December 2023

Fondazione Eni Enrico Mattei

Working Paper

026.2023

Is public debt environmentally friendly? The role of EU fiscal rules on environmental quality: An empirical assessment

Giovanni Carnazza
Thomas I. Renström
Luca Spataro

Is public debt environmentally friendly? The role of EU fiscal rules on environmental quality: An empirical assessment

Giovanni Carnazza (Department of Economics and Management, University of Pisa), **Thomas I. Renström** (Department of Economics and Management, Centre for Environmental and Energy Economics, Durham University), **Luca Spataro** (Department of Economics and Management, University of Pisa)

Summary

The EU has embarked on multiple initiatives reflecting its commitment to environmental enhancement and sustainable transitions. Notable among these are the European Green Deal and the NextGenerationEU recovery plan, both pivotal in fostering eco-friendly policies and sustainable practices within the region. Conversely, the fiscal rules within the EU, designed to manage budgetary deficits and debt-to-GDP ratios, may pose challenges to the implementation of fiscal measures targeted at achieving environmental quality objectives. These regulatory constraints potentially curtail the fiscal space available for policies aligned with the environmental goals set forth by the EU. To address this issue, using a panel of 27 European member countries observed annually from 1995 to 2021, we investigate the impact of two different indicators on the overall carbon intensity: on the one hand, the implicit tax rate on energy reduces environmental pollution; on the other hand, an increase in the stringency of the European fiscal framework and/or the debt-to-GDP ratio increase carbon intensity. From a policy point of view, our outcomes stress the importance of shaping national and European regulations to foster more sustainable environmental development.

Keywords: Fiscal Rules, European Union, Energy taxes, CO2 emissions, Government debt

JEL classification: H23, H63, H87, Q53, Q58

***Address for correspondence*:**
Luca Spataro
Full Professor, Public Economics
Department of Economics and Management, University of Pisa
via C. Ridolfi 10, 56121 Pisa (Italy)
e-mail: luca.spataro@unipi.it

Is public debt environmentally friendly?

The role of EU fiscal rules on environmental quality: An empirical assessment

Giovanni Carnazza [§]

Thomas I. Renström [*]

Luca Spataro [**]

Abstract

The EU has embarked on multiple initiatives reflecting its commitment to environmental enhancement and sustainable transitions. Notable among these are the European Green Deal and the NextGenerationEU recovery plan, both pivotal in fostering eco-friendly policies and sustainable practices within the region. Conversely, the fiscal rules within the EU, designed to manage budgetary deficits and debt-to-GDP ratios, may pose challenges to the implementation of fiscal measures targeted at achieving environmental quality objectives. These regulatory constraints potentially curtail the fiscal space available for policies aligned with the environmental goals set forth by the EU. To address this issue, using a panel of 27 European member countries observed annually from 1995 to 2021, we investigate the impact of two different indicators on the overall carbon intensity: on the one hand, the implicit tax rate on energy reduces environmental pollution; on the other hand, an increase in the stringency of the European fiscal framework and/or the debt-to-GDP ratio increase carbon intensity. From a policy point of view, our outcomes stress the importance of shaping national and European regulations to foster more sustainable environmental development.

Keywords: Fiscal Rules, European Union, Energy taxes, CO2 emissions, Government debt

JEL Classification: H23, H63, H87, Q53, Q58

[§] University of Pisa (Italy), Department of Economics and Management. E-mail: giovanni.carnazza@unipi.it

[*] University of Pisa (Italy), Department of Economics and Management; Centre for Environmental and Energy Economics, Durham University (UK). E-mail: thomas.renstrom@unipi.it

[**] Corresponding author. University of Pisa (Italy), Department of Economics and Management. E-mail: luca.spataro@unipi.it

1. Introduction

This study conducts an empirical analysis to shed new light onto the impact of fiscal policies on environmental quality within the European Union (EU). Examining the influence of fiscal variables on the environment holds particular significance in Europe due to the ambitious goals set by the EU for green transition and the substantial share of public spending compared to other global regions (Dewan and Ettlinger, 2009). Over recent decades, the EU has solidified its global leadership in climate policy, notably with the inception of the Green Deal in 2019. The EU aims to achieve a substantial 55% reduction in greenhouse gas emissions by 2030 compared to 1990 levels and strives for complete carbon neutrality across the continent by 2050[1]. Conversely, the tightening of fiscal constraints integral to the European fiscal framework serves to control budget deficits and regulate the debt-to-GDP ratio. However, this well-intentioned fiscal discipline may have unintended consequences, potentially impacting the effectiveness of environmental policies. Regions with high levels of debt or a significant deficit relative to GDP may face constraints on fiscal capacity, impeding the implementation of robust environmental policies (Korinek *et al.*, 2023). For these reasons the EU is currently involved in a complex process of reform of its economic governance framework[2].

The motivation for this research stems from the scarcity of empirical evidence in existing literature regarding the influence of public policies on air pollution and environmental sustainability

[1] To achieve the ambitious goals outlined in the Green Deal and RepowerEU, in July 2023 the European Commission has estimated that an annual investment exceeding EUR 620 billion will be required. Additionally, the Net Zero Industry Act mandates a total investment of EUR 92 billion within the 2023-2030 period (European Commission, 2023). Notably, the EU has already allocated a substantial budget of EUR 578 billion, constituting at least 30% of its total budget, for climate-related initiatives during the 2021-2027 period. While a substantial portion of the residual funds is expected to originate from private sources, member states' budgets will also be necessary in supporting this transition. For a deeper insight into the issues concerning the EU strategies on Sustainable Development, see Spataro et al. (2023).

[2] The European Commission, after conducting retrospective assessments of the economic governance framework (EGF) in 2020 and 2021, initiated a public consultation leading to a November 2022 communication outlining "guidelines" and principles for reforming the EGF. In April 2023, the Commission introduced a legislative proposal package that revises the Stability and Growth Pact and the requirements for member states' budgetary frameworks. With the anticipated deactivation of the general safeguard clause of the Stability and Growth Pact by the end of 2023, member states and the Commission must reach a consensus on the reform before the budget procedures of the member states. In the absence of such consensus, existing legislation will apply.

in the EU. This gap is particularly evident in relation to the European fiscal framework and its associated constraints on public finance. In contrast, a substantial body of literature focuses on fiscal discipline, advocating for the reduction of public debt levels and emphasizing the need to enhance budgetary balance for fiscal sustainability, especially within the Euro area. Economic literature suggests that fiscal policy in both developed and developing countries tends to be procyclical for various reasons, displaying expansionary tendencies during economic upswings and contractionary characteristics during economic downturns. In the Euro area, this pattern seems influenced by the stringency of fiscal rules (Carnazza et al., 2023). To address this knowledge gap, our study analyzes the repercussions of the European fiscal framework on environmental quality within the EU, considering a panel of 27 member countries with annual observations from 1995 to 2021. More precisely, we examine the influence of two different policy indicators on overall CO_2 emissions per unit of output: the implicit tax rate on energy (ITRE) as a proxy for energy taxes, and the degree of stringency of the European economic fiscal framework interacted with debt-to-GDP ratio. While the first indicator, unaffected by carbon emissions or changes in the tax base, offers an effective measure of the average level of energy taxation, the second one stems from the evidence that the significance of the debt-to-GDP ratio intensifies with the stricter implementation and supervision of supranational fiscal rules in national law.

The rest of the work is organized as follows: Section 2 provides a theoretical overview of the scrutinized issue, while Section 3 offers an empirical analysis of the situation in the European Union. Section 4 outlines the variables used and the methodology applied in this study. Section 5 presents and discusses the primary findings, and Section 6 provides concluding remarks.

2. Overview of related literature

Governments possess a range of strategies to attain environmental protection objectives, offering solutions to address market deficiencies or enhance the efficiency of existing markets. These strategies typically involve the implementation of corrective (or emission) taxes, aimed to internalize the external costs associated with environmental degradation, providing economic incentives for businesses and individuals to reduce their negative impacts.[3]

From a theoretical point of view, a higher environmental tax levied on consumers (say energy consumption) ought to reduce the consumption of the polluting good (if it is non-inferior). If substitution effects are stronger than income effects, also the relative pollution (pollution per income) would also fall. On the production side, if pollution stems from the use of a factor of production (say energy), also the use of this factor would fall due to a higher environmental tax, and consequently pollution. It is possible that a higher factor price (due to the tax) also causes an overall reduction in production, however the pollution per production unit will always fall, see Renström et al. (2021).

