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Do Environmental Taxes Stimulate Eco-Investments? Evidence from Seven EU Member States and the EU-27

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Abstract

The European Green Deal places environmental taxation at the centre of decarbonisation policies. Nevertheless, the empirical evidence for its effectiveness as an incentive for capital eco-investments remains limited, particularly at the sectoral level. The present study analyses this relationship through a country-sector panel of seven EU member states and four sectors under NACE Rev.2 for the period 2014-2023. A five-step empirical strategy is employed, comprising: descriptive statistics, correlation analysis with relative indicators, fixed-effects panel regressions, the Granger causality test, and robustness checks. The results demonstrate a clear scale effect - the correlation between the absolute values of environmental taxes and eco-investments is very high, yet following normalisation against the scale of the economy it becomes practically zero and statistically insignificant. The panel regressions likewise establish no statistically significant relationship, and the Granger test does not confirm causality in either direction. The robustness checks confirm this finding. On this basis, the study concludes that environmental taxation in isolation does not stimulate sectoral eco-investments and functions rather as a fiscal instrument without a discernible investment effect. The findings suggest the need for a policy rethink through more targeted revenue use, sectoral differentiation, and the combining of tax instruments with non-fiscal mechanisms for more effective management of transition financial risk.

Keywords: environmental taxes; eco-investments; transition risk; panel data; Granger causality; sectoral analysis; ESG; fiscal risk; European Union

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1. Introduction

The European Green Deal sets the ambitious goal of the EU becoming climate-neutral by 2050. This transition requires massive capital investments in clean technologies and environmental protection - but also new financial risks. Companies face the so-called transition risk - the financial risk associated with the changing regulations, tax rates, technological standards, and market preferences that accompany the ecological transition (TCFD, 2017; ECB, 2020). One of the key instruments of this transition is environmental taxation.

Environmental taxes - taxes on energy, transport, pollution, and resources - are a fiscal instrument based on Pigouvian logic. By raising the price of pollution, they are intended to incentivise enterprises to invest in cleaner technologies (Pigou, 1920; Baumol, 1972). The logic is compelling. But does it work in practice?

The existing literature provides an ambiguous answer. Some studies find a positive relationship between environmental taxation and environmental outcomes, such as reduced emissions (Andersson, 2019; Sen & Vollebergh, 2018) or eco-innovations (Acemoglu et al., 2012). Others, however, indicate that the effect depends strongly on the level of the tax rate, the institutional environment, and sectoral specificity (Dechezleprêtre & Sato, 2017; Marin & Vona, 2021). Few studies employ sectoral panel data to examine the direct relationship between environmental taxation and the capital eco-investments of enterprises. Most studies use aggregated national data, which does not allow sectoral differences to be accounted for - yet it is precisely these differences that are of key importance for the management of financial risk from the ecological transition.

This study fills that gap. Using a country-sector panel of 7 countries and 4 sectors under NACE Rev.2 for the period 2014-2023, the following research question is posed: Does a statistically significant relationship exist between environmental taxes and capital eco-investments at the sectoral level in the EU? The answer to this question is important not only for environmental policy, but also for financial management - if taxes do not stimulate investments, they represent a pure fiscal burden without a corresponding environmental effect, which is a risk both for enterprises and for public finances.

2. Literature Review

The theoretical framework of environmental taxation is grounded in the concept of Pigou (1920). According to it, taxes on pollution correct negative externalities by bringing private costs into alignment with social ones. Baumol (1972) formalises this idea by proposing the so-called price-and-standard tax - a practical alternative to the theoretically optimal Pigouvian tax. The logic is straightforward - the higher price of pollution incentivises firms to invest in cleaner technologies, simultaneously reducing emissions and long-term costs.

The Porter Hypothesis (Porter & van der Linde, 1995) extends this argument. According to it, well-designed environmental regulations can not only stimulate innovation but also enhance the competitiveness of firms. The double dividend hypothesis (Goulder, 1995) adds a further argument - revenues from environmental taxes can replace distortionary taxes (e.g. income taxes), generating simultaneous environmental and economic benefit.

This outcome, however, is not automatic. Bovenberg & de Mooij (1994) emphasise that in a real environment with multiple taxes and market distortions, the net effect may be weaker than expected. Köppl & Schratzenstaller (2023) and Zhang et al. (2024) confirm that results vary substantially according to exactly how the tax is structured, how the regulation is measured, and in what institutional environment it is applied.

Thus far, the theory outlines why environmental taxes ought to work. The empirical literature, however, presents a more complex picture. The effects operate through different channels and are not always unambiguous.

The first and most studied channel of action of environmental taxes is their impact on greenhouse gas emissions and pollution. Andersson (2019) conducts one of the first quasi-experimental studies, analysing the carbon tax in Sweden through the synthetic control method. The result is that transport CO_2 emissions decrease by approximately 11% following the introduction of the tax. Sen & Vollebergh (2018) apply instrumental variables and establish that an increase of 1 euro in energy taxes leads to a reduction in carbon emissions of 0.73% in the long run. Wolde-Rufael & Mulat-weldemeskel (2023) confirm these results with panel cointegration tests for 20 European countries, finding a significant negative relationship between environmental taxes (total, energy, and transport) and CO_2 emissions. Bretschger & Grieg (2024) demonstrate for the United Kingdom that higher fuel taxation leads to a reduction in transport CO_2 emissions, without a clearly expressed negative effect on economic activity. Kohlscheen et al. (2025) establish that carbon pricing is associated with a statistically significant reduction in CO_2 emissions, particularly in the long run.

Not all studies, however, confirm this picture. Morley (2012) using GMM panel estimates for 25 European countries (1995-2005), establishes an effect on pollution but not on energy consumption. This suggests that the reduction in emissions stems from a technological transition rather than from lower consumption. Liobikienė et al. (2019) analyse 28 EU member states (1995-2012) and find no significant effect - neither direct nor indirect - of energy taxes on greenhouse emissions. The authors recommend reforming tax policy and combining it with the emissions trading system (ETS). Silajdžić & Mehić (2018) on the basis of data for 10 Central and Eastern European countries, find no convincing evidence that environmental taxes lead to effective restriction of carbon dioxide emissions. Godawska

(2024) also reports heterogeneous results, establishing no statistically significant effect on nitrogen oxide emissions and only a weak effect on sulphur oxide emissions.

This group of studies reveals an important pattern. Environmental taxes may have an effect in some contexts yet appear weak or insignificant in others. The differences arise from the design of the tax, the time horizon, the method, and the chosen indicator. Therefore, the key question is not simply whether taxes work, but what exactly is being measured as an effect.

The second key channel is the relationship between environmental taxation and ecological innovations and investments. Acemoglu et al. (2012) develop a model of directed technical change. The model demonstrates that taxes and subsidies can redirect innovative efforts from dirty towards clean technologies. Aghion, et al. (2016) confirm this empirically in the automotive industry - higher fuel prices stimulate the patenting of electric and hybrid vehicles. Further studies confirm this relationship, demonstrating that environmental policies and price incentives encourage the development of cleaner technologies and increase low-carbon innovations in companies ((Johnstone et al., 2010; Calel & Dechezleprêtre, 2016; Feng et al., 2024; Hu et al., 2025).

This strand of the literature is important because it demonstrates that price pressure can alter the direction of technological development. However, it does not provide an automatic answer to the question of whether innovations translate into real eco-investments at the sectoral level. The difference between innovation (patents, R&D) and capital execution (actual investment expenditure) is substantial.

