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Conference Paper — Published Version

The Role of Green Public Spending in Reducing Greenhouse Gas Emissions in Selected European Countries: Aligning Regional and Local Budgets with Green Objectives

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THE ROLE OF GREEN PUBLIC SPENDING IN REDUCING GREENHOUSE GAS EMISSIONS IN SELECTED EUROPEAN COUNTRIES: ALIGNING REGIONAL AND LOCAL BUDGETS WITH GREEN OBJECTIVES

ABSTRACT

Rising environmental degradation and increasing public awareness have prompted countries to adopt policies to reduce ecological damage. Global warming, climate change, and biodiversity loss pose serious economic and social challenges. At the same time, CO_2 emissions continue to rise, particularly in developing countries like Bosnia and Herzegovina, which faces limited institutional capacity. Transitioning toward net-zero emissions by mid-century is essential to prevent irreversible climate risks. Energy efficiency improvements in energy-intensive sectors are central to mitigation efforts. However, financial constraints limit the widespread adoption of sustainable practices. Private initiatives alone are insufficient, highlighting the importance of public investment in green infrastructure at regional and local levels, filling gaps in private capital and stimulating further private-sector engagement.

This paper examines the impact of public spending on environmental protection activities – including waste and wastewater management, pollution abatement, biodiversity and landscape preservation, and ecological R&D - on greenhouse gas (GHG) emissions. Using panel data for EU member states and Bosnia and Herzegovina over 2014-2022, we employ regression models, specifically pooled Ordinary Least Squares (OLS), Fixed Effects (FE), and Random Effects (RE). Lagged effects are also considered, recognising that the benefits of public spending may materialise over time. The findings provide empirical evidence on the effectiveness of fiscal instruments in mitigating environmental degradation and offer insights for aligning regional and local budgets with the EU's and the Western Balkans' long-term climate neutrality objectives. This research further contributes to the limited empirical literature on the role of fiscal policy in reducing GHG emissions.

Keywords: *green public spending, fiscal policy, greenhouse gas emissions, environmental protection, climate neutrality.*
JEL: H30, H61, H72, H76, C23, Q53

1. INTRODUCTION

Since the Second Industrial Revolution, humankind has relied on technological change for societal betterment (Muchiri et al., 2025). Bhuiyan et al. (2022) note that fossil fuels have played a central role in enabling rapid economic growth globally. However, these developments have come at the cost of unabated long-term fossil fuel consumption, leading to significant greenhouse gas (GHG) emissions and, consequently, global warming (Chen & Chen, 2021). Considering that various economic activities increasingly exert pressure on the environment, recent decades have been marked by growing concern over the state of the natural environment. This concern has led to fundamental shifts in thinking about environmental management and public policy design (Nikolajev, 2024). Environmental pollution, including global warming, climate change, and biodiversity loss, has a profound and multidimensional impact on the economy. Air quality and environmental protection represent classic examples of public goods, characterised by non-rival consumption and non-excludability (He et al., 2018). Air pollution, among other factors, is linked to numerous health problems. For instance, $PM_{2.5}$ (particulate matter) can penetrate deep into the respiratory system and enter the bloodstream, being recognised as a primary contributor to various chronic and acute diseases. Climate change is now considered one of the most severe ecological challenges facing humanity, with the past thirty years witnessing a continuous rise in Earth's surface temperature, producing far-reaching consequences for human health, property security, economic system stability, and environmental preservation (Savranlar et al., 2024).

A key component of greenhouse gas emissions is CO_2, whose emissions, predominantly from the combustion of fossil fuels and other non-renewable energy sources, are a primary driver of global warming (Soytas & Sari, 2009; Savranlar et al., 2024). Particularly concerning is the growing trend of CO_2 emissions in developing countries due to rapid industrialisation and urbanisation. Such countries, owing to structural vulnerabilities and limited institutional capacities, may experience significantly more severe ecological and social consequences compared to developed nations. In this context, the gradual transition to net-zero GHG emissions by the mid-21st century is essential to limit the risks of dangerous and irreversible climate change (IMF/OECD, 2021). Achieving this goal requires technological innovation and international cooperation and comprehensive utilisation of fiscal instruments that can shape consumer and producer behaviour toward sustainability.

