificance of the impact of organic farming on health considering the EU's urbanization level and the resulting limited direct impact of the introduction of organic farming on the population's majority. This is distinct from air and noise pollution, which are noted at higher limits in urban areas rather than rural or even suburban areas. In the EU, 75% of the population lives in urban areas, thus the impact of the farming model is more generalized and diffused. Therefore, a direct and quantified impact may be difficult to measure.

6. Conclusions

We aimed to raise the importance of the environment-health nexus. Based on 94 systematic reviews, Rocque *et al.* (2021) indicated ten health outcome categories related to environmental degradation: infectious diseases, mortality, respiratory, cardiovascular and neurological outcomes. The quality of the natural environment significantly affects the condition of our health and therefore measures aimed at fighting environmental degradation should be closely linked with those dedicated to improving our health. This reflection has not received enough attention in global discussions. We aimed to identify the impact of different policies and environmental conditions on population health, as measured by a self-assessment of health statistics. It is a novel and original research approach. The original contribution of this research to the field includes the analysis of the factors and relationships between environmental health, human health and environmental taxes. The results of our research indicate important and sometimes unexpected connections between self-perceived health and a variety of factors affecting the natural environment.

The positive correlation between the increase in environmental taxes in GDP and the increase in the self-perceived health index is a significant discovery. Moreover, the speed of the response to this relationship, thanks to pro-environmental measures, produces rapid effects, sometimes within just one year. This finding is extremely important, because it enables the programming of solutions that bring results in the short term, which, due to the large scale of impact and inertia of processes in health policy, may be a very desirable result of state activities. Policies that aim to develop RES and eliminate fossil fuels from the energy mix further enhance these positive effects.

The discovery of a negative impact from an increase in the share of energy taxes in total taxes on the health index was surprising because it contradicts some findings in the existing literature. However, although we may consider the results contradictory at this stage, a deeper analysis of the interdependencies between the variables may confirm the existence of differences in the research. This, however, should be the subject of more detailed research.

The research showed that when conducting activities in the field of environmental policy, policymakers should use the public expenditure system more often than the tax system. Tax measures such as ecological taxes have a smaller impact on the health indicator than direct subsidy measures. Moreover, The research results confirmed the necessity of addressing climate policy across various areas of government activity simultaneously to improve health indicators. The future scope of the study will focus on the link between health policies, environmental taxation and the environmental pillar of sustainable development in the context of the UN sustainable development goals.

This study has several limitations, such as potentially the research design, which may accidently affect the results, the availability of relevant data for all analyzed countries as well as data quality and cohesion, especially in the area of health self-assessment.

Future research may focus on state tools in the field of ecology influencing the health of the population as a response to the growing challenges of civilization in this area. Due to the multifaceted nature of changes negatively influencing the climate, we should particularly appreciate the possibility of identifying actions that bring quick results in the area of health policy. Although people consider it one of the most important areas of state influence, it does not seem to meet the growing expectations in the area of social policies.

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