There is empirical evidence that environmental taxes reduce emissions. The studies referred to below take the quantity of CO_2 emissions as the dependent variable and proxies the environmental taxes as total environmentally related tax revenue divided by GDP. They also control for GDP. Morley (2012) documents the effect of environmental taxes on CO_2 emissions among EU member countries for the period 1995-2006. Controlling for real GDP, capital formation, and total population, the result is that a 1% increase in the environmental tax is associated with a 1% reduction in emissions. Safi et al. (2021) investigate the effect of environmental taxes and public R&D expenditure on consumption-based CO_2 emissions in the G7 economies over the time horizon 1990-2019. Both R&D expenditure and environmental taxes reduce their CO_2 measure. Controlling for GDP and imports/exports they find that (on average) the environmental taxes reduce consumption-based CO_2 by 0.09% in the short run, and 0.189% in the long run. Doğan et al. (2022), using data for the G7

---

[3] Common instruments encompass emissions taxes, tradable emissions allowances, subsidies for emissions reductions, performance standards, mandates for adopting specific technologies, and incentives for research into innovative, "clean" technologies. Each of these environmental policy instruments, in turn, varies in its capacity to meet significant evaluation criteria, including cost-effectiveness, distributional equity, the ability to address uncertainties, and political feasibility. For a comprehensive exploration of these policy instruments, particularly their mechanisms, effectiveness, and implications, see Bovenberg and Goulder (2002).

economies 1994-2014, also find the environmental taxes reduce CO_2 emissions, when controlling for per-capita GDP, energy renewable/non-renewable energy consumption, and natural resources rent.

On fiscal constraints and environmental policy there is less theoretical research. In principle, second-best optimal environmental policy will depend on how tight the second-best constraint is. A tighter second-best constraint will move the consumption possibilities frontier inwards, making all goods, including the environment less affordable. If the environment is a normal good, tightening the constraint would call for less consumption of the environment and thus weaker environmental policy. Fiscal rules, if binding, would work in this way, therefore one would expect less strict environmental policies in economies with stricter fiscal rules. On the other hand, fiscal rules are there for a reason, to mitigate an incentive problem in policy making. If those rules work, and partially solve the incentive problem, there would be a superior equilibrium, in the sense that the consumption possibilities frontier moves outwards. This would work in the direction stricter environmental policies.[4]

As for the EU, some authors have argued that the existing EU fiscal framework lacks the necessary flexibility for member states to adequately prepare for the green transition by increasing debt-financed green public investments (Korinek et al., 2023). However, until now we lack studies providing empirically-founded estimates of the relationship between the EU policy framework, fiscal policies and environmental improvement[5]. The ongoing reform of the EU fiscal rules presents an opportunity to enhance the EU economic governance framework, ensuring critical investments to address long-term challenges. However, an analysis based on empirically estimated parameters on the consequences of such a reform, is still missing, raising concerns about whether member states

---

[4] See Marsiliani and Renström (2000), where a majority elected policy makers choose taxes under the fiscal rule of tax earmarking. The earmarking rule partially solves a commitment problem and induces an equilibrium with tighter higher environmental policy.

[5] To the best of our knowledge, the only works adopting a quantitative approach are Mang and Caddick (2023) and Van den Noord (2023) according to which, even with the reformed rules of the economic governance framework, only few member states are expected to have sufficient fiscal leeway to meet their public green investment needs. However, projections based on empirical estimates are missing.

will have adequate incentives and flexibility to pursue these crucial investments. In this paper, we aim at filling this gap, providing empirical estimates of the relationship between the European policy rules, national fiscal policies and environmental quality.

3. Setting the issue in the European Union from an empirical point of view

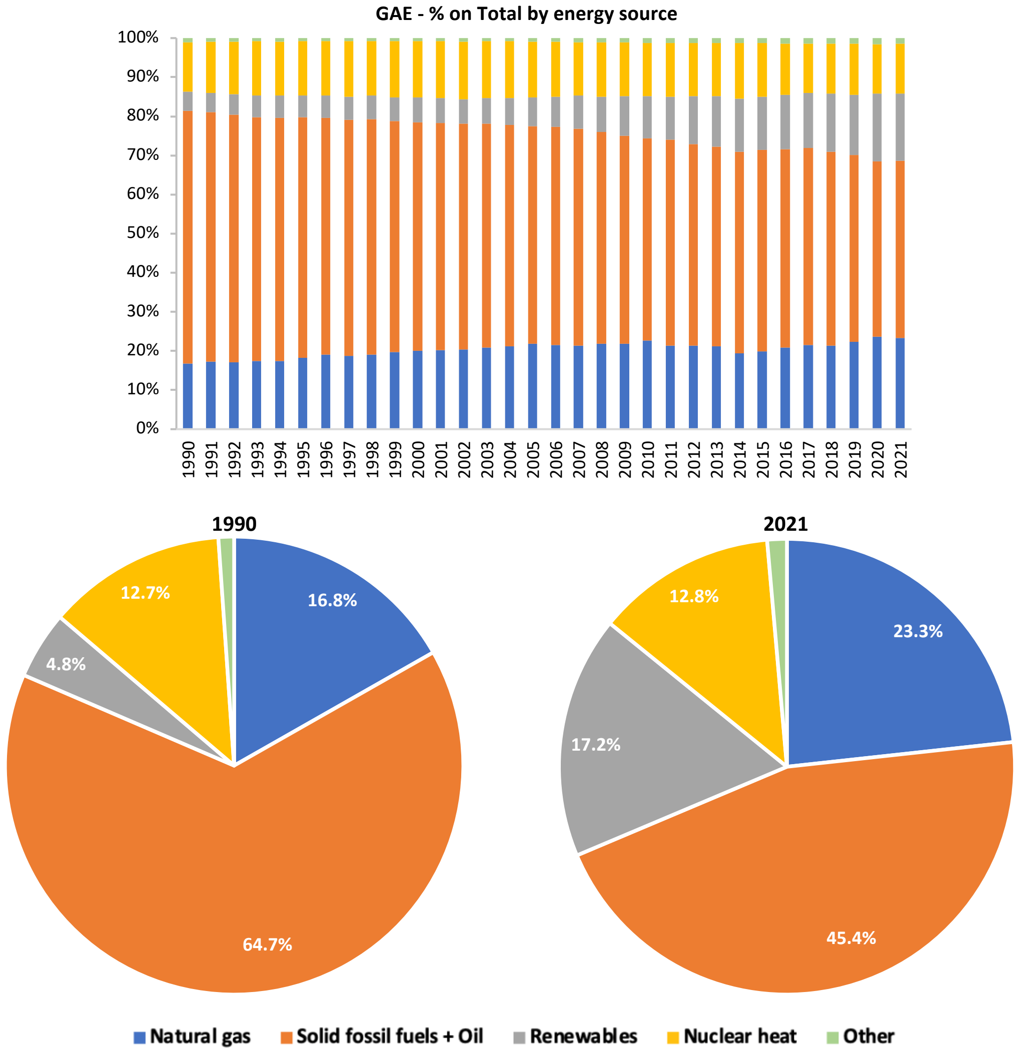
The section provides a historical and descriptive overview of the energy landscape in the European Union. Specifically, Paragraph 3.1 delves into Gross Available Energy (GAE) by source category, highlighting the continued significant role of fossil fuels in the overall energy mix. Paragraph 3.2 explores the trend in greenhouse gas emissions and the associated proportion of carbon dioxide. Paragraph 3.3 discusses environmental and energy taxes, along with the auctioning of emission permits under the EU Emissions Trading Scheme (ETS).

3.1 Gross Available Energy (GAE) by source category

Since 1990, there has been a 12.8% reduction in the use of fossil fuels in the European Union (EU). However, the EU still heavily depends on this energy source, constituting nearly 70% of Gross Available Energy (GAE) in 2021, despite the increase in renewable energies (from 4.8% in 1990 to 17.2% in 2021). GAE is the overall supply of energy within a country. It is calculated as primary production plus recovered products, net imports, and variations in stocks. In absolute terms, GAE exhibited a quadratic trend, reaching its peak in 2006. Subsequently, the indicator gradually declined, returning to the 1990 value by 2021.

Over time, the EU has seen a rise in its energy dependency rate (55.5% in 2021), reflecting the region's reliance on (net) energy imports from abroad. More than half of GAE consistently comes from foreign countries, peaking at 60.5% in 2019. The observed decrease in the share of fossil fuels in GAE is mainly attributed to a reduction in the use of solid fossil fuels, with a nearly 15% decrease. In contrast, oil experienced a slight decline (-4.8%), while the utilization of natural gas increased from 16.8% in 1990 to 23.3% in 2021 (Figure 1).

