

Article

Environmental Spending, Taxation, and Water Quality Outcomes in Romanian Industry

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Abstract

The circular economy integrates a series of principles and activities designed to contribute to the reduction in the impact on the environment and the optimal use of resources, as well as the transformation of waste into resources. Environmental protection spending is a central instrument of industrial sustainability governance. This study examines (i) how environmental capital and operational costs have changed over time, (ii) whether environmental taxes affect green investment decisions, and (iii) whether spending on water protection leads to measurable improvements in river water quality. Spearman's rank correlation analysis is applied to data spanning 2015–2023. The results highlight three main findings. First, although total environmental spending increased by 33.5%, the financial focus shifted toward daily operational costs, which accounted for 79% of all expenditures by 2023. Second, Romania's reliance on energy taxes drives operational compliance, but it fails to encourage long-term capital investments. Third, water management practices are highly reactive. Spending more does not improve water quality. The research provides empirical evidence about the correlation between environmental expenditure and outcomes within the framework of an EU transition economy that offers insights into the formulation of more effective environmental policy tools.

Keywords: green investment; CAPEX; OPEX; sustainability; industrial sustainability governance

1. Introduction

The circular economy has become a fundamental component of environmental governance within the European Union, whereby resource efficiency and pollution reduction are mandatory for long-term economic resilience. Circular economy investment is the most powerful driver of circularity performance because it simultaneously reduces environmental degradation and improves resource efficiency. Also, government research and development spending further supports the transition toward more sustainable resource use [1].

Within this context, environmental protection expenditure can be seen as a key instrument through which industries translate regulatory obligations into measurable ecological outcomes. Environmental protection expenditures include all financial resources used to prevent, mitigate, and eliminate pollution and other types of environmental degradation that arise from economic activities. They are categorized into two groups. Capital expenditure (CAPEX) encompasses singular investments in tangible assets and technologies. Operational expenditure (OPEX) covers the ongoing costs associated with environmental



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management, including internal activities like monitoring and maintenance, as well as external payments to third-party suppliers for services. The allocation of financial resources toward environmental protection, whether through CAPEX or OPEX, reflects the regulatory ambitions of governments and the strategic responses of industries. Understanding whether and how these spending decisions translate into measurable environmental outcomes remains a critical question.

This article analyzes the relationship between environmental spending, taxation, and water quality outcomes in Romania for the period 2015–2023. The data is sourced from national statistics. The analysis is based on three research questions:

1. How have Romanian industries restructured their environmental spending (CAPEX vs. OPEX) over time?
2. To what extent is environmental taxation associated with subsequent industrial environmental capital investment in Romania?
3. Is higher environmental spending associated with subsequent improvements in water quality indicators?

This study presents the situation in Romania, and it shows how an EU developing country manages its environmental responsibilities. The timeframe of 2015–2023 was chosen for practical reasons; 2023 represents the most recent period with complete and available data from national statistics. Meanwhile, 2015 was selected as the starting point because it marks the current and relevant regulatory and economic environment for this analysis. This study's primary contribution is the empirical examination of expenditure structure, the investment-stimulating role of environmental taxation, and water governance performance within Romania's context, whereas prior research has generally examined these dimensions separately. By analyzing CAPEX/OPEX, tax-driven investment behavior, and water quality outcomes using the same dataset and lag-based methodology, the study provides integrated evidence on how fiscal instruments and spending allocation relate to environmental performance.

Romania's environmental tax system relies almost entirely on energy taxes rather than other pollution taxes. This study contributes to the sustainability literature by providing empirical evidence that Romanian industries are restructuring their environmental spending. The country is transitioning from end-of-pipe treatments toward proactive investments in integrated technologies. Moreover, it demonstrates that environmental taxes primarily drive operational compliance costs rather than stimulate long-term capital investment.

The paper is organized as follows. Section 2 reviews the relevant literature on environmental expenditure, the relationship between taxation and green investment, and empirical evidence linking environmental spending to water quality outcomes. Section 3 presents the data sources and methodological approach, including the lag specifications used to test each research question. Section 4 discusses the empirical results across the three research questions. Section 5 concludes with directions for future research.

2. Literature Review

The circular economy significantly reduces emissions and improves environmental quality [2]. Emissions reductions depend on combining investment in renewable energy, efficient allocation of environmental expenditure, and coordinated regional policies. While renewable energy investments reduce emissions, their effects tend to remain local and do not diffuse across the economy. Government environmental spending follows a similar pattern of ineffectiveness. They produce meaningful results up to an estimated threshold of approximately 0.01% of GDP. Beyond this point, additional spending does not generate better results, so it becomes inefficient [3].

