CONFERENCE PROCEEDINGS ARTICLE

Environmental Tax Revenue in the European Union: Composition, Convergence and the Limits of a Revenue-Based Indicator, 2000–2023

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Abstract

Environmental tax revenue expressed as a share of gross domestic product is the indicator most often used to compare the environmental fiscal effort of European Union member states. This paper asks what the indicator shows once it is decomposed into its energy, transport and pollution components. Using a balanced panel of the 27 member states over 2000–2023, we apply the two standard convergence tests, a regression of average growth on the initial level and a trend fitted to the annual coefficient of variation, to the aggregate and to each component. The aggregate declined from a cross-country mean of 2.729 to 2.259 per cent of gross domestic product, while the average national share of energy taxes rose from 71.6 to 77.6 per cent and that of transport taxes fell from 23.4 to 17.5 per cent. The growth regression yields a coefficient of -0.0414 ($p = 0.005$) and an implied half-life of 5.3 years, yet the coefficient of variation rose by 40.2 per cent. The two results are compatible: the regression detects mean reversion in a noisy series, and inferring a narrowing distribution from it would be the regression fallacy. The widening is concentrated in energy taxes, while transport taxes converged. Romania fell from 3.396 to 2.589 per cent of gross domestic product, still eighth in the Union and in the upper third of the distribution, with 94.9 per cent of its receipts raised on energy. Aggregate comparisons hide the structural narrowness that matters most for policy design.

Keywords: regression fallacy; cross-country dispersion; energy levies; fiscal structure; Romania
JEL Classification: H23; Q58; C23; H87

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1. INTRODUCTION

Environmental tax revenue as a percentage of gross domestic product is a convenient number. Eurostat publishes it annually for every member state on a harmonised definition, it is comparable across countries by construction, and it fits into a single column of a policy table. For those reasons it is also the number that most often stands in for the environmental ambition of a tax system. The European Green Deal, the country-specific recommendations issued under the European Semester and a

substantial part of the applied literature all use it in this way, and the Commission's annual review of tax structures reports it alongside the implicit tax rate on energy as a headline measure of green taxation (European Commission, 2024).

This paper takes the indicator seriously enough to decompose it. The exercise is not merely descriptive. A revenue ratio is the product of a tax rate and a tax base, and the two move in opposite directions when a tax does its job: a levy that successfully discourages the activity it falls on erodes its own base and, with it, its own receipts. A falling ratio is therefore consistent with a failing policy and with a succeeding one, and nothing in the aggregate distinguishes the two cases. The ambiguity is well understood in principle (OECD, 2011; Fullerton et al., 2010). What is less often examined is how much it matters in practice for the European Union, and whether the convergence dynamics that are routinely reported for this variable survive once the aggregate is opened into its three statistical components.

The analysis covers the 27 member states over 2000–2023, which gives 648 country-year observations and spans the eastern enlargements, the financial crisis, the energy price shock of 2021–2022 and the first years of the Green Deal. Three questions are put to the data. Has the environmental tax effort of the Union converged? Does the answer depend on which component is examined? And do the two standard convergence tests agree with each other?

Of the three, the last question turns out to be the productive one. The panel exhibits β-convergence and σ-divergence at the same time. Such a combination is not an anomaly to be explained away. It is precisely the situation that Friedman (1992) and Quah (1993) warned about when they argued that a negative coefficient in a growth-on-initial-level regression is compatible with an unchanged or widening dispersion, because that regression measures mean reversion rather than a shrinking distribution. Environmental tax revenue in Europe turns out to be a clean empirical illustration of the point, and one with direct consequences for how member-state performance is read in Brussels and in national capitals. We therefore treat the disagreement between the tests as a result in its own right, and we show, using a simple variance decomposition, why the disagreement is expected rather than puzzling when the series is as noisy as this one.

Section 2 reviews the literature on environmental taxation as an instrument, on the composition of revenue in Europe and on convergence tests and their pitfalls. Section 3 describes the data and the two tests, together with the decomposition that reconciles them. Section 4 reports the results, aggregate first and then component by component, and closes with Romania. Section 5 discusses the findings against the literature, and Section 6 concludes with limitations and extensions.

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2. LITERATURE REVIEW

2.1 Environmental Taxes as Instruments: Rates, Bases and Self-Erosion

The theoretical case for environmental taxation is a case about prices, not about revenue. A tax set equal to marginal external damage corrects the price signal and leaves the level of the activity to be determined by private decisions; the receipts are a by-product. The modern public finance literature added a second layer to this argument by asking whether environmental taxes could replace distortionary labour and capital taxes at no welfare cost, the so-called double dividend. Bovenberg and de Mooij (1994) showed that the answer is generally negative in a second-best setting, because an environmental tax raises the price of consumption and thereby aggravates the labour market distortion it is meant to finance away; Goulder (1995) organised the subsequent debate into a weak form, which survives, and a strong form, which does not. The practical upshot for the present paper is that the fiscal yield of environmental taxes is neither their purpose nor a reliable proxy for their effectiveness.

Empirical work on the price effect confirms that well-designed environmental taxes do erode their own base. Andersson (2019) estimates that the Swedish carbon tax reduced transport emissions by close to 11 per cent relative to a synthetic control, with an elasticity roughly three times larger than the one implied by ordinary fuel price variation. Metcalf and Stock (2023), using the European carbon taxes introduced since the early 1990s, find no evidence that they reduced output or employment, which weakens the political objection to raising them, but they also confirm that emissions respond. Timilsina (2022) surveys this body of evidence and concludes that the environmental effect of carbon taxes is robust while the fiscal effect depends on the base to which the rate is applied. The same logic applies with greater force to taxes on transport fuels and vehicle ownership, whose bases have been shifting under regulatory pressure on vehicle efficiency and, more recently, electrification.

