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The Eroding Environmental Tax Base in the EU-27: Policy Success or Fiscal Sustainability Risk? Evidence from Energy Taxation, 2010–2023

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Abstract

Between 2010 and 2023, environmental tax revenues in the EU-27 fell from 2.47% to 2.06% of GDP. Their average share in total tax and social contribution revenues across Member States fell from 7.72% to 6.21%. Using a balanced Eurostat panel of 27 Member States (378 observations), this study decomposes changes in energy tax revenues as a share of GDP into a real implicit rate effect and an energy intensity effect. At EU level, a 29.1-log-point base contraction outweighed an 11.7-log-point rise in the real implicit rate. The entire net decline occurred in 2019–2023, when the two components contributed equally. Energy intensity fell in all Member States. In the baseline decomposition, the rate component accounts for 69.4% of the cross-country variance in the change. Its contribution remains larger than the base component's under alternative specifications, although individual country classifications are sensitive to the treatment of renewables and EU ETS auction revenues. Nominal environmental tax revenues rose in every Member State except Denmark. The findings document relative revenue erosion and highlight the sensitivity of revenue projections to changes in energy intensity and the composition of tax receipts.

Keywords: environmental taxes; energy taxation; tax base erosion; implicit tax rate; energy intensity; decomposition analysis; fiscal sustainability; green transition; panel data; EU-27

1. Introduction

Environmental taxes occupy a distinctive place in the architecture of European economic policy: they serve simultaneously as a corrective instrument that internalises the externalities of pollution and as a fiscal source upon which hopes for "green" tax reform have been built for decades—shifting the tax burden from labour to the environment. It is against the backdrop of these expectations that the past decade presents a paradoxical picture. Whilst the European Union has been accelerating its climate ambitions—from the Fit for 55 package to the forthcoming expansion of emissions trading—the relative weight of environmental taxes has been declining steadily. According to Eurostat data, their share in total tax and social contribution revenues in the EU fell from 6.1% in 2021 to 5.1% in 2023, and as a percentage of GDP from approximately 2.4% in the early 2010s to 2.0% in 2023; relative to 2008, real revenues have contracted by nearly one fifth, whilst the taxation of labour has remained stable. The promised labour–environment tax swap appears to be unfolding in the opposite direction.

This decline admits two fundamentally different interpretations with opposing policy implications. According to the first, it is a sign of success: environmental taxes are designed to change behaviour, and a contracting tax base—reduced consumption of fossil

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fuels, more efficient economies, electrified transport—is evidence that they are working; revenue erosion is the predictable fiscal cost of decarbonisation. According to the second interpretation, the decline is a symptom of policy erosion: nominal excise rates left unindexed for years and eroded by inflation, crisis-driven reductions introduced in 2022 that have since become permanent, and tax exemptions that have outpaced the development of replacement instruments. Distinguishing between the two explanations is not an academic detail—it determines whether the problem calls for accommodation and fiscal planning or for active rate policy. The question acquires additional urgency ahead of the introduction of the second Emissions Trading System (ETS 2) and in the context of the debate on the fiscal sustainability of the green transition.

The existing literature examines in considerable detail the impact of environmental and energy taxes on emissions, energy consumption, renewable energy and economic activity. What remains significantly less developed is the reverse fiscal relationship—how changes in energy consumption and the structure of the energy mix, associated with the low-carbon transition, feed through to the tax base and to revenues. Available estimates of revenue erosion are predominantly forward-looking, often relate to individual countries or to road transport, and rarely distinguish the change in revenues that has already occurred from changes in effective taxation and in the physical base. The literature reviewed lacks a comparable retrospective analysis covering all 27 EU Member States that employs a unified accounting identity to decompose the change in energy tax revenues as a share of GDP into a rate component and a base component. It is precisely this analytical and comparative gap that the present study addresses.

Earlier work has projected future revenue losses (OECD/International Transport Forum, 2019; Noll et al., 2026) or documented trends in revenue ratios (Delgado et al., 2022; Famulska et al., 2022). This study uses an exact, deflator-consistent identity to separate changes in the real implicit rate from changes in energy intensity after they have occurred. Sub-period and historical comparisons show when erosion occurred and how countries changed revenue regimes. Alternative specifications quantify how the treatment of renewables and EU ETS auction revenues affects the decomposition.

The aim of the study is to establish the extent to which the change in energy tax revenues as a share of GDP observed across the EU-27 during 2010–2023 can be attributed, through an accounting decomposition, to changes in the real implicit tax rate and to changes in energy intensity, and to determine which of the two components better explains cross-country differences among Member States. In accordance with this aim, two hypotheses are tested: first, that the aggregate decline is explained primarily by the negative base effect, measured through the reduction in final energy consumption per unit of real GDP; and second, that cross-country heterogeneity is more strongly associated with the rate effect than with the base effect. The first hypothesis concerns the accounting origin of the decline and does not imply that base contraction is caused solely by tax or climate policy. Equally, the rate effect encompasses not only changes in statutory rates but also exemptions, refunds, collection performance, the structure of energy consumption, and revenues from emissions allowance trading. The decomposition focuses on energy taxes, which account for nearly four fifths of environmental tax revenues. Energy intensity serves as a proxy for the legal energy tax base.

The analysis uses a balanced Eurostat panel of all 27 Member States for 2010–2023 (378 observations), with a historical comparison for 1995–2008. It combines the decomposition and country typology with auxiliary regressions, correlations and robustness checks.

2. Literature Review

2.1. The Double Dividend and Environmental Tax Reform

The theoretical foundation of the present study is rooted in the literature on environmental tax reform and the double dividend hypothesis. In its classical formulation, an environmental tax corrects negative externalities by raising the price of environmentally harmful behaviour. At the same time, the revenues generated may be used to reduce other distortionary taxes, particularly those on labour (Pearce, 1991; Goulder, 1995). The first dividend consists in an improvement in environmental quality, whilst the second lies in a potentially positive effect on employment, social welfare, or the overall efficiency of the tax system. This logic provides the theoretical basis for redirecting part of the tax burden away from economically desirable activities, such as labour and investment, towards pollution and the use of natural resources.

The strong form of the double dividend hypothesis has, however, been called into question in the subsequent theoretical literature. General equilibrium models demonstrate that environmental taxes interact with existing tax distortions and may raise the costs of consumption and production. Consequently, using the revenues to reduce other taxes does not automatically eliminate the economic losses generated by the new levy. The realisation of a second dividend depends critically on the structure of the existing tax system and on the manner in which revenues are deployed (Bovenberg & de Mooij, 1994; Bovenberg & Goulder, 1996; Bovenberg, 1999).

It is therefore necessary to distinguish between the weak and strong forms of the hypothesis. The weak form holds that using environmental tax revenues to reduce other distortionary taxes is more efficient than returning them through undifferentiated transfers. The strong form requires that environmental tax reform generate an additional non-environmental welfare benefit even before any gains from environmental improvement are taken into account.

Empirical surveys and meta-analyses reach equally cautious conclusions. The likelihood of realising a second dividend depends on the type of environmental tax, the revenue recycling mechanism, labour market conditions, and the assumptions of the economic model employed (Bosquet, 2000; Patuelli et al., 2005; Freire-González, 2018). Experience from the Scandinavian reforms and the German ecological tax reform of 1999–2003 suggests that emissions reductions can be combined with moderate positive effects on employment and technological innovation, particularly when revenues are used to reduce the tax burden on labour. The magnitude and durability of these effects remain, however, sensitive to the specific design of the policy and to the broader institutional context (Andersen & Ekins, 2009; Knigge & Görlach, 2005).

More recent research adds a political economy dimension to the double dividend debate. The allocation of revenues affects not only economic efficiency but also public acceptability and the political sustainability of environmental taxation. A systematic review and meta-analysis covering more than 100,000 respondents finds that revenue recycling broadly increases public support for carbon pricing. The most consistently positive effect is observed when revenues are directed towards visible climate and environmental expenditures (Mohammadzadeh Valencia et al., 2024). Revenue use must therefore be regarded as an integral part of the institutional design of environmental taxation, rather than merely a subsequent budgetary decision.

The double dividend literature does, however, contain an inherent tension that has received comparatively little attention. If an environmental tax successfully changes behaviour, the taxable activity—and with it the tax base—gradually contracts. Environmental effectiveness thus weakens the instrument's capacity to generate sustainable revenues.

Conversely, persistently high revenues may signal either a stable fiscal base or insufficient change in taxpayer behaviour.

Revenue stability and maximum environmental effectiveness are not, therefore, necessarily compatible long-term objectives. A decline in environmental tax revenues may be the result of successful decarbonisation, but equally of a failure to index rates, of temporary tax reliefs that have become entrenched, or of structural weaknesses in the tax system. Distinguishing between these mechanisms is of fundamental importance in determining whether the erosion of the environmental tax base represents a policy success or a risk to fiscal sustainability.

2.2. The Concept, Structure, and Erosion of the Environmental Tax Base

The second strand of the literature is concerned with the structure and sustainability of the environmental tax base. Under the harmonised statistical framework of Eurostat, a tax is classified as environmental if its base consists of a physical unit—or a proxy for such a unit—with a proven specific negative impact on the environment, and if it is designated as a tax within the European System of Accounts (Eurostat, 2024). Environmental taxes are distributed across four main categories: energy taxes, transport taxes, pollution taxes, and taxes on natural resources.

This definition rests on the characteristics of the tax base rather than on the stated objective of the tax or the use to which the revenues are put. A tax may therefore be classified as environmental even where its revenues are not used to finance environmental policies. Conversely, taxes with a general fiscal purpose may exert a substantial influence on the behaviour of polluters. The volume of environmental tax revenues is consequently not a direct measure either of policy stringency or of environmental effectiveness.

A further distinction arises from the statistical treatment of revenues from the European Emissions Trading System. In its legal and economic substance, the emissions trading scheme is not a tax, since the price of allowances is determined by market supply and demand. Under the national accounts framework, however, revenues from the auctioning of emissions allowances are recorded as tax revenues and are accordingly included in environmental tax statistics (European Environment Agency, 2025a). This distinction matters because changes in aggregate revenues may stem from classical tax instruments as much as from the market-determined prices and volumes of traded allowances.

The composition of environmental tax revenues is of critical importance for their long-term sustainability. In 2023, energy taxes—including recorded revenues from emissions allowance trading—accounted for 76% of total environmental tax revenues in the EU. Transport taxes represented 19%, whilst pollution taxes and taxes on natural resources together amounted to no more than 5%. Energy and transport taxes thus jointly provided 95% of all environmental tax revenues (European Environment Agency, 2025a). This concentration renders the overall volume of revenues highly dependent on fossil fuel consumption, road transport, and historically established excise structures.

It is precisely this structure that accounts for the self-eroding character of the environmental tax base. The electrification of transport and heating, improvements in energy efficiency, the expansion of renewable energy sources, and the structural reorientation of the economy towards less energy-intensive activities all reduce the physical quantity of taxable fuels and other polluting products. With rates held constant, revenues may decline even as policy achieves its stated environmental objective. Base contraction therefore does not necessarily represent a shortcoming of the tax but may be an expected consequence of its incentive effect.

Revenues are, however, also affected by factors that bear no direct relation to environmental success. Many energy excise duties are set as specific nominal amounts per physical

unit of product. Where rates are not regularly indexed to inflation, the real tax burden and the real value of revenues gradually diminish. Since 2021, this long-term process has been further amplified by the temporary excise reductions and other measures introduced by Member States to contain the price shock from the energy crisis (European Environment Agency, 2025a, 2025b; OECD, 2023). The observed decline may thus simultaneously reflect lower consumption of polluting products, the erosion of nominal rates, and discretionary policy decisions.

Revenue dynamics confirm the significance of this problem. The share of environmental taxes in total tax and social contribution revenues in the EU fell from 6.3% in 2010 to 5.1% in 2023. Between these two years, an increase was recorded only in Bulgaria and Greece, whilst the share declined in the remaining 25 Member States (European Environment Agency, 2025a). The erosion is therefore not an isolated national phenomenon but a prevailing trend across the EU-27.

The trend is not, however, entirely uniform. Delgado et al. (2022) identify distinct convergence trajectories among Member States depending on whether environmental taxation is measured as a share of GDP, as a share of total tax revenues, or through the individual categories of energy and transport taxes. This implies that similar movements in the aggregate indicator may be driven by different national processes. In one country the decline may be attributable primarily to electrification and reduced fuel consumption, in another to the absence of rate indexation, and in a third to shifts between individual tax categories.