Environmental expenditure might reduce pollution levels, but not uniformly everywhere. Generally, it is stronger in regions with higher economic development. Moreover, the reduction in pollution does not occur in isolation within administrative boundaries. Cross-regional spillover effects are also important, especially for pollutants that spread quickly across geographic areas [4]. Similarly, the efficiency of environmental spending does not only depend on the amount of expenditure, but also on the conditions under which it is spent. Higher environmental spending delivers better results in countries that are already transitioning toward renewable energy, have larger urban populations, and maintain strong and transparent institutions. Meanwhile, the presence of fossil fuel subsidies and high pollution levels weakens its impact. This means that if the economic and governance conditions do not align, more spending alone will not generate better environmental outcomes [5].

Increased expenditure on environmental protection does not inherently result in improved environmental outcomes. Efficiency is more significant than budget size, as more expenditure may yield diminishing returns instead of commensurate environmental benefits [6]. While the literature provides valuable insights into the effectiveness of environmental expenditure in reducing pollution levels and driving circular economy development, there is limited understanding of how the structure of this expenditure has evolved over time, particularly in the context of Romanian industry.

In the EU, government environmental expenditure and private sector investment are key drivers of circular economy development, each independently accelerating its progress. Their combined effect is synergistic, which means the most effective approach to advance the circular economy is to leverage both together [7]. A recent study compared the relative effectiveness of two policy instruments. Environmental protection expenditures were found to be roughly eleven times more effective than environmental taxes at reducing GHG emissions. This goes against the common assumption that taxes are the main tool for improving the environment. Taxes may work indirectly instead, which means their revenue is used to fund green infrastructure and investment [8]. This study addresses the gap by investigating how environmental taxes influence green investment decisions in Romania.

The strength of taxation also shapes how firms respond. A study of manufacturing firms finds that low tax levels do little to encourage the adoption of cleaner production or end-of-pipe technologies, while medium and high levels produce increasingly positive effects on green investment. Low taxes still work when paired with public financing such as subsidies and tax credits, and this combination outperforms public support on its own, although the advantage disappears once tax levels are high enough to act as an incentive by themselves. Taxation does not, however, encourage private research and development at any level, which suggests the rates are too low to drive research activity. Technologies aimed at reducing air pollution and energy use are the most responsive, reacting positively even to low taxation [9].

Green investment, fiscal policy, and environmental taxes all support the shift to clean energy. Sustained green investment drives lasting growth in clean energy consumption, while fiscal policy, through tax incentives and subsidies, exerts a strong and enduring influence on the expansion of renewable energy. Environmental taxes work in the same direction, and their effect is asymmetric: tax increases promote clean energy more than tax cuts discourage it. Natural resource rent, by contrast, is negatively associated with renewable energy use, consistent with the resource curse, since abundant traditional energy sources weaken the incentive to invest in renewables. Governments are therefore encouraged to manage resources sustainably, regulate their exploitation, and set energy prices that reflect environmental externalities [10].

More importantly, the effects of government spending do not materialize immediately. They become visible only after a two-year lag, which reflects the time needed for research outputs to translate into operational changes in production processes and resource management practices [1].

Environmental tax revenues significantly support long-run economic growth, with energy, transport, and resource taxes all positively associated with GDP per capita, while short-term effects remain weaker due to adjustment lags and compliance costs. However, effectiveness varies by national context. Resource taxes have the strongest impact in resource-rich economies such as Bulgaria and Romania, while pollution taxes are more effective where enforcement is stronger [11].

In general, environmental taxes can improve the environmental conditions, but the economic implications are not as clear. Environmental and economic benefits from the same tax instrument are theoretically feasible, but the practical evidence suggests that it is not automatic. This depends on the form of the tax, the way in which the revenues are recycled into the economy, and the structural characteristics of the wider tax system and economic climate in which it is implemented [12]. Stronger environmental policies and higher environmental taxes effectively reduce CO₂ emissions, with energy taxes being the most impactful instrument [13]. Green investments, green financing, technical innovation and environmental taxation enhance environmental sustainability by reducing CO₂ emissions and facilitating greener economic growth. However, the scale of these effects is not consistent. It varies across regions and economic settings, which indicates that a one-size-fits-all policy approach is unlikely to be ideal [14].

On the other hand, some scholars argue that eco-innovation represents a more effective instrument than environmental taxation when it comes to improving overall fiscal performance. While environmental taxes do generate revenues over the long run, they simultaneously drive up public expenditures, which produces a less favorable net budgetary outcome. By contrast, eco-innovation offers a dual fiscal advantage. It can increase government revenues and save budgets [15].

Environmental taxation can also affect water pollution directly. Higher tax rates lead to lower emissions of key water pollutants such as chemical oxygen demand and ammonia nitrogen. The effect is uneven across firms: those with higher emission intensities cut their emissions more than less polluting firms, and private enterprises respond more strongly to tax increases than state-owned ones. Higher environmental taxes may contribute to meaningful reductions in industrial water pollution, suggesting that pricing instruments can help control pollution in emerging economies [16].