Popp (2002) and Jaffe & Palmer (1997) demonstrate that higher energy prices stimulate patenting and R&D expenditure, but evidence for a real investment effect is weaker - firms respond first with preparation rather than with capital outlays. Benatti, et al. (2024) confirm this - environmental regulations stimulate clean innovations, but the effect is considerably stronger in combination with direct R&D subsidies.

The literature on renewable energy adds a further important qualification. Johnstone et al., (2010) demonstrate that renewable energy policies influence patent activity, but results depend on the type of technology and the type of instrument. It is not sufficient to speak in general terms about environmental policy - what matters is the precise nature of the instrument: tax, subsidy, standard, or combination (Palage et al., 2019; Hille et al., 2020; Blagoeva & Georgieva, 2023).

Dechezleprêtre & Sato, (2017) present a systematic review of the literature on the impact of environmental regulations on competitiveness. The conclusion is nuanced - regulations lead to significant but small negative effects on trade, employment, and productivity in the short run - principally in energy- and pollution-intensive sectors. At the same time, there is evidence of stimulating innovation, but the benefits are insufficient to compensate the costs for regulated enterprises. Ambec et al. (2013) summarise the literature on the Porter Hypothesis and emphasise that positive effects are more likely when policies are well-designed, predictable, and consistent. Marin & Vona (2021), analysing micro-data from French manufacturing enterprises, establish that the impact of energy prices depends critically on sectoral specificity and firm characteristics. Calel & Dechezleprêtre (2016) demonstrate that the EU ETS stimulates low-carbon innovations among regulated firms. This result is an important counterpoint - price instruments can work, but the effect depends on the specific mechanism, scope, and institutional environment.

Of particular importance for the present study is the research of Carfora et al., (2021). The authors analyse the role of environmental taxes and public support policies for investments in renewable energy in the EU. Using spatial econometric models for 26 member states (2007-2018), they establish that the tax burden acts more as a barrier to renewable energy investments than as an incentive. At the same time, targeted support policies - including feed-in tariffs - demonstrate a positive effect. This result draws an important distinction - tax pressure and investment incentive are not the same thing. A sector may bear a high tax burden without this automatically leading to greater ecological investments. It is precisely this distinction that is also key to our analysis, which examines not the general ecological effect but specifically the investment response. The conclusion of Carfora et al. (2021) is in accordance with the broader literature. The effect of price instruments depends on

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accompanying policies. When taxes are combined with predictable support, access to financing, and clear regulatory signals, the likelihood of an investment response is higher. When such a package is absent, the tax is perceived primarily as a cost.

The growing awareness of the financial risks associated with climate change has led to the creation of institutional frameworks for the management of transition risk. TCFD (2017) defines four principal categories of climate financial risks - regulatory, technological, market, and reputational. Environmental taxes fall precisely within the category of regulatory risks, since changes in tax rates or in the scope of taxation can alter the cost structure of enterprises, their profitability, and their investment decisions. The question of whether environmental taxes stimulate eco-investments is therefore not only ecological but also financial-managerial. In this connection, ECB (2020) formulates expectations for banks to integrate climate risks into management and disclosure, whilst Nerlich, et al. (2025) identify a significant gap between the required and the actually realised green investments in the European Union. This supports the conclusion that tax policy in itself is insufficient if it is not combined with capital market reforms and regulatory predictability (Krastev & Krasteva-Hristova, 2024). The connection with the present study is direct - when taxes increase cost pressure but do not lead to investment adaptation, transition risk rises both for enterprises and for their creditors. Battiston, et al. (2017) demonstrate that such effects can be transmitted through the financial system and, through network effects, create systemic risk.

This perspective is important for the interpretation of our results. Even when no direct relationship between taxes and eco-investments is observed, this does not mean that tax policy is insignificant. Rather, it means that the effect may manifest through other channels - cost pressure, changes in the risk profile, technological deferral, or the redirection of investments. It is precisely for this reason that the empirical verification of the direct relationship is necessary rather than superfluous.

In this sense, the literature on climate financial risk and the literature on environmental taxation meet in a common question - not simply whether the policy is "green," but whether it is effective as a mechanism for real adaptation. The present study rests precisely upon this intersection - between fiscal instrument, investment behaviour, and risk management under conditions of green transition.

The literature review reveals three substantial gaps. First, most studies focus on emissions rather than on capital eco-investments - the tax-investment relationship remains poorly studied, despite its key significance for the assessment of fiscal risk. Second, few studies combine the cross-country and cross-sector dimension, even though sectoral differences are fundamental - the same tax may act as an incentive in one sector and as a barrier in another. Third, the predominant use of absolute values without eliminating the influence of the size of the economy can lead to systematically erroneous conclusions.

The present study addresses these gaps with a country-sector panel of 7 countries and 4 NACE sectors for the period 2014-2023. Unlike most studies, which work with aggregated national data in absolute terms, here we combine the cross-country and cross-sector dimension with relative values and a five-step empirical strategy - descriptive statistics, correlations with relative values, fixed-effects panel regressions, the Granger test, and seven robustness checks. The focus is on the effectiveness of environmental taxes as a financial instrument for the management of transition risk.

3. Materials and Methods

3.1. Data and Sample

The study uses panel data extracted from the publicly available databases of Eurostat. The sample covers seven EU member states (Belgium, Bulgaria, France, Hungary, Italy, Poland, and Romania), plus EU-27 as a reference aggregate. The countries are selected so as to ensure geographical and economic diversity. Both old and new EU members are included, as well as large and small economies, and Western and Eastern European countries.

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The panel has two dimensions. The first is the country-sector dimension - each unit of observation is the combination of country and sector (e.g. Bulgaria - Manufacturing). The second is the time dimension: the period 2014-2023 (10 years). Four sectors under NACE Rev.2 are covered: A (Agriculture, Forestry and Fishing), B (Mining and Quarrying), C (Manufacturing), and D (Energy). This yields a balanced panel of 7 × 4 × 10 = 280 observations (320 with EU-27).

3.2. Variables

Table 1 describes the variables employed. The dependent variable is eco-investments (EcoInvest) - capital expenditure on environmental protection, reported under the EPEA (Environmental Protection Expenditure Accounts) methodology. The main independent variable is environmental taxes (EnvTax), reported in accordance with Regulation 691/2011 of the EP and of the Council (European Parliament and Council of the European Union, 2011).

In order to eliminate the effect of the size of the economy, relative indicators are also employed - eco-investments and environmental taxes as a percentage of gross value added (% of GVA) of the respective sector. All monetary values are in millions of euros, at current prices.

Table 1. Variable descriptions.

Variable	Description	Source (Eurostat)	Unit
Dependent variable			
EcoInvest	Eco-investment by sector	env_ac_epneis	million euro
Independent variables			
EnvTax	Environmental taxes by sector	env_ac_tax	million euro
EcoExpend	Eco-expenditure by sector	env_ac_epiap1	million euro
VA	Gross value added by sector	nama_10_a10	million euro
GDP	Gross domestic product	nama_10_gdp	million euro
Derived indicators			
Invest %VA	Eco-investment / sectoral GVA	Computed	%
Tax %VA	Env. taxes / sectoral GVA	Computed	%
ΔVA	Annual GVA growth rate (%)	Computed	%

Source: Eurostat, author's calculations.

3.3. Analytical Framework

The analysis follows a five-step strategy (Table 2).

Table 2. Analytical framework.

Stage	Method	Purpose
1	Descriptive statistics	Characterise distributions, heterogeneity, and dynamics
2	Correlation analysis (Pearson)	Assess bivariate associations and examine scale effects
3	Panel regressions (FE, RE, Hausman)	Test the direct link controlling for unobserved specifics
4	Granger causality test	Examine directionality (taxes → investments and/or reverse)
5	Robustness checks	Confirm findings under alternative specifications

In the correlation analysis, the Pearson coefficient (r) is employed for the assessment of the linear relationship between variables, both in absolute values and in relative ones (as a percentage of GVA).