Aggregate environmental tax revenues are therefore insufficient for distinguishing between environmental success and fiscal weakening. A decomposition of changes by tax category and by country is required, alongside a separation of changes in taxable physical quantities from changes in effective rates and from shifts in the relative importance of individual revenue sources. It is precisely this need that justifies the analysis of environmental tax base erosion as a compositional and fiscal process, rather than simply as a reduction in a single summary indicator.

2.3. Environmental Effectiveness, Empirical Heterogeneity, and Reverse Causality

The third strand of the literature encompasses empirical studies of the relationship between environmental taxation and the outcomes of the green transition. The great majority of these treat environmental taxes as the explanatory variable, with emissions, energy consumption, renewable energy, or environmental investment as the dependent variables. The central research question is typically whether higher environmental taxation leads to reductions in pollution and to changes in production and consumption behaviour. Considerably less attention has been devoted to the reverse relationship—how achieved decarbonisation alters the size and structure of tax revenues themselves.

Early panel studies generally identify environmentally favourable, though not always unambiguous, effects. Morley (2012) finds a statistically significant negative relationship between environmental taxes and pollution in a panel of European countries, but does not establish a robust association between taxes and energy consumption. This suggests that emissions reductions may be achieved not only through a contraction in overall energy use but also through changes in the energy mix, the technologies deployed, and the structure of production.

Using a panel vector autoregressive model for the EU-27 over the period 1995–2018, Savranlar et al. (2024) find that an increase in environmental taxes is associated with a reduction in CO_2 emissions of approximately 0.14%. The authors also identify bidirectional causality between environmental tax revenues and emissions. This result is of particular importance for the present study, as it demonstrates that the relationship does not run solely

from tax policy to environmental outcomes. Changes in emissions and in the use of taxable energy products may in turn affect the volume of revenues collected.

Effects differ substantially across country groups. In a study covering 16 old and 11 new Member States over the period 1995–2020, Fatur Šikić and Hodžić (2023) find a negative long-run impact of environmental taxes on final energy consumption in both groups. The effect is, however, considerably weaker in the new Member States. This divergence is associated with differences in institutional development, energy infrastructure, economic structure, and the implementation of environmental tax reforms.

Comparable institutional heterogeneity is identified by Dmytrenko et al. (2026) in a comparison of Western and Central European countries. Environmental policy stringency exerts a statistically significant effect on emissions only in the Western European group, whilst expenditure on research and development proves a more substantial factor for both groups. This suggests that the outcome of environmental taxation depends on complementary policies, technological capacity, and institutional quality, and not merely on the volume of tax revenues.

Further heterogeneity emerges when environmental taxes are disaggregated by category. Özmen and Mutascu (2025) examine 23 EU countries over the period 1995–2020 using the method of moments quantile regression. Their results show that energy taxes are associated with reductions in CO_2 emissions across varying income and emissions levels. For transport taxes, however, a positive association with emissions is found. The different categories of environmental taxes cannot therefore be treated as a homogeneous policy instrument. High transport tax revenues, for example, may reflect a large vehicle fleet and intensive car use rather than a more stringent or more effective environmental policy.

Findings regarding the transition to renewable energy are equally mixed. Dogan et al. (2023) find that energy taxes and aggregate environmental taxes are negatively associated with renewable energy deployment in EU Member States. The authors attribute this result to the need for the tax structure to be complemented by targeted incentives, technological support, and investment mechanisms. In contrast, Lobonț et al. (2025) identify a statistically significant negative relationship between environmental tax revenues and CO_2 emissions in the EU-27 over the period 2012–2023. Taken together, these findings suggest that taxes may contribute to emissions reductions without necessarily acting independently as a driver of renewable energy deployment.

Evidence for the investment channel is also cautious. Georgieva (2026) analyses a panel of seven Member States and four economic sectors over the period 2014–2023. The strong positive correlation between environmental taxes and eco-investments, measured in absolute terms, disappears once both are normalised relative to sectoral gross value added. Fixed-effects models and causality tests do not establish a robust direct relationship between taxes and eco-investments. High absolute values may therefore reflect primarily the scale of the economy rather than the incentive effect of tax policy.

These divergences in empirical findings need not be regarded as mutually contradictory. They may arise from the use of different tax categories, indicators of environmental outcomes, time periods, country groups, and econometric methods. The manner in which environmental taxation is measured also matters considerably. Tax revenue is the product of the effective rate and the size of the taxable base. High revenues may therefore reflect either high rates or large consumption of polluting products. Conversely, low revenues may result either from low taxation or from a successful contraction of polluting activity.

This feature creates a potential problem of simultaneity and reverse causality in panel models. If environmental tax revenues are used as a proxy for policy stringency without accounting for changes in the tax base, the estimated coefficient may conflate the effect of rates with the effect of consumption and emissions. The existing body of research directed

from taxes towards environmental outcomes is consequently insufficient for assessing the fiscal sustainability of the instrument. The reverse relationship—from decarbonisation to tax revenues—must be analysed in its own right.

It is precisely this perspective that the present study inverts. Decarbonisation is treated not solely as an outcome of environmental taxation but as a factor that alters the physical size and composition of the tax base. The analysis thus moves from the conventional question of whether environmental taxes support the green transition to the less examined question of whether the transition itself undermines the long-term revenue sustainability of these taxes.

2.4. The Fiscal Sustainability of the Transition and the Replacement of Eroding Tax Bases

The fourth strand of the literature examines the implications of the transition to carbon neutrality for public finances. Decarbonisation affects budgets through several interrelated channels. On the one hand, carbon taxes and emissions allowance trading may generate new revenues, whilst the removal of fossil fuel subsidies may reduce public expenditure. On the other hand, the transition requires substantial budgetary resources to support investment, technological change, and affected households and businesses. At the same time, the reduction in the production and consumption of fossil fuels narrows traditional revenue sources such as fuel excise duties, carbon taxes, and certain transport taxes (Fouré et al., 2023; OECD, 2023).

The modelling of Fouré et al. (2023) demonstrates that the overall fiscal outcome of the transition depends on the combination of instruments employed. Carbon pricing and the removal of fossil fuel support may improve the budgetary position, whilst subsidies and tax incentives generate direct costs or foregone revenues. Alongside these direct effects, substantial indirect impacts arise as economic activity shifts between sectors with differing tax burdens. The fiscal sustainability of the transition cannot therefore be assessed solely through the lens of environmental tax revenues but must be considered in the context of the broader change in the tax and economic structure.

Revenue erosion is particularly evident in road transport. Fuel excise duties have traditionally provided relatively predictable revenues, being based on mass-consumed products with limited short-run substitution possibilities. Rising fuel efficiency, the shift to electric vehicles, and changing mobility patterns are gradually eroding this base. The scenario analysis conducted by the OECD/International Transport Forum (2019) for Slovenia indicates that, absent policy change, revenues from fuels used by passenger cars could be 56% lower in 2050 than in 2017. This process is gradual, owing to the slow turnover of the vehicle fleet, but it is precisely this characteristic that creates an opportunity to begin tax reform before the fiscal shortfall becomes significant.

Carbon pricing may offset part of the declining revenues in the short to medium term. As the scope of carbon pricing is broadened and the carbon price rises, receipts from carbon taxes or the sale of emissions allowances may initially increase. This compensation is, however, temporary. As emissions fall, so too does the base to which the carbon price applies. Revenues may therefore initially rise, reach a peak, and subsequently begin to decline as carbon neutrality is approached (OECD, 2023). For this reason, carbon pricing cannot be regarded as a permanent substitute for disappearing fuel excise duties.

The scale of global fiscal exposure is assessed by Noll et al. (2026), who analyse 168 countries. They estimate that revenues from fuel taxes amounted to approximately 900 billion US dollars in 2023. The authors identify substantial cross-country variation when the potential loss is measured relative to total public revenues. This implies that an identical technological shift may have very different budgetary consequences depending on the structure of the tax system, the level of fuel excise duties, the size of the vehicle fleet, and the availability of alternative revenue sources.

Electrification reduces the fuel tax base while leaving external costs such as congestion, road wear and noise. The literature therefore considers distance-, time- and location-based charging (van Dender, 2019; OECD, 2023). For the Berlin region, Nguyen and Müsgens (2026) estimate that a dynamic congestion charge could offset projected fuel tax losses by 2030.

From a fiscal standpoint, the central question is therefore not whether declining revenues should mechanically be restored in full. What is required is to determine what proportion of those revenues finances general budgetary expenditure, what proportion compensates for specific external costs, and what proportion could be replaced by more efficient and equitable tax instruments. An attempt to preserve revenues by continuously raising rates on a contracting base may temporarily slow erosion but does not resolve the long-term problem and may intensify social resistance.

The fiscal sustainability of the green transition accordingly requires early and gradual adaptation of the tax system. In the short run, the indexation of specific rates and the curtailment of unjustified exemptions can reduce the passive loss of revenues. In the medium term, carbon pricing may partially compensate for contracting fuel excise duties. In the long run, however, alternative bases are required—ones that do not disappear upon successful decarbonisation. From this perspective, the erosion of the environmental tax base is not merely a future scenario but a process already under way, one that demands advance planning and coordination across environmental, transport, and general tax policy.

2.5. The EU Institutional Framework and the Research Gap

The institutional framework governing environmental and energy taxation in the European Union has evolved more slowly than its decarbonisation objectives. The taxation of energy products and electricity continues to be regulated primarily by Directive 2003/96/EC, which establishes minimum rates for motor and heating fuels and for electricity (Council of the European Union, 2003). These rates are fixed as nominal amounts in euros and are not automatically updated in line with inflation. Their real value consequently declines gradually. The numerous exemptions and reduced rates further weaken the revenue potential of the system and do not always provide price signals consistent with the EU's climate objectives (European Commission, 2019).

The 2021 proposal to revise the Energy Taxation Directive would align minimum rates with energy content and environmental performance and phase out certain fossil fuel exemptions (European Commission, 2021). Adoption requires unanimity, and agreement had not been reached by November 2025 (Council of the European Union, 2025). Directive (EU) 2023/959 established ETS 2 for buildings, road transport and additional sectors. The system is due to become fully operational in 2028, and part of the proceeds supports the Social Climate Fund (European Parliament & Council of the European Union, 2023a, 2023b; European Commission, 2026).

ETS 2 may broaden the environmental revenue base in the short to medium term, but it does not eliminate the risk of its gradual contraction. The market price of allowances and their full allocation by auction may initially increase public revenues. As the emissions cap is tightened and fossil fuel consumption declines, however, the number of allowances and the physical size of the taxable base will also diminish. Revenues from ETS 2 may therefore offset part of the loss of traditional energy tax receipts, but they do not constitute a permanent fiscal base. The question of whether revenues from allowance trading will prove sufficient to halt the sustained decline in the share of environmental taxes in total tax revenues remains open (European Environment Agency, 2025a, 2026).

The two-factor identity shares the exact additivity of logarithmic decompositions used in energy and emissions research (Ang, 2004, 2015). Eurostat's implicit rate and the

OECD's effective rates provide complementary benchmarks for comparing energy taxation across countries, fuels and sectors (Eurostat, 2024; OECD, 2019). Studies of revenue ratios document trends and convergence without separating changes in the rate from changes in the physical base (Delgado et al., 2022; Famulska et al., 2022). The auxiliary panel regressions adapt the tax buoyancy approach by using energy consumption as the physical base (Dudine & Jalles, 2018).

The review of the literature indicates that the primary focus of research has been directed towards the impact of environmental taxes on emissions, energy consumption, renewable energy, and economic activity. The reverse fiscal relationship—how changes in energy consumption, energy efficiency, and the structure of the energy mix feed through to the tax base and to revenues—has received considerably less attention. Existing estimates of revenue erosion are predominantly forward-looking and are frequently limited to individual countries or to road transport. The literature reviewed does not yield a comparable retrospective analysis covering all 27 EU Member States that distinguishes the change in revenues that has already occurred from changes in effective taxation and in the relative size of the energy base.

A further limitation arises from the use of aggregate environmental tax revenues as a single indicator. This measure combines energy, transport, resource, and pollution taxes, notwithstanding that the individual categories have different physical bases, rates, and degrees of fiscal durability. Changes in aggregate revenues may be driven primarily by one dominant category whilst the others remain stable or move in the opposite direction. A structural analysis is therefore necessary to identify which revenue component is the principal source of the observed erosion.

The present study addresses this gap through a retrospective panel analysis of all 27 Member States over the period 2010–2023. The overall dynamics and structure of environmental tax revenues are traced by main category, after which the change in the dominant energy component is decomposed through a unified accounting identity into an effect of the real implicit rate and an effect of energy intensity. This approach makes it possible to distinguish the EU-wide trend, cross-country differences, and the relative contribution of the rate and base components, without attributing an independent causal interpretation to the accounting decomposition.

