

**PUBLIC POLICIES FOR ENVIRONMENTAL PROTECTION AND  
SUSTAINABLE ECONOMIC DEVELOPMENT IN THE CONTEXT  
OF THE TRANSITION TO A GREEN ECONOMY**

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**Abstract**

*This study examines the effectiveness of public policies in promoting sustainable economic development within the framework of the green economy transition across the 27 European Union Member States from 2013 to 2023. Using a fixed effects panel data model, it assesses the impact of recycling rates, circular material use, packaging waste generation, energy consumption, GDP per capita, and environmental tax revenues on resource productivity. The findings indicate that recycling and circular material use positively influence resource productivity, while higher energy consumption in households has a negative impact. Real GDP per capita is strongly associated with improved resource productivity, whereas environmental tax revenues show limited effectiveness. The study highlights the need for better-coordinated policies, enhanced recycling infrastructure, improved energy efficiency, and reformed environmental taxes to support the green transition. By providing empirical evidence on these relationships, it offers valuable insights for policymakers aiming to enhance resource efficiency and achieve sustainable development within the European Union.*

**Keywords:** *Green economy, public policies, Resource productivity, Sustainable development, European Union.*

**Clasificare JEL:** *H23, J18, Q01*

**1. Introduction and context of the study**

The transition to a green economy is one of the most pressing challenges posed by the continuing degradation of ecosystems, accelerated climate change and increasing pressure on natural resources. In this context, public policies become essential instruments to guide societies towards sustainable economic development models that effectively integrate environmental protection objectives with economic progress. At European level, the strategic framework for this transition is outlined in the European Ecological Pact (European Commission, 2023a), which sets the objective of making the European Union a climate-neutral economy by 2050. It is supported by complementary initiatives such as the 2030 Biodiversity Strategy (European Commission, 2023b), the Circular Economy Action Plan (European Commission, 2023c), the Fit for 55 Package (European Council, 2023), and the Just Transition Facility (European Commission, 2021b, 2024),

which promotes social equity in the process of structural transformation. These policies propose a redefinition of the development model by mainstreaming the environmental dimension into all sectoral policies, with a particular focus on technological innovation, energy efficiency, sustainable mobility and digitization of the economy. There is growing support in the literature that sustainability-oriented public policies need to be systemic, coherent and evidence-based. According to research (Environmental policy stringency, ICT, and technological innovation for achieving sustainable development: Assessing the importance of governance and infrastructure Usman et al., 2024; Hariram et al., 2023; Roberts, 2023), integrating environmental policies into economic governance can no longer be seen as a marginal option, but as a necessity for maintaining the competitiveness and resilience of economic systems. Also, recent OECD (Borowiecki et al., 2023) and European Commission (European Commission, 2021a) studies show that effective green policies are those that combine regulatory instruments (environmental standards and norms), economic instruments (green taxes, green subsidies, innovation support schemes) and voluntary mechanisms (eco-labels, public-private partnerships). At the same time, there are significant variations between EU Member States in the pace and quality of implementation of these policies, determined by factors such as administrative capacity, economic structure or the degree of involvement of national actors (Fernández-i-Marín et al., 2024; Santos et al., 2025; Zhelyazkova et al., 2024). This calls for a comparative analysis based on empirical evidence to assess the impact of public policies on economic and environmental performance in an integrative and contextualized manner.

The novelty of this study lies in the application of a panel data econometric model with fixed effects, which allows to assess the relationship between public policies and resource productivity at the level of the 27 EU Member States for the period 2013-2023. Unlike previous research which often focuses on a specific dimension of the green transition, this study integrates a wide range of indicators reflecting both recycling and circular material use policies as well as economic and fiscal aspects relevant to sustainable development. This study also contributes to the literature by assessing the impact of environmental fiscal policies, an under-explored area in the context of the green economy.

The aim of this study is to assess the extent to which public policies effectively contribute to promoting sustainable economic development in the transition to a green economy at the EU level.