As the main econometric instrument, a fixed-effects (FE) panel regression by units is applied. This model absorbs all unobserved and time-invariant characteristics of the units (e.g. regulatory tradition, technological structure, geographical location) and identifies the effect from within variation. Four specifications are employed:

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Модел 1 (log-log): $\ln(EcoInvest_{it}) = \alpha_i + \beta1 \cdot \ln(EnvTax_{it}) + \beta2 \cdot \ln(VA_{it}) + \varepsilon_{it}$ (1)

Модел 2 (intensity): $InvInt_{it} = \alpha_i + \beta1 \cdot TaxInt_{it} + \varepsilon_{it}$ (2)

Модел 3 (FE + TE + lag): $\ln(EcoInvest_{it}) = \alpha_i + \gamma_t + \beta1 \cdot \ln(EnvTax_{i,t-1}) + \beta2 \cdot \ln(VA_{it}) + \varepsilon_{it}$ (3)

Модел 4 (intensity + lag): $InvInt_{it} = \alpha_i + \beta1 \cdot TaxInt_{i,t-1} + \varepsilon_{it}$ (4)

where i denotes the unit (country-sector), t denotes the year, α_i denotes the unit fixed effect, and γ_t denotes the time effect. All models employ clustered standard errors (SE) by units for the correction of heteroscedasticity and autocorrelation within units. The choice between FE and RE is verified using the Hausman test (Hausman, 1978).

To verify the direction of the relationship, a panel Granger causality test (Granger, 1969) is applied. Two directions are examined - whether past values of environmental taxes improve the forecast for eco-investments (taxes → investments) and the reverse (investments → taxes). Owing to the limited time dimension (T = 10), 1 and 2 lags are employed.

4. Results

4.1. Descriptive Statistics and Trend Analysis

Table 3 demonstrates that the observations in the panel are highly heterogeneous and are appreciably influenced by scale effects. The mean eco-investment per country-sector pair is 666.76 million EUR, yet the typical value is considerably lower - the median is 84.25 million EUR. This divergence means that several very large observations (including the EU-27 aggregate and large economies such as France and Italy) dominate the distribution and elevate the mean value. Consequently, mean values should be interpreted with caution, as they do not describe the "centre" of the data but are sensitive to extreme observations.

Table 3. Summary statistics of the key variables.

Variable	Mean	Std. Dev.	Min	Q1	Median	Q3	Max
Eco-investment (million euro)	666.76	1508.94	0.00	28.40	84.25	425.20	10691.20
Eco-expenditure (million euro)	2704.42	8241.81	0.00	4.53	107.00	724.60	52250.30
Env. taxes (million euro)	2416.49	6239.42	6.48	96.00	363.70	1313.41	42320.53
GVA (million euro)	109646.13	364925.90	143.00	3168.05	11901.95	42025.83	2526727.0
Eco-invest. (% of GVA)	1.40	2.09	0.00	0.28	0.71	1.43	12.19
Env. taxes (% of GVA)	4.04	3.99	0.19	1.75	3.03	4.87	32.21

Source: Author's calculations based on Eurostat data.

A similar picture is observed for environmental taxes: the mean value is 2,416.49 million EUR against a median of 363.70 million EUR, which again suggests a concentration of volumes in a limited number of observations and the presence of pronounced right skewness.

The relative indicators provide a more comparable perspective, as they reduce the influence of size. Expressed in this form, mean eco-investments amount to 1.40% of sectoral GVA, whilst environmental taxes stand at 4.04% of GVA. This ratio demonstrates that within the panel the tax burden (as a relative share) systematically exceeds the observed investment response, which motivates subsequent analysis of whether higher environmental taxes are associated with higher investment intensity.

Table 4 delineates substantial cross-country differences. France stands out as the largest investor in absolute terms (mean 1,056.40 million EUR), followed by Poland (268.68 million EUR) and Italy

(226.66 million EUR). In relative terms, however, Belgium registers the highest investment intensity - 2.57% of GVA, followed by France (1.96%) and Romania (1.59%). Hungary records the lowest intensity (0.58%), alongside the EU-27 aggregate (1.03%).

Table 4. Mean values and growth dynamics by country (2014-2023).

Country	Eco-invest. (million euro)	Eco-expend. (million euro)	Env. taxes (million euro)	Eco-invest. (% of GVA)	Env. taxes (% of GVA)	CAGR invest. (%)	CAGR taxes (%)
BE	162.15	337.93	419.78	2.57	4.43	+5.9	+6.6
BG	39.10	54.11	147.27	1.20	4.58	-1.5	+17.9
FR	1056.40	2153.52	1091.22	1.96	2.71	+4.2	+3.6
HU	32.10	79.34	165.53	0.58	3.13	-5.4	+9.3
IT	226.66	2018.28	2261.28	0.78	5.05	-8.3	-0.4
PL	268.68	0.00	910.87	1.51	2.20	-1.1	+12.0
RO	60.76	219.68	672.32	1.59	6.23	-9.2	+1.6
EU-27	3488.20	16772.53	13663.69	1.03	3.19	+3.6	+4.8

Source: Author's calculations based on Eurostat data. CAGR = compound annual growth rate, 2014-2023.

Particularly telling is the growth dynamics. Whilst environmental taxes increase in all countries with the exception of Italy (CAGR: −0.4%), with especially rapid growth in Bulgaria (+17.9%), Poland (+12.0%), and Hungary (+9.3%), eco-investments contract in four of the seven national economies. Romania (−9.2%), Italy (−8.3%), and Hungary (−5.4%) record the steepest declines, whilst Belgium (+5.9%) and France (+4.2%) demonstrate sustained growth. This asymmetry between the rising tax burden and declining investments in a number of countries raises initial questions regarding the effectiveness of environmental taxation as an investment incentive and necessitates thorough econometric investigation.

Figure 1 illustrates the temporal evolution of eco-investments. Among the national economies (panel a), France demonstrates a clear upward trajectory - from 3,695 million EUR in 2014 to 5,371 million EUR in 2022. Belgium follows a similar positive trend. Conversely, Italy registers a sharp decline - from 1,020 million EUR (2014) to 468 million EUR (2022-2023), whilst Poland and Romania display fluctuating patterns without a clear direction. At the EU-27 level, total eco-investments increase from 13,050 million EUR in 2014 to approximately 18,000 million EUR in 2023, representing cumulative growth of 37.9% (CAGR: 3.6%). The slight decline in 2020 most likely reflects the economic disruptions caused by the COVID-19 pandemic.

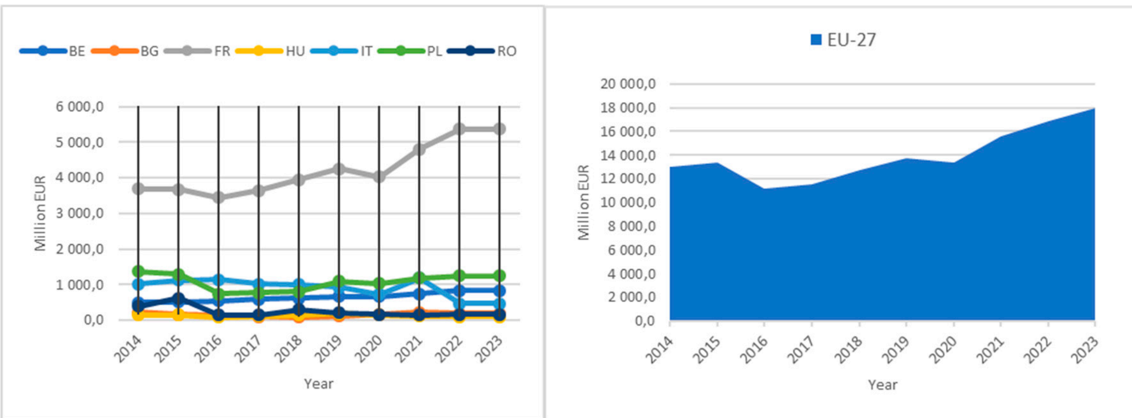

Figure 1. Dynamics of eco-investments by country and EU-27, 2014-2023 (million euro).