The policy literature has drawn the consequence for measurement explicitly. The OECD's guide for policy makers on environmental taxation (OECD, 2011) warns that revenue shares of gross domestic product reflect the interaction of rates, bases and the size of the economy and should not be read as measures of environmental stringency, and the same organisation's work on effective carbon rates was developed largely to provide a price-based alternative (OECD, 2023). The Commission's annual review of taxation trends has for years reported both the revenue ratio and the implicit tax rate on energy for this reason, and has noted that the two often move in different directions (European Commission, 2024). Parry et al. (2021) approach the same issue from the opposite side, by measuring the gap between actual and efficient energy prices, and find that revenue-rich tax systems can nonetheless price energy far below its social cost. A revenue ratio, in short, is an accounting fact that the literature has declined to treat as a policy measure, and yet it remains the measure that cross-country comparisons most often use.

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2.2 The Composition of Environmental Tax Revenue in Europe

Eurostat fixed the statistical definition that underlies the indicator in its statistical guide (Eurostat, 2013) and given a legal footing by the regulation on European environmental economic accounts (European Union, 2011). A tax is environmental if its base is a physical unit, or a proxy for one, that has a proven specific negative impact on the environment. The definition is a base definition, not a purpose definition: a tax counts because of what it falls on, not because of why it was introduced. Receipts are grouped into energy taxes, which include taxes on transport fuels and, since 2008, receipts from auctioned emission allowances; transport taxes, which cover vehicle registration and circulation charges; and taxes on pollution and resources, a small residual category that ranges from landfill levies to water abstraction charges.

On this definition the Union's environmental tax revenue has been drifting down in relation to output for two decades. Eurostat's own descriptive analysis puts total receipts at close to 2.0 per cent of gross domestic product for the EU-27 aggregate in recent years, with energy taxes accounting for more than three quarters of the total (Eurostat, 2024a). The Commission's review of taxation trends reports the same downward drift and attributes it to a combination of nominal excise rates that are not indexed to inflation, a slow improvement in energy efficiency and a decline in the transport tax base as vehicle fleets renew (European Commission, 2024). The European Environment Agency reaches a compatible conclusion from the emissions side: the fiscal signal embedded in environmental taxes has weakened relative to the size of the economy even as regulatory ambition has increased (European Environment Agency, 2023). The OECD's revenue statistics record the same pattern for its European members, with environmentally related tax revenue losing ground as a share of total taxation over the past decade (OECD, 2024).

The composition of the revenue matters for two reasons that the literature has explored separately. The first is harmonisation. Energy taxation in the Union is governed by the Energy Taxation Directive (European Union, 2003), which sets minimum rates that have not been updated since 2003 and which most member states exceed by wide and varying margins. The Commission's proposal to recast the directive (European Commission, 2021) was motivated precisely by the observation that the minima had become non-binding and that national rate structures had diverged. Transport taxes are not harmonised by directive at all, yet vehicle registration and circulation regimes have been pushed towards similar designs by internal market pressure and by a common shift towards carbon-dioxide-based differentiation. The European Court of Auditors, reviewing energy taxation and carbon pricing across the Union, documented the resulting patchwork of effective rates and the extent to which subsidies offset them (European Court of Auditors, 2022).

A second reason is the exposure of each component to shocks. Energy tax receipts depend on volumes of fuel consumed, and the price shock of 2021–2022 led member states to cut excise rates, cap prices and introduce compensation measures on a scale and with a design that differed widely from one country to the next (Sgaravatti et al., 2023; Ari et al., 2022). The International Monetary

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Fund's fiscal monitor devoted to climate policy noted that these responses often worked against the carbon price signal that the same governments were committed to strengthening (International Monetary Fund, 2023), and the World Bank's annual stocktake of carbon pricing records the same tension between short-run affordability and long-run pricing (World Bank, 2024a). Transport taxes, being levied on stocks of vehicles rather than on flows of fuel, were largely untouched by the shock. Any convergence result for the aggregate is therefore a weighted mixture of components with different legal regimes and different shock exposure, and the weights themselves have been moving.

2.3 Convergence Tests and Their Pitfalls

Two concepts that applied work often conflates are distinguished in the convergence literature. β-convergence is present when units starting from a lower level grow faster, and it is tested by regressing the average growth rate over a period on the initial level, as in Barro and Sala-i-Martin (1992). σ-convergence is present when the cross-sectional dispersion of the variable falls over time, and it is tested by tracking a dispersion measure, usually the standard deviation of logarithms or the coefficient of variation, and asking whether it trends downwards. Sala-i-Martin (1996) set out the relation between the two: β-convergence is necessary but not sufficient for σ-convergence, because the dispersion at the end of a period depends both on how strongly units revert towards the mean and on how large the shocks are that push them apart in the meantime.

Friedman (1992) and Quah (1993) made the same point more sharply and gave it a name. A negative coefficient in a growth-on-initial-level regression is what one obtains from any series subject to transitory noise, because units that happen to be high in the base year will on average be lower in the next, and units that are low will be higher, whether or not the distribution as a whole is narrowing. This is Galton's regression towards the mean, and the mistake of reading it as evidence of a shrinking distribution is the regression fallacy. The fallacy lies in the inference, not in the coefficient: the regression is correctly estimated and the coefficient is a genuine feature of the data, but the conclusion that disparities are closing does not follow from it. Bernard and Durlauf (1996) formalised the difference by showing that the regression test and the time series definition of convergence can disagree even in well-behaved data, and that the regression approach cannot distinguish between economies converging to a common limit and economies that are merely mean-reverting around distinct limits.