To achieve this goal, the following specific objectives have been formulated:

O1. Literature review reflecting public policies oriented towards environmental protection and sustainable economic development

O2. Application of a panel data econometric model with fixed effects to estimate the relationship between selected public policies and resource productivity in the 27 Member States of the European Union over the period 2013-2023

O3. Formulate public policy recommendations, based on the results obtained, to improve the efficiency of the transition to a green economy at European level.

This research contributes to a better understanding of how public policies can be used to support the transition to a green economy in the European Union and provides a solid basis for the formulation of relevant recommendations in this area.

## 2. Literature review

In the context of increasing environmental pressures, international commitments to climate neutrality and the need for structural reform of the traditional economic model, the transition to a green economy is becoming a priority direction in academic research and public policy formulation. The literature has increasingly focused on understanding and assessing the mechanisms through which public policies can facilitate sustainable economic development with low environmental impact and resource efficiency (F. Wang et al., 2023; Wenjuan Wang et al.,

2024; Wilts & O'Brien, 2019). This line of research is underpinned by the conviction that the green transition cannot be left to the market alone but requires coherent and systemic state intervention.

In the light of increasing concerns for sustainability and the strengthening of the European policy framework on the transition to a green economy, the relationship between public policies and sustainable economic development is gaining increasing relevance in the literature. Investigating this relationship requires a systematic review of existing theoretical and empirical contributions in order to provide a robust analytical framework to support the interpretation of the results obtained in this study. Recent research emphasizes the importance of integrated, contextually adapted public policies supported by mixed instruments - regulatory, fiscal and voluntary - for advancing the goals of the circular economy and increasing resource efficiency (Ahmed et al., 2025; Chenavaz & Dimitrov, 2024; Santiago et al., 2025). Against this backdrop, the literature provides key insights into the conceptualization of the green economy, the diversification of intervention instruments, variations in policy implementation at the national level, and the empirical evaluation methods used in the analysis of their impact. The present study capitalizes on these directions while contributing to filling some of the gaps identified in previous research. The thematic structuring of the literature review section aims to capture the major research directions that shape the current conceptual and methodological framework: (I) the theoretical foundations of the green economy; (II) the role and typology of sustainability-oriented public policy instruments; (III) national variations in the implementation of these policies; (IV) the econometric models used to quantify impacts; and (V) the performance indicators adopted in empirical evaluations. The integration of these perspectives allows the delimitation of the scope of the investigation and the identification of persistent limitations in the literature, providing argumentative support for the objectives and hypotheses formulated in the research.

### *2.1. Green economy as a paradigm for sustainable development*

The green economy was conceptualized as a reaction to the limits of the conventional economic model, based on unlimited growth and intensive exploitation of natural resources. Ever since the Brundtland report (United Nations, 1987), the idea of sustainable development has gained ground, but it is only in the last decade that the green economy paradigm has clearly emerged, understood as an economy that "results in improved human well-being and social equity, while significantly reducing environmental risks and environmental deprivation"(UNEP, 2025). In contrast to more general concepts of sustainability, the green economy emphasizes the dimension of structural transformation, implying a profound change in productive technologies, consumption patterns, the organization of labor markets, and the relations between the state and the market (Bohnenberger, 2022; Schulze Waltrup, 2023).

Expert studies emphasize that the green economy should not be seen just as a green alternative to the current model, but as an opportunity for innovation and economic recovery (Awan et al., 2025; Pang et al., 2024; Sohail et al., 2022). In the post-pandemic context, green investments have been seen as a more resilient form of economic reconstruction, capable of reducing systemic vulnerabilities in the global economy (Butollo et al., 2024; W. Zhao et al., 2022). În acest sens, OECD (OECD, 2023, 2024a) and World Bank (World Bank, 2020) have highlighted that economic stimulus policies geared towards decarbonization, energy efficiency and circularity can produce multiplier effects in terms of employment, innovation and competitiveness.

At the same time, some papers draw attention to the risk of the green economy becoming an abstract discourse without solid anchors in the economic and institutional reality of the countries. The lack of clear regulatory frameworks, fragmentation of initiatives and the lack of coherence between sectoral strategies may jeopardize the effectiveness of the green transition (Fontana & Vannuccini, 2024; Gao, 2025). Understanding how public policies can turn the principles of the green economy into measurable realities thus becomes essential.