Figure 2 presents the corresponding trajectory of environmental taxes. The most remarkable characteristic is the sharp acceleration in Poland after 2020, where tax revenues nearly quadruple -

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from 2,069 million EUR (2014) to 7,840 million EUR (2022), driven primarily by rising energy taxation. Environmental tax revenues in Bulgaria also increase sharply, with a CAGR of 17.9% over the period. Italy, the largest collector of environmental taxes in absolute terms (mean 2,261 million EUR across sectors), remains relatively stable throughout the decade. At the EU-27 level, environmental taxes increase from 43,400 million EUR in 2014 to a peak of 72,044 million EUR in 2022, followed by a slight correction in 2023 (66,098 million EUR), yielding an overall CAGR of 4.8%.

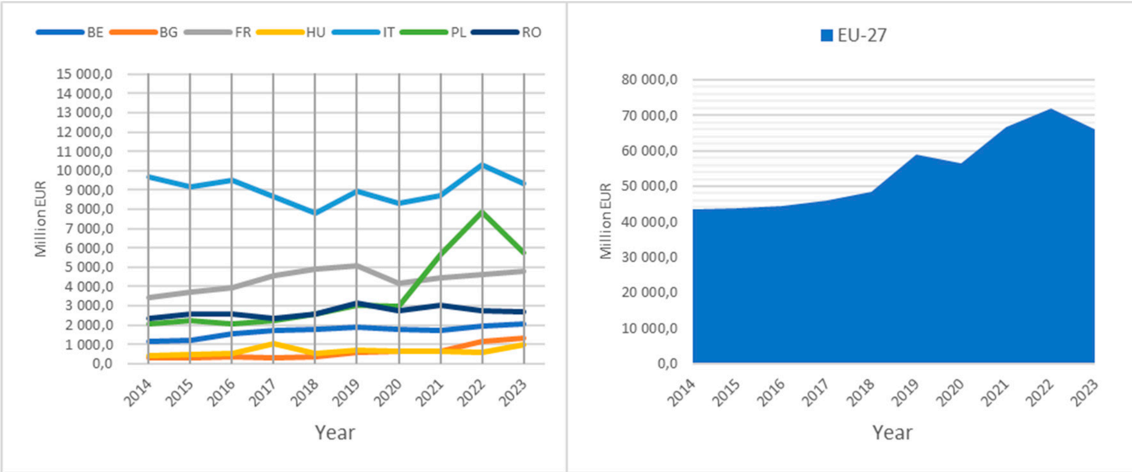

Figure 2. Dynamics of environmental taxes by country and EU-27, 2014-2023 (million euro).

Thus far, the data have been examined in their entirety and by country. Yet behind the aggregated figures lies the question: are environmental taxes and eco-investments distributed equally across individual sectors? The answer is an unequivocal "no," and it is precisely this unevenness that constitutes one of the most interesting signals in the data.

The sectoral decomposition in Table 5 reveals a pronounced asymmetry between the distribution of environmental taxes and eco-investments. Manufacturing (sector C) bears 67.0% of total environmental taxes yet realises only 46.1% of eco-investments. This demonstrates that manufacturing enterprises carry a disproportionately high tax burden relative to their ecological capital expenditure. The Agriculture sector (A) presents the mirror image: it contributes only 13.6% of environmental taxes yet absorbs 32.1% of eco-investments and registers the highest investment intensity (2.71% of GVA). This pattern may reflect the presence of targeted subsidies from the CAP (e.g. greening measures under the Common Agricultural Policy), which stimulate ecological investments beyond the fiscal channel.

Table 5. Mean values and structural shares by NACE sector (national economies, 2014-2023).

Sector (NACE)	Eco-invest. (million euro)	Eco-expend. (million euro)	Env. taxes (million euro)	Eco-invest. (% of GVA)	Env. taxes (% of GVA)	Share of invest. (%)	Share of taxes (%)
A - Agriculture	338.82	1780.58	439.54	2.71	3.26	32.1	13.6
B - Mining	24.82	21.24	100.32	1.06	5.42	2.4	3.1
C - Manufacturing	486.53	872.33	2168.88	0.49	2.10	46.1	67.0
D - Electricity & gas	204.61	104.63	530.27	1.57	6.54	19.4	16.4

Source: Author's calculations based on Eurostat data. EU-27 excluded to avoid double-counting.

The energy sector (D) is distinguished by the highest tax intensity (6.54% of GVA), which is consistent with its exposure to energy taxation and emissions trading mechanisms. Its investment intensity of 1.57% of GVA, whilst moderate, may underestimate total ecological capital expenditure if the costs of compliance with the EU Emissions Trading Scheme (EU ETS) are not fully reflected in the investment data.

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Figure 3 presents the sectoral structure of the two indicators for the seven national economies in aggregate over the period 2014-2023. The picture reveals a distinct imbalance. Manufacturing (sector C) bears 67.0% of all environmental taxes yet realises only 46.1% of eco-investments. In other words, this sector pays disproportionately more in taxes relative to what it invests in environmental protection. Agriculture (sector A) contributes only 13.6% of tax revenues yet absorbs 32.1% of investments - most likely owing to the targeted subsidies under the EU Common Agricultural Policy.

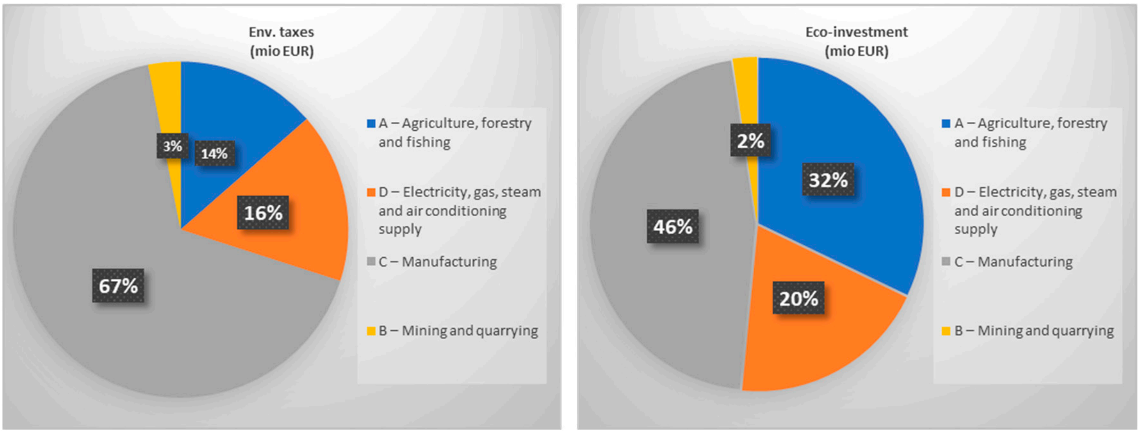

Figure 3. Sectoral distribution of eco-investments and environmental taxes (national total, 2014-2023).