3. Methodology

3.1. Data and Sample

The study is based on a balanced panel covering all 27 Member States of the European Union over the period 2010–2023, yielding 378 country-year observations (27 × 14). All source series were retrieved from the Eurostat database via the official programmatic data dissemination interface.

Five datasets are used: environmental tax revenues by category (env_ac_tax); the share of energy from renewable sources in gross final energy consumption (nrg_ind_ren); greenhouse gas emissions by source (env_air_gge); complete energy balances (nrg_bal_c); and national accounts for gross domestic product at current prices and in chain-linked volumes with reference year 2015 (nama_10_gdp). The env_ac_tax dataset presents environmental tax revenues by category in monetary values, as a percentage of GDP, and as a percentage of total tax and social contribution revenues; for the latter indicator, the unit PC_TSCO_X_ISCO is used, which excludes imputed social contributions. Greenhouse gas emissions data are compiled by the European Environment Agency and redistributed by Eurostat. The definitions of all variables, their units of measurement, and their sources are summarised in Table 1. The robustness checks also use Member States' 2023 EU ETS auction revenues reported to the European Environment Agency (European Environment Agency,

2024). The Eurostat renewables share is used to approximate non-renewable energy use (Section 3.6).

Table 1. Variables, definitions, units of measurement and data sources.

Variable	Symbol	Definition and Construction	Unit of Measurement	Source
Total environmental tax revenue	ETR	Revenue from energy taxes, transport taxes, and pollution and resource taxes	EUR million; % of GDP; % of total taxes and social contributions	Eurostat, env_ac_tax
Energy tax revenue	R^N	Nominal revenue from taxes classified as energy taxes	EUR million	Eurostat, env_ac_tax
Final energy consumption	E	Final energy consumption for energy purposes; all energy products (FC_E, TOTAL)	Thousand tonnes of oil equivalent (ktoe)	Eurostat, nrg_bal_c
Share of renewable energy	RES	Share of energy from renewable sources in gross final energy consumption	%	Eurostat, nrg_ind_ren
Greenhouse gas emissions	GHG	Total greenhouse gas emissions in CO_2 equivalent, excluding LULUCF and memo items (TOTX4_MEMO)	Thousand tonnes of CO_2 equivalent	Eurostat/EEA, env_air_gge
Nominal GDP	Y^N	GDP at market prices (B1GQ)	EUR million, current prices	Eurostat, nama_10_gdp
Real GDP	Y^R	GDP at market prices in chain-linked volumes	EUR million, reference year 2015	Eurostat, nama_10_gdp
GDP deflator	D	Ratio of nominal GDP to real GDP, normalised to 2015 = 100	Index, 2015 = 100	Author's calculations
Energy tax revenue as a share of GDP	TAX	$100 \times R^N/Y^N$	% of GDP	Author's calculations
Energy intensity	INT	E/Y^R, after conversion into comparable units	kg of oil equivalent per EUR 1000 at 2015 prices	Author's calculations
Nominal implicit tax rate on energy	ITR^N	R^N/E	EUR per tonne of oil equivalent	Author's calculations
Real implicit tax rate on energy	ITR^R	$(R^N/d)/E$, where $d = D/100$	2015 EUR per tonne of oil equivalent	Author's calculations
Change between the initial and final year	$\Delta \ln X$	$\ln X_{t1} - \ln X_{t0}$	Log points	Author's calculations
Real energy tax revenue	RR	R^N/d	EUR million at 2015 prices	Author's calculations
Non-renewable final energy consumption (robustness)	E^n_r	$E \times (1 - RES/100)$	Thousand tonnes of oil equivalent (ktoe)	Author's calculations
ETS auctioning revenue (robustness)	ETS	Revenues from the auctioning of EU ETS allowances, 2023	EUR million	European Environment Agency (2024)

Note: All source series are annual. LULUCF denotes land use, land-use change and forestry. Revenue from the auctioning of allowances under the European Emissions Trading System is included in energy taxes where the corresponding receipts are classified as tax revenue under the European System of Accounts (ESA 2010; Eurostat, 2024). Unit conversions do not affect the logarithmic decomposition. Sources: Eurostat, European Environment Agency and author's calculations.

The base year of 2010 was selected as the first year following the immediate effects of the global financial crisis, thereby providing a consistent post-crisis observation period. All series used are disseminated on a harmonised methodological basis, including ESA 2010 for the national accounts and SIEC for the energy balances. The final year of 2023 represents

the end of the pre-defined primary period for which full joint coverage of all series was available at the date of extraction.

To verify temporal robustness, the decomposition was replicated for the earlier period 1995–2008. This interval begins with the first year for which comparable data are available for the majority of countries and ends before the sharp contraction in economic activity and energy consumption in 2009. For Malta, the starting year is 2000 owing to the absence of earlier observations, meaning that the historical comparison does not constitute a fully balanced panel. No missing values were imputed or interpolated.

EU-27 level indicators were aggregated in a manner consistent with their economic interpretation. The shares of environmental and energy tax revenues in GDP were calculated as the ratio of the sum of national revenues to the sum of nominal GDP. Structural shares by tax category were obtained as the ratio of aggregated revenues for the relevant category to total aggregated environmental tax revenues. Aggregated energy intensity was calculated as the ratio of total final energy consumption to the sum of real GDP, and the real implicit rate as total nominal energy tax revenues divided by the aggregate GDP deflator and total final energy consumption. The aggregate deflator is the ratio of summed nominal GDP to summed real GDP. EU-27 emissions were obtained by summing national values. The average share of renewables and the average share of environmental taxes in total tax and social contribution revenues are presented as unweighted arithmetic means across the 27 Member States, since for these indicators it is the typical national position that is of interest rather than the aggregate for the Union as a whole. The aggregation method is indicated in each table and figure.

3.2. Construction of the Indicators

The descriptive analysis draws on three groups of indicators. The relative weight of environmental taxes is measured through their share in GDP and through the share in total tax and social contribution revenues, excluding imputed social contributions (PC_TSCO_X_ISCO), as published in env_ac_tax. The structure of revenues is represented by the share of each tax category—energy, transport, and pollution and resource taxes—in total environmental tax revenues:

$$ETR^{GDP}{}_{it} = 100 \times ETR_{it}/Y^{N}{}_{it} \quad (1)$$

$$S_{k\prime it} = 100 \times R_{k\prime it}/ETR_{it} \quad (2)$$

where ETR_{it} it denotes total environmental tax revenues for country i in year t, $R_{k\prime it}$ it denotes revenues from category k, and $S_{k\prime it}$ is the share of the corresponding category. Cross-country dispersion in the initial and final years is assessed through the range (minimum, maximum) and the coefficient of variation:

$$CV_t = s_t/\bar{x}_t \quad (3)$$

where s_t and $\bar{x}_t$ are the standard deviation and the unweighted mean of national values in year t. The coefficient of variation is calculated separately for the GDP-based indicator and for the indicator relative to total tax and social contribution revenues, since the choice of denominator may affect both the level and the direction of the measured differences.

The central indicators in the decomposition analysis are energy intensity and the implicit tax rate on energy. Energy intensity is defined as the ratio of final energy consumption to real GDP:

$$INT_{it} = E_{it}/Y^{R}{}_{it} \quad (4)$$

The indicator is expressed in kilograms of oil equivalent per 1000 euros at 2015 prices. The use of GDP in chain-linked volumes limits the influence of price changes, such that a decline in the indicator reflects changes in real energy consumption relative to real economic activity.

The nominal implicit tax rate is the ratio of energy tax revenues to final energy consumption:

$$ITR^{N}_{it} = R^{N}_{it}/E_{it} \quad (5)$$

The construction follows the logic of the Eurostat indicator for the implicit tax rate on energy, which relates energy tax revenues to final energy consumption (Eurostat, 2024). For the purposes of the present study, a real variant of the rate is constructed in which nominal revenues are deflated by the implicit GDP deflator:

$$ITR^{R}_{it} = (R^{N}_{it}/d_{it}) \; / \; E_{it}, \; d_{it} = D_{it}/100 = Y^{N}_{it}/Y^{R}_{it} \quad (6)$$

The use of the GDP deflator rather than the harmonised index of consumer prices is necessary for the precise alignment of the real implicit rate with energy intensity and with the share of revenues in nominal GDP (see Section 3.3). ITR^{R} should therefore be regarded as a real indicator constructed for the purposes of the study rather than as a direct reproduction of a published Eurostat series.

Two features of the implicit rate are material to the interpretation of the results. First, it is an effective rather than a statutory rate: the indicator summarises the outcome of various national excise duties, electricity taxes, carbon components, and revenues from emissions allowance auctions where these are statistically classified as tax receipts. Changes in the rate may consequently reflect movements in statutory rates as much as in exemptions, refunds, the structure of consumption, and tax collection performance. Second, the denominator encompasses total final energy consumption, including energy from renewable sources. Where renewable energy is untaxed or taxed less heavily than fossil fuels, a rising share of renewables can lower the measured rate even if statutory rates are unchanged. Section 4.7 tests this sensitivity using an approximation of non-renewable consumption. Final energy consumption serves as a proxy for the legal tax base. A decline in energy intensity need not imply a proportional decline in taxable energy use.

3.3. Decomposition Identity

The analytical framework is built around an accounting identity that separates the change in the share of energy tax revenues in GDP into an implicit rate effect and a tax base effect. Once the variables are expressed in comparable units of measurement, the following holds:

$$R^{N}_{it}/Y^{N}_{it} \equiv [(R^{N}_{it}/d_{it})/E_{it}] \times [E_{it}/Y^{R}_{it}] = ITR^{R}_{it} \times INT_{it} \quad (7)$$

The logarithmic change between the initial period t_0 and the terminal period t_1 therefore decomposes without residual into two additive components:

$$\Delta \ln(R^{N}/Y^{N}) = \Delta \ln ITR^{R} + \Delta \ln INT \quad (8)$$

The first term in Equation (8) is defined as the rate effect and the second as the base effect. The identity is exact because the deflator d enters both the real implicit rate and the real GDP used in the calculation of energy intensity, so that the price component cancels out.

Equation (8) is an accounting decomposition rather than an econometric estimate. It holds for every country and every period and requires no assumptions regarding functional form, exogeneity, or causal identification; no residual term exists, and the observed deviations from additivity in the tables presented do not exceed ± 0.001 logarithmic points, arising solely from rounding. For the EU-27, the two components are calculated from the aggregated numerators and denominators in the manner described in Section 3.1, rather than as unweighted means of national values, so that the size of each economy and its energy

consumption are accounted for implicitly. The decomposition compares two terminal years and therefore does not describe the trajectory between them; the annual dynamics of the two components are presented separately in the descriptive analysis.

3.4. Hypotheses and Evaluation Criteria

The decomposition permits the testing of two working hypotheses.

H1. *The decline in the share of energy tax revenues in EU-27 GDP is explained primarily by the negative base effect, manifested through the reduction in energy intensity. This dynamic is consistent with improvements in energy efficiency and with structural changes associated with the low-carbon transition, without implying an independent causal identification of the policy impact.*

H2. *Cross-country differences in the change in energy tax revenues are more strongly associated with the rate effect than with the base effect. The rate effect reflects the combined influence of national tax policy, tax exemptions and refunds, the structure of energy consumption, and tax collection performance.*

For periods in which the EU-27 revenue share falls, H1 is supported if the negative base effect is at least as large in absolute value as the total decline. H2 is supported if the rate effect has both a larger standard deviation across countries and a stronger correlation with the total change than the base effect.

Both hypotheses are evaluated descriptively. The correlations used for H2 are partly mechanical because the two effects sum to the total change. Sections 3.5 and 3.6 describe the auxiliary analyses and robustness checks.

3.5. Analytical Strategy

The empirical analysis is organised into six steps, corresponding to Sections 4.1–4.6. Section 4.7 reports the robustness checks.

First, descriptive analysis is used to examine the dynamics and structure of total environmental tax revenues and of their three components—energy taxes, transport taxes, and taxes on pollution and resources—over the period 2010–2023. The annual trajectories of revenues as a percentage of GDP and as a percentage of total revenues from taxes and social contributions are set against the trajectories of the share of renewables, energy intensity, and the real implicit rate, in order to delineate the paradox under investigation.