The distinction has been demonstrated empirically many times. Young et al. (2008), using county-level data for the United States, find strong β-convergence in per capita income alongside no σ-convergence at all, and they show analytically that the two are reconciled by the variance of the innovation term. The recent revival of interest in cross-country income convergence has been careful on this point: Patel et al. (2021) and Kremer et al. (2022) document a shift towards unconditional β-convergence since the late 1990s but report σ-convergence separately, and note that the speeds estimated in cross-sectional regressions on noisy data can overstate the pace at which distributions

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actually close. Orders of magnitude matter here. The growth literature's canonical estimate of the speed of β-convergence is close to 2 per cent per year, which implies a half-life of around 35 years (Barro & Sala-i-Martin, 1992). Speeds several times faster than that, obtained from a series with substantial year-to-year noise, are the signature of mean reversion rather than of structural catch-up.

Two further pitfalls are relevant here. The first concerns the inference on the dispersion trend itself. The annual coefficient of variation is a short, serially correlated series, and a trend fitted by ordinary least squares with conventional standard errors will overstate its significance; the standard remedy is to use heteroskedasticity- and autocorrelation-consistent standard errors of the type proposed by Newey and West (1987). The second concerns the alternative of abandoning the β and σ framework altogether. Phillips and Sul (2007) proposed a log-t regression test that allows for heterogeneous transition paths and identifies convergence clubs rather than imposing a single steady state, and this approach has become the usual second step when the two classical tests disagree. We return to it in the conclusions as the natural extension of the present exercise.

2.4 Convergence Studies of Environmental Taxation

Applied work on the convergence of environmental taxation in Europe is comparatively thin and has reported mixed findings. Delgado et al. (2022) examine environmental tax revenue in the Union with cluster and convergence techniques and find that member states group into a small number of clubs rather than converging to a single level, with the composition of revenue differing between clubs. Earlier descriptive work by the Commission and by Eurostat has repeatedly observed that the dispersion of the revenue ratio across member states has not narrowed despite two decades of common environmental legislation (European Commission, 2024; Eurostat, 2024a). What has not been done, to our knowledge, is to apply both classical tests to the aggregate and to each of its three components on the same panel and horizon, and to ask whether the tests agree. That is the gap this paper addresses. The broader literature on fiscal convergence in the Union, which tends to find β-convergence in tax-to-output ratios but slow or no σ-convergence, suggests that the answer may well be negative, and the results below confirm that suggestion for environmental taxes in particular.

3. METHODOLOGY

3.1 Data and Variable Definitions

The panel is built from the Eurostat environmental tax accounts, dataset env_ac_tax, which reports environmental tax revenue by category as a percentage of gross domestic product for each member state on the definition described in Section 2.2 (Eurostat, 2024b). The World Bank's World Development Indicators supplied real gross domestic product per capita, which is used only to describe the sample and to check the ordering of countries (World Bank, 2024b). The 27 current member states are observed annually over 2000–2023, giving 648 country-year observations across 24

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years. The panel is balanced on the four fiscal variables: total environmental tax revenue and its three components, energy taxes, transport taxes and taxes on pollution and resources, each expressed as a percentage of gross domestic product. Component shares are computed for each country and year as the component divided by that country's total; when a Union-wide share is reported, it is the unweighted mean of the 27 national shares, so that each member state counts equally regardless of its size.

Table 1 reports the four variables at the two endpoints of the period. The decline in the total is driven by transport taxes, which lost close to half of their weight in relation to output, while energy taxes fell much less in absolute terms and therefore gained in relative terms. The share columns are averages of national shares and not ratios of the means in the first two columns; the distinction is spelled out in the note, because the two ways of computing a Union-wide share give different numbers and the paper uses the first throughout.

Table 1.
Environmental tax revenue in the EU-27: cross-country means at the endpoints of the period

Category	2000 (% of GDP)	2023 (% of GDP)	Change (pp)	Share 2000 (%)	Share 2023 (%)
Total environmental taxes	2.729	2.259	-0.470	100.0	100.0
Energy taxes	1.918	1.769	-0.149	71.6	77.6
Transport taxes	0.670	0.377	-0.293	23.4	17.5
Pollution and resource taxes	0.141	0.113	-0.028	5.0	4.9

Note: The first two columns are unweighted means across the 27 member states. Shares are the unweighted mean of the 27 national shares (each country's component divided by its own total), which is why they differ from the ratio of the cross-country means: for energy in 2000, 1.918/2.729 gives 70.3%, against 71.6% for the mean of national shares. Shares may not sum to exactly 100 because of rounding. pp: percentage points.

Source: Eurostat (2024b), dataset env_ac_tax. Author's own calculations.

Neither endpoint is innocent. The year 2000 precedes the eastern enlargements, so the early observations for the ten states that joined in 2004 and the three that joined later describe tax systems that were still adjusting to the acquis. The year 2023 sits immediately after the energy price shock, during which several member states cut excise rates on fuels temporarily. The trend tests described below use every year of the panel and are therefore less exposed to the choice of endpoints than the endpoint comparisons in Table 1; where the final years matter for interpretation, we say so.