### *2.2. Public policies for sustainable development: approaches and dimensions*

A central theme in the literature is how public policies can be designed and implemented to support the objectives of the green economy. According to an established typology, policy instruments fall into three categories: (1) direct regulation (command-and-control), such as emission standards, recycling standards or energy efficiency requirements (EEA, 2023; Mehmood et al., 2024); (2) economic instruments such as environmental taxes, environmental subsidies and innovation support schemes (Citil, 2024; D. Wang et al., 2024); and (3) voluntary and market-based mechanisms such as eco-labeling, ESG reporting or public-private partnerships (Chang et al., 2024; Elliott et al., 2024).

Comparative studies suggest that a balanced combination of these types of instruments produces the best results in terms of reducing environmental impacts and stimulating innovation (Chen et al., 2022; Fouquet & Hippe, 2022; Wei Wang et al., 2025). The combination of stringent regulation and financial support for innovation fosters 'regulatory-induced innovation', which motivates firms to adopt more efficient technologies (Herman & Shenk, 2021; S. Zhao et al., 2023).

Another relevant aspect analyzed in the literature is the capacity of green policies to generate co-benefits, particularly in the field of employment. Thus, the transition to a green economy is associated with the emergence of green jobs, but also with challenges related to retraining and territorial equity (ILO, 2022, 2023; Tănăsie et al., 2022). At the same time, some studies point out that these transformations may generate inequalities between regions or economic sectors, especially in the absence of retraining policies and support for disadvantaged areas (Bianchi et al., 2024; Rodríguez-Pose & Bartalucci, 2024). The challenges associated with just transition thus become central in assessing the effectiveness and equity of green public policies. Recent studies underline that integrating the social dimension into environmental policies, through training measures, tax incentives for employers and investment in local infrastructure, contributes not only to mitigating the social costs of transition but also to enhancing public acceptability of green reforms (Adebayo, 2025; Mello & Ter-Minassian, 2024; Zimmermann & Gengnagel, 2023). Coherence between environmental, economic and social objectives therefore becomes a prerequisite for the long-term success of the transition to an inclusive green economy.

### *2.3. Differentiated implementation in the European Union*

While the European Union has built a broad and coherent policy framework to support the transition to a green economy - anchored in initiatives such as the European Green Pact (European Commission, 2023a), Circular Economy Action Plan (European Commission, 2023c) and the Just Transition Facility (European Commission, 2021b) - the actual implementation of these policies is far from uniform across Member States. Studies on differentiated implementation point to the persistence of significant disparities, driven by a variety of contextual factors such as administrative capacity, institutional culture, domestic social pressures, level of economic development and the sectoral structure of economies (Akwei & and Nwachukwu, 2023; Kapucu et al., 2024; Zhelyazkova et al., 2024).

Central and Eastern European countries in particular are more often late in transposing and implementing EU environmental directives (Bocková & and Augustín, 2024; Hosnedlová & Pitrová, 2023). This situation is attributed to systemic constraints such as poor technical and administrative infrastructure, low level of institutional digitization, lack of specialized expertise and limited financial capacity to support the investments needed to adapt to new standards. Also, in some cases, national political priorities or the conflict between immediate economic and environmental objectives lead to a selective or formalistic application of EU policies (Kalpakchiev et al., 2025; Niklas, 2025).

At the same time, research shows that the level of compliance depends not only on structural constraints, but also on the level of participation of local and regional actors in decision-making, the quality of governance and institutional maturity (Paraskeva & Tsoulfas, 2025; von Malmborg, 2024). Top-down implementation models often face resistance from local actors in the absence of

effective policy co-design mechanisms or adequate financial support (Lata et al., 2024; OECD, 2024b).