Figure 1 – Gross Available Energy (GAE) in the EU



Note: GAE is calculated as follows:

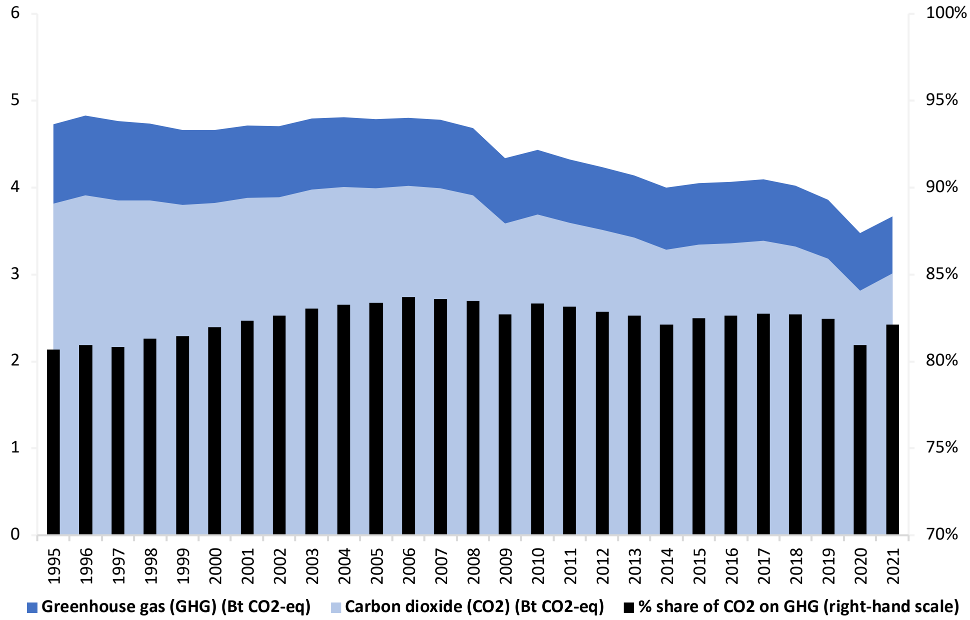
$$GAE = Primary\ production + Recovered\ \&\ Recycled\ products + Imports - Export + Stock\ changes$$

Note: for certain member states the category "Other" can assume negative values due to net exports of electricity.
Note: "Oil" is the abbreviation for "Oil and petroleum products"; "Renewables" is the abbreviation for "Renewables and biofuels"; the category "Other" includes "Manufactured gases", "Peat and peat products", "Oil shale and oil sands", "Non-renewable waste", "Electricity" and "Heat".
Source: own elaborations on Eurostat data

3.2 Greenhouse gas (GHG) and carbon dioxide ($CO2$) emissions

Carbon dioxide (CO_2) stands as the primary greenhouse gas (GHG) responsible for global warming and climate change. In 1995, CO_2 constituted around 82% of GHG emissions from EU countries. Although there is a discernible decrease in both GHG and CO_2 emissions from European countries over time, the proportional contribution of CO_2 to total GHG has steadily increased until stabilizing in 2021 at the initial value (see Figure 2).

Figure 2 – Greenhouse gas (GHG) and carbon dioxide (CO_2) emissions in the EU



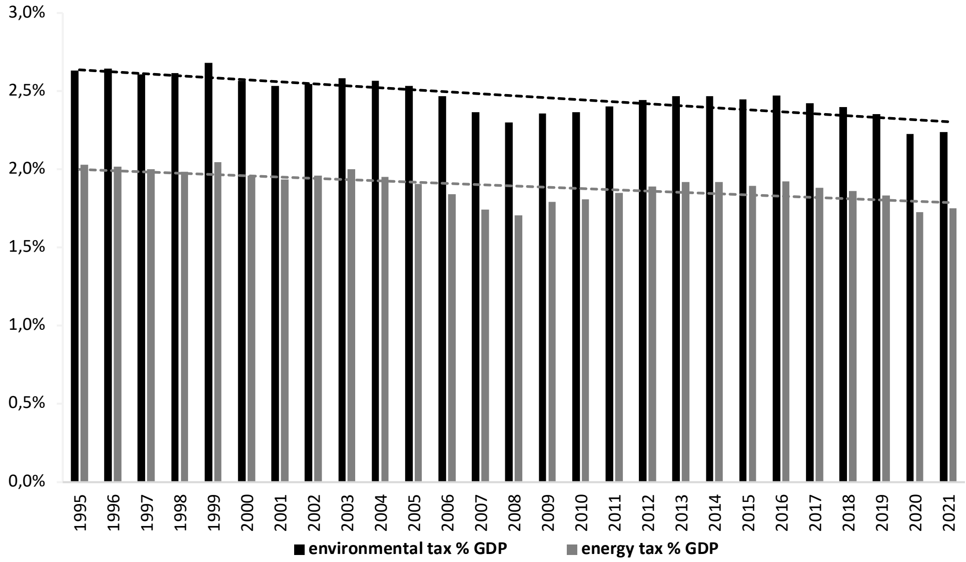
Note: total air emissions exclude memo items (*i.e.*, transport and storage of CO_2, international bunkers, multilateral operations, biomass – CO_2 emissions) and land use, land-use change and forestry (LULUCF), while include international transport.
Note: measurement (left-hand) scale is billions of tons.
Note: the GHG aggregate is expressed in billion tons of CO_2 equivalent (Bt CO_2-eq).
Source: own elaborations on European Environment Agency (EEA) data

3.3 Environmental and Energy Taxes and EU ETS

Environmental taxes are categorized into four main types: (i) energy taxes, (ii) transport taxes, (iii) pollution, and (iv) resource taxes. Given that energy taxes contribute to over three-quarters of EU environmental tax revenue, our focus centers on this category (Figure 3). Energy taxes cover levies on energy products like coal, oil products, natural gas, and electricity. CO_2 taxes are often included in this category, imposed on energy products due to their carbon content.[6] Figure 3 also illustrates the weight of environmental taxes and energy taxes as percentage of GDP (European average from 1995 to 2021). Both ratios display a consistent negative trend, progressively diminishing their already limited role.

[6] While CO_2 taxes share characteristics of both energy and pollution taxes, they are classified as energy taxes in EU statistics.

Figure 3 – Environmental and energy taxes in the EU



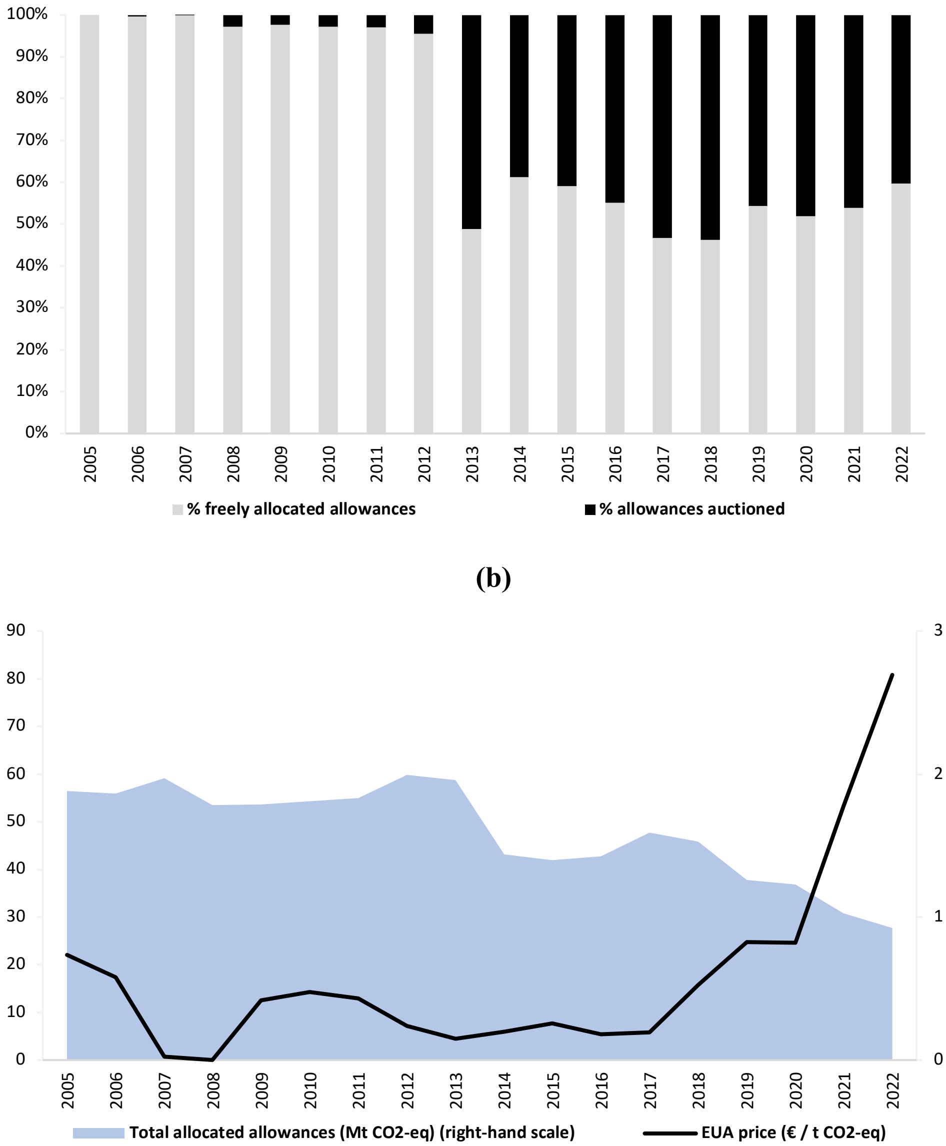
Source: own elaborations on Eurostat data

Generally, energy taxes can be applied to any GHG, but the most common type is a carbon tax, imposing charges on each unit of emitted CO_2 subject to taxation. CO_2 taxes, also termed carbon taxes, target the carbon content in fossil fuels. Given that, differently from other taxes, CO_2 taxes necessitate a specific tax base (carbon content), this kind of taxes typically promote the use of lower-carbon fuels. In addition to country-specific charges, EU CO_2 taxes encompass government revenues from auctioning emission permits within the EU Emissions Trading System (EU ETS). According to the European System of Accounts 2010 (ESA 2010), earnings from the auctioning of emission permits in the EU are categorized as taxation. With the cap-and-trade principle, governments increasingly adopt emission trading systems to control CO_2 emissions.[7] As auctions commenced in 2013, the total allocated allowances gradually decreased, coupled with a sharp rise in the average European Union Allowances (EUA) price from 2018 (Figure 4b).