3.2 The Test for σ-Convergence

For each fiscal variable and each year, we compute the coefficient of variation across the 27 member states, that is, the cross-sectional standard deviation divided by the cross-sectional mean. The coefficient of variation is preferred to the standard deviation of logarithms because four member states report zero revenue from pollution and resource taxes in some years, and the logarithm is undefined at zero. σ-convergence is then tested by fitting a linear trend to the resulting series of 24 annual observations, as in Equation (1):

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$$CV_t = a + b \cdot t + u_t \quad (1)$$

where t indexes the year. A negative and significant b indicates σ-convergence; a positive and significant b indicates divergence. Because the annual coefficient of variation is serially correlated by construction, the standard error of b is computed with the Newey and West (1987) heteroskedasticity- and autocorrelation-consistent estimator, with a bandwidth of three lags, and the p-values reported in Section 4 are robust in that sense. We also report the percentage change in the coefficient of variation between 2000 and 2023, which is easier to communicate but depends on the endpoints.

3.3 The Test for β-Convergence

β-convergence is tested in its absolute (unconditional) form, by regressing the average annual growth rate of each fiscal variable over the full period on its natural logarithm in the initial year, as in Equation (2):

$$(1/T) \cdot [\ln(y_{i,t}) - \ln(y_{i,0})] = \alpha + \beta \cdot \ln(y_{i,0}) + \varepsilon_i \quad (2)$$

where $y_{i,0}$ and $y_{i,t}$ are the revenue ratio of country i in 2000 and 2023, T = 23 is the number of annual intervals between them, and ε_i is a country-specific disturbance. A negative and significant β indicates that states with lower initial revenue ratios grew faster. The implied annual speed of convergence λ and the half-life h follow from β in the usual way, as in Equation (3):

$$\lambda = -\ln(1 + \beta \cdot T)/T, \quad h = \ln(2)/\lambda \quad (3)$$

The regression is estimated by ordinary least squares on 27 observations, one per country, with heteroskedasticity-consistent standard errors. The small cross-section limits the precision of the estimate and rules out the conditional form of the test, which would require controls for country-specific steady states that 27 observations cannot support. The absolute form is nevertheless the one relevant to the cohesion question, since it asks whether member states are converging to a common level rather than to their own. For pollution and resource taxes, the four states with zero revenue in 2000 are dropped, leaving 23 observations.

3.4 Why the Two Tests Can Disagree

Because the two tests answer different questions, the relation between them can be made exact. Suppose that the deviation of each country from the cross-country mean follows a first-order process with a common reversion parameter, so that the deviation in year t equals (1 + β) times the deviation in year t − 1 plus an idiosyncratic shock with variance σ^2_ε. Taking the cross-sectional variance on both sides gives Equation (4):

$$\sigma^2_t = (1 + \beta)^2 \cdot \sigma^2_{t-1} + \sigma^2_\varepsilon \quad (4)$$

With β negative, the first term on the right-hand side is smaller than σ^2_{t-1} and pulls the dispersion down; the second term pushes it up. Dispersion falls only if $(1 + \beta)^2 \cdot \sigma^2_{t-1} + \sigma^2_\varepsilon$ is smaller than σ^2_{t-1},

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that is, if the shocks are small relative to the reversion. When the shocks are large, the series can display a strongly negative β, because each year's high values tend to be followed by lower ones, and at the same time a constant or rising variance, because new shocks keep replenishing the spread. A large estimated β on a noisy series is therefore not evidence that the distribution is closing; it is evidence that the series is noisy. The empirical strategy is to estimate both tests on the aggregate and on each component and to interpret any disagreement between them through Equation (4) rather than by choosing one test over the other.

4. RESULTS

4.1 Dispersion Widened

The coefficient of variation of total environmental tax revenue rose from 0.2288 in 2000 to 0.3208 in 2023, an increase of 40.2 per cent. The fitted trend in Equation (1) has a slope of 0.00437 per year with a robust p-value below 0.001, so the widening is a property of the whole series and not an artefact of the two endpoints. On the standard reading, the environmental tax systems of the member states became less alike over the twenty-four years examined.

Component by component, the picture changes, and the change is the substantive finding of this section. Figure 1 plots the annual coefficient of variation for the aggregate and for each component. Energy taxes track the aggregate closely for most of the period and then jump above it in 2022, when the dispersion of national responses to the price shock is visible as a spike; their coefficient of variation rose from 0.2796 to 0.3906, an increase of 39.7 per cent with a robust p-value of 0.005. In relative terms the increase is almost identical to the 40.2 per cent recorded for the total; in absolute terms the coefficient of variation of energy taxes rose by more, 0.111 against 0.092, which is what one would expect given that energy taxes make up the bulk of the aggregate and that the spike of 2022 originates in this component. Taxes on pollution and resources, already the most dispersed category in 2000 with a coefficient of variation of 1.1982, diverged slightly further, to 1.2533, an increase of 4.6 per cent that is nonetheless significant on the trend test ($p = 0.003$), largely because of a step upwards around 2007 that was never reversed. Transport taxes went the other way: their coefficient of variation fell from 0.8722 to 0.6473, a decline of 25.8 per cent with a robust p-value below 0.001, and they are the only category to converge.