Investment in environmental technologies and R&D is essential for improving the environmental quality through cleaner production processes and more efficient use of resources. Such investments, along with well-designed fiscal mechanisms, especially tax systems that rely on the polluter-pays principle, ensure that the costs of environmental degradation will be paid by the individuals responsible and not by the whole society. Financial incentives, including tax credits and subsidies, also facilitate this transition by lowering the barriers to adoption of green technologies and spurring private sector innovation [17].

Water charges are the best way to balance increasing demand for water against increasingly constrained availability, especially in the context of a lack of resources. Water price policies internalize the environmental externalities associated with water use and reduce pollution discharge. Land-use controls and fiscal incentive structures at the local level need to be aligned with water conservation objectives so that development decisions and budget priorities do not inadvertently undermine broader water resource management goals [18].

Artificial intelligence is increasingly used to monitor and assess water quality. A review of these tools finds that methods such as random forest, XGBoost, and neural networks predict water quality indices with high accuracy, and that combining models improves robustness, though results are hard to replicate because models trained on one region rarely transfer to others [19]. Machine learning is also applied directly to the classification of water quality. One study tests several algorithms and finds that CATBoost performs best among the individual classifiers, followed closely by random forest. Building on these results, the authors develop a stacking ensemble that combines multiple classifiers through a meta-learner, reaching full accuracy with meta-classifiers such as a decision tree and CATBoost. This approach outperforms the individual classifiers and compares favorably with earlier models, showing that ensemble stacking enhances accuracy and can support real-time monitoring across diverse water quality datasets [20].

The transition toward sustainable water management is particularly critical for enterprises operating within natural monopolies, such as the water, sewerage, and waste management sectors. These entities frequently act as dominant polluters because of the high water consumption, and wastewater generation. The water-intensive sector might become greener by evaluating water consumption efficiency through water productivity and alternative sourcing, followed by an analysis of wastewater management quality, which includes treatment effectiveness and reuse rates. Furthermore, regulatory standards and social responsibility, as well as technological progress through the implementation of innovative, water-saving technologies and research and development initiatives, should be assessed [21].

Recent studies further emphasize the necessity of multidimensional models to address inefficiencies in the water sector. An integrated GIS-based model was proven effective in processing large datasets, simulating future scenarios, and monitoring water resource resilience. In Bulgaria, up to 60% of water is lost just during transportation, investments in wastewater treatment dropped by 40% between 2016 and 2023, and very little treated water is actually reused. These problems occur due to outdated pipes, poor consumption habits, and competing water demands from hydropower. Because of these systems, about 4.5% of the population faces restricted water access [22]. While the literature recognizes the role of water pricing and charges in managing water resources and reducing pollution, there is limited empirical evidence on the extent to which water protection spending directly improves water quality outcomes, especially in the Romanian context.

3. Methodology

This study presents a quantitative research based on secondary data collected from the National Institute of Statistics of Romania (INS). The analysis covers the period 2015–2023.

Five datasets were used in this study. PMI105A provides data on environmental protection expenditure by economic activity, broken down into capital expenditure and current expenditure across all major industrial sectors classified according to CAEN. Capital expenditure (CAPEX) is divided into two structural categories: “end-of-pipe solutions,” which consist of equipment installed at the end of the production cycle to treat or capture pollution, and “integrated technologies,” which represent proactive modifications to the core manufacturing process designed to prevent pollution at its source. Operational expenditure (OPEX) is separated into “internal costs,” which cover expenses managed directly within the enterprise, and “external costs,” which reflect payments to third-party contractors for outsourced services. PMI105B provides environmental protection expenditure by environmental domain, covering water protection, air protection, waste management, and other domains. PMI103 contains data on river water quality, reporting the length of monitored river sections classified into five quality categories, from Category I (very good) to Category V (bad). It evaluates a combina-

tion of standardized physical, chemical, and biological parameters to determine the overall ecological status of the monitored water bodies. PMI109A contains data on the population connected to sewerage and wastewater treatment infrastructure.

Financial variables, including environmental protection expenditures by economic activity and by environmental domain, as well as environmental tax revenues, are all measured and reported in millions of RON. Environmental outcome variables such as river water quality are measured as a percentage of the monitored river lengths, and the population connected to sewerage and wastewater is also expressed as a percentage.

All data were analyzed using statistical software. Descriptive analysis was used to examine trends and structural changes in environmental spending over time. Spearman's rank correlation analysis was applied to test the direction and strength of relationships between key variables across lag specifications of zero, one, and two years. Prior to the correlation analysis, the stationarity of each series was examined using the augmented Dickey–Fuller (ADF) test in levels and first differences. Most financial series were non-stationary in levels (ADF $p > 0.10$) and became stationary after first differencing, indicating trend-driven behavior. Among the water indicators, nitrogen was stationary in levels, while the remaining series were non-stationary or borderline. Given the short annual sample ($n = 9$), these tests are indicative rather than definitive, and formal cointegration analysis was not feasible. Their main implication is that the reported relationships should be read as statistical associations rather than causal effects. The significant associations were subjected to several robustness checks. Pearson correlations agreed with the Spearman estimates across all pairs, and a leave-one-out procedure produced no sign reversals, which confirms that the results are not driven by the rank-based method.