This imbalance raises an important question: if the tax burden in itself were to stimulate investments, one would expect sectors with higher taxes to invest more. Yet the data demonstrate precisely the opposite in the case of Manufacturing. This suggests that the tax-investment relationship is not straightforward and most likely depends on sectoral specificities - a hypothesis that will be tested formally in the regression analysis.

Figure 4 offers a cross-sectional presentation of the two key intensity indicators. Panel (a) demonstrates that the energy sector of Bulgaria bears the highest mean tax burden (14.77% of GVA), closely followed by the energy sector of Romania (14.62%) and the mining and quarrying sector of Italy (8.74%). Panel (b) demonstrates that the agriculture sector of Belgium registers the highest investment intensity (9.71% of GVA), followed by the agriculture sector of France (4.68%) and the mining and quarrying sector of Romania (4.26%). Notably, a number of country-sector pairs with a high tax burden do not exhibit a correspondingly high investment intensity (e.g. the energy sector of Romania: 14.62% taxes against 1.53% investments; the energy sector of Bulgaria: 14.77% taxes against 2.01% investments). This further underscores the necessity of a multifactorial analysis that controls for unobserved heterogeneity across countries and sectors.

(**a**)

Country	Agriculture (A)	Mining (B)	Manufacturing (C)	Electricity (D)
BE	4.59%	4.98%	1.88%	6.14%
BG	2.88%	2.23%	1.69%	14.77%
FR	2.79%	6.72%	1.32%	0.53%
HU	3.24%	3.49%	1.76%	2.11%
IT	3.59%	8.74%	2.24%	6.41%
PL	3.63%	1.26%	2.88%	1.71%
RO	0.54%	4.08%	4.75%	14.62%
Average	3.04%	4.50%	2.36%	9.38%

(**b**)

Country	Agriculture (A)	Mining (B)	Manufacturing (C)	Electricity (D)
BE	9.71%	0.00%	0.56%	0.00%
BG	1.27%	0.45%	1.08%	2.01%
FR	4.68%	0.84%	0.90%	1.44%
HU	1.47%	0.27%	0.20%	0.38%
IT	0.24%	1.15%	0.18%	1.56%
PL	1.18%	0.45%	0.35%	4.05%
RO	0.40%	4.26%	0.18%	1.53%
Average	2.14%	1.06%	0.49%	1.57%

Figure 4. Heatmaps of average environmental tax burden and eco-investment intensity by country and sector (% of GVA, 2014-2023). (**a**) Avg. Environmental Tax Burden (% of GVA, 2014-2023). (**b**) Avg. Eco-Investment Intensity (% of GVA, 2014-2023).

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The descriptive analysis delineates three key preliminary conclusions. First, eco-investments and environmental taxes differ drastically across individual countries and sectors. There is no typical behaviour - Belgium and France invest increasingly, whilst Romania and Italy contract. This diversity means that answers cannot be sought through simple mean values - a panel approach is required that accounts for what is specific to each country and sector. Second, taxes and investments move in different directions. Environmental taxes increase in almost all cases, yet eco-investments decline in four of the seven countries. If taxes were automatically to stimulate investments, one would expect the two curves to move together. Since they do not, it most likely depends on how the taxes are designed, what additional policies accompany them, and which sector they fall within. Third, the sectoral picture tells its own story. Manufacturing pays the most in taxes (67% of the total) yet does not invest proportionately more. Agriculture does the opposite - it invests intensively under a low tax burden, most likely because it has access to targeted subsidies under the EU CAP. In other words, taxes alone are insufficient - what matters is the package of instruments that underpins them.

4.2. Correlation Analysis

Before proceeding to the regression analysis, an examination is conducted of whether a statistical relationship exists between environmental taxes and eco-investments - and to what extent it is real, as opposed to being explained by the influence of the size of the economy.

At first glance, the relationship appears very strong. Figure 5a demonstrates that the correlation between eco-investments and environmental taxes in absolute terms is $r = 0.926$ ($p < 0.001$). However, this is an illusion. Both variables correlate strongly with GVA ($r = 0.90$ and $r = 0.94$) and GDP ($r = 0.74$ and $r = 0.70$). Larger economies simply have more of everything - more taxes, more investments, greater GVA. This does not mean that taxes stimulate investments - it means that both grow with the size of the economy.

a. Absolute values (million euro)

	Eco-Investment	Eco-Expenditure	Env. Tax	GVA	GDP
Eco-Investment	1.00	0.68	0.93	0.90	0.74
Eco-Expenditure	0.68	1.00	0.60	0.57	0.66
Env. Tax	0.93	0.60	1.00	0.94	0.70
GVA	0.90	0.57	0.94	1.00	0.56
GDP	0.74	0.66	0.70	0.56	1.00

b. Intensity ratios (% of GVA)

	Eco-Invest (% of GVA)	Env. Tax (% of GVA)
Eco-Invest (% of GVA)	1.000	0.079
Env. Tax (% of GVA)	0.079	1.000

Figure 5. Pearson correlation matrices: (a) absolute values; (b) intensity ratios (% of GVA).

How does the relationship appear once the influence of the size of the economy is removed? Figure 5b presents the correlations between the relative indicators (% of GVA), which are already adjusted for the size of the sector. The result is surprising - the correlation between tax burden and investment intensity falls to $r = 0.079$ and is not statistically significant ($p = 0.161$). In other words, when the size of the economy is accounted for and the tax burden and investment activity are compared as shares of gross value added, the apparently strong relationship breaks down.

4.3. Panel Regression Analysis

The correlation analysis demonstrated that the observed simple relationship between taxes and investments is to a significant extent the result of the scale effect. However, correlation does not control for unobserved specificities of countries and sectors - such as regulatory traditions, technological structure, or the policy environment. For this reason, the analysis proceeds to fixed-effects (FE) panel regressions, which isolate within variation - that is, they answer the question: when taxes change over time within the same country-sector unit, do investments change as well?

A balanced panel of 28 units (7 countries × 4 sectors) over 10 years (2014-2023) is employed. Table 6 presents four model specifications: Model 1 examines the logarithmic relationship (elasticity), Model 2 employs relative indicators (% of GVA), Model 3 adds time effects and a lagged tax variable, and Model 4 combines intensity with a lag. All models employ clustered standard errors by units.

Table 6. Fixed-effects panel regressions: eco-investment as dependent variable.

	Model 1 FE log-log	Model 2 FE intensity	Model 3 FE+TE lag	Model 4 FE int. lag
ln(Env. Tax)	0.0203 (SE=0.1099) [p=0.854]			
Tax intens. (%GVA)		1.1924 (SE=3.8921) [p=0.760]		
ln(Env. Tax_{t-1})			0.0977 (SE=0.1290) [p=0.450]	
Tax $intens._{t-1}$				3.7477 (SE=3.9241) [p=0.341]
ln(GVA)	0.0636 (SE=0.1878)		0.1752 (SE=0.3902)	
R^2 within	0.0015	0.0009	0.0058	0.0075
N	280	280	252	252
Entity FE	Yes	Yes	Yes	Yes
Time FE	No	No	Yes	No
F-test (p)	0.826	0.642	0.361	0.197

Source: Author's calculations.

The results are unambiguous: not one of the four models finds a statistically significant effect of environmental taxes on eco-investments. In Model 1, the elasticity is 0.02 ($p = 0.854$) - practically zero. In Model 2, the coefficient of tax intensity is 1.19, yet with a very large standard error (3.89) and $p = 0.760$. Model 3 examines whether taxes operate with a lag - yet the lagged value is likewise insignificant ($p = 0.450$). Model 4 repeats the same result for the intensities.