Reducing pollution and improving air quality can be conceptualized as national public goods, given their non-excludable and non-rival nature. Given the public dimension of environmental protection, governments bear the responsibility to develop policies that regulate negative externalities and preserve natural resources. In line with sustainable development principles, environmental policy is defined as a systemic approach to environmental management, encompassing the establishment of regulatory frameworks followed by the implementation of appropriate measures and instruments necessary for effective enforcement. To address global warming challenges, joint international initiatives have been established, such as the Paris Agreement of 2015 and the United Nations Conference of the Parties on Climate Change (COP26 and COP27) (UNFCCC, 2015, 2021, 2022). In alignment with these global efforts, the European Union, through the European Green Deal and the latest Communication on Strengthening Climate Ambitions by 2030, has set a goal to become the first climate-neutral continent in terms of carbon dioxide (CO_2) emissions by 2050 (European Commission, 2021). In light of these European and global efforts, Western Balkan countries, including Bosnia and Herzegovina, have demonstrated their commitment to a green transition by signing the Sofia Declaration on the Green Agenda for the Western Balkans on 10 November 2020. Specifically, Bosnia and Herzegovina, as a signatory, has expressed readiness to align its national policies with European legislation. This approach is further justified by the fact that, as a consequence of past and current greenhouse gas emissions, Bosnia and Herzegovina is already experiencing the negative impacts of climate change. To achieve internationally set targets for mitigating the harmful effects of climate change (Regional Cooperation Council, 2020), the main driver — CO_2 emissions — must be significantly reduced. Considering global efforts to protect the environment, particularly regarding CO_2 emission reductions, the effectiveness of economic policies in environmental protection has become increasingly prominent in political and scientific discussions (Silajdžić & Mehić, 2018).

In pursuit of sustainable practices to curb CO_2 emissions, Sohail et al. (2024) note that several policy options have been proposed, including the promotion of green finance and increasing the share of modern renewables. According to Lei et al. (2021), the development of green, clean, and renewable energy, as well as its effects on economic development and ecosystems, has been a major topic of debate over the past two decades. Increased renewable energy consumption has been found globally to positively influence environmental sustainability by reducing GHG emissions (Muchiri et al., 2025). Green finance encompasses investments in environmentally friendly projects to conserve and protect the environment (Zhang et al., 2022). The UN Environmental Programme defines green financing as the increase of financial flows from private, public, and non-profit sectors toward sustainable development priorities that help manage social and environmental risks (UNEP, 2018; Muchiri et al., 2025). Gu et al. (2021) add that green financing can involve transferring resources from high-carbon-intensive industries to less polluting sectors through structural effects. Similarly, Sun (2022) notes that investments promoting a green industrial structure qualify as green investments. Given the crucial role of CO_2 emission reductions for Bosnia and Herzegovina's European integration, it is critical to investigate this issue. This forms the primary motivation for analysing the efficiency of public spending in reducing CO_2 emissions in Bosnia and Herzegovina relative to EU countries.

Building upon the established understanding of green public spending (environmental protection public expenditures) within the European context, this paper aims to bridge critical gaps by examining the role of green public spending in reducing CO_2 emissions. Specifically, the study investigates how the scale of green public spending affects CO_2 emission reductions, as well as how the structure of public spending — i.e., the composition of different categories of green public spending — influences emission levels. Using panel data for EU countries and Bosnia and Herzegovina over the period 2014–2022 and employing panel regression analysis, this research extends existing frameworks to understand better how public spending contributes to climate goals. Furthermore, a robustness analysis will be conducted to examine whether introducing one and two-period lags in green public spending affects the consistency and significance of the estimated results, thereby offering policymakers valuable insights tailored to this context.

The rest of the paper is structured as follows. The first part of the paper presents previous research and theoretical background on the impact of green public spending on GHG emissions. The second part of the paper outlines the empirical design, including the selection of variables and data sources, and econometric model construction. The third part of the paper provides the results and discussion. The last part of the paper provides the conclusions and recommendations, summarising the key research findings and offering policy suggestions.

2. PREVIOUS RESEARCH AND THEORETICAL BACKGROUND

Green government spending has emerged by integrating green development principles into fiscal policy frameworks. In a narrow sense, environmental protection public expenditure encompasses government spending on energy conservation and environmental protection aimed at supporting environmental sustainability, stimulating technological innovation, and promoting energy efficiency and emissions reduction (Fang et al., 2024). Increasing green public spending signifies that governments are allocating more financial resources toward environmental management, thereby reinforcing national commitments to environmental governance. Strengthening environmental management enhances public trust in governmental efficiency, fosters the development of positive societal attitudes, and encourages collective environmental responsibility (Niu, 2024).