RQ1 is addressed descriptively, by tracking the level and composition of CAPEX and OPEX between 2015 and 2023. RQ2 and RQ3 are examined using Spearman rank correlations estimated at lags of zero, one, and two years. For RQ2, environmental tax revenue is correlated with subsequent expenditure to assess whether taxation precedes investment. For RQ3, water-protection spending is correlated with subsequent water quality indicators, and the reverse pairing is also examined to determine which variable leads.

4. Results

4.1. How Have Romanian Industries Restructured Their Environmental Spending (CAPEX vs. OPEX) over Time?

The objective of the first research question was to determine how the environmental spending is structured. Therefore, the analysis examines how environmental spending is structured. From 2015 to 2023, the total environmental protection spending increased from 9262.7 million RON to 12,370.5 million RON, which represents 33.5% cumulatively. However, growth was not linear. It declined sharply in 2016 before it recovered and accelerated after 2020 to reach a record high in 2023. CAPEX data show high volatility. Investments in end-of-pipe solutions declined from 2801.89 million RON in 2015 to 747.84 million RON in 2023. On the other hand, investments in integrated technologies were more resilient. They bounced back strongly to 1827.73 million RON in 2023. Integrated technologies accounted for 42% of total CAPEX in 2015 and climbed to 71% in 2023. This signals a strategic shift from reactive compliance to process-level environmental modernization. Looking at OPEX, it can be seen that it increased from 4434.16 to 9794.89 million RON, with external costs increasing by 250% over the period (from 1727.95 to 6056.79 million RON). This shows a progressive outsourcing of environmental management functions. On the other hand, internal costs increased less from 2706.21 to 3738.10 million RON. By 2023, OPEX accounted for 79% of total environmental expenditure, which reflects the increased operational burden of environmental compliance (Table 1).

Table 1. Environmental spending in Romania from 2015 to 2023 (million Ron).

Year	Total Spending	CAPEX (Total)		OPEX (Total)	
		End-of-Pipe	Integrated Technologies	Internal Costs	External Costs
2015	9262.70	2801.89	2026.68	2706.21	1727.95
2016	4844.70	555.11	678.54	1507.78	2103.24
2017	5253.30	379.99	507.68	1671.86	2693.79
2018	6953.30	885.54	771.87	1947.59	3348.34
2019	6215.10	589.51	585.01	1802.71	3237.88
2020	6457.90	296.13	813.57	2135.48	3212.72
2021	9243.60	340.82	757.72	2129.72	6015.32
2022	11,587.20	518.82	1119.87	3492.16	6456.32
2023	12,370.50	747.84	1827.73	3738.10	6056.79
Change 2015–2023	+33.5%	−73.3%	−9.8%	+38.1%	+250.5%

Source: INS Romania.

Next, the top 10 sectors with the highest spending were identified. Energy production leads with a peak at 4554.6 M RON in 2021. After that, the sums decline, probably because of the EU emissions regulations and pressure on Romania's energy mix. Water capture and distribution follow a U-shaped pattern. Initially, it decreased from 2767.4 M RON in 2015 to 996.7 M RON in 2019, then increased back to 2772.9 M RON by 2023. Oil and gas extraction nearly quadrupled from 518.2 M RON to 2435.0 M RON in 2022. This might reflect the growing environmental compliance demands in the extractive industry. All of the remaining sectors stayed below 600 M RON annually, with two exceptions. Rubber and plastics manufacturing recorded an outlier of 1242.8 M RON in 2015, and chemical manufacturing declined steadily from 510.0 M RON to 66.0 M RON in 2021, before increasing again. The automotive industry had a clear growth, likely because of Romania's automotive supply chain integration and stricter environmental requirements (Table 2).

Table 2. Top 10 sectors by average environmental expenditure (M RON).

Sector	2015	2016	2017	2018	2019	2020	2021	2022	2023
Energy production & supply	2612.9	1202.5	1583.0	2196.0	1860.2	2180.9	4554.6	3927.8	3395.5
Water capture & distribution	2767.4	1257.8	1013.8	1115.5	996.7	1242.3	1305.1	1995.1	2772.9
Oil & gas extraction	518.2	451.3	592.2	1541.5	1175.0	885.7	937.5	2435.0	2198.2
Land transport & pipelines	222.4	222.9	268.1	229.2	236.3	198.5	219.3	551.0	385.8
Rubber & plastics manufacturing	1242.8	51.6	53.2	56.4	65.8	69.0	62.8	71.4	405.5
Forestry & logging	46.7	270.0	247.0	270.7	36.0	61.8	253.6	316.6	371.0
Food & beverage industry	131.3	136.2	183.0	166.4	167.0	202.4	280.8	259.0	305.0
Metallurgical industry	176.0	131.9	137.0	235.8	223.2	196.1	227.9	228.0	245.6
Automotive industry	125.1	109.0	138.3	133.8	134.7	121.5	120.2	145.0	430.1
Chemical manufacturing	510.0	148.4	133.4	134.6	142.4	112.6	66.0	74.5	118.0

Source: INS Romania.