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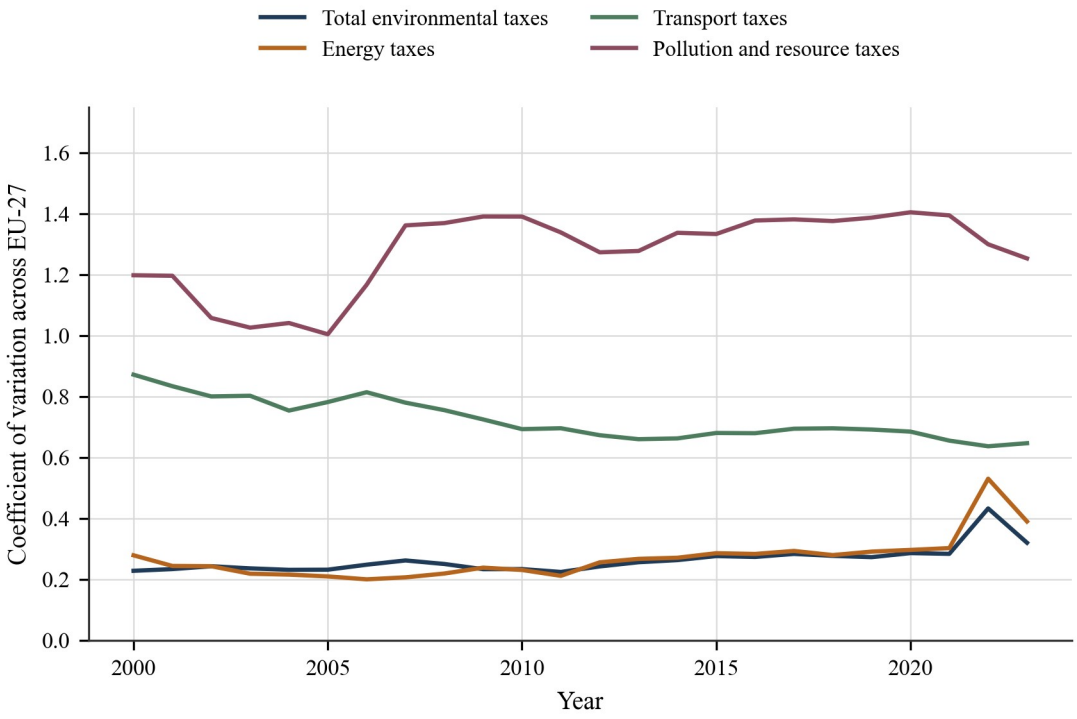


Figure 1. Cross-country dispersion of environmental tax revenue and its components, EU-27, 2000–2023. Dispersion is measured by the coefficient of variation computed across the 27 member states in each year.

Source: Author's own elaboration on Eurostat (2024b), dataset env_ac_tax.

Once the components are separated, the reading is straightforward. Transport taxation is the most harmonised part of the environmental tax base in practice if not in law, being tied to vehicle registration and circulation regimes that have moved towards similar carbon-dioxide-based designs under internal market pressure and under the influence of common vehicle standards. Energy taxation is where national discretion remains widest, since the minimum rates of the Energy Taxation Directive have long ceased to bind, and it is also the component most exposed to the price shock of 2021–2022, which member states absorbed through very different combinations of excise cuts, price caps and transfers. The aggregate divergence is, in substance, energy tax divergence.

4.2 Poorer Starters Grew Faster

At first sight the β-convergence regression in Equation (2) tells the opposite story. The estimated coefficient on the initial log level of total environmental tax revenue is -0.0414, with a standard error of 0.0135, a t-statistic of -3.071 and p = 0.005 on 27 countries, and the regression accounts for 27.4 per cent of the cross-country variation in average growth rates. Through Equation (3) the coefficient implies a speed of convergence of 13.2 per cent per year and a half-life of 5.3 years.

Figure 2 shows the fit. Each point is one member state, with average annual growth over 2000–2023 on the vertical axis and the logarithm of the revenue ratio in 2000 on the horizontal axis. The negative slope is visible and not driven by a single observation, although Denmark, which started from by far the highest ratio and recorded one of the largest declines, anchors the right-hand end of the

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line, and Ireland and Luxembourg lie well below it. Greece and Bulgaria, which started from low or middling levels and grew fastest, sit above the line at the left. Romania started from a high level and declined at roughly the rate the line predicts.

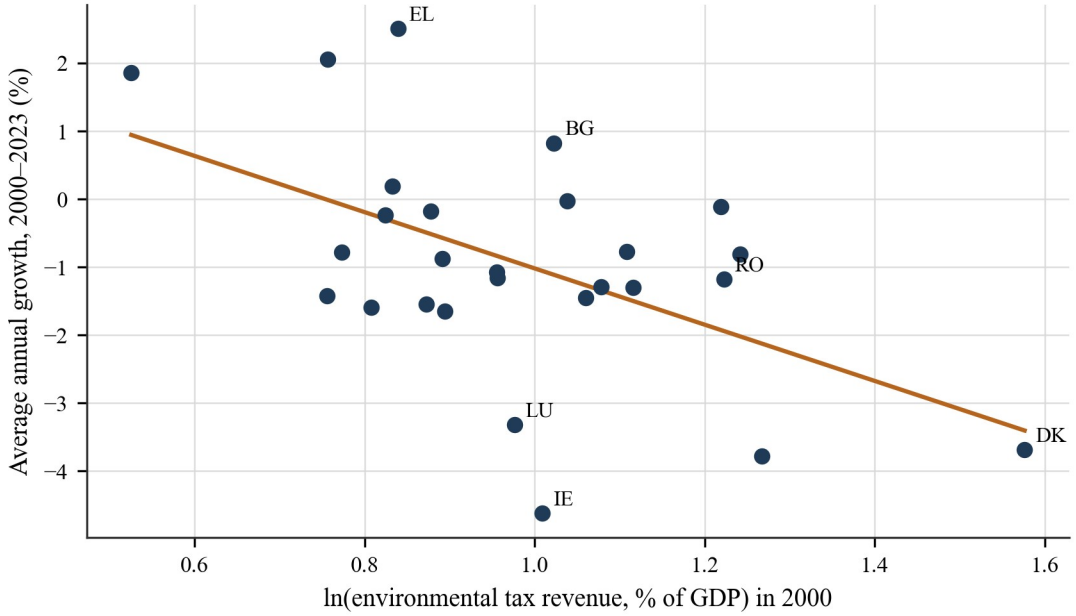


Figure 2. Absolute β-convergence in total environmental tax revenue, EU-27, 2000–2023. Each point is one member state; the line is the fitted regression of average annual growth on the initial logarithm of the revenue ratio. Selected states are labelled.