Particularly telling is the R^2 within - the indicator that measures how much of the variation within units the model explains. In all four models it is below 1%. This means that when environmental taxes increase in a given sector of a given country, this is of practically no use in predicting how investments will change.

The Hausman test (Table 7) does not reject the null hypothesis in either case ($p = 0.181$ and $p = 1.000$), indicating that the RE model is acceptable. However, this does not alter the main conclusion - the RE estimates are likewise insignificant for the tax variable (Model 1 RE: $\beta = 0.07$, $p = 0.566$; Model 2 RE: $\beta = 3.32$, $p = 0.442$).

Table 7. Hausman test: FE vs. RE.

Test	χ^2	df	p-value	Decision
Model 1: log-log	3.4181	2	0.181	RE acceptable ($p > 0.05$)
Model 2: intensity	-	1	1.000	RE acceptable ($p > 0.05$)

Source: Author's calculations.

This means that when environmental taxes rise in a given sector, this does not lead to greater eco-investments. Neither immediately, nor after one year. Neither in absolute nor in relative terms. This does not prove that taxes are useless - it is possible that they operate through indirect channels or with a longer lag. However, within the framework of this panel, the direct relationship is not confirmed.

4.4. Granger Causality Test

The regression analysis found no significant relationship from taxes to investments. However, the question remains - might the relationship run in the opposite direction, with higher investments leading to higher taxes? The Granger test examines both directions - whether past values of one variable improve the forecast for the other, beyond its own lags.

The results are categorical (Table 8). Not one of the eight tests rejects the null hypothesis. Taxes do not predict investments (highest F = 1.64, p = 0.202), yet neither do investments predict taxes (lowest p = 0.318). The result is identical at lags of 1 and 2 and in both specifications (log-log and intensity). In other words, the two variables move independently of one another over time.

Table 8. Panel Granger causality test.

Direction	Lags	F-stat	p-value	Result
Tax → Invest (log)	1	1.4259	0.234	Not signif.
Invest → Tax (log)	1	0.0767	0.782	Not signif.
Tax → Invest (log)	2	0.8882	0.413	Not signif.
Invest → Tax (log)	2	0.0548	0.947	Not signif.
Tax int. → Invest int. (%GVA)	1	1.6402	0.202	Not signif.
Invest int. → Tax int. (%GVA)	1	0.8992	0.344	Not signif.
Tax int. → Invest int. (%GVA)	2	0.2440	0.784	Not signif.
Invest int. → Tax int. (%GVA)	2	1.1540	0.318	Not signif.

Source: Author's calculations. F-test for joint significance of X lags in FE model.

4.5. Robustness Checks

The question nevertheless remains of whether the absence of an effect is attributable to the particularities of the chosen model or to the composition of the sample. The main model is therefore repeated under seven alternative specifications (Table 9).

Table 9. Robustness checks: environmental tax coefficient across specifications.

Specification	β(EnvTax)	SE	p-value	R^2 within
Baseline (Model 1 FE)	0.0203	0.1099	0.854	0.0015
R1: Excl. Italy	0.0729	0.0529	0.168	0.0056
R2: Excl. France	0.0184	0.1170	0.875	0.0007
R3: New EU only (BG, HU, PL, RO)	0.1125	0.0672	0.096	0.0055
R4: Old EU only (BE, FR, IT)	−0.1479	0.2635	0.576	0.0127
R5: Excl. 2020-21 (COVID)	0.0348	0.1182	0.768	0.0008
R6: First differences	−0.0215	0.1675	0.898	0.0090
R7: Intensity + time FE	1.6187	3.7946	0.669	0.0008

Source: Author's calculations. SE - clustered standard errors.

The result is consistent: all seven checks confirm the insignificance of the tax coefficient. The closest to significance is R3 (new members only: p = 0.096), yet even there it does not cross the conventional threshold of 5%. Changing the sample, excluding the COVID years, switching to first differences, and adding time effects - none of these alters the main conclusion.

These checks reinforce the confidence that the null result is not coincidental. Within the framework of this panel, there exists no econometrically confirmed direct relationship between environmental taxes and eco-investments - in either direction.

4. Discussion

An interesting finding of the study is the sharp divergence between correlations calculated using absolute values and those based on relative values. The correlation between the absolute values of environmental taxes and eco-investments is exceptionally high ($r = 0.926$), yet it reflects primarily the scale of the economy - large economies pay more taxes and make more investments, but not necessarily owing to a causal relationship between the two variables. When the influence of scale is eliminated through relative values (taxes and investments as a percentage of GVA), the correlation falls to $r = 0.079$ ($p = 0.161$) - statistically insignificant and practically zero.

This result has direct significance for financial analysis and risk management. Many of the existing policy analyses and ESG assessments work with absolute values, which creates a risk of systematic error in the evaluation of policy effectiveness and in the pricing of transition risk. This problem is analogous to the phenomenon known in statistics as spurious correlation, where two variables correlate strongly solely because both are a function of a third variable - in this case, the scale of the economy. For investment portfolios and ESG ratings that include indicators of environmental taxation, this result means that absolute values are not a reliable indicator of policy effectiveness, particularly in the presence of divergences in methodologies and measurement between different assessors (Chatterji et al., 2016; Berg et al., 2022).

Our central result - the absence of a statistically significant relationship between environmental taxes and eco-investments ($\beta = 0.020$, $p = 0.854$, R^2 within < 1%) - is not isolated in the literature, but adds an important new dimension. Morley (2012) establishes an effect on emissions but not on energy consumption, suggesting that taxes can reduce pollution without stimulating capital investments. Liobikienė et al. (2019) analysing 28 EU member states for the period 1995-2012, establish no statistically significant direct or indirect (through energy intensity, fossil energy consumption, and renewable energy) effect of energy taxes on greenhouse gas emissions in the panel analysis. The present study confirms this conclusion but extends it in a new direction: the absence of an effect relates not only to emissions but also to capital eco-investments at the sectoral level.

Particularly interesting is the comparison with Carfora et al. (2021), who establish that the environmental tax burden represents a barrier to renewable energy investments in the EU. Our result is compatible with the interpretation that environmental taxes can operate through two opposing channels - on the one hand, they raise the price of pollution (the Pigouvian effect); on the other, they reduce the disposable capital available for investment (the crowding-out effect). The net effect may be close to zero, which is precisely what is observed.

At the same time, our result contrasts with the positive conclusions of Andersson (2019) and Sen & Vollebergh (2018). This, however, is not a contradiction but a difference in the object of analysis. These studies measure the effect on emissions, which is a more immediate channel (through the reduction of consumption), whereas we measure the effect on capital investments - a longer-term and more indirect channel that requires a stronger and more sustained price signal. As Dechezleprêtre & Sato (2017) note, even when regulations stimulate innovation, the benefits are often insufficient to compensate the costs for regulated enterprises.

The descriptive analysis reveals a substantial sectoral imbalance - manufacturing (NACE C) pays 67% of environmental taxes yet accounts for only 46% of eco-investments. Agriculture (NACE A) pays 14% yet receives 32% of investments. This imbalance undermines the polluter-pays principle and represents a fiscal risk in the context of TCFD (2017) - revenues are generated in some sectors whilst investments are directed towards others.

This result is compatible with the findings of Marin & Vona (2021), who emphasise that the impact of energy prices depends critically on sectoral specificity. The energy sector (NACE D) in our data exhibits the highest tax intensity but comparatively low investment activity - revealing a potential tax trap - a sector that pays high taxes without a corresponding environmental effect. This mechanism is of key importance for the assessment of the financial risk of enterprises in regulated sectors.