Second, cross-country differences are described through the values of the two revenue indicators in the initial and final years, through their change in percentage points, and through the range and the coefficient of variation given by Equation (3), calculated separately for 2010 and 2023. The comparison of the results across the two denominators also serves as a check on the sensitivity of the conclusions to the choice of indicator.

Third, the exact logarithmic decomposition given by Equation (8) is applied to each Member State individually and to the EU-27 aggregate.

Fourth, countries are classified by means of a two-dimensional typology according to the signs of $\Delta \ln \mathrm{ITR}^{\mathrm{R}}$ and $\Delta \ln \mathrm{INT}$. The four logically possible combinations form four quadrants: "effective transition" ($\Delta \ln \mathrm{ITR}^{\mathrm{R}} > 0; \Delta \ln \mathrm{INT} < 0$), "double erosion" ($\Delta \ln \mathrm{ITR}^{\mathrm{R}} \leq 0; \Delta \ln \mathrm{INT} < 0$), "passive revenues" ($\Delta \ln \mathrm{ITR}^{\mathrm{R}} \leq 0; \Delta \ln \mathrm{INT} \geq 0$), and "tax consolidation" ($\Delta \ln \mathrm{ITR}^{\mathrm{R}} > 0; \Delta \ln \mathrm{INT} \geq 0$). Zero values are assigned by convention to the quadrants with a non-positive rate effect and a non-negative base effect; exact zeros do not occur in the observed data, so the convention does not affect the results. The line

$$\Delta \ln \mathrm{ITR}^{\mathrm{R}} = -\Delta \ln \mathrm{INT} \tag{9}$$

separates observations with a rising share of revenues in GDP from those with a falling share. The typology is applied both to the principal period 2010–2023 and to the historical period 1995–2008. The historical replication serves two functions: it establishes whether the empty quadrants result from the construction of the classification or from structural change, and it permits the migration of countries between quadrants to be measured. The two periods are compared by the number of countries in each quadrant, by the mean values of the rate and base effects, and by the number of countries that change quadrant.

Fifth, the relationship between the components of the decomposition and the decarbonisation indicators is assessed through Pearson and Spearman correlation coefficients calculated across the cross-country changes between the initial and final years. Six prespecified pairs are considered: the total change in the share of energy tax revenues, the rate effect, and the base effect, each set separately against the change in the share of renewables in percentage points and the logarithmic change in greenhouse gas emissions. The statistical significance of the Pearson coefficients is assessed by means of a two-sided *t*-test:

$$t = r\sqrt{[(n-2)/(1-r^2)]} \quad (10)$$

With $n = 27$, the test uses 25 degrees of freedom; at a significance level of $\alpha = 0.05$, the critical value of $|r|$ is approximately 0.381. The Pearson coefficient measures linear association, whilst the Spearman coefficient examines the robustness of the results to rank transformation and to the influence of extreme observations. Given the small number of observations and the comparison between two terminal years, the correlation results are interpreted as associations rather than as causal effects. Pearson *p*-values are adjusted across six tests using Holm's (1979) procedure. The rate–renewables correlation is assessed using a bootstrap confidence interval (10,000 replications) and leave-one-out estimates. The association is also examined in a country-level regression controlling for real GDP growth and initial rate and intensity levels, and in the full panel with country and year fixed effects.

Sixth, as an auxiliary analysis, a two-way fixed-effects model is estimated on the full panel structure (378 observations):

$$\ln RR_{it} = \alpha_i + \lambda_t + \beta_1 \ln E_{it} + \beta_2 \ln Y^R{}_{it} + \beta_3 RES_{it} + \varepsilon_{it} \quad (11)$$

Here, $RR_{it} = R^N{}_{it}/d_{it}$ is real energy tax revenue, E_{it} is final energy consumption, $Y^R{}_{it}$ is real GDP, RES_{it} is the renewables share in percentage points, and α_i and λ_t are country and year fixed effects. Equation (11) avoids the shared GDP denominator in the original ratio specification. The coefficient β_1 measures the conditional elasticity of real revenue with respect to energy consumption, holding real GDP and the renewables share constant. Unit elasticity corresponds to proportional co-movement. An elasticity below one implies that the measured implicit rate moves inversely with energy use, conditional on the controls. Year effects absorb shocks common to all Member States. A first-difference specification examines year-to-year changes:

$$\Delta\ln RR_{it} = \lambda_t + \beta_1 \Delta\ln E_{it} + \beta_2 \Delta\ln Y^R{}_{it} + \beta_3 \Delta RES_{it} + u_{it} \quad (12)$$

The models use least squares with country and year indicators where applicable. Standard errors are clustered by country. Year effects absorb common shocks, and the 2010–2021 specification tests sensitivity to omitting 2022–2023. Driscoll–Kraay standard errors provide an inference check allowing for cross-sectional dependence (Driscoll & Kraay, 1998). Other checks lag the regressors by one year or exclude Ireland.

The regressions describe co-movement within countries. Taxation may influence energy use, and lagging the regressors does not rule out simultaneity or omitted-variable bias. The 95% confidence intervals show the range of elasticities compatible with the data. Given the descriptive aim and the short panel ($T = 14$), dynamic GMM is outside the scope of the analysis.

3.6. Robustness Checks

The decomposition is repeated for 2010–2019 and 2019–2023, and with Ireland excluded, both alone and together with Luxembourg and Malta. Variant B uses approximate non-renewable final energy consumption, $E^{n_r}{}_{it} = E_{it} \times (1 - RES_{it}/100)$. This proxy applies a renewables share measured against gross final consumption to final consumption. The rate is recalculated on the same basis, preserving identity (7). Variant C deducts Member States' reported 2023 EU ETS auction revenues (European Environment Agency, 2024) from energy tax receipts. Auction revenue in 2010 is set to zero as an approximation. Reported auction proceeds may differ from tax receipts recorded under ESA 2010, so the deduction is a sensitivity check. Variant D applies both adjustments.

3.7. Limitations of the Approach

The approach adopted has five limitations that it is appropriate to identify in advance. First, the decomposition compares two terminal years and is consequently sensitive to their selection; a replication for an independent earlier period is therefore provided, and the annual dynamics are presented descriptively. Second, the implicit rate is an effective rather than a statutory indicator, meaning that the rate effect combines discretionary rate policy, preferential arrangements, and collection performance, and does not permit these to be distinguished from one another. Third, the tax base is measured through final energy consumption, which is fuel-mix neutral; the compositional effect of the growing share of untaxed renewable energy manifests in the rate component rather than in the base component (its size is assessed in Section 4.7)—a circumstance that is material to the interpretation of the correlation analysis. Fourth, with n = 27, cross-country correlations have low statistical power, and borderline significant results are therefore presented as indications rather than established relationships. Fifth, the rate effect includes revenues from ETS allowance auctions, whose price is set by the market rather than by legislation; their role is assessed approximately in Section 4.7.

Data processing and calculations were carried out using Microsoft Excel 2016 and Python 3.14.6.

4. Results

4.1. Dynamics and Structure of Environmental Tax Revenues in the EU-27, 2010–2023

Environmental tax revenues in the EU-27 increased in nominal terms throughout the period under study—from 273.4 billion euros in 2010 to 356.0 billion euros in 2023, a rise of 30.2%. The erosion that is the subject of the present study is therefore not absolute but relative: measured against the economic and fiscal base from which they arise, these revenues have steadily lost weight.

The share of environmental taxes in EU-27 GDP follows a two-phase trajectory (Figure 1). During the first phase, under conditions of post-crisis fiscal consolidation, their relative weight rose from 2.47% of GDP in 2010 to a peak of 2.72% in 2014. This increase reflects both the discretionary excise rate increases introduced in a number of Member States and the subdued growth of the denominator during those years. From 2014 onwards the direction reversed durably and the share declined to 2.39% in 2021. The decline is not strictly monotonic: a brief recovery to 2.70% was observed in 2016, but this remained below the 2014 level and was not repeated in subsequent years. Measured against total tax and social contribution revenues (unweighted mean across Member States), the indicator peaked two years later—at 7.81% in 2016—before declining without interruption to 6.21% in 2023. The divergence in the peak year indicates that the choice of denominator affects the dating but not the direction of the identified trend.

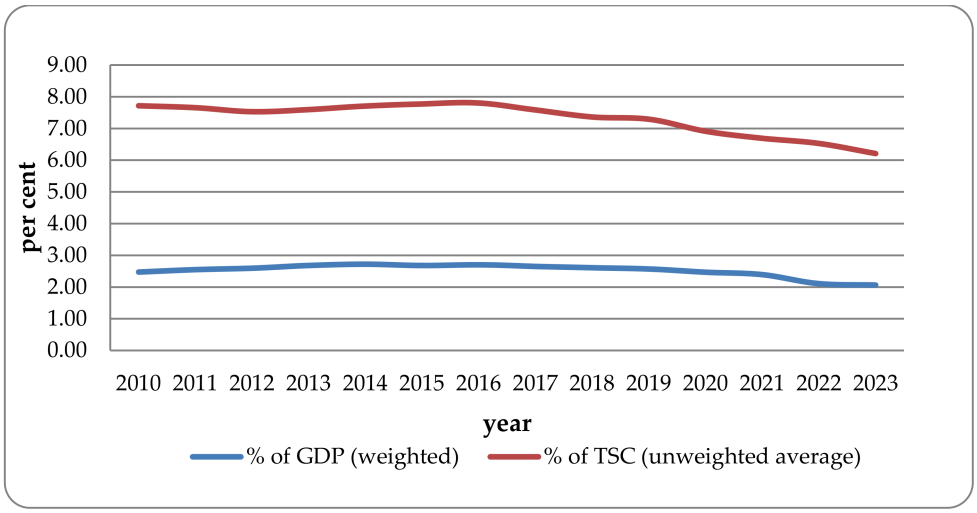


Figure 1. Environmental tax revenues in the EU-27, 2010–2023: % of GDP (weighted aggregate) and % of total revenues from taxes and social contributions excluding imputed social contributions (unweighted average across Member States). Source: own calculations based on Eurostat data (env_ac_tax, nama_10_gdp).

The environmental tax share began falling before the energy crisis. In 2022 it fell by 0.28 percentage points to 2.11% of GDP, its largest annual decline over the period. The fall coincided with high energy prices and temporary excise relief in several Member States. The panel estimates are checked against a sample ending in 2021 (Section 4.6). The share fell further to 2.06% in 2023, leaving a decline of 0.41 percentage points since 2010. The unweighted average share in total tax and social contribution revenues fell by 1.50 percentage points.

Placing this dynamic alongside indicators of the green transition reveals the essence of the paradox under investigation. Over the same period, the share of energy from renewable sources in gross final consumption (unweighted mean) rose from 16.4% to 27.3%, whilst the aggregated energy intensity of the EU-27 economy fell by one quarter—from 83.3 to 62.2 kg of oil equivalent per 1000 euros at 2015 prices. The measured base of the most significant category of environmental taxes is contracting systematically, in line with the objectives of energy and climate policy, although declining energy intensity also reflects structural change, productivity growth, and cyclical factors that are not directly related to that policy.

Base contraction does not in itself predetermine a decline in revenues: it could in principle be offset by a rising effective rate. The real implicit tax rate on energy has not, however, fulfilled this role. Having risen from 231 to 293 euros per tonne of oil equivalent at 2015 prices between 2010 and 2014, it remained at the level thus reached until 2019 (291.8 euros), before declining to 273 euros in 2021 and to 257 euros in 2022, recovering only partially to 259 euros in 2023. Relative to the 2014 peak, the real rate stood 11.4% lower at the end of the period, whilst energy intensity fell by 16.0% over the same interval. The two indicators consequently moved in the same direction throughout the second phase of the period. Part of the measured decline in the effective rate moreover reflects the change in the consumption structure itself: since the denominator encompasses total final energy consumption, the growing share of less heavily taxed renewable energy reduces the indicator even when statutory rates remain unchanged—a property examined in Sections 4.5 and 4.6. The quantitative separation of the contribution of the rate and base effects is the subject of the decomposition analysis in Section 4.3.

The structure of revenues by category is characterised simultaneously by high stability and marked concentration (Figure 2). Energy taxes—including revenues from allowance

auctions under the European Emissions Trading System—accounted for between 77.6% and 79.9% of total revenues throughout the period, standing at 78.3% in 2023. Transport taxes ranked second, with their share declining from 19.0% in 2010 to 16.9% in 2014 before stabilising at around 17%. Their slight increase to 17.6% in 2023 does not reflect an intensification of transport taxation but rather the contraction of the denominator: in absolute terms, revenues from transport taxes rose from 52.0 to 62.8 billion euros, that is to say more slowly than total environmental revenues up to 2019 and more rapidly than them after 2021. Pollution and resource taxes remained marginal—between 3.1% and 4.1%—but since 2020 their share has grown consecutively, and revenues from this category increased by 58.9% over the full period, an increase associated with the introduction of new instruments such as taxes on plastic packaging in a number of Member States.