[7] The EU ETS, initiated in 2005, initially allocated allowances for free until 2012. Since the start of phase 3 (2013-2020) of the ETS, auctioning has become the standard allocation method. In phase 4 (2021-2030), the total number of emission permits will decrease, narrowing the free allocation to vulnerable sectors and phasing it out for less exposed sectors post-2026.

Figure 4 – Emission allowances (Emissions Trading System – ETS) in the EU

(a)



Note: total allocated allowances are expressed in million tons of CO_2equivalent (Mt CO_2-eq).
Note: data include aviation (activity type 10) and stationary installations (activity types 20-99).
Note: EUA price = European Union Allowances price (the price of emissions allowances traded on the EU ETS).
Source: own elaborations on European Environment Agency (EEA) data

4. Data and methodology

We next outline all the variables used and the methodology employed. Descriptive statistics of dependent (section 4.1) and main independent variables (sections 4.2 and 4.3) and their respective sources are presented in Table 1. The methodology is elaborated on in section 4.4. Our analysis covers 27 countries within the EU with annual observations from 1995 to 2021.

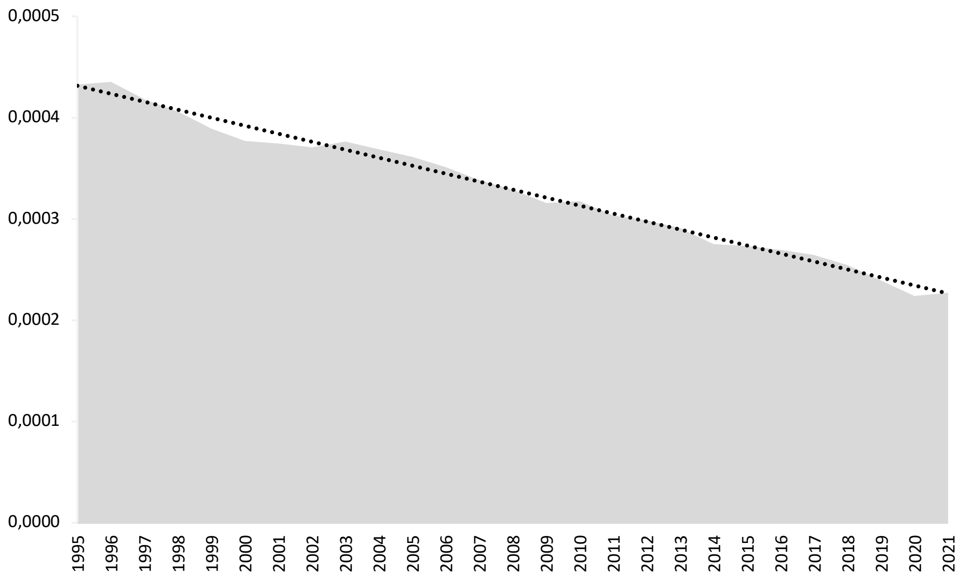
Table 1 – Descriptive statistics

Name	Definition	Unit of measure	Obs	Mean	Std. Dev.	Skewness	Kurtosis	Source
CO2intensity	Overall carbon intensity (carbon emitted per unit of real GDP)	toe per €	724	0.00051	0.00034	1.75	6.46	Eurostat and EEA
ITRE	Implicit tax rate on energy (energy tax revenue on final energy consumption)	€ per toe	724	185.33	82.08	0.84	3.97	Eurostat
FRI_Debt	Fiscal Rules Index * debt-to-GDP ratio	%	725	24.62	20.44	1.00	3.86	IMF
VAservicesGDP	Services, value added (% of GDP)	%	729	61.60	6.61	0.16	3.34	The World Bank
Renewables	Renewables and biofuels on total final consumption - energy use	%	729	9.99	6.79	0.57	2.60	Eurostat
netcapitalstockpe	Net capital stock (at constant prices), per person employed	Thousand €	729	139.70	91.11	0.24	1.64	AMECO

4.1 Overall Carbon Intensity

Following Jeffrey and Perkins (2015), our focus is on a specific measure of CO_2 emissions, namely the overall carbon intensity (CO_2 intensity). This metric is our dependent variable and is defined as metric tons of carbon dioxide (CO_2) per unit of real GDP. We utilize overall carbon intensity as a proxy for carbon emissions due to its significance in assessing a global measure of emissions. It concurrently captures elements of both effectiveness (related to the carbon content of energy consumed) and efficiency (related to the carbon content per unit of production). The decreasing trend of overall carbon intensity is depicted in Figure 5.

Figure 5 – Overall carbon intensity in the EU (toe per €)