This structural and institutional variability justifies the choice of a fixed effects econometric model in the present study, as it allows controlling for unobservable but constant over time characteristics of each Member State. By isolating these effects, it becomes possible to robustly estimate the influence of common factors - such as recycling policies, energy consumption or fiscal instruments - on resource productivity without the results being distorted by the institutional or administrative specificities of each country. The analysis thus contributes not only to understanding the effectiveness of green public policies across the European Union as a whole, but also to identifying the factors that may mediate or amplify their impact in different national contexts.

#### *2.4. Green policy impact assessment: methodological perspectives*

Assessing the effects of green policies requires the adoption of rigorous methodologies to identify causal relationships between public interventions and economic and environmental outcomes. Given the complexity of the interactions between environmental policies, economic structure and agents' behavior, panel data econometric models have emerged in the recent literature as a robust approach for comparative analysis over the medium and long term (Al khatib, 2023; Galiano Bastarrica et al., 2023; Laverde & Correa, 2021; Rising et al., 2022). These models allow controlling for unobservable heterogeneity between the units of analysis - in this case, the EU Member States - and capture more faithfully the dynamics of public policy effects over time.

For example, the authors Fatima et al. (Fatima et al., 2024) used a fixed-effects model to investigate the impact of energy efficiency on greenhouse gas emissions in OECD countries, demonstrating that policies aimed at reducing final energy consumption can have significant effects on climate performance. Similarly, Metcalf și Stock (Metcalf & Stock, 2020) have analyzed the relationship between environmental taxation and total factor productivity, confirming a positive, albeit moderate, effect on economic efficiency, particularly in advanced economies. Recent literature provides additional relevant contributions. Usman et al. (Usman et al., 2024) propose a panel model to assess the interaction between the stringency of environmental policies, digital infrastructure and technological innovation, emphasizing that the effects of green policies depend on the institutional capacity and the level of governance. Also, Raihan et al. (Raihan et al., 2024) uses an ARDL panel approach to investigate the short- and long-run relationship between green investment, innovation and environmental performance in European countries, providing an alternative methodological framework based on dynamic relationships and long-run equilibria.

However, there is an important methodological limitation in the existing literature: most studies focus on one or two explanatory variables, failing to integrate multiple dimensions of the green transition reduces the ability to capture the complexity of the phenomenon under analysis. For example, much research focuses exclusively on CO<sub>2</sub> emissions or energy efficiency, without linking these results to indicators of the circular economy, green taxation or economic development (Balsalobre-Lorente et al., 2024; Chatzistamoulou & Koundouri, 2024; Imran et al., 2024; Sohail et al., 2025).

This paper responds to this gap by constructing a fixed effects panel model that simultaneously integrates seven relevant explanatory variables - environmental, economic and fiscal - thus providing a comprehensive approach to the impact of green policies on resource productivity. By using harmonized data across the 27 EU Member States for the period 2013-2023, the proposed analysis captures the multiple interdependencies between public policies and the sustainability of resource use, thus contributing to better informed policies based on robust empirical evidence.

#### *2.5. Indicators for measuring the green transition*

The identification and use of relevant indicators is an essential element in the process of monitoring and assessing progress towards a green economy. To this end, Eurostat, together with other international organizations such as OECD, UNEP or the European Commission, has

developed a set of harmonized indicators reflecting different dimensions of environmental, economic and social sustainability. Among these, resource productivity occupies a central position as a summary indicator of how efficiently an economy transforms natural resources into economic value (Eurostat, 2024b; Radivojević et al., 2024; Tang et al., 2025) (Eurostat, 2024b; OECD, 2023). This indicator provides an integrative perspective on environmental pressure in relation to economic performance and is commonly used as a proxy for assessing the decoupling of economic growth from resource consumption.