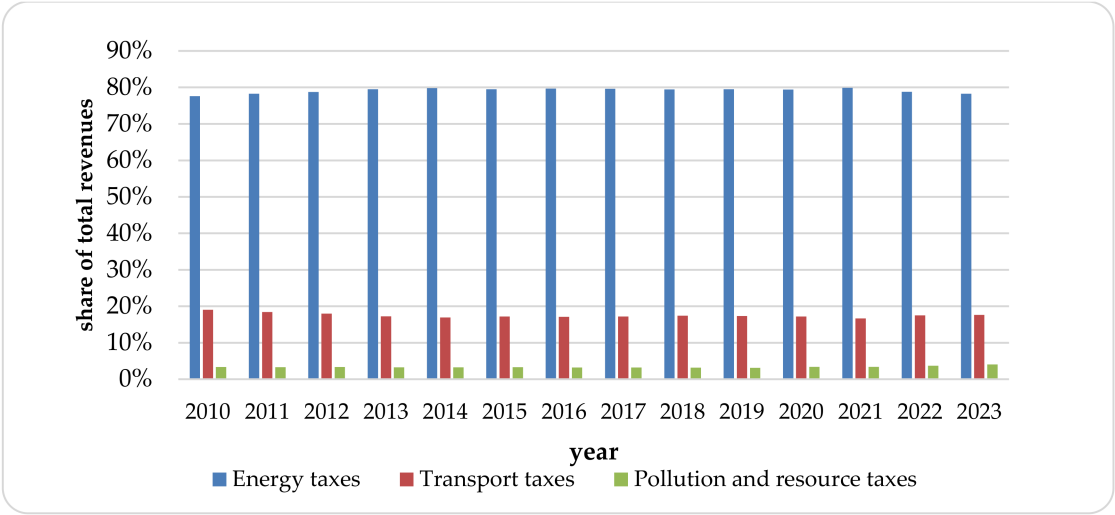


Figure 2. Structure of environmental tax revenues in the EU-27 by category (energy, transport, pollution and resources), 2010–2023, % of total environmental tax revenues. Source: own calculations based on Eurostat data (env_ac_tax).

This structure has a direct bearing on revenue sustainability. The concentration of nearly four fifths of the base on energy consumption means that the fiscal fortunes of environmental taxation in the EU are almost entirely tied to the trajectory of fossil fuel consumption. The stability of structural shares throughout the period indicates that the expansion of pollution and resource taxes, although accelerating in recent years, remains far too limited in scale to offset the erosion of the energy base.

4.2. Differences Among Member States

Behind the aggregate declining trajectory lie deep and, more significantly, widening differences among Member States (Table 2). In 2010, the relative weight of environmental taxes ranged from 1.64% of GDP in Spain to 4.01% in Denmark, and from 4.23% of total tax and social contribution revenues in France to 10.81% in Bulgaria. By 2023, the range had not narrowed but widened: from 0.94% of GDP in Ireland to 4.12% in Greece, and from 2.99% of total tax revenues in Luxembourg to 11.21% in Bulgaria. The spread between the extreme values increased from 2.37 to 3.18 percentage points for the GDP-based indicator and from 6.58 to 8.22 percentage points for the indicator relative to total tax revenues, whilst the coefficient of variation per Equation (3) rose from 0.23 to 0.32 and from 0.24 to 0.34, respectively. Both indicators point to divergence rather than convergence: the overall erosion is proceeding at sufficiently different rates that the distances between national tax systems are increasing.

Table 2. Environmental tax revenues by Member State, 2010 and 2023.

Code	Member State	% of GDP, 2010	% of GDP, 2023	Δ, pp	% of TSC, 2010	% of TSC, 2023	Δ, pp
BE	Belgium	2.43	2.30	−0.13	5.28	5.19	−0.09
BG	Bulgaria	2.75	3.36	0.61	10.81	11.21	0.40
CZ	Czechia	2.24	1.55	−0.69	6.89	4.58	−2.31
DK	Denmark	4.01	2.07	−1.94	8.67	4.63	−4.04
DE	Germany	2.44	1.68	−0.76	6.37	4.19	−2.18
EE	Estonia	3.29	2.59	−0.70	9.92	7.64	−2.28
IE	Ireland	2.45	0.94	−1.51	8.62	4.25	−4.37
EL	Greece	2.67	4.12	1.45	7.73	10.15	2.42
ES	Spain	1.64	1.54	−0.10	5.11	4.14	−0.97
FR	France	1.87	1.81	−0.06	4.23	3.98	−0.25
HR	Croatia	3.81	3.30	−0.51	10.48	8.95	−1.53
IT	Italy	2.92	2.53	−0.39	7.03	6.12	−0.91
CY	Cyprus	3.02	2.07	−0.95	8.93	5.51	−3.42
LV	Latvia	3.02	2.40	−0.62	10.38	7.28	−3.10
LT	Lithuania	1.85	1.67	−0.18	6.35	5.18	−1.17
LU	Luxembourg	2.26	1.24	−1.02	6.10	2.99	−3.11
HU	Hungary	2.64	2.18	−0.46	7.15	6.22	−0.93
MT	Malta	2.78	1.49	−1.29	8.69	5.57	−3.12
NL	Netherlands	3.83	2.87	−0.96	10.43	7.23	−3.20
AT	Austria	2.40	2.00	−0.40	5.69	4.64	−1.05
PL	Poland	2.72	3.42	0.70	8.41	9.53	1.12
PT	Portugal	2.42	1.99	−0.43	7.20	5.35	−1.85
RO	Romania	2.07	2.59	0.52	7.79	9.41	1.62
SI	Slovenia	3.90	2.80	−1.10	10.03	7.61	−2.42
SK	Slovakia	2.07	2.16	0.09	7.34	6.10	−1.24
FI	Finland	2.67	2.26	−0.41	6.55	5.29	−1.26
SE	Sweden	2.68	2.03	−0.65	6.14	4.77	−1.37
	EU-27 (weighted aggregate)	2.47	2.06	−0.41	–	–	–
	EU-27 (unweighted average)	2.70	2.26	−0.44	7.72	6.21	−1.50

Note: TSC denotes total revenues from taxes and social contributions, excluding imputed social contributions (Eurostat unit PC_TSCO_X_ISCO); Δ is the change in percentage points between 2010 and 2023. The weighted EU-27 aggregate is the sum of national revenues over the sum of nominal GDP; the unweighted average is the arithmetic mean across the 27 Member States and is the basis of the TSC series reported in Section 4.1. Member States are listed in EU protocol order. Source: own calculations based on Eurostat data (env_ac_tax, nama_10_gdp).

It is, however, important to clarify in what sense revenues are declining. In 26 of the 27 Member States, environmental tax revenues increased in nominal terms between 2010 and 2023, and the decline in the relative indicators reflects the fact that nominal GDP and total tax revenues grew more rapidly. The sole exception is Denmark, where revenues fell in absolute terms as well—from 9.8 to 7.7 billion euros, a decline of 20.8%, against nominal GDP growth of 53.7%. The erosion of the environmental tax base in the Union is therefore primarily relative: it manifests as a lag of revenues behind the expanding economic and fiscal base rather than as their outright contraction. This qualification is material to the interpretation, since relative erosion is compatible with rising nominal receipts and therefore tends to go politically unnoticed for a prolonged period.

The decline encompasses the great majority of the Union—22 of the 27 Member States on the GDP-based indicator and 23 on the indicator relative to total tax revenues—and is most pronounced in a group of high-income Western and Northern European economies. The largest decline relative to GDP is observed in Ireland (from 2.45% to 0.94%, the only

value below one per cent in the Union), followed by Denmark (from 4.01% to 2.07%) and Malta (from 2.78% to 1.49%); declines exceeding three percentage points relative to total tax revenues are also recorded in Cyprus, the Netherlands, Malta, Luxembourg, and Latvia. The Irish case requires an explicit qualification, however. Environmental tax revenues there increased from 4.1 to 4.9 billion euros, whilst nominal GDP more than tripled, with a substantial portion of this growth concentrated in the one-off revision of the national accounts in 2015 associated with the transfer of multinational enterprise assets. The Irish terminal value therefore predominantly reflects the behaviour of the denominator and should be interpreted with particular caution. A similar, though less pronounced, situation applies to Malta and Luxembourg, where nominal GDP grew by 205% and 94%, respectively, against virtually unchanged revenues. Without Ireland, the aggregate environmental tax share falls from 2.47% to 2.10% of GDP. The coefficient of variation in national tax-to-GDP ratios still rises, from 0.24 to 0.30 without Ireland and from 0.24 to 0.27 when Luxembourg and Malta are also excluded (see Section 4.7 for the energy tax decomposition).

At the opposite pole, a compact group of four countries stands out in which the share of environmental taxes in total tax revenues increased: Greece (+2.42 percentage points), Romania (+1.62), Poland (+1.12), and Bulgaria (+0.40). The Greek case is the most conspicuous on both indicators—rising from 2.67% to 4.12% of GDP, the highest value in the Union in 2023; revenues grew by 54.9% against a virtually unchanged nominal GDP over the period, reflecting the series of energy excise increases undertaken as part of the fiscal consolidation programmes. Bulgaria's position is structurally distinctive: the country ranks first in the fiscal significance of environmental taxes at both terminal points of the period, with these taxes accounting for 11.21% of total tax and social contribution revenues in 2023—the highest degree of dependence on this revenue source in the Union. The composition of the group depends in part on the indicator chosen: measured relative to GDP, Slovakia also records a slight increase (+0.09 percentage points), which becomes a decline of 1.24 points relative to total tax revenues owing to the faster growth of the overall tax burden—an illustration of the importance of the denominator in comparisons of this kind.

The heterogeneity identified has a direct analytical implication. The contraction of the energy base is a pan-European process, as shown in Section 4.1. Such divergent national outcomes can, however, only arise if Member States also differ substantially in the second component of revenues—the real level of effective tax rates. Descriptive comparison alone does not permit the two sources of difference to be distinguished, and the ranking by size of decline does not necessarily coincide with the ranking by mechanism: Ireland and Denmark occupy adjacent positions near the top of the table but, as the following section demonstrates, arrive there by different paths. The quantitative separation of the contribution of the rate and base effects for each country individually is the task of the decomposition analysis in Section 4.3.

4.3. Decomposition of the Change: Rate Effect Versus Base Effect

The central question of the study—whether the decline in revenues reflects a policy success or an erosion of taxation—receives a quantitative answer through the decomposition introduced in Section 3.3. Since energy tax revenues as a share of GDP are by construction equal to the product of the real implicit tax rate and the energy intensity of the economy, their change in logarithmic terms decomposes without residual into two additive components in accordance with Equation (8). The first measures the rate effect—the extent to which the real taxation of each unit of energy consumed has changed; the second measures the base effect—the extent to which the energy content of economic activity has contracted. It should be emphasised that this is an accounting identity rather than an econometric estimate: the

decomposition is exact for every country and rests on no assumptions regarding functional form, but for that same reason establishes no causal relationship.

Energy tax revenues in the EU-27 fell from 1.92% to 1.61% of GDP, a decline of 17.4 log-points (Table 3). The base effect was −29.1 log-points, partly offset by an 11.7-log-point increase in the real implicit rate. This meets the accounting criterion for H1 in Section 3.4.

Table 3. Decomposition of the change in energy tax revenues (% of GDP), 2010–2023.