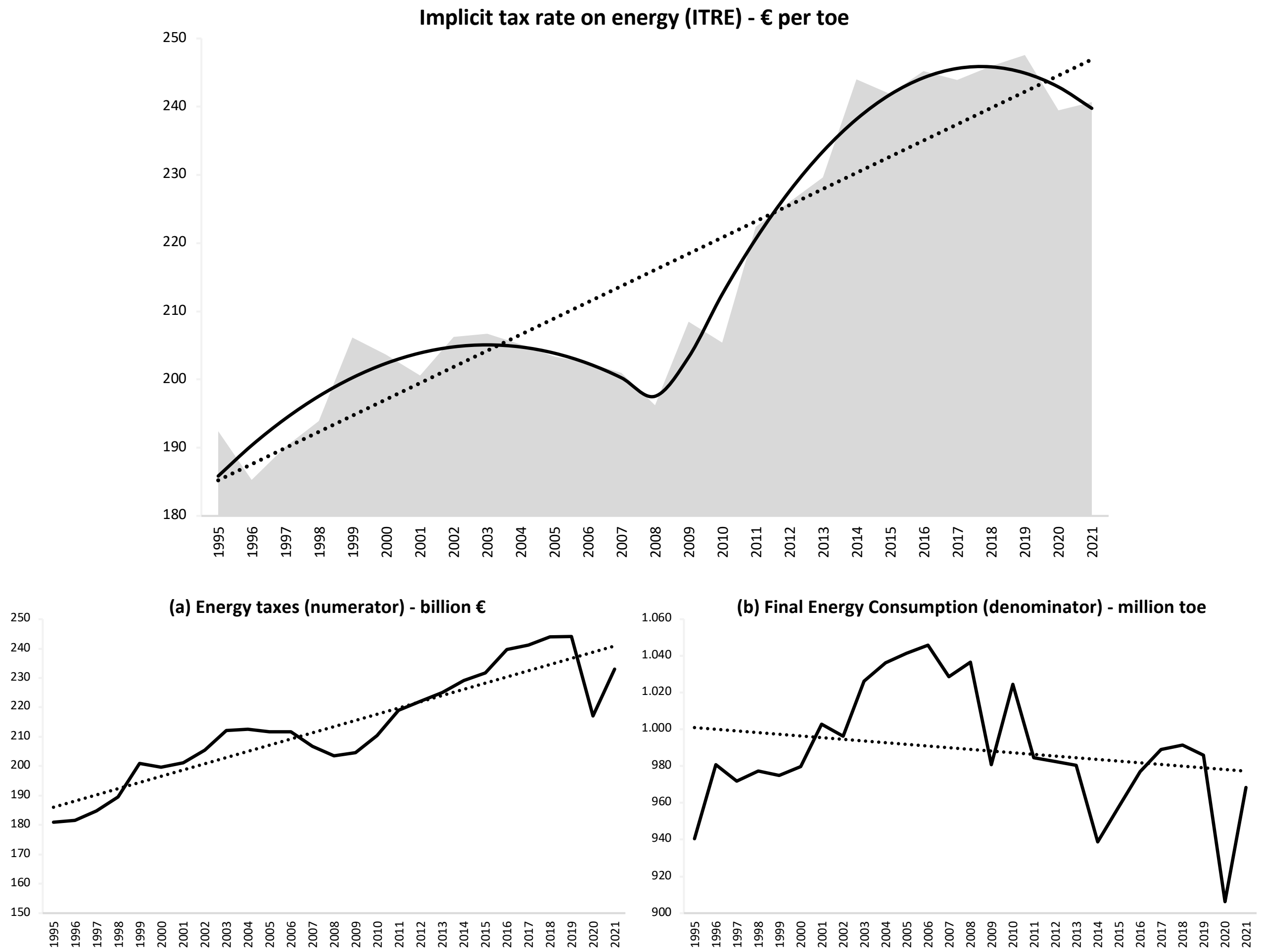


Source: own elaborations on Eurostat and European Environment Agency (EEA) data

4.2 Implicit Tax Rate on Energy

The implicit tax rate on energy ($ITRE$) is one of the primary regressors in our analysis, calculated as the ratio of energy tax revenue to final energy consumption for a given calendar year. This indicator reflects the implicit tax rate on energy in relation to energy tax revenues and final energy consumption, summarizing – among other things – the degree to which a country is sensitive to environmental issues. Both energy tax revenues (deflated with the implicit GDP deflator, prices of the year 2015) and final energy consumption (measured in tonnes of oil equivalent, toe) contribute to expressing $ITRE$ in euros per tonne of oil equivalent (€ per toe). Thus, we proxy energy taxes with $ITRE$, adhering to official guidelines that deem it an appropriate measure for analytical purposes due to its straightforward interpretation. Importantly, $ITRE$ is not influenced by carbon emissions or any erosion in the tax base, providing an effective measure of the average level of energy taxation. The overall linear increasing trend of this indicator is depicted in Figure 6, revealing distinct phases. Notably, from 1995 to 2008, a modest increase is observed, primarily attributable to constant energy consumption (excluding peaks in the early 2000s) and a gradual rise in energy tax revenues. Subsequently, energy taxes continue to rise over time (excluding a reduction in 2020), while final energy consumption, despite fluctuations, shows a slight decrease.

Figure 6 – Implicit tax rate on energy in the EU



Note: (a) energy tax revenues are measured at constant price euros (deflated with the implicit GDP deflator, prices of year 2015). The EU aggregate does not include the United Kingdom. The implicit tax rate on energy is expressed in terms of euro per tonne of oil equivalent (toe): the dotted line represents the linear trend, while the solid line the quadratic trend where an unknown structural break (2009) was detected with the Quandt Likelihood Ratio (QLR) test.
Source: own elaborations on Eurostat data

4.3 Fiscal Rules Index

Among the EU countries, fiscal rules have gained in importance. The number of rules has tripled since the adoption of the stability and growth pact in 1997, and doubled in the last 15 years (Manescu *et al.*, 2023). The stringency of fiscal rules become more important when the debt to GPD is larger

(Carnazza *et al*., 2023). In particular, when the public debt level is high, the government may adopt a more restrictive fiscal policy in economic downturns to avoid being in breach of the 3% debt to GDP reference value (Huart, 2013; Reuter, 2019).

To measure stringency, as in Gootjes et al. (2021), we use a fiscal-rules index based on the IMF dataset (Davoodi *et al*., 2022). The data set translates rule stringency into a numerical score for each country and year for each dimension, a higher score implying more stringency. One dimension is coverage, taking on 0 if no coverage, 1 if general government and 2 if wider. The second dimension is legal basis, with 1 for political commitment, 2 for coalition agreement, 3 for statutory rule, 4 for international treaty, 5 for constitutional rule. The third, supporting procedures, relates to the presence of multi-year expenditure ceilings, fiscal responsibility law, and independent fiscal body in monitoring, taking on 1 if present or 0 otherwise. The fourth is enforcement, taking on 1 if there is a formal enforcement procedure, and 0 otherwise. The first two dimensions are normalised to lie between 0 and 1.

We focus on two types of rules budget-balance rule (BBR) and debt rule (DR) at national and supra-national levels. For j = 1 (BBR, national), 2 (BBR, supra-national), 3 (DR, national), 4 (DR, supra-national), we calculate the fiscal sub index (FSI):

$$FSI_{i,t}^{j} = coverage_{i,t}^{j} + legal\ basis_{i,t}^{j} + supporting\ procedures_{i,t}^{j} + enforcement_{i,t}^{j} \tag{1}$$

for country i and year t.

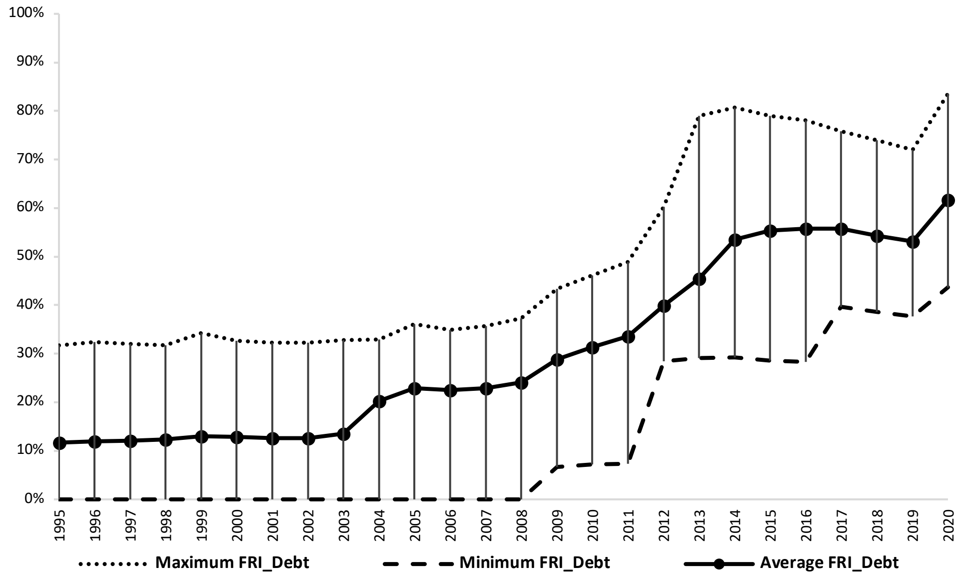
Our fiscal-rules index is then

$$FRI_{i,t} = \left(normalisation \sum_{j=1}^{4} FSI_{i,t}^{j} \right) \tag{2}$$

where the normalisation is such that FRI is between 0 and 1. Note that each component carries equal weight. As mentioned earlier, the fiscal rules stringency is likely to matter when the public debt level is high, so multiplying FRI by the debt to GDP ratio, we obtain the variable FRI_Debt.

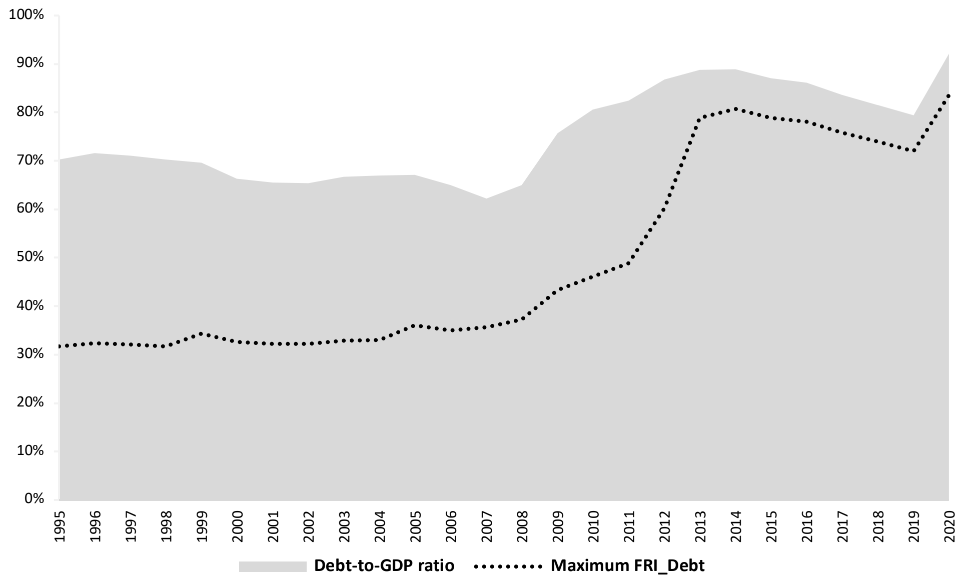
Figure 7 displays the result of this interaction in our sample, while Figure 8 compares the debt-to-GDP ratio with the maximum level of the interaction between this ratio and the Fiscal Rules Index (FRI). Interestingly, the significant increase in the severity of fiscal regulations, which began in 2011, has pushed the maximum value of FRI_Debt almost to coincide with the debt-to-GDP ratio.