Following, to determine where exactly the spending went, its breakdown was examined. Most funds went to air protection. Water protection had the most sustained growth from 1.37 billion RON in 2017 to 3.09 billion RON in 2023. This highlights its strengthening position as a key operational priority. The expenditure on waste management was generally lower, but doubled in 2022 compared to 2021. Together, these trends suggest that while air pollution remains a key regulatory concern, focus on water protection is increasing (Table 3).

Table 3. Environmental spending breakdown (M Ron).

Year	Water Protection	Air Protection	Waste Management	Others
2015	2882.5	2566.3	1844.5	1969.4
2016	1514.3	972.2	837.8	1520.3
2017	1375.8	1155.4	1135.1	1587.0
2018	1455.6	2761.7	1223.0	1513.1
2019	1387.3	2168.6	1213.9	1445.3
2020	1607.6	1884.3	1326.5	1639.3
2021	1727.4	3981.8	1379.2	2155.1
2022	2498.2	3537.2	2296.5	3255.4
2023	3096.2	3715.0	1656.0	3903.1
Change 2015–2023	+7.4%	+44.8%	−10.2%	+98.2%

Source: INS Romania.

Finally, the relationships between CAPEX and OPEX across all possible pairings and at multiple time lags (Lag-0, Lag-1, and Lag-2) were examined. There is a correlation ($\rho = +0.883$) between integrated capital investment and internal operating costs in the same year. As the link disappears completely with subsequent lags, it may indicate a size effect. Additionally, end-of-pipe capital investment has a negative relationship with external operational costs at Lag-1 ($\rho = -0.786$) and Lag-2 ($\rho = -0.857$). This might suggest that investment in treatment infrastructure progressively displaces payments to third-party contractors over a one-to-two-year horizon. Also, external operational costs significantly predict internal operational costs at both Lag-1 and Lag-2 ($\rho = +0.857$), indicating that the two cost types grow in tandem rather than substituting for each other. All remaining correlations are non-significant (Table 4).

Table 4. Spearman Correlation between CAPEX and OPEX.

Pair	Lag-0 ($n = 9$)		Lag-1 ($n = 8$)		Lag-2 ($n = 7$)	
	ρ	Sig.	ρ	Sig.	ρ	Sig.
CAPEX_Int $\rightarrow$ CAPEX_EoP	+0.400	ns	+0.095	ns	−0.286	ns
CAPEX_Int $\rightarrow$ OPEX_Internal	+0.883	*	−0.071	ns	+0.107	ns
CAPEX_Int $\rightarrow$ OPEX_External	+0.200	ns	+0.000	ns	−0.143	ns
CAPEX_EoP $\rightarrow$ CAPEX_Int	+0.400	ns	−0.429	ns	−0.643	ns
CAPEX_EoP $\rightarrow$ OPEX_Internal	+0.167	ns	−0.571	ns	−0.607	ns
CAPEX_EoP $\rightarrow$ OPEX_External	−0.150	ns	−0.786	*	−0.857	*
OPEX_Internal $\rightarrow$ CAPEX_Int	+0.883	*	+0.452	ns	+0.107	ns
OPEX_Internal $\rightarrow$ CAPEX_EoP	+0.167	ns	+0.167	ns	−0.357	ns
OPEX_Internal $\rightarrow$ OPEX_External	+0.533	ns	+0.333	ns	+0.000	na
OPEX_External $\rightarrow$ CAPEX_Int	+0.200	ns	+0.690	ns	+0.750	ns
OPEX_External $\rightarrow$ CAPEX_EoP	−0.150	ns	+0.143	ns	−0.214	ns
OPEX_External $\rightarrow$ OPEX_Internal	+0.533	ns	+0.857	*	+0.857	*

* = significant; ns = not significant. Source: INS Romania.

4.2. To What Extent Is Environmental Taxation Associated with Subsequent Industrial Environmental Capital Investment in Romania?

The scope of the second research question was to identify the relation between environmental taxes and environmental spending. Therefore, the environmental taxes breakdown was

analyzed. From 2015 to 2023, Romania's total environmental tax burden grew by approximately 27.6%, from 17,568.1 M RON to 22,420.1 M RON. The highest taxes are in energy and consist of over 89% of total environmental taxation. Transport taxes represent the second largest component, while pollution and resource taxes remain negligible across the entire period. These have never exceeded 32 M RON combined. This indicates Romania's environmental fiscal framework relies mostly on energy taxation rather than general pollution (Table 5).