Code	Member State	Energy Taxes, % of GDP, 2010	Energy Taxes, % of GDP, 2023	Δln Total	Δln Real ITR (Rate Effect)	Δln Intensity (Base Effect)
BE	Belgium	1.55	1.65	0.062	0.419	−0.357
BG	Bulgaria	2.42	3.09	0.246	0.429	−0.184
CZ	Czechia	2.08	1.53	−0.309	−0.017	−0.292
DK	Denmark	2.36	1.08	−0.779	−0.431	−0.348
DE	Germany	2.12	1.42	−0.402	−0.083	−0.319
EE	Estonia	2.94	2.43	−0.191	0.270	−0.461
IE	Ireland	1.51	0.58	−0.952	−0.089	−0.863
EL	Greece	1.99	3.36	0.522	0.633	−0.111
ES	Spain	1.34	1.18	−0.123	0.110	−0.233
FR	France	1.48	1.45	−0.019	0.258	−0.278
HR	Croatia	2.14	2.06	−0.041	0.246	−0.287
IT	Italy	2.34	1.98	−0.168	0.035	−0.203
CY	Cyprus	1.81	1.48	−0.197	0.168	−0.365
LV	Latvia	2.60	1.92	−0.304	0.085	−0.389
LT	Lithuania	1.78	1.37	−0.265	0.091	−0.356
LU	Luxembourg	2.09	1.14	−0.604	−0.054	−0.550
HU	Hungary	2.08	1.69	−0.205	0.146	−0.351
MT	Malta	1.35	0.72	−0.626	−0.230	−0.397
NL	Netherlands	2.23	1.65	−0.301	0.193	−0.494
AT	Austria	1.61	1.22	−0.282	−0.052	−0.231
PL	Poland	2.29	3.16	0.322	0.703	−0.381
PT	Portugal	1.77	1.47	−0.185	−0.007	−0.177
RO	Romania	1.74	2.46	0.343	0.703	−0.360
SI	Slovenia	3.33	2.39	−0.334	0.041	−0.374
SK	Slovakia	1.79	1.98	0.100	0.578	−0.478
FI	Finland	1.71	1.71	−0.002	0.185	−0.187
SE	Sweden	2.18	1.59	−0.315	−0.046	−0.270
	EU-27 (weighted aggregate)	1.92	1.61	−0.174	0.117	−0.291

Note: Δln is the change in the natural logarithm between 2010 and 2023. By construction, Δln total = Δln real ITR + Δln intensity (Equation (8)); reported figures may differ by ±0.001 owing to rounding. The real implicit tax rate on energy is deflated by the GDP deflator (2015 = 100). The EU-27 row is a weighted aggregate: the sum of national energy tax revenues over the sum of nominal GDP, with the aggregate rate and intensity constructed as described in Section 3.2. Member States are listed in EU protocol order. Source: own calculations based on Eurostat data (env_ac_tax, nrg_bal_c, nama_10_gdp).

Viewed by country, the base effect is notable above all for its universality: it is negative in all 27 Member States without exception—ranging from −0.111 in Greece to −0.863 in Ireland (Figure 3). There is not a single economy in the Union whose energy intensity did not decline over the period; base contraction is a pan-European fact rather than a characteristic of individual frontrunners. The Irish case illustrates the extreme form of this process: of the total decline there of −0.952, fully 90.6% is attributable to the base component. As noted in Section 4.2, however, Irish energy intensity is calculated relative to a real GDP heavily influenced by multinational enterprise activity, so this value also

reflects a denominator effect rather than real energy transformation alone. Finland offers the mirror-image illustration: a base contraction of −0.187 is almost entirely neutralised by an increase in the real rate of +0.185, leaving the share of energy taxes in GDP virtually unchanged (−0.002).

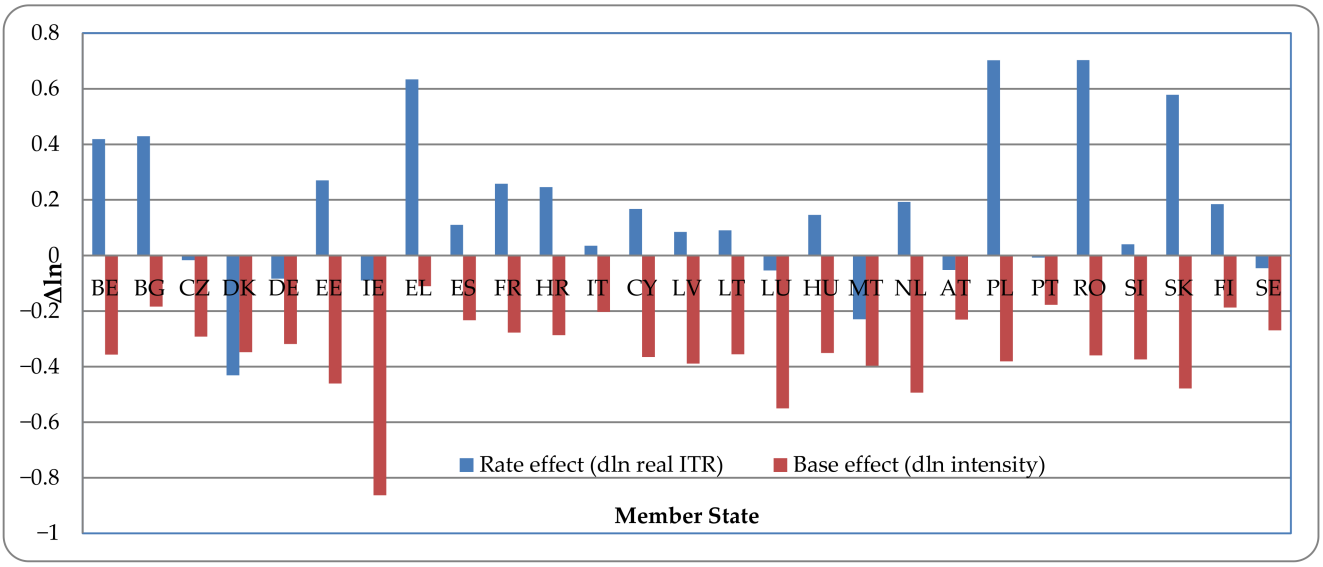


Figure 3. Decomposition of the change in energy tax revenues by Member State, 2010–2023: rate effect (Δln real implicit tax rate) and base effect (Δln energy intensity). Member States are shown in EU protocol order. Source: own calculations based on Eurostat data (env_ac_tax, nrg_bal_c, nama_10_gdp).

The real implicit rate rose in 18 countries, most markedly in Romania and Poland (+0.703 each), Greece (+0.633), Slovakia (+0.578) and Bulgaria (+0.429). The measured increases in Bulgaria and Poland are sensitive to the inclusion of EU ETS auction revenues (Section 4.7). In seven of the nine countries with a falling real implicit rate, the decline was below 9 log-points. The largest declines were in Malta (−0.230) and Denmark (−0.431). Denmark was the only Member State where the negative rate effect exceeded the negative base effect (−0.348) in magnitude.

The two effects also differ substantially in their cross-country variability, permitting hypothesis H2 to be tested against the criteria set out in Section 3.4. The standard deviation of the rate effect across the 27 countries is 0.279 against 0.148 for the base effect—almost twice as large—whilst its range is 1.13 against 0.75 in log units. At the same time, the rate effect is considerably more strongly associated with the total change in the share of energy tax revenues ($r = 0.90$) than is the base effect ($r = 0.57$). Since the correlation between the two effects is weak ($r = 0.15$), the variance of the total change is distributed as follows: 69.4% is attributable to the variance of the rate effect, 19.5% to the base effect, and 11.1% to their covariance. The variance shares describe how the components contribute to dispersion. The rate component also captures the energy mix and auction revenues. Both descriptive criteria for H2 are met.

Base contraction accounts for the aggregate decline, while the rate component accounts for most of the differences in national outcomes. The following section groups countries by the signs of the two components.

4.4. Typology of Member States

The two components of the decomposition form a natural coordinate system within which each Member State can be positioned unambiguously (Figure 4, Panel A). The

horizontal axis plots the base effect (Δln of energy intensity) and the vertical axis the rate effect (Δln of the real implicit rate) for the period 2010–2023. The four quadrants delineated by the axes correspond to four qualitatively distinct regimes: "effective transition" (rising real rate alongside a contracting base), "double erosion" (simultaneous weakening of both the rate and the base), "passive revenues" (an expanding base compensating for an eroding rate), and "fiscal consolidation" (simultaneous growth of both components). The diagonal of Equation (9) further divides the space into a zone of rising and a zone of declining revenues: countries above it increase the share of energy taxes in GDP regardless of the quadrant in which they fall.

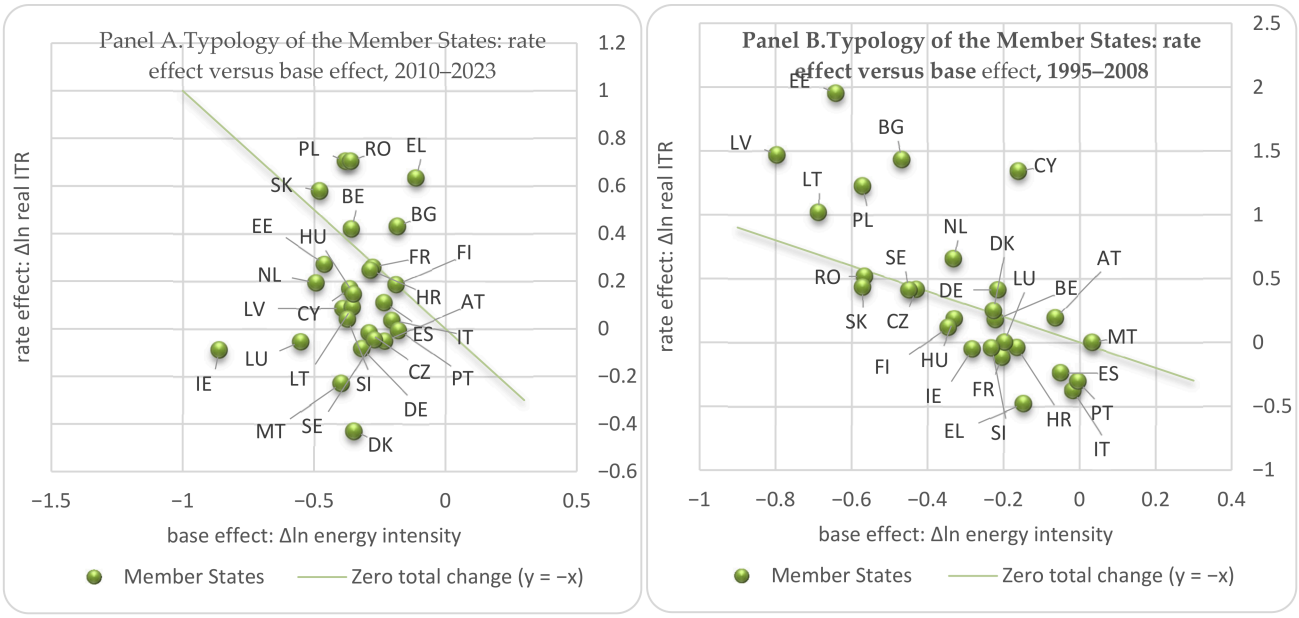


Figure 4. Typology of the Member States: rate effect versus base effect. Panel (**A**) 2010–2023; Panel (**B**) 1995–2008 (Malta: 2000–2008). The dashed diagonal marks zero total change in the share of energy tax revenues in GDP. Source: own calculations based on Eurostat data (env_ac_tax, nrg_bal_c, nama_10_gdp).

All 27 Member States had declining energy intensity in 2010–2023 (Table 4). The 18 with a rising real implicit rate fall in Quadrant I. The nine with a falling rate fall in Quadrant II. Quadrants III and IV are empty.

Seven of the nine countries in Quadrant II are EU-15 members (Austria, Germany, Denmark, Ireland, Luxembourg, Portugal and Sweden), joined by Czechia and Malta. Both countries that joined in 2007 and eight of the ten that joined in 2004 fall in Quadrant I. EU minimum excise rates may help explain this pattern, but the decomposition does not identify their effect.

Within Quadrant I, the zero-change diagonal demarcates two sub-groups. Six countries—Greece, Romania, Poland, Bulgaria, Slovakia, and Belgium—lie above it: in these cases the increase in the real rate does not merely attenuate but more than offsets base contraction, so that the share of energy taxes in GDP increases. Finland lies virtually on the diagonal itself (total change of −0.002), whilst the remaining eleven countries in the quadrant achieve only partial compensation. Bulgaria's position is instructive: the country combines the third weakest base effect in the Union (−0.184, after Greece and Portugal)—reflecting its still high energy intensity and the slower pace at which it is declining—with the fifth strongest increase in the real rate (+0.429). Under the approximate EU ETS adjustment, Bulgaria's rate effect turns slightly negative (−0.08; Section 4.7). Auction proceeds were equivalent to about two fifths of its recorded energy tax revenues in 2023.

Table 4. Typology of the Member States by the sign of the two effects: 2010–2023 and comparison with 1995–2008.