Environmental protection public expenditure thus represents an essential indicator of society's response to ecological pressures. It consists of both capital and current expenditures directed toward environmental protection activities, which may include investments in equipment, labour, production techniques, information systems, and products whose primary objective is to collect, treat, prevent, or mitigate pollutants and environmental degradation. Moreover, environmental protection public expenditure can generate marketable by-products and financial savings or be subsidised through government programs. In such cases, environmental protection public expenditure should be reported on a gross basis, without deducting any cost offsets (Eurostat, 2005). Governments allocate environmental protection public expenditure through pollution control, biodiversity preservation, environmental research and development, regulatory enforcement, and investments in green infrastructure.

Theoretically, environmental protection public expenditure can enhance the effectiveness of green finance through several channels. Environmental protection public expenditure first establishes the institutional infrastructure required to design and implement green projects effectively (Muchiri et al., 2025), while Zhang and Zhao (2024) argue that budget allocations to environmental protection can signal policy stability, potentially reducing the risk premium on green investments. López et al. (2011) further explored the broader environmental impact of fiscal spending through scale, composition, and technique effects, showing that while increased government spending does not automatically reduce air and water pollution, a strategic reallocation toward social and public goods can yield positive environmental outcomes. Empirical evidence supports these theoretical arguments. Several studies, including Sharma (2011), Morley (2012), Miceikienė et al. (2021), and Yilmaz (2025), consistently demonstrate that green public spending contributes to reductions in air pollutants such as nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), and carbon dioxide (CO_2). Adewuyi (2016) complements these findings by showing that, in the long run, the negative direct impact of government expenditure on environmental quality is mitigated by positive indirect effects, leading to an overall beneficial effect on aggregate carbon emissions. In contrast, in the short run, negative direct and indirect effects reinforce reductions in emissions. Other studies emphasise the importance of the interaction between public spending and institutional quality. Halkos and Paizanos (2013) and Bernauer and Koubi (2013) found that indirect effects of public spending are often more consequential than direct effects, with higher spending reducing sulfur and nitric oxide emissions, though not always affecting CO_2 emissions. Similarly, Abid (2017) highlighted that public spending in EU countries contributes to reductions in GHG emissions. In contrast, the impact is negligible in MENA (Middle East and North Africa) countries, pointing to the mediating role of governance and institutional frameworks. Bernauer and Koubi (2013) also suggest that larger government sizes can, under certain conditions, exacerbate pollution due to bureaucratic inefficiencies and the influence of special interests. Efficiency considerations are also crucial. Barrell et al. (2021) found diminishing returns to environmental protection public expenditures in EU countries between 2005 and 2015, indicating that higher spending does not necessarily yield proportional environmental benefits beyond a certain level. In contrast, Akdag et al. (2024) demonstrated that in European countries from 1995 to 2019, even marginal increases in EPE were associated with substantial reductions in GHG emissions, highlighting the potential effectiveness of well-targeted environmental expenditure.

Based on the reviewed theoretical perspectives and empirical findings, the relationship between environmental protection public expenditures and environmental outcomes is complex and context-dependent. While some studies highlight the efficiency and long-term benefits of such spending, others point to potential inefficiencies, diminishing returns, or the mediating role of institutional quality and governance. Overall, the evidence suggests that well-targeted and efficiently managed environmental protection public expenditures can contribute to reducing greenhouse gas emissions and promoting sustainable growth.

3. EMPIRICAL DESIGN

3.1. Selection of variables and data sources

This paper investigates the effects of green public spending on CO_2 emissions, using data from EU countries and Bosnia and Herzegovina for the period 2014–2022, sourced from Eurostat and national statistical reports. The dependent variable in this study is CO_2 emissions, while the independent variable is environmental protection public expenditures, with urbanisation included as a control variable.

CO_2 emissions. To measure CO_2 emissions, data on total annual emissions from four key sectors —energy, industry, agriculture, and waste management — are used. The land use, land-use change, and forestry (LULUCF) sector is excluded from the analysis due to its specific methodological characteristics and different impacts on emissions. Emission values are expressed in thousand tonnes, using the Global Warming Potential (GWP) factor defined in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR5), representing the most relevant scientific framework for quantifying greenhouse gases.