Table 5. Environmental taxes (M RON).

Year	Energy	Transport	Pollution	Resources	Total Taxes
2015	15,740.10	1791.50	20.5	16	17,568.10
2016	16,498.30	1799.70	21.4	25.6	18,345.00
2017	15,407.10	1179.80	24	20.7	16,631.60
2018	17,420.20	1307.30	23.9	20.1	18,771.50
2019	20,921.70	1489.70	26	16	22,453.40
2020	18,766.30	1492.10	19.2	25	20,302.60
2021	21,376.40	1850.80	23.1	27.3	23,277.60
2022	20,322.90	1943.20	25.3	31	22,322.40
2023	20,303.20	2059.20	26.3	31.4	22,420.10
Change 2015–2023	+29.0%	+14.9%	+28.3%	+96.3%	+27.6%

Source: INS Romania.

Next, the correlation between environmental taxes and environmental spending was analyzed. The results show no significant relation between taxes and CAPEX, which indicates that rising taxes do not influence capital investment decisions. In contrast, both tax variables are significantly associated with OPEX variables. The relationships also strengthen over time. These results suggest that Romania reacts to growing environmental tax pressure by increasing operational environmental spending rather than making commitments to capital investment. This indicates a compliance-driven rather than investment-driven behavior (Table 6).

Table 6. Spearman Correlation between environmental taxes and CAPEX and OPEX.

Pair	Lag-0 (<i>n</i> = 9)		Lag-1 (<i>n</i> = 8)		Lag-2 (<i>n</i> = 7)	
	ρ	Sig.	ρ	Sig.	ρ	Sig.
Tax_Total → CAPEX_Total	−0.100	ns	+0.024	ns	+0.357	ns
Tax_Total → CAPEX_Integrated	+0.050	ns	+0.619	ns	+0.750	ns
Tax_Total → CAPEX_EoP	−0.217	ns	−0.476	ns	−0.071	ns
Tax_Total → OPEX_Total	+0.683	*	+0.786	*	+0.857	*
Tax_Total → OPEX_Internal	+0.333	ns	+0.786	*	+0.857	*
Tax_Total → OPEX_External	+0.717	*	+0.571	ns	+0.714	ns
Tax_Energy → CAPEX_Total	−0.133	ns	+0.024	ns	+0.357	ns
Tax_Energy → CAPEX_Integrated	+0.033	ns	+0.619	ns	+0.750	ns
Tax_Energy → CAPEX_EoP	−0.267	ns	−0.476	ns	−0.071	ns
Tax_Energy → OPEX_Total	+0.700	*	+0.786	*	+0.857	*
Tax_Energy → OPEX_Internal	+0.317	ns	+0.786	*	+0.857	*
Tax_Energy → OPEX_External	+0.733	*	+0.571	ns	+0.714	ns

* = significant; ns = not significant. Source: INS Romania.

4.3. Is Higher Environmental Spending Associated with Subsequent Improvements in Water Quality Indicators?

The scope of the third research question is to dive deep into the water quality and pollution indicators. The Water Quality Index (WQI) is defined as the share of monitored river length classified in Category II (good), and the Degradation Index as the share in Categories III–V (moderate to bad), both taken directly from the official INS classification. In the period 2015–2023, the water quality index (WQI) has declined from 57.86% to 31.85%. In contrast, the Degradation Index has increased from 42.14% to 68.15%. This means that over two-thirds of the river lengths have been categorized as degraded quality. On a positive note, the wastewater discharge volume has declined by 22% from 1005.25 M m³ in 2015 to 784.97 M m³ in 2023, which demonstrates that the decline in volume alone is not enough to improve water quality outcomes. Industrial biochemical oxygen demand (BOD5 industrial) is an indicator of the intensity of organic pollution. It rose from 99.80 t O₂/day in 2015 to 132.77 t O₂/day in 2022, before it recovered to 118.43 t O₂/day in 2023. This indicates that even though the amount of wastewater decreased, the organic pollution per unit deteriorated. Industrial nitrogen loads (Nitrogen industrial) fluctuated without a consistent trend, ranging between 14.16 and 26.23 t/day across the period, which suggests no systematic improvement. Taken together, these findings suggest that reducing the volume of industrial wastewater discharge is not enough to improve river water quality (Table 7).

Table 7. Development of water quality and industrial pollution indicators.