Quadrant	Condition	Interpretation	Member States, 2010–2023	Count 2010–2023	Count 1995–2008
I—effective transition	Δln ITR > 0; Δln int. < 0	Contracting base, fully or partially offset by a rising real rate	BE, BG, CY, EE, EL, ES, FI, FR, HR, HU, IT, LT, LV, NL, PL, RO, SI, SK	18	18
II—double erosion	Δln ITR ≤ 0; Δln int. < 0	Contracting base accompanied by erosion of the real rate	AT, CZ, DE, DK, IE, LU, MT, PT, SE	9	8
III—passive revenues	Δln ITR ≤ 0; Δln int. ≥ 0	Expanding energy base under an eroding rate	–	0	1
IV—tax consolidation	Δln ITR > 0; Δln int. ≥ 0	Expanding base and rising real rate	–	0	0

Note: ITR denotes the real implicit tax rate on energy; int. denotes energy intensity. The classification for 2010–2023 is based on the decomposition in Table 3; that for 1995–2008 on an identical decomposition applied to the earlier period (for Malta, 2000–2008). Both intervals span thirteen years. Between the two periods, 13 of the 27 Member States change quadrant. Source: own calculations based on Eurostat data (env_ac_tax, nrg_bal_c, nama_10_gdp).

The robustness of the typology is directly testable. If Quadrants III and IV are empty by construction, the classification would be tautological; if they have become empty over time, however, it measures a genuine structural change. To this end, the decomposition is replicated for the earlier period 1995–2008—from the start of the available data to the pre-crisis peak in energy consumption (Figure 4, Panel B; for Malta the starting year is 2000 owing to the absence of earlier data). The two intervals are of equal length—thirteen years—making them directly comparable. The results reject tautology: Quadrant III is populated by Malta, whose energy intensity increased during the earlier period. The base effect, whilst again negative for 26 of the 27 countries, proves to be a long-standing characteristic of European economies: energy intensity declined at a similar average rate even during the years of rising absolute consumption (on average −0.31 log units against −0.34 over 2010–2023), since GDP outpaced energy use. What distinguishes the two periods is not the base but the rate: the mean rate effect contracted by more than half—from +0.39 to +0.16 in log units—and the number of countries with a rising share of energy taxes in GDP fell from 11 to 6.

Still more telling is the instability of quadrant membership itself: between the two periods, 13 of the 27 countries changed quadrant. Six economies—Austria, Germany, Denmark, Luxembourg, Czechia, and Sweden—moved from Quadrant I to Quadrant II; Germany, for example, recorded a rate effect of +0.41 during 1995–2008, the period of the ecological tax reform of 1999–2003, against −0.08 after 2010. Malta also ended up in Quadrant II but arrived from Quadrant III: its rate effect was negative in both periods, and the change arose from the reversal of its energy intensity. Moving in the opposite direction were six Southern and South-Eastern European countries—Greece, Spain, France, Croatia,

Italy, and Slovenia—in which the pre-2008 erosion was replaced by consolidation-driven increases in taxation. This migration demonstrates that the typology does not label enduring "country types" but describes tax policy regimes that change over time in step with episodes of national fiscal policy. The similar aggregate counts across the two periods conceal an almost complete recomposition of the groups, which the matrix makes visible.

4.5. Relationship with Decarbonisation Indicators

The correlation analysis compares changes in the decomposition components with changes in the renewables share and greenhouse gas emissions across the 27 Member States (Table 5). Between 2010 and 2023 the average renewables share rose from 16.4% to 27.3%, and aggregate EU-27 emissions fell by 25.9%.

Table 5. Correlations between the decomposition effects and decarbonisation indicators (n = 27).

Variable Pair (Changes 2010→2023)	Pearson r	t-Statistic	Spearman ρ	*p*-Value	Holm-Adjusted *p*
Δln intensity ~ Δ share of RES	0.072	0.36	0.045	0.721	1.000
Δln intensity ~ Δln GHG emissions	−0.183	−0.93	−0.167	0.361	1.000
Δln energy tax revenues (% of GDP) ~ Δ share of RES	−0.290	−1.52	−0.308	0.142	0.709
Δln energy tax revenues (% of GDP) ~ Δln GHG emissions	0.017	0.08	0.113	0.933	1.000
Δln real ITR ~ Δ share of RES	−0.387 *	−2.10	−0.305	0.046	0.277
Δln real ITR ~ Δln GHG emissions	0.118	0.59	0.132	0.559	1.000

Note: * indicates an unadjusted Pearson *p*-value below 0.05. All variables are changes between 2010 and 2023. RES denotes the share of energy from renewable sources in gross final energy consumption; GHG denotes greenhouse gases. ITR denotes the real implicit tax rate on energy. The *p*-value is the two-sided *p*-value of the Pearson coefficient; the Holm-adjusted *p*-value corrects for the six pairs tested (Holm, 1979). None of the six Pearson coefficients is significant at $\alpha = 0.05$ after adjustment. Source: own calculations based on Eurostat data (env_ac_tax, nrg_bal_c, nrg_ind_ren, env_air_gge, nama_10_gdp).

The base effect is weakly correlated with changes in the renewables share ($r = 0.072$) and emissions ($r = -0.183$). The total change in the energy tax share is also weakly correlated with these indicators ($r = -0.290$ and 0.017, respectively).

The correlation between the change in the real implicit rate and the change in the renewables share is the only Pearson coefficient with an unadjusted *p*-value below 0.05 ($r = -0.387$, $p = 0.046$). It is consistent with a composition effect because the implicit rate uses total final energy consumption, including renewable energy that may be untaxed or taxed less heavily.

With 27 countries and six comparisons, evidence for this association is weak. The Spearman coefficient is −0.305, and none of the Pearson correlations is statistically significant after Holm adjustment (Table 5).

For the rate–renewables correlation, the adjusted *p*-value is 0.277, the bootstrap 95% interval is [−0.68, 0.04], and leave-one-out estimates range from −0.48 to −0.25. The renewables coefficient is imprecisely estimated in the country-level regression (−0.010, $p = 0.18$) and the panel regression (−0.014, $p = 0.15$). In the country-level regression, the initial rate is negatively associated with its subsequent change (−0.41, $p = 0.012$). The initial rate also enters the calculation of that change, which limits a convergence interpretation. Using the non-renewable denominator reduces the correlation to −0.07, underscoring its sensitivity to the rate definition.

4.6. Auxiliary Panel Regressions

Table 6 reports the auxiliary panel regressions. The baseline uses 378 observations across 27 countries and 14 years. The first-difference model uses 351 observations.

Table 6. Auxiliary fixed-effects panel regressions; dependent variable: ln(real energy tax revenues), unless stated otherwise.

Regressor	(1) Ratio Specification (First Version)	(2) Two-Way FE	(3) Lagged Regressors	(4) 2010–2021	(5) Excluding Ireland	(6) First Differences
ln(energy intensity)	1.187 *** (0.233)	–	–	–	–	–
ln(final energy consumption)	–	0.827 ** (0.303)	0.863 * (0.356)	0.621 (0.321)	0.610 (0.369)	0.219 (0.164)
ln(real GDP)	–	−0.208 (0.222)	−0.208 (0.226)	−0.152 (0.178)	0.077 (0.377)	−0.036 (0.142)
Share of RES, pp	−0.013 (0.009)	−0.014 (0.009)	−0.014 (0.010)	−0.009 (0.008)	−0.015 (0.009)	−0.004 (0.004)
95% CI of the energy elasticity	[0.73; 1.64]	[0.23; 1.42]	[0.17; 1.56]	[−0.01; 1.25]	[−0.11; 1.33]	[−0.10; 0.54]
t-test H0: elasticity = 1	0.80	−0.57	−0.38	−1.18	−1.06	−4.77
R^2 (within)	0.265	0.127	0.117	0.094	0.131	0.009
Robust F-statistic (p)	13.66 (0.000)	2.87 (0.037)	2.17 (0.091)	1.57 (0.197)	2.21 (0.087)	1.15 (0.330)
Country fixed effects	yes	yes	yes	yes	yes	differenced out
Year fixed effects	yes	yes	yes	yes	yes	yes
Countries	27	27	27	27	26	27
Observations	378	378	351	324	364	351

Note: Standard errors clustered by country are reported in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Dependent variable: column (1), ln(energy tax revenues, % of GDP); columns (2)–(5), ln(real energy tax revenues); column (6), Δln(real energy tax revenues). In column (3) all regressors are lagged by one year. Column (1) reproduces the specification of the first version of the manuscript and is shown for comparison only. R^2 (within) refers to the model after removal of the fixed effects. With Driscoll–Kraay standard errors, column (2) yields an elasticity of 0.827 (0.122) and a coefficient on the renewables share of −0.014 (0.003). Source: own calculations based on Eurostat data (env_ac_tax, nrg_bal_c, nrg_ind_ren, nama_10_gdp).

In the baseline model (column 2), the estimated elasticity of real energy tax revenues with respect to energy consumption is 0.83 ($p = 0.007$, 95% CI 0.23 to 1.42). The estimate is similar with lagged regressors (0.86), but smaller and imprecise without 2022–2023 (0.62) or without Ireland (0.61). In first differences, the estimate is 0.22 (95% CI −0.10 to 0.54), below unit elasticity. Column 1 retains the original ratio specification for comparison. Its common GDP denominator limits interpretation.

The level estimates leave the degree of rate compensation imprecisely determined. Using Driscoll–Kraay standard errors narrows the baseline elasticity interval to 0.59–1.07. The renewables coefficient is significant with these standard errors (−0.014, $p < 0.001$), but imprecise with country-clustered errors.

4.7. Robustness: Sub-Periods, Outliers, the Measurement of the Base, and ETS Revenues

During 2010–2019 the EU-27 energy tax share increased by 6.2 log-points, as the rate effect (+23.5) outweighed the base effect (−17.3) (Table 7). The whole net decrease was concentrated in 2019–2023 (−23.6 log-points), when the rate and the base each contributed −11.8 log-points. The base effect was negative in every country in both periods. Both H2 criteria were satisfied in each period. H1 is upheld for the full period, while the base explains half of the decline in 2019–2023.

Table 7. Robustness checks for the rate and base effects.

Specification	EU-27 Δln Total	EU-27 Rate Effect	EU-27 Base Effect	SD Rate	SD Base	r (Rate, Total)	r (Base, Total)	Rate Share (%)	Counts I/II	H1	H2
Baseline, 2010–2023	−0.174	0.117	−0.291	0.279	0.148	0.90	0.57	69.4	18/9	yes	yes
Sub-period 2010–2019	0.062	0.235	−0.173	0.175	0.105	0.88	0.61	64.2	23/4	n.a. (rise)	yes
Sub-period 2019–2023	−0.236	−0.118	−0.118	0.199	0.063	0.95	0.28	92.4	8/19	no (50%)	yes
Excluding Ireland	−0.157	0.119	−0.276	0.279	0.107	0.94	0.39	85.0	18/8	yes	yes
Excluding Ireland, Luxembourg, Malta	−0.155	0.120	−0.275	0.274	0.100	0.94	0.26	94.0	18/6	yes	yes
B: non-renewable energy base	−0.174	0.244	−0.418	0.260	0.163	0.88	0.65	60.6	25/2	yes	yes
C: excluding ETS auction revenues	−0.299	−0.008	−0.291	0.279	0.148	0.89	0.51	74.1	10/17	no (97%)	yes
D: B and C combined	−0.299	0.119	−0.418	0.261	0.163	0.87	0.60	64.7	20/7	yes	yes

Note: EU-27 values are weighted aggregates (Section 3.1); SD and correlations are computed across Member States (n = 27, 26, or 24). The variance share is the variance of the rate effect divided by the variance of the total change; the remainder is attributable to the base effect and the covariance. Quadrant counts refer to Quadrant I (effective transition) and Quadrant II (double erosion); Quadrants III and IV are empty in all specifications. H1 applies when the revenue share falls and requires the negative base effect to be at least as large in absolute value as the decline. Parentheses show the percentage of the decline accounted for by the base. H2: greater dispersion of the rate effect and stronger correlation with the total change. Variant B measures the base by E × (1 − RES/100); variant C deducts 2023 ETS auctioning revenues by Member State (European Environment Agency, 2024) from energy tax revenues. Source: own calculations based on Eurostat data (env_ac_tax, nrg_bal_c, nrg_ind_ren, nama_10_gdp) and EEA data.

Leaving out Ireland keeps the aggregate pattern largely unchanged (total −15.7, rate +11.9 and base −27.6 log-points). The rate share of cross-country variance climbs from 69.4% to 85.0%, and to 94.0% when Luxembourg and Malta are also left out.

Under the approximate non-renewable denominator (variant B), the EU-27 base effect is −41.8 log-points and the rate effect is +24.4. Seven countries shift from double erosion to Quadrant I (Czechia, Germany, Ireland, Luxembourg, Austria, Portugal and Sweden). Denmark and Malta stay in double erosion, and Finland remains in Quadrant I with a larger positive rate effect.