Source: Author's own elaboration on Eurostat (2024b), dataset env_ac_tax.

The speed deserves comment before the component results. A convergence speed of 13.2 per cent per year and a half-life of 5.3 years are far above the 2 per cent per year and roughly 35-year half-life that the growth literature regards as typical of catch-up in income levels (Barro & Sala-i-Martin, 1992; Sala-i-Martin, 1996). Nothing in the institutional history of European environmental taxation suggests adjustment that fast. What such a speed resembles is the coefficient one obtains from regressing changes on levels in any series with a large transitory component: a country whose revenue ratio was unusually high in 2000 for reasons that did not persist will show a large decline over the following years, and a country that was unusually low will show a large rise, regardless of whether the two are moving towards a common level. This is the mechanism of Equation (4), and it is the reason the estimate should be read as the signature of mean reversion in a noisy series rather than as a structural speed of adjustment.

4.3 Convergence Tests by Component

Table 2 collects both tests for the aggregate and for each component. The β coefficients are negative and significant throughout, with p-values between 0.001 and 0.031, and the explanatory power of the regression ranges from 17.3 per cent for transport taxes to 39.0 per cent for pollution and resource taxes. Every component displays β-convergence, including the two that display σ-divergence.

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Transport taxes are the only category in which the two tests agree in sign: they show β-convergence and a falling coefficient of variation, and for that category alone the inference from the growth regression to a narrowing distribution would be correct.

Table 2.
Convergence tests by component, EU-27, 2000–2023

Component	β coefficient	p (β)	R^2	N	CV 2000	CV 2023	Change in CV (%)	p (trend)
Total environmental taxes	-0.0414	0.005	0.274	27	0.2288	0.3208	+40.2	0.0001
Energy taxes	-0.0304	0.010	0.238	27	0.2796	0.3906	+39.7	0.0049
Transport taxes	-0.0163	0.031	0.173	27	0.8722	0.6473	-25.8	0.0000
Pollution and resource taxes	-0.0237	0.001	0.390	23	1.1982	1.2533	+4.6	0.0029

Note: β is the coefficient on the initial log level in Equation (2), estimated on one observation per country with heteroskedasticity-consistent standard errors. CV is the coefficient of variation across the 27 member states. The last column reports the p-value of the linear trend in Equation (1), fitted to the 24 annual CV observations with Newey and West (1987) standard errors. The pollution and resource regression uses 23 countries because four states report zero revenue in that category in 2000.

Source: Author's own calculations on Eurostat (2024b), dataset env_ac_tax.

Where the aggregate β comes from is also clarified by the component results. The coefficient for the total, -0.0414, is larger in absolute value than the coefficient for any single component, which is possible because the aggregate combines the mean reversion within each component with the reshuffling of weights between them. A country that started with an unusually large transport component, for example, experienced both the mean reversion of that component and its shrinking weight, and the two effects reinforce each other in the aggregate growth rate.

4.4 The Migration of the Base Towards Energy

A negative β with a rising coefficient of variation is the configuration that Friedman (1992) associated with the regression fallacy, and it bears repeating that the fallacy is the inference, not the data. The β regression compares each country with its own starting point and finds mean reversion; the coefficient of variation compares countries with each other and finds them spreading apart. Both are correct descriptions of the panel. What would be wrong is to conclude from the first that the second cannot be true. The data illustrate why the inference would be wrong: the ordering of countries churns, states move towards the middle from wherever they started and then overshoot or are pushed off course by new shocks, and the distribution is no narrower at the end than at the beginning.

The composition data show the mechanism from another angle. Figure 3 plots the average national shares of the three components over the whole period. The Union's environmental tax base shifted steadily towards energy, from 71.6 to 77.6 per cent of total receipts, with most of the movement concentrated between 2008 and 2012, when vehicle taxes were reformed in many member states and emission allowance receipts began to appear in the energy category; transport fell from 23.4 to 17.5 per cent over the same period, and pollution and resource taxes were flat at close to 5 per cent. Because energy is the component where national discretion is widest and where the shock of 2021–

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2022 landed, the base of the aggregate migrated into its least harmonised part. Mean reversion within each component coexists with a rising weight on the component that generates the most cross-country variance, and the aggregate inherits the divergence of that component.