Alongside it, indicators on the recycling rate of municipal waste and the rate of use of circular materials provide essential information on the level of circularity of economies, reflecting the extent to which resources are reused or reintroduced into the economic cycle (Marques & Teixeira, 2022; Rincón-Moreno et al., 2021; Zhang et al., 2024; Zorpas, 2024). These are considered as outcome indicators for circular economy policies and are integrated into the monitoring of the implementation of the EU Circular Economy Action Plan (European Commission, 2023c). Indicators such as packaging waste generation per capita and household final energy consumption express the extent of environmental pressure and are directly correlated with consumption patterns, urbanization and infrastructure efficiency (Firoiu et al., 2025; Guney et al., 2025; Loizia et al., 2021). Complementarily, revenues from environmental taxes, expressed as a percentage of GDP, provide an indirect measure of the intensity of environmental regulation and the extent to which negative externalities are internalized through fiscal instruments (Sackitey, 2023; Samour et al., 2024; Xu et al., 2023). Although this indicator should be interpreted with caution, as high values may reflect both the efficiency and rigidity of tax systems, it remains an important benchmark in the assessment of economically oriented environmental policies.

At the same time, real GDP per capita is often included in econometric models to control for the influence of general economic development on environmental behaviour and the ability to implement public policies. Recent research argues that countries with higher GDP have more resources for investment in green infrastructure, research and development, but also increased societal pressure for the green transition (Qamruzzaman & Karim, 2024; Trinh et al., 2023).

Combining these indicators in an integrated analytical framework allows a multidimensional approach to sustainability, offering the possibility to assess not only the isolated effectiveness of public policies, but also the interdependencies between the components of the green economy. Their use in a rigorous econometric model, such as the one proposed in this study, contributes to advancing the empirical basis of the research and to the formulation of better-informed policy recommendations with comparability and cross-national applicability.

Although the literature on the green economy and public policy for sustainable development is expanding significantly, several major gaps persist that justify the need for further research. First, few studies adopt a multidimensional approach that simultaneously links fiscal, economic and environmental policies into a unified model. Second, the literature is geographically unbalanced, often focusing on Western European countries or small groups of developed economies rather than on a comparative analysis across the European Union. Third, environmental fiscal policies are often treated superficially, without in-depth analysis of the effectiveness and redistribution of the funds raised. The present study contributes to mitigating these shortcomings through an integrative approach applied to a large sample (EU-27) over a relevant period (2013-2023), using multiple indicators and a robust methodology.

The literature review reveals that the transition to a green economy is a complex, multidimensional process that requires a profound transformation of economic, institutional and behavioral mechanisms. Public policies play a key role in facilitating this transition, but their effectiveness depends on the type of instruments used, the national context and the capacity for implementation. Rigorous evaluation of these policies requires sophisticated econometric models and relevant indicators that capture the dynamics of economy-environment interactions. By identifying well-established research directions as well as existing gaps, this section provides a

solid conceptual and empirical framework for the analytical approach of this paper, thus contributing to the advancement of knowledge in the field of policies for sustainable development and the transition to the green economy in the European space.

### 3. Method

In order to analyse the impact of public policies on environmental protection and sustainable economic development in the context of the transition to a green economy, we applied a panel data econometric model with fixed effects. The study uses a dataset consisting of 27 EU Member States, covering the period 2013-2023. The data were collected from the Eurostat database, and relevant indicators were chosen that reflect both environmentally oriented public policies and specific dimensions of sustainable economic development. Table 1 presents the analysed indicators.

Table no. 1. Presentation of the analyzed indicators

Symbol	Indicators	U.M	Source
RecyRWast	Recycling rate of municipal waste	Percentage	Eurostat (Eurostat, 2025)
ResProd	Resource productivity	Euro per kilogram	Eurostat (Eurostat, 2024b)
CircMatUseR	Circular material use rate	Percentage	Eurostat (Eurostat, 2024a)
GenPackWast	Generation of packaging waste	Kilograms per capita	Eurostat (Eurostat, 2025c)
FinEnCons	Final energy consumption in households per capita	Kilogram of oil equivalent (KGOE)	Eurostat (Eurostat, 2025b)
RealGDP	Real GDP per capita	Euro per capita	Eurostat (Eurostat, 2025d)
EnvTaxRev	Environmental tax revenues	Percentage of gross domestic product (GDP)	Eurostat (Eurostat, 2025a)

Source: Elaborated by the authors based on Eurostat data

The dependent variable in this study is Resource Productivity (ResProd), measured in euros per kilogram, a commonly used indicator to assess resource use efficiency in the context of the green economy. It was considered appropriate to capture the transition towards more sustainable and efficient resource use as public policies and investments in the green economy develop.