Environmental protection public expenditures. Environmental protection public expenditures represent the sum of both capital and current expenditures directed toward environmental protection activities. These activities include the use of equipment, labour, production techniques, information networks, and products whose primary purpose is the collection, treatment, reduction, prevention, or elimination of pollutants and environmental degradation resulting from economic activities. Environmental protection public expenditures may also relate to activities that generate marketable by-products, result in cost savings, or are financed through government subsidies or tax incentives. In such cases, expenditures are reported on a gross basis, without deducting these offsets. In this study, environmental protection public expenditures are measured as total annual general government spending in millions of euros, covering areas such as waste management, wastewater management, pollution abatement, biodiversity and landscape protection, as well as research and development in environmental protection.

Urbanisation. Urbanisation is included as a control variable and captures the level of urban development across countries.
Table 1 presents the definitions and explanations of all variables used in the analysis.

Table 1. Selection of variables – definition and explanation

Variable	Symbol	Definition
Carbon dioxide emissions	CO_2	Amount of CO_2 emissions (in thousand tonnes)
Environmental public protection expenditure	EPEA	Government expenditure on environmental protection for the total economy (mil EUR)
Waste management expenditure	WME	Government expenditure on waste management (mil EUR)
Wastewater management expenditure	WWME	Government expenditure on wastewater management (mil EUR)
Pollution abatement expenditure	PAE	Government expenditure on pollution abatement activities (mil EUR)
Biodiversity and landscape protection expenditure	BLP	Government expenditure on the protection of biodiversity and landscape (mil EUR)
Research and development for environmental protection expenditure	RDEP	Government expenditure on research and development in the field of environmental protection (mil EUR)
Urbanisation	URBAN	Number of households by degree of urbanisation (thousand households)

Source: Compiled by authors

3.2. Econometric model construction

According to Yilmaz (2025), three panel models were employed to evaluate the relationship between environmental protection public expenditures and CO_2 emissions. Specifically, pooled OLS, fixed effects, and random effects models were estimated to assess which regression specification best fits the data. In line with Muchiri et al. (2025), model adequacy was examined using the Hausman test, and the Breusch–Pagan test will be applied if conditions require it.

The following regression equation represents the model to examine the impact of scale environmental protection public expenditures on CO_2 emissions:

$$CO2_{i,t} = \alpha_{i,t} + \beta_0 EPPE_{i,t} + \beta_j Control_{i,t} + \varepsilon_{i,t} \quad (1)$$

where *i* and *t* are the individual and the year, respectively, α is a constant term, β is a parameter to be estimated, ε is a random error term, EPE is the environmental protection public expenditures, and *control* denotes the control variable. The control variable is urbanisation.

Not all components of environmental protection public expenditures have an equal effect on CO_2 emissions. To explore the influence of various components of environmental protection public expenditures related to environmental protection, the following model is developed:

$$CO2_{i,t} = \alpha_{i,t} + \beta_0\, WME_{i,t} + \beta_1\, WWME_{i,t} + \beta_2\, PAE_{i,t} + \beta_3\, BLP_{i,t} + \beta_4\, RDEP_{i,t} + \beta_j\, Control_{i,t} + \varepsilon_{i,t} \quad (2)$$

where *i* and *t* are the country and year, respectively, WME_{it} is the waste management expenditures, $WWME_{it}$ is the wastewater management expenditures, PAE_{it} represents pollution abatement expenditures, BLP_{it} stands for biodiversity and landscape protection expenditures, and $RDEP_{it}$ refers to research and development for environmental protection expenditures.

4. RESULTS AND DISCUSSION

4.1. Descriptive statistics

The descriptive statistics of the main variables are presented in Table 2. As shown, the mean value of CO_2 emissions is 88,130.30 (thousand tonnes), with a standard deviation of 126,787.80, indicating substantial variation in carbon emissions across the observed countries. The table also presents descriptive statistics for the structure of environmental protection public expenditures across the countries under study. Finally, urbanisation has a mean of 7,181.64 and a standard deviation of 9,960.51, reflecting the diverse levels of urban development across the sample.