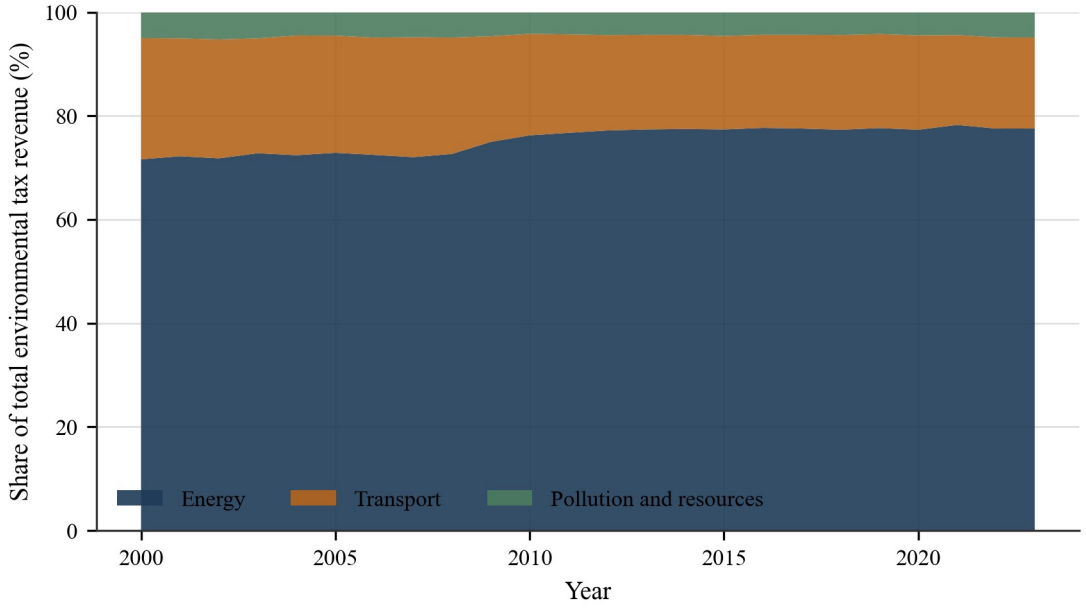


Figure 3. Composition of environmental tax revenue in the EU-27, 2000–2023. Shares are unweighted means of the 27 national shares of each component in total environmental tax revenue.

Source: Author's own elaboration on Eurostat (2024b), dataset env_ac_tax.

4.5 Romania

Romania is a useful case because its aggregate position is respectable while its structure is extreme. The revenue ratio fell from 3.396 per cent of gross domestic product in 2000 to 2.589 per cent in 2023, a decline of about 1.2 per cent per year that places the country close to the fitted line in Figure 2. The 2023 value ranks eighth among the 27 member states and lies above the cross-country mean of 2.259 per cent, so on the aggregate indicator Romania sits in the upper third of the distribution, not near the median. Read on its own, the headline number suggests a member state whose effort is above average and whose decline is unremarkable in a Union where most ratios fell.

The structure tells a different story. In 2023, 94.9 per cent of Romanian environmental tax revenue came from energy taxes, against a mean national share of 77.6 per cent for the Union, which makes the Romanian instrument mix among the narrowest in the panel. The country operates, in effect, a single-instrument environmental tax system. Transport and pollution instruments are marginal, which removes two of the three margins on which behaviour can be influenced and concentrates the entire fiscal signal on a base whose price is administratively sensitive and politically protected, as the sequence of fuel excise adjustments during 2022 showed. An above-average revenue ratio and a near-absence of instrument diversity are not in tension in the data; they are the same fact seen at two levels of aggregation. An indicator that reports only the aggregate cannot see the second level, and it is the second level that determines what a reform could work with.

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5. DISCUSSION

What the results establish first is descriptive and uncontroversial once stated. Environmental tax revenue in the Union fell in relation to output over 2000–2023, and its composition tilted towards energy. The direction agrees with the Commission's own reading of taxation trends (European Commission, 2024) and with Eurostat's descriptive statistics (Eurostat, 2024a), and the magnitude of the decline, close to half a percentage point of gross domestic product on the cross-country mean, is not small in fiscal terms. Any narrative of a steadily greening tax system is not supported by the revenue data. Whether it is contradicted by them is a different question, and the answer depends entirely on the point made in Section 2.1: a falling ratio is what a working tax produces when its base contracts, and the revenue data cannot tell whether that is what happened. The evidence from carbon and fuel taxation reviewed by Timilsina (2022) and the estimates of Andersson (2019) make base erosion a live explanation for part of the decline, and the shift of the vehicle tax base towards low-emission cars makes it plausible for the transport component in particular.

A second result is methodological and, we think, more consequential for how the indicator is used. Reporting β-convergence for environmental taxation without the companion σ test produces a conclusion that the dispersion data contradict. The panel displays a growth regression coefficient that would, on a naive reading, imply convergence at 13.2 per cent per year, and a coefficient of variation that rose by 40.2 per cent over the same period. Through Equation (4) the two are not merely compatible but expected: the variance of the idiosyncratic shocks to environmental tax revenue, which include changes in excise rates, the arrival and departure of one-off levies, the fiscal treatment of allowance auctions and, at the end of the period, the very different national responses to the energy price shock, is large enough relative to the reversion term to keep the dispersion from closing. This is exactly the pattern that Young et al. (2008) documented for regional income in the United States and that Quah (1993) predicted on theoretical grounds. The implication for the reader of applied work is that a reported β-convergence result on a fiscal ratio should be treated as evidence about noise until the dispersion series has been examined.

This reading is reinforced by the magnitude of the estimated speed. Half-lives of five years are not what one obtains from processes of institutional catch-up; Kremer et al. (2022) and Patel et al. (2021), working with income data that are far less noisy than annual tax ratios, find speeds that remain in the low single digits even in the period of strongest unconditional convergence. The gap between 13.2 per cent and 2 per cent is not a sign that environmental tax systems adjust faster than economies grow; it is a sign that the regression is picking up transitory movements. Bernard and Durlauf (1996) made the general point that the regression test cannot separate convergence towards a common level from mean reversion around different levels, and the Romanian case in Section 4.5 shows what the second possibility looks like in practice: a country that regressed towards the mean from above while retaining a structure unlike that of any country near it in the ranking.