In terms of independent variables, seven main indicators were selected reflecting different dimensions of the circular economy, environmental protection and economic development. The recycling rate of municipal waste (RecyRWast), expressed in percentages, measures the waste recycling capacity and sustainable behaviour of the population. The CircMatUseR (CircMatUseR), also expressed in percentages, captures the share of recycled materials used in the total materials consumed, a key indicator of the circular economy. Packaging waste generation (GenPackWast), measured in kilograms per capita, reflects the negative impact of packaging consumption on the environment and the effectiveness of recycling programs. Final household energy consumption per capita (FinEnCons), measured in kilograms of oil equivalent, indicates energy efficiency at the household level and reflects the impact of public policies to reduce energy consumption. Real GDP per capita (RealGDP), expressed in euro per capita, is used as a proxy for overall economic development. Environmental tax revenue (EnvTaxRev), expressed as a percentage of GDP, is a proxy for green fiscal policies and incentives created to reduce negative environmental impacts.

The econometric model applied is a panel data fixed effects model selected based on the results of preliminary specification tests. The choice of this model is justified by the assumption that the individual effects associated with each country are correlated with the explanatory variables, which requires the use of a fixed effects model to obtain consistent estimators. The

estimates were produced using the generalized least squares (GLS) method, which allows adjustment for heteroscedasticity and autocorrelation within the time series.

Table no. 2. Hausman test results

	Coef.
Chi-square test value	20.989
P-value	0.001

Source: Elaborated by the authors using Stata 18 program

Hausman test results presented in Table 2 indicate a Chi-square statistic value of 20.989, with an associated probability (p-value) of 0.001, suggesting the rejection of the null hypothesis that the random effects model is appropriate for panel data analysis. The high significance of this result points to the existence of a significant correlation between the explanatory variables and the effects specific to each EU Member State, which validates the use of the fixed effects model as methodologically more appropriate. The choice of the fixed-effects model is justified by the fact that it allows controlling for unobserved but time-constant characteristics that differ across countries and that could directly influence the relationship between public policies and resource productivity. This methodological decision is essential to ensure the consistency and robustness of the estimates in the analysis carried out, providing a basis for the correct interpretation of the results and the formulation of relevant recommendations in the context of the transition towards a green economy in the European Union.

The proposed methodology allows for a rigorous assessment of the relationship between public policies and sustainable economic performance in the context of the transition to a green economy, using relevant and up-to-date data from the European Union for the period under analysis.

The fixed effects panel data econometric model equation applied in this study is formulated as follows:

$$ResProd_{it} = \alpha_i + \beta_1 RecyRWast_{it} + \beta_2 CircMatUseR_{it} + \beta_3 GenPackWast_{it} + \beta_4 FinEnCons_{it} + \beta_5 RealGDP_{it} + \beta_6 EnvTaxRev_{it} + \epsilon_{it} \quad (1)$$

Where:

$ResProd_{it}$  - Resource productivity for country i in year t (dependent variable)

$\alpha_i$  - Country-specific fixed effect, capturing specific unobservable characteristics that do not vary over time

$\beta_1, \beta_2 \dots \beta_6$  - Regression coefficients measuring the impact of each explanatory variable on resource productivity

$\epsilon_{it}$ , - Random error, capturing unobserved effects or shocks not included in the model

$RecyRWast_{it}$  - Recycling rate of municipal waste

$CircMatUseR_{it}$  - Circular material use rate

$GenPackWast_{it}$  - Generation of packaging waste

$FinEnCons_{it}$  - Final energy consumption in households per capita

$RealGDP_{it}$  - Real GDP per capita

$EnvTaxRev_{it}$  - Environmental tax revenues

The following hypotheses were formulated:

- Hypothesis 1 (H1): There is a positive and statistically significant relationship between municipal waste recycling rate (RecyRWast) and resource productivity (ResProd) within the EU Member States.
- Hypothesis 2 (H2): A higher circular material utilization rate (CircMatUseR) positively and significantly influences resource productivity in the European Union.
- Hypothesis 3 (H3): Household final energy consumption (FinEnCons) has a negative and significant effect on resource productivity in the European Union.
- Hypothesis 4 (H4): Revenues from environmental taxes (EnvTaxRev) have a negative impact on resource productivity in the EU Member States.