Figure 7 – The *FRI_Debt* variable in the EU



Source: authors' elaborations on IMF and Eurostat data

Figure 8 – Debt-to-GDP ratio in the EU



Source: authors' elaborations on IMF and Eurostat data

4.5 Methodology

In formal terms, for each country i, we have the following equation expressed at first differences (Δ):

$$\Delta ln\_CO2intensity_{i,t} = \alpha + \beta_1 ETS_{i,t} + \beta_2 \Delta ln\_ITRE_{i,t} + \beta_3 \Delta FRI\_Debt_{i,t} + \phi' \boldsymbol{\Delta V}_{i,t} + \boldsymbol{u}_{i,t} \qquad (3)$$

where ETS is a dummy variable that considers the membership in the EU ETS (it equals 1 if the country participates in the EU ETS in the corresponding year)[8], $\boldsymbol{V}$ represents a vector of control variables ($VAservicesGDP$, $renewables$, and $ln\_netcapitalstockpe$), and $\boldsymbol{u}_{it}$ includes country fixed-effects γ_i (to control for unobserved time-invariant country characteristics), time fixed-effects λ_t (to deal with possible exogenous shocks common to all countries in a specific year) and the error component ε_{it}.[9] The three control variables are defined and justified as follows. First, $VAservicesGDP$ is the valued added produced by the service sector as a percentage of GDP. In this way, we take into account the distribution between service sector and industrial sector which, by definition, requires more energy consumption. Secondly, $renewables$ represents the consumption of renewables and biofuels as a percentage of final energy consumption. The share of renewable energy used in total energy needs describes the energy mix available to a country and the dependence on fossil fuels. Finally, $netcapitalstockpe$ denotes net capital stock (at constant prices) per person employed so as to take into account the relative weight between capital and labour within each country.

As specified, each variable is expressed at first differences to address the issue of stationarity, avoiding the possibility of spurious regressions. Non-stationary variables, while independent, could be highly correlated only because of their trend (Granger and Newbold, 1974). Stationarity for panel data is addressed with two unit root tests: the Fisher-type Augmented Dickey Fuller (ADF) test and the cross-sectional ADF ($CADF$) test proposed by Pesaran (2007). Based on these tests, all variables

[8] Since the ETS program begins in 2005 (see Paragraph 3.3), this dummy variable includes the information related to the late entry of some member states.
[9] Natural logarithm is applied when variables are not expressed as an index or percentage.

are found to be stationary at first differences (Table 2). The pairwise correlation matrix between all variables at first differences shows the absence (or negligible presence) of correlation relationships.

Table 2 – Panel unit-root tests

	Im-Pesaran-Shin test		Fisher-type tests	
	no trend	trend	ADF	PP
Δln_CO2int	***	***	***	***
Δln_ITRE	***	***	***	***
ΔFRI_Debt	***	***	***	***
ΔVAservicesGDP	***	***	***	***
Δrenewables	***	***	***	***
Δln_netcapitalstockpe	***	***	***	***

Note: ***, **, * denote significance at 1%, 5% and 10% level, respectively. If the variable is significant, this implies stationarity.

Table 3 – Pairwise correlation matrix

	Δln_CO2int	Δln_ITRE	ΔFRI_debt	ΔVAservicesGDP	Δrenewables	Δln_netcapitalstockpe
Δln_CO2intensity		**-0.1569**	0.0138	**-0.0853**	**-0.1140**	-0.0099
		*(0.000***)*	*(0.7179)*	*(0.0243**)*	*(0.0026***)*	*(0.7934)*
Δln_ITRE	**-0.1569**		**0.0636**	-0.0084	0.0299	0.0340
	*(0.000***)*		*(0.0944*)*	*(0.8255)*	*(0.4307)*	*(0.3699)*
ΔFRI_Debt	0.0138	**0.0636**		0.0292	0.0351	**0.1014**
	(0.7179)	*(0.0944*)*		*(0.4287)*	*(0.3259)*	*(0.0065***)*
ΔVAservicesGDP	**-0.0853**	-0.0084	0.0292		0.0264	**0.1081**
	*(0.0243**)*	*(0.8255)*	*(0.4287)*		*(0.4688)*	*(0.0037****)
Δrenewables	**-0.1140**	0.0299	0.0351	0.0264		**0.0894**
	*(0.0026***)*	*(0.4307)*	*(0.3259)*	*(0.4688)*		*(0.0162**)*
Δln_netcapitalstockpe	-0.0099	0.0340	**0.1014**	**0.1081**	**0.0894**	
	(0.7934)	*(0.3699)*	*(0.0065***)*	*(0.0037***)*	*(0.0162**)*	

Note: p-values are given in parentheses. ***, **, * denote significance at 1%, 5% and 10% level, respectively.

We rely on a Generalised Least Squares (GLS) estimator controlling for panel specific autocorrelation structure ($AR1$) and heteroskedastic and correlated error structure. A standard assumption in panel data models is that the error terms are independent across cross-sections. In the worst case, cross-sectional dependence can lead to endogeneity and therefore to inconsistent estimates. In this context, the previous estimator allows us to deal with cross-sectional dependence in the error term.

5. Main results

Table 4 presents the key findings concerning the relationship between carbon intensity and energy taxes, as well as the interaction between fiscal rules and the debt-to-GDP ratio.

Table 4 – Main results

Dependent variable	*Δln_CO2int*					
Model	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Estimator	**FE**	**GLS**	**GLS**	**FE**	**GLS**	**GLS**
Δln_ITRE	-0.09016 ***	-0.07472 ***	-0.08713 ***	-0.08572 ***	-0.07225 ***	-0.08667 ***
ΔFRI_Debt	0.00127 ***	0.00117 ***	0.00128 ***	0.00119 ***	0.00106 ***	0.00142 ***
ΔVAservicesGDP				-0.00074	-0.00058	-0.00278 ***
Δrenewables				-0.00339	-0.00505 ***	-0.00335 ***
Δln_netcapitalstockpe				0.18558	0.18999 **	0.24468 ***
Constant	Yes	Yes	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes
Time dummies	Yes	Yes	Yes	Yes	Yes	Yes
ETS dummies	Yes	Yes	Yes	Yes	Yes	Yes
Heteroskedastic and uncorrelated error structure	No	Yes	No	No	Yes	No
Heteroskedastic and correlated error structure	No	No	Yes	No	No	Yes
Panel-specific AR1 autocorrelation structure	No	Yes	Yes	No	Yes	Yes
Number of observations	693	693	567	693	693	567
Number of countries	27	27	27	27	27	27
Time period	1995 - 2021	1995 - 2021	2002 - 2021	1995 - 2021	1995 - 2021	2002 - 2021
Wald chi^2	-	***	***	-	***	***

Note: in models (3) and (6), the heteroskedastic and correlated error structure requires the panel to be closely balanced. Due to missing observations, this implies that our estimates are performed from 2002 to 2021. ***, **, * denote significance at 1%, 5% and 10% level, respectively. FE = Fixed Effects (robust standard errors); GLS = Generalised Least Squares (controlling for panel-specific AR1 autocorrelation structure, heteroskedastic but uncorrelated error structure, and heteroskedastic and correlated error structure).

As previously mentioned, the impact of energy taxes is assessed by estimating $ITRE$, while the interaction is evaluated by multiplying the Fiscal Rules Index (FRI) with the debt-to-GDP ratio (FRI_Debt). The coefficients associated with the two main regressors (β_2 for Δln_ITRE and β_3 for

ΔFRI_Debt – see also equation 3) are consistently significant at the 1% level across all specifications, whether employing Fixed Effects or Generalized Least Squares. The analysis controls for a panel-specific AR1 autocorrelation structure, heteroskedastic but uncorrelated error structure, and heteroskedastic and correlated error structure. The results also remain robust when introducing the three control variables.

As expected, β_2 is negative, indicating that an increase in $ITRE$ reduces the amount of CO_2 contained per unit of real GDP. In contrast, β_3 is positive, suggesting that the interaction between the European fiscal framework (approximated by FRI) and the evolution of the debt-to-GDP ratio plays a crucial role in shaping overall carbon intensity. In other words, considering that the significance of a specific level of the debt-to-GDP ratio increases in proportion to the strictness of the implementation and monitoring of supranational fiscal regulations incorporated within national legislation (see also Paragraph 4.3), a positive change in FRI_Debt is associated with an increase in the CO_2 content per unit of real GDP. This significant result may be explained by recognizing that policy makers, especially in highly debt-burdened countries with very restrictive fiscal rules, are often confronted with the urgency of fiscal consolidation. This implies the need to reshape the public budget by reducing spending items that are less attractive to voters and less rigid. Unfortunately, environmental protection expenditures often exhibit both characteristics. Along these lines, many countries may not have enough fiscal space to cover the costs of climate-related expenditure.[10] This result emphasizes even more the conclusion reached by Carratù *et al.* (2019), pointing out the existence of a trade-off between the role of EU as a regulator aiming to mitigate environmental pollution (*e.g.*, the EU ETS) and its role within the Stability and Growth Pact.

---

[10] From this perspective, although energy taxes have increased in absolute terms (Figure 6 – panel a), we have also observed that their share in GDP is not only low but has also decreased over time. Similar considerations can be made regarding public spending on environmental protection (Figure A3 in the Appendix).

Finally, the three control variables show a predictable impact on the change in overall carbon intensity (see the column 6 in Table 4): firstly, a production structure that relies more on services than manufacturing results in lower CO_2 emissions contained per unit of real GDP; secondly, renewable energy improves environmental pollution; thirdly, the utilization of more capital per unit of labor results in higher carbon intensity.

6. Conclusions and policy implications

In this paper we have empirically explored the interplay between European policy rules, national fiscal policies, and environmental quality in 27 Member countries of the European Union.