Table 2. Descriptive statistics

Variable	Obs.	Mean	Std. dev.	Min.	Max.
CO2	253	88,130.300	126,787.800	1,345.031	666,026.500
EPPE	252	3,849.211	6,259.906	7.874	28,612.000
WME	243	1,765.691	3,205.528	14.300	14,061.000
WWME	243	733.532	1,255.372	0.000	5,493.000
PAE	234	656.604	1,168.253	1.900	7,528.000
BLP	242	387.822	623.711	0.000	2,568.000
RDEP	234	190.528	389.089	0.000	1,765.000
URBAN	243	7,181.644	9,960.512	164.100	41,355.100

Source: Authors' calculations using StataMP 17 software

4.2. Baseline results

The baseline analysis investigates the relationship between the scale of environmental protection public expenditures and CO_2 emissions. Table 3 presents the estimated coefficients and statistical significance for each specification.

Table 3. Panel regression results – environmental protection public expenditures (scale)

Variable	OLS model (a)	Fixed-effect model (b)	Random-effect model (c)
EPPE	-9.792*** (p = 0.000)	-14.861*** (p = 0.000)	-11.567*** (p = 0.000)
URBAN	17.638*** (p = 0.000)	27.345** (p = 0.013)	18.684*** (p = 0.000)
Constant	3,194.455 (p = 0.279)	-46,291.940 (p = 0.503)	2,764.813 (p = 0.744)
Observations	243	243	243
Number of countries (ID)	—	27	27
Adj. R^2 / R^2 (Overall)	0.887	0.887 (overall)	0.886 (overall)

Note: Significance levels of 1%, 5% and 10% are denoted by ***, ** and *, respectively.
Source: Authors' calculations using StataMP 17 software

As observed in the table, environmental protection public expenditures consistently show a negative impact on CO_2 emissions across all model specifications, confirming its potential to reduce carbon intensity. Urbanisation has a positive effect, although the level of statistical significance differs depending on the model.

Table 4. Hausman test (FE vs. RE)

Variable	FE Coef. (b)	RE Coef. (B)	Difference (b-B)	Std. err. of difference
CO2	—	—	—	—
EPPE	-18.034	-11.567	-6.467	25.556
URBAN	21.626	18.684	2.942	10.545
b = consistent under H_0 and H_a; obtained from xtreg, fe B = inconsistent under H_a, efficient under H_0; obtained from xtreg, re Test of H_0: Difference in coefficients not systematic $\chi^2(2) = 0.13$ Prob > $\chi^2 = 0.9366$				

Source: Authors' calculations using StataMP 17 software

The Hausman test was employed to determine the appropriate model specification between the fixed effects (FE) and random effects (RE) estimators. The null hypothesis of the Hausman test assumes that the random effects model is appropriate, implying no systematic difference in the coefficients between the FE and RE estimators (Bell et al., 2019; Muchiri et al., 2025). If the p-value is below 0.05, the null hypothesis is rejected in favour of the fixed effects model. As shown in Table 4, the Hausman test produced a chi-square statistic of $\chi^2(2) = 0.13$ with a p-value of 0.9366, indicating that the difference in coefficients between the FE and RE models is not statistically significant. Therefore, the null hypothesis could not be rejected, suggesting that the random effects model is the more appropriate empirical specification for this study.

The authors ran the Breusch-Pagan Lagrange Multiplier (LM) test to assess whether the random effect model was more appropriate compared to the pooled OLS model. This test is used to determine which empirical model is more suitable for the panel data: the pooled OLS model or the random effects model (Bobbitt, 2020; Muchiri et al., 2025). The null hypothesis of this test is that the pooled OLS model is appropriate, while the alternative hypothesis states that the random effects model provides a better fit for the sampled data. The null hypothesis is rejected if the probability of chi² is less than 0.05 at a 5% significance level. The results of the LM test are presented in Table 5. As shown, the variance of the random effects component (u) is 0.3329, with a standard deviation of 0.5770. The test statistic Chibar² (01) is 164.74 with a p-value of 0.0000, which is below the 0.05 threshold. This indicates that the null hypothesis is rejected and that the random effects model is more suitable than the pooled OLS model for the given panel data.