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A third result concerns the indicator itself. A revenue ratio conflates rate and base, and the decomposition performed here shows that the conflation is not innocuous: the aggregate diverges because its weight migrated into the least harmonised component, not because national ambitions moved apart uniformly. For the purpose of assessing environmental fiscal effort, the implicit tax rate on energy, the effective carbon rates compiled by the OECD (2023) and the component shares carry information that the headline ratio destroys. The recast of the Energy Taxation Directive proposed by the Commission (European Commission, 2021) would, if adopted, act directly on the component that drives the divergence, by re-anchoring minimum rates to energy content and environmental performance. The results here suggest that the effect of such a reform on the dispersion of the aggregate indicator would be substantial, and that the aggregate is, in that sense, a poor guide to how much harmonisation has already taken place in the parts of the base where harmonisation has occurred.

Something should be said about the final years of the panel. The spike in the dispersion of energy taxes in 2022, visible in Figure 1, reflects national compensation measures whose fiscal design differed widely (Sgaravatti et al., 2023), and the European Court of Auditors (2022) had already noted before the shock that energy subsidies and energy taxes were being adjusted in opposite directions in several member states. The trend tests use all 24 years and remain significant when estimated with robust standard errors, so the divergence result does not depend on 2022. The endpoint comparison of 2000 with 2023 is more exposed, and the percentage changes in the coefficient of variation should be read with that in mind. The finding that energy taxation is the source of divergence is if anything strengthened by the shock, which revealed how differently member states treat the same base under pressure.

The Romanian illustration has a practical corollary. A country whose environmental tax receipts are almost entirely energy receipts is a country whose environmental tax revenue will fall as the energy transition proceeds, whatever happens to policy ambition, and whose fiscal exposure to the transition is correspondingly concentrated. The relevant question for such a country is not where it stands in the ranking of revenue ratios but whether it has instruments on the transport and pollution margins that can carry a price signal once the energy base contracts. The aggregate indicator cannot pose that question, and a comparison of member states that relies on it will systematically overlook the countries for which the question is most urgent.

6. CONCLUSIONS

This paper set out to ask what the environmental tax revenue ratio shows once it is decomposed and tracked over a long horizon, and whether the convergence dynamics reported for it survive the decomposition. Three answers emerge from the panel of 27 member states over 2000–2023. The ratio declined, from a cross-country mean of 2.729 to 2.259 per cent of gross domestic product, and its composition shifted towards energy, whose average national share rose from 71.6 to 77.6 per cent

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while that of transport taxes fell from 23.4 to 17.5 per cent. The two classical convergence tests disagree: the growth regression yields a coefficient of -0.0414 with a half-life of 5.3 years, while the coefficient of variation rose by 40.2 per cent, and the disagreement is resolved by recognising the first as mean reversion in a noisy series rather than as evidence of a closing distribution. The divergence is a property of energy taxes, which rose in weight and in dispersion, while transport taxes, the one component whose designs have converged in practice, are also the one component in which both tests agree. Romania, eighth in the Union at 2.589 per cent of gross domestic product and in the upper third of the distribution, raises 94.9 per cent of that revenue on energy alone, and illustrates how much the aggregate hides.

For those who use the indicator, the recommendation that follows is modest and specific. A comparison of environmental fiscal effort across member states should report the component shares alongside the aggregate, should report the dispersion series alongside any growth regression, and should treat convergence speeds of the order found here as a warning about noise rather than as a finding about catch-up. Where the question is stringency rather than yield, the implicit tax rate on energy and the effective carbon rate are the measures to use, and the revenue ratio should be confined to the fiscal questions it can actually answer.

The analysis has clear limits. The absolute β test uses one observation per country and cannot separate convergence towards a common steady state from convergence towards country-specific ones; the small cross-section also rules out the conditional form of the test and leaves the estimate sensitive to a handful of influential observations, Denmark and Ireland among them. The revenue data cannot distinguish a rate change from a base change, which is the very ambiguity the paper documents rather than resolves. The coefficient of variation is one dispersion measure among several, and although the qualitative results are unlikely to depend on it, a Gini coefficient or the standard deviation of logarithms would weight the tails differently. The Eurostat classification assigns emission allowance receipts to energy taxes, which mechanically raises the energy share after 2008 for the member states that auction allowances and complicates the comparison of shares across the period. The period ends immediately after an energy price shock whose fiscal treatment differed across member states, so the final observations should be read with caution even though the trend results do not depend on them.

Three extensions seem most useful. The first is to repeat the exercise on implicit tax rates and effective carbon rates, where they are available, and to test whether the divergence documented here survives once rates are separated from bases; if it does not, the aggregate divergence is a base phenomenon, and the policy reading changes accordingly. The second is to apply the log-t test of Phillips and Sul (2007) to the same panel, which would allow for heterogeneous transition paths and identify convergence clubs rather than forcing the 27 states onto a single steady state; the clustering reported by Delgado et al. (2022) suggests that clubs are the more accurate description. The third is to exploit the panel dimension more fully with a dynamic specification that estimates the reversion

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parameter and the shock variance in Equation (4) directly, which would turn the reconciliation offered here from an interpretation into a test.

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AUTHOR CONTRIBUTIONS

Conceptualisation, D.O.N.; methodology, D.O.N.; software, D.O.N.; formal analysis, D.O.N.; data curation, D.O.N.; writing, original draft, D.O.N.; writing, review and editing, D.O.N. The author has read and agreed to the published version of the manuscript.

DATA AVAILABILITY

The panel is built from the Eurostat environmental tax accounts, dataset env_ac_tax (environmental tax revenues by category, percentage of GDP), and from the World Bank World Development Indicators (GDP per capita, constant prices), both publicly available. The assembled dataset and the estimation code are available from the author on reasonable request. The same panel is used, for a different research question and without overlap of results, in a companion article by the author in No. 74 of this journal.

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The author declares no competing interests.

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