Reported EU ETS auction proceeds in 2023 came to roughly EUR 33 billion, equal to 11.8% of recorded EU-27 energy tax revenues. Deducting them under variant C brings the aggregate rate effect down to −0.8 log-points and raises the total decline to −29.9. The base explains 97% of that decline, below the strict H1 threshold. Seventeen countries are classified in double erosion. With both adjustments (variant D), 20 countries fall in Quadrant I and seven in Quadrant II, compared with 18 and nine in the baseline.

H2 is upheld across the robustness checks. For 2010–2023 the base is the largest contributor to the aggregate decline under every variant, although H1's strict threshold is missed under variant C. Individual country classifications are sensitive to how the rate and base are defined (Table A1).

5. Discussion

At EU level, the drop in the energy tax share over 2010–2023 is attributable to declining energy intensity. The net decrease was concentrated in 2019–2023, when the real implicit rate and energy intensity made equal contributions. Lower energy intensity may mirror efficiency improvements, structural shifts, productivity gains and cyclical influences. Earlier studies associate energy taxes and carbon pricing with reduced emissions (Sen & Vollebergh, 2018; Best et al., 2020). The decomposition tackles a separate question by measuring how much energy intensity contributes to revenue changes.

Between countries, the rate component explains more of the variance than the base component. It reflects statutory tax changes, exemptions, collection, the energy mix and auction revenues. Approximating the deduction of EU ETS proceeds leaves the aggregate real rate effect close to zero, which shows how heavily the choice of numerator shapes its interpretation.

The relative character of the identified erosion is also material. In almost all countries, nominal environmental tax revenues increased between the initial and final year but lagged behind the growth of GDP and total tax revenues. This explains why the process may go politically unnoticed for a prolonged period: budgetary receipts increase in nominal terms whilst the significance of environmental taxes in the revenue system gradually diminishes. The result confirms the conclusion of Filipović and Golušin (2015) that the assessment of the environmental tax burden is sensitive to the choice of denominator. Ireland is a particularly illustrative case, since the pronounced decline in the revenue share relative to GDP is explained to a substantial degree by the exceptionally rapid growth of GDP itself rather than by any reduction in nominal revenues.

The growing dispersion stands in contrast to the convergence within the EU-15 documented by Villar Rubio et al. (2015) for 1987–2008, though the samples and time frames are not the same. The finding holds even after Ireland, Luxembourg and Malta are left out. The historical comparison further indicates that country classifications may shift over time.

The fall in the environmental tax share extends the pattern identified by Famulska et al. (2022) and the European Environment Agency (2025a). The negative energy intensity component aligns with anticipated pressures on fuel tax bases (OECD/International Transport Forum, 2019; Noll et al., 2026). Dependence on the energy mix and on auction receipts limits the use of revenue ratios and implicit rates as proxies for policy stringency (Morley, 2012; Lobonț et al., 2025). The differences between countries are consistent with the heterogeneous convergence paths set out by Delgado et al. (2022).

In the baseline, Denmark and Sweden display double erosion, whereas Finland almost cancels out its declining base through a higher real implicit rate. The non-renewable denominator raises the rate effect in Sweden and Finland and shifts Sweden into Quadrant I. Denmark stays in double erosion across all four variants (Table A1).

Minimum rates under Directive 2003/96/EC provide a possible institutional account of differences in rate effects. Evaluating this would call for evidence on national statutory rates and on which minima were binding. ETS 2 establishes a distinct revenue stream whose value hinges on allowance prices and auction volumes.

The steep drop in the environmental tax share in 2022 coincided with temporary excise relief and elevated energy prices. The 2019–2023 decomposition relates to changes in the

energy tax share over the whole sub-period. The panel checks sensitivity to excluding 2022–2023, while the effects of individual national measures remain unidentified.

A greater share of lightly taxed renewable energy may lower the measured implicit rate even where statutory rates are unchanged. The observed cross-country correlation depends on the denominator and drops below conventional significance thresholds once the Holm adjustment is applied.

An analogous problem is observed in the transport sector. Improvements in fuel efficiency and the penetration of electric vehicles are gradually eroding the revenue potential of traditional fuel excise duties. van Dender (2019) proposes shifting gradually from fuel taxation towards road-use charges. Distance-based charging may provide a more durable base and reflect more directly the costs associated with congestion, infrastructure use, and other externalities. Such a shift must take into account the distributional implications for low-income households, residents of peripheral areas, and those without an accessible alternative to private car use.

Bulgaria demonstrates how far apparent rate compensation depends on auction proceeds. When EU ETS revenues are approximately deducted, its rate effect turns marginally negative. This leaves revenue projections exposed both to patterns in energy use and to shifts in allowance prices and auction volumes.

The decomposition identifies accounting contributions. The auxiliary panel estimates and the cross-country correlations are of limited precision. The non-renewable denominator and the ETS adjustment are approximate, and reported auction proceeds differ in concept from the corresponding tax receipts recorded under ESA 2010.

6. Conclusions

This study decomposes the change in energy tax revenues as a proportion of GDP across the EU-27 during 2010–2023 into a real implicit rate effect and an energy intensity effect.

Environmental tax revenues grew in nominal terms in 26 of the 27 Member States. Denmark proved the exception. The erosion was thus chiefly relative to GDP and to total tax revenues.

H1 is supported in accounting terms for the whole period. The EU-27 energy tax share dropped from 1.92% to 1.61% of GDP, as the negative base effect (−29.1 log-points) outweighed the positive rate effect (+11.7). The entire net decline took place in 2019–2023, when the two components contributed equally. Energy intensity acts as a proxy for the taxable base and may decline for a number of reasons, including structural change and productivity growth.

H2 is supported descriptively. In the baseline, the rate component accounts for nearly 70% of the variance across countries. The country classifications are sensitive to the definitions: double erosion covers 17 countries when auction revenues are deducted and two when the approximate non-renewable base is used, compared with nine in the baseline. Thirteen countries shifted regime between the historical and main periods.

The renewables correlation is sensitive to how the implicit rate is computed and is statistically inconclusive once adjustment for multiple testing is applied. The panel estimates leave the degree of rate compensation imprecisely determined.

The findings point to a need to distinguish auction proceeds from statutory energy taxes when projecting revenues. Excise indexation and broader bases, including pollution and resource taxes, are options warranting further assessment. Their revenue and distributional effects fall outside the scope of this study.

Future work could compare the implicit rate with effective statutory rates by sector and assess the fiscal and distributional effects of ETS 2 once it is operational.

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Data Availability Statement: The source data used in this study are publicly available from the Eurostat database (https://ec.europa.eu/eurostat/data/database) (accessed on 18 November 2026) under the following online data codes: env_ac_tax (environmental tax revenues by tax category), nrg_bal_c (complete energy balances and final energy consumption), nrg_ind_ren (share of energy from renewable sources in gross final energy consumption), env_air_gge (greenhouse gas emissions by source sector), and nama_10_gdp (GDP at current prices and in chain-linked volumes with 2015 as the reference year). The implicit GDP deflator was calculated from the nominal and chain-linked-volume GDP series. The 1995–2008 replication reported in Section 4.4 used env_ac_tax, nrg_bal_c, and nama_10_gdp; for Malta, the comparison begins in 2000 because earlier observations were unavailable. The balanced 2010–2023 country–year panel comprises 27 Member States and 378 observations. The real implicit tax rate on energy and the two decomposition components were derived from the source series using the procedures described in Section 3. No individual-level or restricted-access data were used. The derived analytical dataset and the code used to construct it are available from the author upon reasonable request. The robustness checks additionally use Member State revenues from the auctioning of EU ETS allowances in 2023, published by the European Environment Agency (European Environment Agency, 2024).

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Abbreviations

The following abbreviations are used in this manuscript:

CV	Coefficient of variation
EEA	European Environment Agency
ESA	European System of Accounts
ETR	Environmental tax revenue
ETS 2	Second Emissions Trading System
EU	European Union
EU-15	European Union Member States before the 2004 enlargement
EU-27	European Union, 27 Member States
FE	Fixed effects
GDP	Gross domestic product
GHG	Greenhouse gas emissions
INT	Energy intensity
ITR	Implicit tax rate on energy
LSDV	Least squares dummy variable estimator
LULUCF	Land use, land-use change and forestry
OECD	Organisation for Economic Co-operation and Development
RES	Share of energy from renewable sources
SIEC	Standard International Energy Product Classification
TAX	Energy tax revenue as a share of GDP
TSC	Total revenues from taxes and social contributions
ETS	EU Emissions Trading System
LMDI	Logarithmic mean Divisia index
RR	Real energy tax revenue

Appendix A

Table A1. Country-level robustness results: sub-period decomposition and alternative measures of the rate and base, 2010–2023.

Code	Rate 2010–2019	Base 2010–2019	Rate 2019–2023	Base 2019–2023	Rate B	Base B	Rate C	Rate D	Quadrant A/B/C/D
BE	0.399	−0.213	0.020	−0.143	0.515	−0.453	0.340	0.436	I/I/I/I
BG	0.166	−0.072	0.264	−0.112	0.543	−0.297	−0.083	0.031	I/I/II/I
CZ	0.112	−0.214	−0.129	−0.077	0.077	−0.386	−0.191	−0.097	II/I/II/II
DK	−0.081	−0.235	−0.350	−0.113	−0.103	−0.676	−0.540	−0.212	II/II/II/II
DE	0.203	−0.199	−0.286	−0.120	0.035	−0.437	−0.220	−0.102	II/I/II/II
EE	0.430	−0.354	−0.160	−0.107	0.515	−0.706	−0.219	0.026	I/I/II/I
IE	−0.025	−0.564	−0.064	−0.298	0.017	−0.969	−0.143	−0.037	II/I/II/II
EL	0.543	−0.026	0.090	−0.084	0.818	−0.296	0.417	0.602	I/I/I/I
ES	0.219	−0.145	−0.109	−0.089	0.249	−0.372	−0.116	0.023	I/I/II/I
FR	0.429	−0.163	−0.171	−0.114	0.377	−0.396	0.206	0.325	I/I/I/I
HR	0.383	−0.176	−0.137	−0.111	0.287	−0.327	0.143	0.184	I/I/I/I
IT	0.273	−0.091	−0.238	−0.113	0.109	−0.276	−0.052	0.021	I/I/II/I
CY	0.251	−0.166	−0.083	−0.199	0.330	−0.527	−0.102	0.060	I/I/II/I
LV	0.346	−0.306	−0.261	−0.083	0.290	−0.593	−0.043	0.162	I/I/II/I
LT	0.282	−0.236	−0.191	−0.119	0.257	−0.522	−0.029	0.137	I/I/II/I
LU	−0.020	−0.238	−0.034	−0.312	0.071	−0.676	−0.064	0.062	II/I/II/I
HU	0.033	−0.210	0.113	−0.141	0.197	−0.402	0.005	0.056	I/I/I/I
MT	0.142	−0.241	−0.372	−0.155	−0.072	−0.554	−0.583	−0.425	II/II/II/II
NL	0.251	−0.282	−0.058	−0.211	0.346	−0.647	0.116	0.270	I/I/I/I
AT	0.097	−0.128	−0.149	−0.102	0.112	−0.394	−0.130	0.034	II/I/II/I
PL	0.197	−0.244	0.505	−0.137	0.788	−0.466	0.447	0.532	I/I/I/I
PT	0.158	−0.118	−0.166	−0.060	0.149	−0.334	−0.215	−0.059	II/I/II/II
RO	0.387	−0.262	0.316	−0.097	0.742	−0.398	0.627	0.665	I/I/I/I
SI	0.170	−0.210	−0.129	−0.164	0.092	−0.426	−0.090	−0.038	I/I/II/II
SK	0.531	−0.314	0.047	−0.164	0.669	−0.569	0.410	0.500	I/I/I/I
FI	0.212	−0.090	−0.026	−0.097	0.506	−0.508	0.052	0.373	I/I/I/I
SE	−0.109	−0.224	0.063	−0.045	0.427	−0.742	−0.084	0.388	II/I/II/I

Note: Rate and base denote the rate effect (Δln real implicit rate) and the base effect (Δln energy intensity). Variant A is the baseline (Table 3); variant B approximates non-renewable final energy consumption, E × (1 − RES/100); variant C deducts 2023 ETS auctioning revenues from energy tax revenues (its base effect equals that of A); variant D combines B and C (its base effect equals that of B). Source: own calculations based on Eurostat and EEA data.

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