Table 5. Breusch-Pagan Lagrange Multiplier test (RE vs. OLS)

Variable	**Var**	**SD = sqrt(Var)**
CO2	2.5332	1.5916
e (residual)	0.0034	0.0585
u (random effect)	0.3329	0.5769
Test: Var(u) = 0 Chibar² (01): 164.74 Prob > Chibar²: 0.0000		

Source: Authors' calculations using StataMP 17 software

The previous results indicated that an increase in green public spending reduces CO_2 emissions. However, assuming that not all categories of environmental protection public expenditures have the same impact on CO_2 emissions, the analysis further examines the heterogeneity of public spending effects across these categories. The results of the panel regression analysis assessing the heterogeneity of effects are presented in Table 6.

Table 6. Panel regression results by categories of environmental protection public expenditures (structure)

Variable / Model	**OLS model (a)**	**Fixed-effect model (b)**	**Random-effect model (c)**
WME	-26.427*** (p = 0.000)	31.252** (p = 0.007)	-19.771*** (p = 0.000)
WWME	-4.858 (p = 0.233)	-66.607*** (p = 0.001)	-11.438** (p = 0.049)
PAE	11.251** (p = 0.002)	-15.255* (p = 0.048)	6.201 (p = 0.298)
BLP	84.688*** (p = 0.000)	-5.992 (p = 0.928)	58.915 (p = 0.179)
RDEP	-94.455** (p = 0.001)	-148.457 (p = 0.053)	-139.727* (p = 0.047)
URBAN	17.287*** (p = 0.000)	21.702 (p = 0.255)	19.615*** (p = 0.000)
Constant	-5,900.676* (p = 0.037)	-32,283 (p = 0.796)	-7,836 (p = 0.280)
Observations	234	234	234
Number of IDs	—	26	26
Adj. R² / R² (Overall)	0.927	0.617 (overall)	0.918 (overall)

Note: Significance levels of 1%, 5% and 10% are denoted by ***, ** and *, respectively.
Source: Authors' calculations using StataMP 17 software

The Hausman test shown in Table 7 indicates that the null hypothesis is rejected, suggesting that there is a systematic difference between FE and RE coefficients. Therefore, the fixed effects model is preferred for this specification.

Table 7. Hausman test (FE vs. RE)

Variable	FE Coef. (b)	RE Coef. (B)	Difference (b-B)	Std. err. of difference
WME	31.2516	-19.7708	51.0224	9.8449
WWME	-66.6068	-11.438	-55.1688	16.7623
PAE	-15.2546	6.2012	-21.4558	6.9196
BLP	-5.9920	58.9148	-64.9068	26.6736
RDEP	-148.4571	-139.7265	-8.7306	31.7655
URBAN	21.7021	19.6148	2.0873	11.5815
b = consistent under H_0 and H_a; obtained from xtreg, fe B = inconsistent under H_a, efficient under H_0; obtained from xtreg, re Test of H_0: Difference in coefficients not systematic $Chi^2(6) = 43.22$, Prob > $Chi^2 = 0.0000$				

Source: Authors' calculations using StataMP 17 software

The results indicate that the effects of different categories of green public spending on CO_2 emissions are heterogeneous. Specifically, the panel regression suggests that some categories, such as waste management, pollution abatement, and wastewater management, have statistically significant effects. In contrast, others, including biodiversity and landscape protection and research and development for environmental protection, are not statistically significant in the fixed effects model.

4.3. Robustness checks

As part of the robustness analysis, we introduce lagged explanatory variables to account for potential delayed effects of green finance on CO_2 emissions. Following the approach of Liu and Zhu (2024), green finance may not produce immediate effects on carbon emission intensity, and the impact could manifest with a time lag. Therefore, we include environmental protection public expenditures lagged by one period in Model (1), reconstructing the model as follows:

$$CO2_{i,t} = \alpha_{i,t} + \beta_0 EPPE_{i,t-1} + \beta_j \, Control_{i,t} + \varepsilon_{i,t} \tag{3}$$

Where: $EPPE_{i,t-1}$ represents environmental protection public expenditures lagged by one period.