The Granger test detects no causality in either direction - neither do taxes predict investments, nor does the reverse hold true (all 8 specifications with $p > 0.05$). This result means that the two variables move independently over time. From a policy perspective, this calls into question the effectiveness of environmental taxation as a mechanism for managing transition financial risk. If taxes

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do not generate an investment response with a lag of 1-2 years, they function as a pure fiscal burden without a corresponding environmental investment effect.

This observation corresponds with the theoretical model of Acemoglu et al. (2012), which demonstrates that optimal policy requires a combination of carbon taxes and research subsidies, rather than taxes alone. Our empirical data support this position - standalone taxation is insufficient to generate ecological investments at the sectoral level. A holistic approach is required, combining fiscal and non-fiscal instruments (subsidies, regulatory standards, mandatory ESG disclosure) for the effective management of transition financial risk.

The null result is not coincidental. The seven robustness checks - exclusion of individual countries, separation of old and new EU members, exclusion of COVID years, first differences, relative indicators with time fixed effects - all confirm insignificance ($p > 0.05$ in all specifications). The closest to significance is the subsample of new member states (R3: $p = 0.096$), which may reflect a stronger marginal effect of taxes in economies where eco-investments are only beginning to gather momentum - a hypothesis that merits future investigation.

5. Conclusions

The present study poses a simple yet important empirical question - do higher environmental taxes lead to greater eco-investments in the EU? Panel data for seven member states and four sectors (NACE Rev.2: A-D) for the period 2014-2023 are employed. The result is consistent - within the data under examination, no direct positive relationship between environmental taxes and eco-investments is found. This null effect is not the consequence of one particular model specification, but recurs across the descriptive analysis, correlation checks, and panel regressions, and remains robust under the robustness tests.

First, at first glance taxes and investments appear strongly related in nominal values ($r = 0.926$), yet this relationship primarily reflects the size of the economy - larger sectors simultaneously have greater tax revenues and larger investment volumes. When comparable values are compared - as a share of sectoral GVA - the correlation practically disappears ($r = 0.079$; $p = 0.161$). This is important for fiscal analysis, because conclusions based solely on nominal aggregates may overestimate the real effect of policy.

Second, fixed-effects panel regressions find no statistically significant effect of environmental taxes on eco-investments across all tested specifications (log-log, intensities, lagged tax variables, and models with time effects). The explanatory power over within variation is minimal (R^2 within < 1%), meaning that when the tax burden changes over time within the same country-sector unit, this is not associated with a systematic change in eco-investments within the same unit.

Third, the panel Granger causality tests show no statistically significant predictability in either direction at lags of 1-2 and in both specifications (logarithms and intensities). Within the time horizon under examination, tax changes do not precede investment changes in a manner that would permit one to speak of a clearly expressed dynamic dependence - and the reverse is likewise not observed.

Fourth, the descriptive results delineate a distinct sectoral imbalance between who “pays” and where investments are concentrated. Manufacturing generates 67% of environmental taxes yet realises 46% of eco-investments, whilst agriculture accounts for 14% of taxes and accumulates 32% of investments. The polluter-pays principle evidently does not automatically translate into investment logic at the sectoral level. In all likelihood, the investment decision is determined by the regulatory environment rather than by the tax burden as such.

From a practical standpoint, the results suggest that the current model of environmental taxation requires rethinking:

1. The mere existence of a tax does not guarantee an investment response. A more effective alternative is a predictable mechanism whereby a portion of revenues is returned to the sectors that generate them - for example, through co-financing of eco-projects. This improves the predictability of financial flows and reduces investment uncertainty for enterprises.

2. A uniform tax approach fails to account for the fact that sectors differ in their technological structure and investment capacity. Sectoral differentiation and/or combining the tax with targeted instruments is therefore justified in cases where tax intensity is high but the investment response is weak (for example, in the energy sector).
3. The absence of a direct effect supports the argument that taxes function most effectively as part of a package rather than as a standalone incentive. The attempt to manage transition risk solely through a tax instrument appears insufficient - a coordinated combination of fiscal and regulatory measures is required.
4. In order to avoid the influence of scale, the effectiveness of policies should be assessed primarily through relative indicators (such as % of GVA/GDP) and through internal changes over time, rather than through absolute volumes. This is important both for public assessments and for financial analysis and ESG risk management.

The study has several limitations that outline directions for future work. The sample is limited in terms of countries and aggregated sectors, and the time horizon (T = 10) does not permit reliable testing of longer lags. The data are in current prices, which may introduce additional distortions; the use of deflated values would yield more precise estimates. The analysis examines whether taxes directly influence eco-investments, but it is possible that the effect operates through an indirect path - for example, through eco-expenditure, technological changes (patents), or changes in energy intensity. Future studies may therefore incorporate such intermediate factors and employ dynamic panel models (e.g. GMM) in order to trace the mechanism of influence more precisely.

The study does not deny the role of environmental taxes as a price signal and instrument for limiting pollution. However, in the countries and sectors under examination, the specific expectation that higher environmental taxes lead to higher eco-investments is not confirmed, which underscores the necessity of evaluating policy instruments empirically rather than by presumption.

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Abbreviations

The following abbreviations are used in this manuscript:

CAP	Common Agricultural Policy
CAGR	Compound Annual Growth Rate
CO_2	Carbon Dioxide
ECB	European Central Bank
ESG	Environmental, Social and Governance
EPEA	Environmental Protection Expenditure Accounts
ETS	Emissions Trading System
EU	European Union
EU ETS	European Union Emissions Trading System
EU-27	European Union - 27 Member States
FE	Fixed Effects
GDP	Gross Domestic Product
GMM	Generalised Method of Moments
GVA	Gross Value Added

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NACE	Statistical Classification of Economic Activities in the European Community
R&D	Research and Development
RE	Random Effects
SE	Standard Error
TCFD	Task Force on Climate-related Financial Disclosures

References

Acemoglu, D., Aghion, P., Bursztyn, L., & Hemous, D. (2012). The environment and directed technical change. American Economic Review, 102(1), 131-166. https://doi.org/10.1257/aer.102.1.131.

Aghion, P., Dechezleprêtre, A., Hémous, D., Martin, R., & Van Reenen, J. (2016). Carbon taxes, path dependency, and directed technical change: Evidence from the auto industry. Journal of Political Economy, 124(1), 1-51. https://doi.org/10.1086/684581.

Ambec, S., Cohen, M. A., Elgie, S., & Lanoie, P. (2013). The Porter hypothesis at 20: Can environmental regulation enhance innovation and competitiveness? Review of Environmental Economics and Policy, 7(1), 2-22. https://doi.org/10.1093/reep/res016.

Andersson, J. (2019). Carbon Taxes and CO_2 Emissions: Sweden as a Case Study. American Economic Journal: Economic Policy, 11(4), 1-30. https://doi.org/10.1257/pol.20170144.

Battiston, S., Mandel, A., Monasterolo, I., Schütze, F., & Visentin, G. (2017). A climate stress-test of the financial system. Nature Climate Change, 7(4), 283-288. https://doi.org/10.1038/nclimate3255.

Baumol, W. J. (1972). On taxation and the control of externalities. American Economic Review, 62(3), 307-322.

Benatti, N., Groiss, M., Kelly, P., & Lopez-Garcia, P. (2024). The impact of environmental regulation on clean innovation: are there crowding out effects? (ECB Working Paper Series No. 2946). European Central Bank.

Berg, F., Kölbel, J. F., & Rigobon, R. (2022). Aggregate confusion: The divergence of ESG ratings. Review of Finance, 26(6), 1315-1344. https://doi.org/10.1093/rof/rfac033.