Examining a period from 1995 to 2021, providing stationarity of all variables under consideration and considering cross-sectional dependence, we investigate the impact of two different indicators on the overall carbon intensity, *i.e.* the emission of CO_2 per monetary unit of real GDP. On the one hand, our results confirm the role of energy taxation in reducing environmental pollution. In this regard, energy taxes are proxied using the implicit tax rate on energy ($ITRE$), which is not influenced by carbon emissions or any erosion in the tax base and then provides an effective measure of the average level of energy taxation. This outcome should encourage policy makers to increase the relative weight of environmental taxation on national GDP over time in order to reduce the CO_2 content per unit of product. On the other hand, we wonder whether the increase in public debt has fostered more environmentally sustainable growth. In doing so, we decide to consider not the debt-to-GDP ratio, but its interaction with the evolving stringency of the European fiscal framework. The idea behind this decision is that the debt-to-GDP ratio's significance intensifies with the stricter implementation and supervision of supranational fiscal rules in national law. The coefficient associated with this indicator is significantly positive, implying that an increase in the stringency of European fiscal framework and/or debt-to-GDP ratio was linked to a rise in carbon intensity. From a policy point of view, this seems to suggest that the expansion of public debt and the progressive increase in the rigidity of fiscal rules have not been fully compatible with environmentally sustainable development. As a consequence, a greater attention on decoupling environmental spending from the fiscal restraint imposed by the European framework could represent an important and recommendable step forward.

The evolving shift towards sustainable practices presents substantial challenges for future research at the intersection of the green transition, economic growth, and fiscal sustainability. Firstly, a critical aspect involves analyzing the productivity dynamics associated with investments aimed at reducing reliance on fossil fuels. This raises questions about whether such investments, while beneficial for environmental quality, result in immediate productivity gains or introduce obstacles to short-term enhancements. Secondly, with the zero-emission target propelling rapid changes, scholarly attention should be directed towards the immediate and prospective impacts on goods and labor markets. Regarding the latter, inquiries should concentrate on the likelihood of labor market contractions and the challenges faced by industries in securing skilled workforces. Third, within the societal sphere, the green transition prompts inquiries into economic inequalities. This necessitates a meticulous examination of governmental measures, with transfers and subsidies emerging as crucial instruments to alleviate the fiscal burden, particularly for lower-income groups contending with substantial costs associated with transitioning to green technologies. However, these interventions, though necessary, pose fiscal challenges as they strain state budgets. The challenge lies in exploring ways through which governmental bodies can navigate the delicate balance between mitigating societal impacts and meeting the fiscal demands imposed by the green transition. A specific concern is the expected reduction in tax receipts, particularly stemming from levies on fuel and gasoline, due to the shift to renewable energies. For instance, in the UK, projections by the Office for Budget Responsibility suggest that the share of tax revenue derived from these levies, constituting approximately 1.2% of GDP, is anticipated to halve by 2030, ultimately becoming obsolete by 2050. Therefore, the central issue is how governments in the future will finance such interventions in scenario of decreasing fiscal resources. This scholarly endeavor extends beyond mere academic inquiry; it serves as a guiding compass for policymakers and stakeholders, navigating them through the evolving landscape of this transformative epoch.

References

Bovenberg, A. L., & Goulder, L. H. (2002). Environmental taxation and regulation. In Handbook of public economics (Vol. 3, pp. 1471-1545). Elsevier.

Carnazza, G., Liberati, P. and Sacchi, A. (2023). Does politics matter? A comparative assessment of discretionary fiscal policies in the euro area, *European Journal of Political Economy*, 102435.

Carratù, M., Chiarini, B., D'Agostino, A., Marzano, E. and Regoli, A. (2019). Air pollution and public finance: evidence for European countries, *Journal of Economic Studie*s, 46(7), 1398-1417.

Choi, I. (2001). Unit root tests for panel data, *Journal of International Money and Finance*, 20(2), 249-272.

Davoodi, H., Elger, P., Fotiou, A., Garcia-Macia, D., Lagerborg, A., Lam, R., & Pillai, S. (2022). Fiscal Rules Dataset: 1985-2021. *International Monetary Fund*, Fiscal Affair Department, Washington, D.C.

Dewan, S. and Ettlinger, M. (2009). Comparing public spending and priorities across OECD countries, *Center for American Progress*.

Doğan, B., Chu, L. K., Ghosh, S., Truong, H. H. D., and Balsalobre-Lorente, D. (2022). How environmental taxes and carbon emissions are related in the G7 economies? *Renewable Energy* 187, 645-656.

European Commission (2023). Communication from the Commission to the European Parliament and the Council, 2023 Strategic Foresight Report, 376.

Gootjes, B., de Haan, J., & Jong-A-Pin, R. (2021). Do fiscal rules constrain political budget cycles?, *Public Choice*, 188, 1-30.

Granger, C. W. J. and Newbold, P. (1974). Spurious regressions in econometrics, *Journal of Econometrics*, 2(2), 111-120.

Huart, F. (2013). Is fiscal policy procyclical in the euro area?. *German Economic Review*, 14(1), 73-88.

Jeffrey, C. and Perkins, J. D. (2015). The association between energy taxation, participation in an emissions trading system, and the intensity of carbon dioxide emissions in the European Union, The International Journal of Accounting, 50(4), 397-417.

Korinek, L., Bertram, L., Frohn, J., Hafele, J. (2023): Linking EU fiscal rules to climate targets: A proposal for climate-linked extension of budgetary adjustment paths. *ZOE Institute for Future-fit Economies*: Cologne.

Manescu, C. B., Bova, E., Hoogeland, M. and Mohl, P. (2023). Do national fiscal rules support numerical compliance with EU fiscal rules? *European Commission, Discussion Paper*, 181.

Mang, S., and Caddick, D. (2023). Beyond the Bottom Line: How Green Industrial Policy can Drive Economic Change and Speed up Climate Action. *New Economics Foundation*.

Marsiliani, L. and Renström, T. I. (2000). Time-Inconsistency in Environmental Policy: Tax Earmarking as a Commitment Solution, *Economic Journal*, 110 (462), 123-138.

Morley, B. (2012). Empirical evidence on the effectiveness of environmental taxes, *Applied Economics Letters* 19(18), 1817-1820.

Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross-section dependence, *Journal of Applied Econometrics*, 22(2), 265-312.

Renström, T. I., Spataro, L. and Marsiliani, L. (2021). Can subsidies rather than pollution taxes break the trade-off between economic output and environmental protection? *Energy Economics*, 95, 105084.

Reuter, W. H. (2019). When and why do countries break their national fiscal rules?, *European Journal of Political Economy*, 57, 125-141.

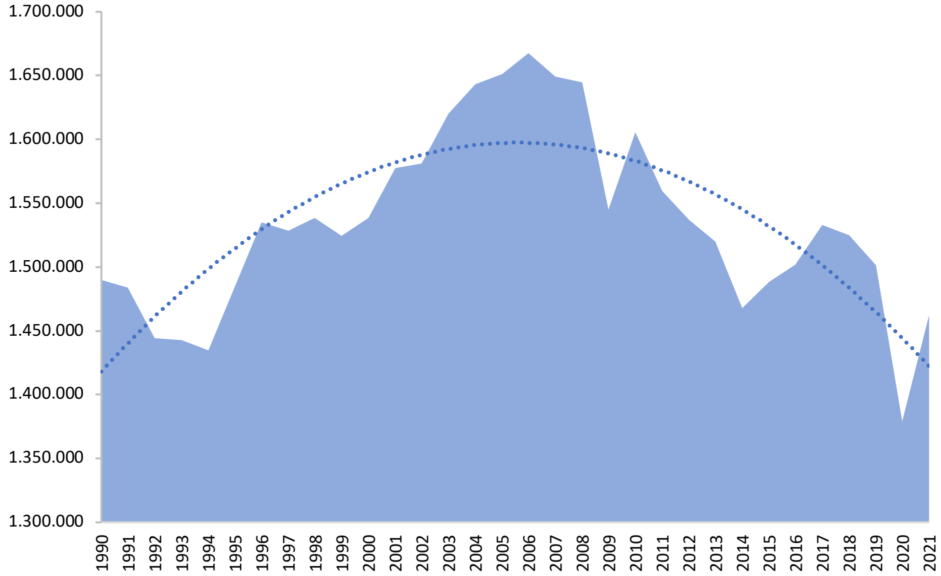
Safi, A., Chen, Y., Wahab, S., Zheng, L. and Rjoub, H. (2021). When and why do countries break their national fiscal rules?, *Journal of Environmental Management*, 293, 112908.

Spataro, L., Quirici, M. C., & Iermano, G. (Eds.). (2023). *ESG Integration and SRI Strategies in the EU: Challenges and Opportunities for Sustainable Development*. Cham: Springer Nature Switzerland.