Year	WQI (% Cat. II)	Degradation Index (% Cat. III–V)	Wastewater vol. (M m ³ /yr)	BOD5 Industrial (t O ₂ /day)	Nitrogen Industrial (t/day)
2015	57.86	42.14	1005.25	99.80	18.88
2016	61.25	38.75	971.31	107.16	19.12
2017	51.28	48.72	950.49	103.92	19.87
2018	40.15	59.85	972.71	106.34	19.03
2019	40.15	59.85	966.13	111.50	16.37
2020	40.15	59.85	783.71	107.05	21.12
2021	37.76	62.24	844.39	127.48	26.23
2022	34.51	65.49	850.99	132.77	19.43
2023	31.85	68.15	784.97	118.43	14.16
Change 2015–2023	−45.0%	+61.7%	−21.9%	+18.7%	−25.0%

Source: INS Romania.

Next, whether CAPEX or OPEX predicts improvements in water quality outcomes was examined. In the case of CAPEX, no significant relationships were found at either Lag-1 or Lag-2 across any of the five water indicators, suggesting that capital investment does not produce measurable improvements in river water quality within this timeframe. In the case of OPEX, higher operational spending significantly predicts worse water quality one year later, with lower WQI and higher Degradation Index at Lag-1, and both remaining marginally significant at Lag-2. BOD5 industrial loads also increase a year after higher OPEX, while wastewater volumes are significantly lower at Lag-2. These results confirm the same pattern. Operational spending tends to rise in response to deteriorating environmental conditions, which means that the country tracks the problem rather than solving it (Table 8).

Table 8. Spearman Correlation between OPEX → water indicators.

Variable	Lag-1 (n = 8)		Lag-2 (n = 7)	
	ρ	Sig.	ρ	Sig.
WQI (% Cat. II)	−0.878	*	−0.741	**
Degradation Index (% Cat. III–V)	0.878	*	0.741	**
BOD5 industrial (t O ₂ /day)	0.905	*	0.607	ns
Nitrogen industrial (t/day)	−0.214	ns	−0.036	ns
Wastewater vol. (M m ³ /yr)	−0.571	ns	−0.821	*

* $p < 0.05$; ** $p < 0.1$; ns = not significant. Source: INS Romania.

Next, whether water protection spending improves water quality or whether the relationship runs in the opposite direction was examined. Surprisingly, water protection does not significantly influence the quality of the water at any time. Meaning, higher water protection spending does not lead to a better quality of the water. However, the reverse direction analysis reveals that deteriorating water quality conditions significantly predict higher water protection spending in subsequent years. The Water Quality Index measures the percentage of rivers in good condition (Category II), whereas the Degradation Index measures the percentage of rivers in poor condition (Categories III–V). Lower WQI and higher Degradation Index significantly predict increased spending one and two years later, while rising BOD5 loads predict at Lag-2 ($\rho = +0.821$). Wastewater volume shows a marginally significant negative relationship at both lags, and nitrogen remains non-significant throughout. This confirms a reactive, instead of a proactive, approach of the country to water management (Table 9).

Table 9. Spearman Correlation between water indicators → water protection spending.

Variable	Lag-1 (n = 8)		Lag-2 (n = 7)	
	ρ	Sig.	ρ	Sig.
WQI (% Cat. II)	−0.830	*	−0.852	**
Degradation Index (% Cat. III–V)	+0.830	*	+0.852	**
BOD5 industrial (t O ₂ /day)	+0.619	ns	+0.821	*
Nitrogen industrial (t/day)	+0.405	ns	+0.500	ns
Wastewater vol. (M m ³ /yr)	−0.690	ns	−0.714	ns
WQI (% Cat. II)	−0.830	*	−0.852	*

* $p < 0.05$; ** $p < 0.1$; ns = not significant. Source: INS Romania.

5. Discussion

The results of this research offer empirical evidence on three interconnected topics of industrial environmental management in Romania: the evolution of the environmental expenditure, the role of environmental taxation as an investment driver, and the relationship between spending and water indicators.

The shift from end-of-pipe investments to integrated technologies is in line with the literature on the circular economy, which indicates that firms are gradually moving to pollution prevention instead of downstream treatment. After 2016, total environmental investment dropped sharply. End-of-pipe investments were cut much more aggressively. Meanwhile, integrated technology investments fell much less and recovered faster. This might suggest that Romanian firms, when forced to choose, are increasingly treating integrated environmental investment as strategically valuable rather than just a regulatory

obligation. This is a sign of genuine environmental modernization rather than minimum compliance behavior.

The lag applied throughout this study was not chosen arbitrarily but is grounded in the existing literature. Lehmann et al. (2022) [1] demonstrate that the effects of environmental investment and government spending do not materialize immediately, but they become visible after approximately a two-year lag. Environmental taxes predict operational spending but not capital investment in the same year, while showing a positive association with integrated technology investment two years later. This is consistent with the literature's position that fiscal instruments do not automatically produce investment.