Blagoeva, N., & Georgieva, V. (2023). Pesticide tax - the new challenge in Europe's green tax policy. Bulgarian Journal of Agricultural Science, 29(1), 3-13.

Bovenberg, A. L., & de Mooij, R. A. (1994). Environmental levies and distortionary taxation. American Economic Review, 84(4), 1085-1089.

Bretschger, L., & Grieg, E. (2024). Carbon taxes, CO2 emissions, and the economy: The effects of fuel taxation in the UK. Energy Policy, 195, 114359. https://doi.org/10.1016/j.enpol.2024.114359.

Calel, R., & Dechezleprêtre, A. (2016). Environmental policy and directed technological change: Evidence from the European carbon market. The Review of Economics and Statistics, 98(1), 173-191. https://doi.org/10.1162/REST_a_00470.

Carfora, A., Pansini, R. V., & Scandurra, G. (2021). The role of environmental taxes and public policies in supporting RES investments in EU countries: Barriers and mimicking effects. Energy Policy, 149, 112044. https://doi.org/10.1016/j.enpol.2020.112044.

Chatterji, A. K., Durand, R., Levine, D. I., & Touboul, S. (2016). Do ratings of firms converge? Implications for managers, investors and strategy researchers. Strategic Management Journal, 37(8), 1597-1614. https://doi.org/10.1002/smj.2407.

Dechezleprêtre, A., & Sato, M. (2017). The impacts of environmental regulations on competitiveness. Review of Environmental Economics and Policy, 11(2), 183-206. https://doi.org/10.1093/reep/rex013.

European Central Bank (ECB). (2020). Guide on climate-related and environmental risks: Supervisory expectations relating to risk management and disclosure. Frankfurt am Main: European Central Bank.

European Parliament and Council of the European Union . (2011). Regulation (EU) No 691/2011 of 6 July 2011 on European environmental economic accounts. Official Journal of the European Union, L 192, 1-16.

Feng, T., Wang, X., Shi, Y., & Tu, Q. (2024). The role of carbon price signal in green innovation: Evidence from China. Journal of Environmental Management, 370, 122787. https://doi.org/10.1016/j.jenvman.2024.122787.

Godawska, J. (2024). The impact of environmental taxes on the level of NOx and SOx emissions. Economics and Environment, 89(2), Article 744. https://doi.org/10.34659/eis.2024.89.2.744.

Goulder, L. H. (1995). Environmental taxation and the double dividend: A reader's guide. International Tax and Public Finance, 2(2), 157-183. https://doi.org/10.1007/BF00877495.

Granger, C. W. (1969). Investigating causal relations by econometric models and cross-spectral methods. Econometrica, 37(3), 424-438. https://doi.org/10.2307/1912791.

Hausman, J. A. (1978). Specification tests in econometrics. Econometrica, 46(6), 1251-1271. https://doi.org/10.2307/1913827.

Hille, E., Althammer, W., & Diederich, H. (2020). Environmental regulation and innovation in renewable energy technologies: Does the policy instrument matter? Technological Forecasting and Social Change, 153, 119921. https://doi.org/ 10.1016/j.techfore.2020.119921.

Hu, H., Zhu, Y., Ye, L., & Wang, Y. (2025). How does environmental tax reform drive corporate innovation to green technologies? Quasi-natural experimental evidence from China. Journal of Business Economics and Management, 26(4), pp.798-824. https://doi.org/10.3846/jbem.2025.24354.

Jaffe, A. B., & Palmer, K. (1997). Environmental regulation and innovation: A panel data study. Review of Economics and Statistics, 79(4), 610-619. https://doi.org/10.1162/003465397557196.

Johnstone, N., Haščič, I., & Popp, D. (2010). Renewable energy policies and technological innovation: Evidence based on patent counts. Environmental and Resource Economics, 45(1), 133-155. https://doi.org/10.1007/s10640-009-9309-1.

Känzig, D. R. (2023). The Unequal Economic Consequences of Carbon Pricing (NBER Working Paper No. 31221). National Bureau of Economic Research.

Kohlscheen, E., Moessner, R., & Takáts, E. (2025). Effects of carbon pricing and other climate policies on CO2 emissions. National Institute Economic Review, https://doi.org/10.1017/nie.2025.10066.

Köppl, A., & Schratzenstaller, M. (2023). Carbon taxation: A review of the empirical literature. Journal of Economic Surveys, 37(4), 1353-1388. https://doi.org/10.1111/joes.12531.

Krastev, B., & Krasteva-Hristova, R. (2024). Challenges and trends in green finance in the context of sustainable development - A bibliometric analysis. Journal of Risk and Financial Management, 17(7), 301. https://doi.org/10.3390/jrfm17070301.

Liobikienė, G., Butkus, M., & Matuzevičiūtė, K. (2019). The contribution of energy taxes to climate change policy in the European Union (EU). Resources, 8(2), 63. https://doi.org/10.3390/resources8020063.

Marin, G., & Vona, F. (2021). The impact of energy prices on socioeconomic and environmental performance: Evidence from French manufacturing establishments, 1997-2015. European Economic Review, 135, 103739. https://doi.org/10.1016/j.euroecorev.2021.103739.

Morley, B. (2012). Empirical evidence on the effectiveness of environmental taxes. Applied Economics Letters, 19(18), 1817-1820. https://doi.org/10.1080/13504851.2011.650324.

Nerlich, C., Köhler-Ulbrich, P., Andersson, M., Pasqua, C., Abraham, L., Bańkowski, K., . . . Groß, J. e. (2025). Investing in Europe's green future: Green investment needs, outlook and obstacles to funding the gap (ECB Occasional Paper Series No. 367; revised December 2025). European Central Bank.

Palage, K., Lundmark, R., & Söderholm, P. (2019). The innovation effects of renewable energy policies and their interaction: The case of solar photovoltaics. Environmental Economics and Policy Studies, 21(2), 217-254. https://doi.org/10.1007/s10018-018-0228-7

Pigou, A. C. (1920). The economics of welfare. London: Macmillan.

Popp, D. (2002). Induced innovation and energy prices. American Economic Review, 92(1), 160-180. https://doi.org/10.1257/000282802760015658.

Porter, M. E., & van der Linde, C. (1995). Toward a new conception of the environment-competitiveness relationship. Journal of Economic Perspectives, 9(4), 97-118. https://doi.org/10.1257/jep.9.4.97.

Sen, S., & Vollebergh, H. (2018). The effectiveness of taxing the carbon content of energy consumption. Journal of Environmental Economics and Management, 92, 74-99. https://doi.org/10.1016/j.jeem.2018.08.017.

Silajdžić, S., & Mehić, E. (2018). Do environmental taxes pay off? The impact of energy and transport taxes on CO_2 emissions in transition economies. South East European Journal of Economics and Business, 13(2), 126-143.

Task Force on Climate-related Financial Disclosures (TCFD). (2017). Recommendations of the Task Force on Climate-related Financial Disclosures. Financial Stability Board (FSB).

Wolde-Rufael, Y., & Mulat-weldemeskel, E. (2023). Effectiveness of environmental taxes and environmental stringent policies on CO2 emissions: The European experience. Environment, Development and Sustainability, 25(6), 5211-5239. https://doi.org/10.1007/s10668-022-02262-1.

Zhang, W., Zhu, B., Li, Y., & Yan, D. (2024). Revisiting the Porter hypothesis: A multi-country meta-analysis of the relationship between environmental regulation and green innovation. Humanities and Social Sciences Communications, 11, 232. https://doi.org/10.1057/s41599-024-02671-9.