Table 8. Panel regression results with lagged effects

	Lag by one period			Lag by two periods		
Variable / Model	**OLS model (a)**	**Fixed-effect model (b)**	**Random-effect model (c)**	**OLS model (a)**	**Fixed-effect model (b)**	**Random-effect model (c)**
CO_2 (Dependant var.)	—	—	—	—	—	—
L.EPPE	-10.018*** (p = 0.000)	-21.411*** (p = 0.000)	-20.341*** (p = 0.000)	-5.958 (p = 0.572)	-15.532*** (p = 0.000)	-14.959*** (p = 0.000)
L2.EPPE	—	—	—	-3.988 (p = 0.702)	-7.402*** (p = 0.001)	-5.692** (p = 0.012)
URBAN	17.678*** (p = 0.000)	21.362*** (p = 0.000)	23.300*** (p = 0.000)	17.456*** (p = 0.000)	23.308*** (p = 0.000)	23.415*** (p = 0.000)
Constant	2,291.878 (p = 0.409)	20,039.800 (p = 0.380)	1,917.752 (p = 0.833)	2,729.254 (p = 0.350)	11,081.200 (p = 0.658)	1,543.721 (p = 0.859)
Observations	216	216	216	189	189	189
Number of countries (ID)	—	27	27	—	27	27

Note: Significance levels of 1%, 5% and 10% are denoted by ***, ** and *, respectively.
Source: Authors' calculations using StataMP 17 software

Regression results for the lag-one-period specification are reported in Table 8, columns (a)–(c). The OLS, fixed-effect, and random-effect models all indicate a negative and statistically significant coefficient of lagged green finance, confirming that green finance continues to reduce CO_2 emission intensity when accounting for delayed effects.

To further test the temporal persistence of public spending effects, we include environmental protection public expenditures lagged by two periods in the model, yielding the following specification:

$$CO2_{i,t} = \alpha_{i,t} + \beta_0 EPPE_{i,t-1} + \beta_0 EPE_{i,t-2} + \beta_j\, Control_{i,t} + \varepsilon_{i,t} \quad (4)$$

Where:

- $EPE_{i,t-2}$ represents environmental protection public expenditures lagged by two periods.

Table 8 also reports regression results for the lag-two-period specification. Both lagged terms of green finance maintain negative coefficients, and all coefficients are statistically significant at conventional levels in the fixed effects and random effects models. In contrast, the OLS model shows some coefficients that are not statistically significant. According to the Hausman test, the fixed effects model is the appropriate specification, confirming that green public spending has a persistent effect on reducing CO_2 emission intensity over time.

5. CONCLUSIONS

The findings of this paper confirm the significant role of green public spending in reducing CO_2 emissions, which aligns with the broader theoretical and empirical literature on green fiscal policy. Consistent with Muchiri et al. (2025), this research highlights that government environmental expenditures create the necessary institutional and fiscal framework to implement effective green projects. Our analysis also complements the scale, composition, and technique effects discussed by López et al. (2011). While they noted that increased spending alone does not automatically reduce pollution, strategic allocation toward specific environmental activities can yield measurable benefits. This is mirrored in our results, where different environmental protection public expenditures categories show heterogeneous effects. Specifically, the panel regression suggests that some categories, such as waste management, pollution abatement, and wastewater management, have statistically significant effects. In contrast, others, including biodiversity and landscape protection and research and development for environmental protection, are not statistically significant in the fixed effects model. Empirical evidence from Sharma (2011), Morley (2012), Miceikienė et al. (2021), and Yilmaz (2025) supports our findings by demonstrating that public spending on environmental services contributes to reductions in key air pollutants, including CO_2. Furthermore, Adewuyi (2016) emphasises that, in the long run, the negative direct effects of government expenditure on environmental quality are mitigated by positive indirect effects, resulting in overall emission reductions, which resonates with our lagged-effects analysis showing persistent CO_2 reduction over time.

As noted by Halkos and Paizanos (2013), Bernauer and Koubi (2013), and Abid (2017), countries with stronger institutional frameworks tend to achieve more significant reductions in GHG emissions from public spending. Our results from EU countries and Bosnia and Herzegovina are in line with this, indicating that well-targeted and efficiently managed environmental expenditures can reduce CO_2 emissions. Efficiency considerations are also relevant. While Barrell et al. (2021) found diminishing returns to environmental protection expenditures in EU countries, suggesting that excessive spending may not proportionally reduce emissions, Akdag et al. (2024) highlight that even marginal increases in well-targeted expenditures can lead to substantial emission reductions. Our study confirms this nuance, showing that the overall scale of green public spending is important, but the composition of expenditures across specific categories determines the magnitude of their environmental impact.

In summary, this study corroborates the theoretical and empirical literature by demonstrating that green public spending can be an effective policy instrument for mitigating CO_2 emissions. The scale and structure of expenditures play critical roles, and the institutional and governance context influences their effectiveness.

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