The two-year lag results suggest that cumulative fiscal pressure eventually pushes firms toward process-level investment. When taxes rise, firms do not immediately invest in new technologies. Instead, they first increase their operational spending, because this is faster and easier than committing to capital projects. Only after two years does investment in cleaner technologies follow. This suggests that firms react to fiscal pressure by managing their costs in the short term rather than using it as a trigger for strategic change. Because Romania's environmental tax revenue is concentrated almost entirely in energy taxes, firms may interpret this as a cost-management issue rather than evidence of a structural shift in regulatory intent, which supports operational rather than strategic responses.

Based on the literature, it was expected that water protection spending would start showing improvements in river quality within one to two years. However, the data shows the opposite pattern. Spending does not predict better water quality, but worse water quality predicts more spending in the following years. When rivers deteriorate, budgets increase in response. Romania is therefore not investing ahead of the problem, but it reacts after it worsens. This is consistent with the literature: environmental spending only produces results when governance conditions support proactive decision-making. The fact that Romania's river quality declined from 57.86% to 31.85% despite growing expenditure suggests that the issue is not how much is being spent, but when and how. The only partial positive finding is that higher operational spending does reduce the volume of wastewater discharged two years later. Lower volume alone does not mean cleaner water. If the remaining discharge is more concentrated in pollutants, river quality can still worsen. This does not necessarily mean that the spending is wasted, but it may be a timing problem, or that the funds are not spent where they would have the most impact.

Taken together, the three findings point in different directions. The only positive result from the study is the structural shift towards integrated technologies in CAPEX. However, this shift cannot be attributed to the tax system because environmental taxes were found to stimulate operational spending, rather than capital investment. Therefore, it can be said that the growth in integrated technologies is driven by factors outside the fiscal instruments examined here. Those could be EU co-financing, sector-specific modernization pressure, or firm-level strategic choices. Another noteworthy result is that higher capital investment does not necessarily lead to improvement in water quality.

Additionally, it should be noted that the reported correlations may also reflect omitted variables such as GDP growth, industrial output, energy consumption, EU structural funds, and rainfall, which influence both environmental spending and outcomes and raise the possibility of omitted variable bias.

Overall, the results demonstrate that Romanian industrial environmental management is reactive across all dimensions: taxes drive operational adjustments rather than investment; water protection budgets grow in response to deterioration rather than preventing it; and the system is oriented toward compliance and response rather than prevention. This has significant economic consequences, as delayed or insufficient investment in environmental infrastructure and technologies can lead to higher long-term costs and reduced

competitiveness in the green economy. The one positive signal is the growing number of integrated technologies within CAPEX. This suggests that firms start making smarter choices, but the scale remains insufficient relative to the growing operational burden.

These coefficients should be read as indicative rather than precise. With nine annual observations and many pairs tested across lags, statistical power is low, and some associations could arise by chance, so we give weight only to relationships that hold across adjacent lags and agree between the Spearman and Pearson estimates. The fuller limitations are discussed in the conclusion.

6. Conclusions

This study examined Romania's environmental spending over the period 2015–2023. The findings reveal a system that is growing but reactive, with policy implications that follow directly from each research question.

On the structure of environmental spending (RQ1), the shift toward integrated technologies within CAPEX suggests that when firms invest in capital projects, they increasingly favor pollution prevention over end-of-pipe solutions. This could point to a policy opportunity: public co-financing and incentive schemes should specifically target integrated, process-level technologies rather than generic capital subsidies.

On the role of environmental taxation (RQ2), the finding indicates that Romania's energy-tax-dominated system signals short-term cost pressure rather than a structural shift in regulatory intent. This supports a clear policy recommendation: diversifying the tax base toward pollution-specific charges, rather than relying almost exclusively on energy taxes, would target the capital investment decisions directly. To facilitate this transition, Romania could implement a comprehensive policy package that includes targeted subsidies and tax incentives for businesses to adopt cleaner technologies and practices. Additionally, public awareness campaigns could be launched to build support for the charges and encourage behavior change, emphasizing the health and environmental benefits of reducing pollution.

On water governance (RQ3), the absence of a link between water protection spending and water quality improvement, combined with evidence that spending rises only after deterioration occurs, points to a need for reallocating water protection budgets from reactive remediation toward planned infrastructure investment with longer measurement horizons.

This study has several limitations that should be acknowledged. First, the findings are exploratory rather than confirmatory, and the low statistical power of some tests suggests that the reliability of the results may be limited. Further research with larger sample sizes and more robust methods is needed to confirm the identified relationships. Second, the analysis is at the aggregate national level, masking potential sector-level and regional variations. Future studies should use panel data at the firm or sector level, incorporate governance indicators, and examine the interaction between EU structural fund transfers and domestic environmental spending. Finally, the reliance on rank correlations limits the ability to establish definitive causal relationships. While our study identifies significant statistical associations that provide insights into the potential drivers and consequences of environmental expenditure in Romania, the interpretation of these results as causal mechanisms should be qualified. Future research could apply more advanced econometric methods, such as distributed lag models, ARDL models, or panel regression models, to provide stronger evidence for causality, subject to data availability.

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