Van den Noord, P. (2023). A targeted golden rule for public investments? A comparative analysis of possible accounting methods in the context of the review of the SGP (PE Linking EU fiscal rules to climate targets ZOE Institute for Future-fit Economies 733.740). *Economic Governance and EMU scrutiny Unit (EGOV)*. https://www.europarl.europa.eu/RegData/etudes/STUD/2023/733740/IPOL_STU(2023)733740_EN.pdf

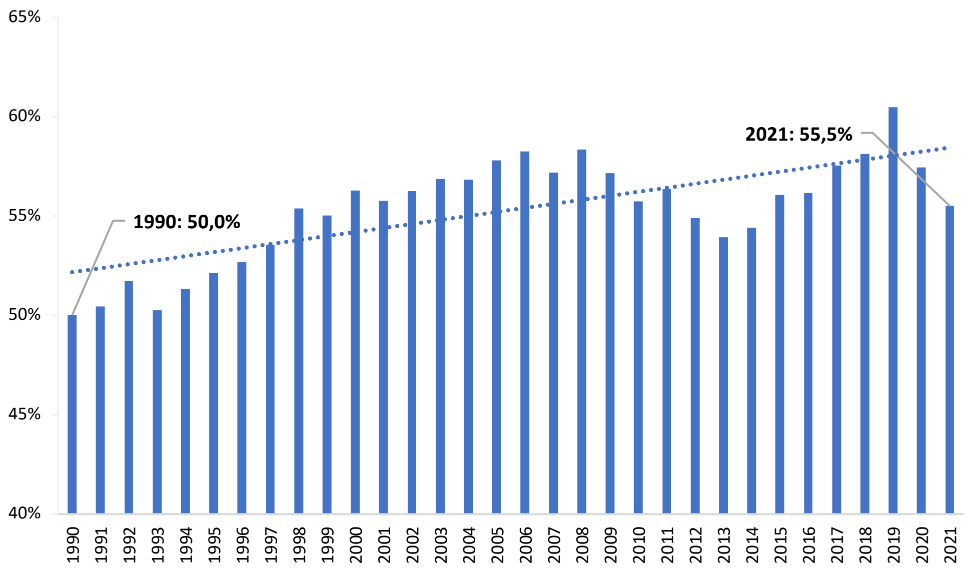
Appendix

Figure A1 – Gross Available Energy in the EU-27



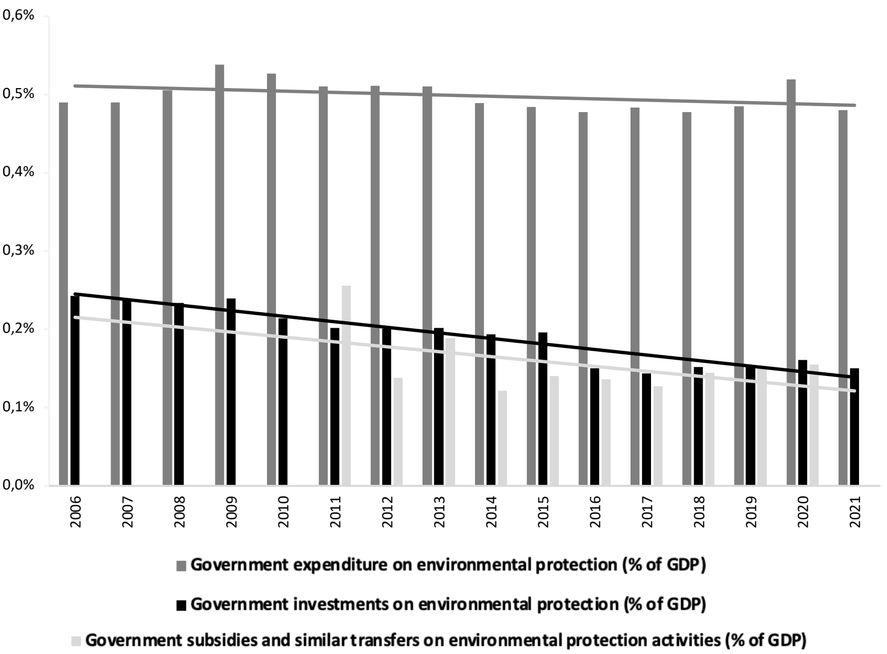
Note: tonne(s) of oil equivalent (toe) is a normalized unit of energy. By convention, it is equivalent to the approximate amount of energy that can be extracted from one tonne of crude oil (41,868 kilojoules/kg). It is a standardized unit used to compare the energy from different sources. The left-hand scale is expressed in thousand tonnes of toe.
Note: the dotted blue line represents the quadratic trend of GAE over time.
Source: own elaborations on Eurostat data

Figure A2 – Import dependency in the EU-27



Note (1): the import dependency is the ratio of net imports (imports minus exports) to GAE.
Note (2): the dotted line represents the linear trend.
Source: own elaborations on Eurostat data

Figure A3 - Government expenditure on environmental protection in the EU27



Note: data related to government subsidies and similar transfers on environmental protection activities are not available for Austria, Belgium, Croatia, Cyprus, Czechia, Estonia, Finland, France, Germany, Greece, Hungary, Italy and Poland, Slovakia.
Source: authors' elaborations on Eurostat data

Our Working Papers are available on the Internet at the following address:
https://www.feem.it/pubblicazioni/feem-working-papers/

"NOTE DI LAVORO" PUBLISHED IN 2023

1. 2023, G. Maccarone, M.A. Marini, O. Tarola, Shop Until You Drop: the Unexpected Effects of Anti-consumerism and Environmentalism
2. 2023, F. Andreolli, C. D'Alpaos, P. Kort, Does P2P trading favor investments in PV-Battery Systems?
3. 2023, M. Buso, C. Dosi, M. Moretto, Dynamic Regulation of Public Franchises with Imperfectly Correlated Demand Shocks
4. 2023, A. Ugolini, J. C. Reboredo, J. Ojea-Ferreiro, Is climate transition risk priced into corporate credit risk? Evidence from credit default swaps
5. 2023, F. Cornacchia, A. G. Martínez-Hernández, M. Bidoia, C. Giupponi, Towards a modelling process for simulating socio-ecosystems with a focus on climate change adaptation
6. 2023. S. Zanini, Water challenges in socio-ecological systems: is human decision-making accounted for in the analysis of climate change adaptation options?
7. 2023, L. Cavalli, C. Boeri, Carbon neutral lifestyles and NDCs: advice and policy perspectives
8. 2023, F. Calamunci, F. Frattini, When Crime Tears Communities Apart: Social Capital and Organised Crime
9. 2023, D. Bazzana, M. Rizzati, E. Ciola, E. Turco, S. Vergalli, Warming the MATRIX: a climate assessment under uncertainty and heterogeneity
10. 2023, A. L. Baraldi, E. Papagni, M. Stimolo, Neutralizing the Tentacles of Organised Crime. Assessment of the Impact of an Anti-Crime Measure on Mafia Violence in Italy
11. 2023, A. Bastianin, C. Casoli, M. Galeotti, The connectedness of Energy Transition Metals
12. 2023, C. Drago, F. Fortuna, Investigating the Corporate Governance and Sustainability Relationship A Bibliometric Analysis Using Keyword-Ensemble Community Detection
13. 2023, C. Drago, L. Di Nallo, M. L. Russotto, Social Sustainability in European Banks: A Machine Learning Approach using Interval-Based Composite Indicators
14. 2023, V. Cirulli, G. Marini, M.A. Marini, O.R. Straume, Do Hospital Mergers Reduce Waiting Times? Theory and Evidence from the English NHS
15. 2023, C. Castelli, M. Castellini, C. Gusperti, V. Lupi, S. Vergalli, RICE-MED, an integrated assessment model for the Mediterranean basin: assessing the climate-economy-agriculture nexus
16. 2023, R. Levaggi, M. Moretto, P. Pertile, Dynamic, incentive-compatible contracting for health services
17. 2023, L. Mauro, F. Pigliaru, Italy's National Recovery and Resilient Plan: Will it Narrow the North-South Productivity Gap?
18. 2023, P. Casciotti, A Comparison between Sustainability Frameworks: an Integrated Reading through ESG Criteria for Business Strategies and Enterprise Risk Management
19. 2023, F. Vona, Skills and human capital for the low-carbon transition in developing and emerging economies
20. 2023, I. Valsecchi, Forecasts as Repeated Cheap Talk from an Expert of Unknown Statistical Bias
21. 2023, D. Valenti, D. Bertoni, D. Cavicchioli, A. Olper, Understanding the role of supply and demand factors in the global wheat market: a Structural Vector Autoregressive approach
22. 2023, M. Compagnoni, M. Grazzi, F. Pieri, C. Tomasi, Extended producer responsibility and trade flows in waste: The case of batteries
23. 2023, F. Ravazzolo, L. Rossini, Is the price cap for Gas useful? Evidence from European countries
24. 2023, M. Marini, S. Nocito, Climate Activism Favors Pro-environmental Consumption
25. 2023, D. Bazzana, N. Comincioli, C. Gusperti, D. Legrenzi, M. Rizzati, S. Vergalli, Gotta Catch 'Em All: CCUS with endogenous technical change

Fondazione Eni Enrico Mattei
Corso Magenta 63, Milano – Italia

Tel. +39 02 403 36934

E-mail: letter@feem.it
www.feem.it

Fondazione Eni Enrico Mattei