These hypotheses reflect the influence of selected independent variables on resource productivity and provide a basis for interpreting the results and formulating policy recommendations.

#### 4. Results and Discussion

Econometric analysis using a panel data fixed effects model provides a detailed insight into how public policies for environmental protection and sustainable economic development influence resource productivity in the context of the European Union. In a framework characterized by ambitious transition objectives towards a green economy promoted by the European Green Pact and the 2030 Agenda for Sustainable Development, this study aims to identify the impact of relevant factors on resource efficiency in the 27 EU Member States over an 11-year period from 2013 to 2023. Table 3 provides a description of the descriptive statistics for the variables used in the econometric analysis, illustrating their diversity and characteristics across the 27 EU Member States over an 11-year period from 2013 to 2023.

Table no. 3. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
ResProd	297	1.866	1.134	0.299	5.623
RecyRWast	297	37.036	15.153	9.1	70.3
CircMatUseR	297	9.109	6.379	1.3	30.6
GenPackWast	296	145.451	46.032	46.91	242.41
FinEnCons	297	564.428	182.821	170	1076
RealGDP	297	31294.108	20934.271	7600	107570
EnvTaxRev	297	2.653	0.791	0.85	5.6

Source: Elaborated by the authors using Stata 18 program

Resource productivity, as measured by the ResProd indicator, averages 1.866 euro per kilogram, with a standard deviation of 1.134, suggesting moderate variability between countries and periods. The extreme values, ranging from a minimum of 0.299 to a maximum of 5.623, point to significant differences in resource use efficiency between EU Member States. High levels of this indicator suggest important progress towards a more resource-efficient economy, while low values indicate a persistence of inefficient practices in terms of the circularity of the economy.

The recycling rate of municipal waste (RecyRWast) averages 37.036% with a standard deviation of 15.153. This relatively high level of variability suggests important differences between member countries, ranging from a low of 9.1% to a high of 70.3%. The significant discrepancies between Member States indicate that some countries have implemented effective recycling and waste management policies, while others still face difficulties in adopting sustainable recycling practices.

The CircMatUseR (CircMatUseR) shows an average of 9.109%, suggesting a modest level of material reuse in the context of the circular economy at EU level. The standard deviation of 6.379 shows considerable variability, and the range from 1.3% to 30.6% indicates that some Member States have adopted the principles of the circular economy more effectively than others. This variable directly reflects progress towards a green economy and the low values for some countries suggest an increased need for more effective public policies in the area of materials management.

Packaging waste generation per capita (GenPackWast) shows an average of 145,451 kilograms per capita, with a standard deviation of 46,032. The minimum and maximum values, between 46.91 and 242.41 kilograms per capita, highlight the significant differences in waste generation between Member States. These differences reflect not only the economic and social particularities of each Member State, but also the effectiveness with which public policies are applied to reduce waste generation and promote recycling.

Household final energy consumption per capita (FinEnCons), measured in kilograms of oil equivalent, averages 564,428 with a standard deviation of 182,821. These values suggest a large variability between Member States, with a minimum of 170 and a maximum of 1076. These differences can be explained both by regional climatic variations and by national policies on energy

efficiency and the transition to renewable energy sources. Real Gross Domestic Product per capita (RealGDP) shows an average of € 31294,108, with a high standard deviation of 20934,271, reflecting significant economic differences between member countries. The minimum value of 7600 and the maximum value of 107570 highlight the major economic disparities that persist in the European Union. These differences are important to bear in mind because economic development is closely linked to the capacity of each country to implement and sustain effective green policies. Revenues from environmental taxes (EnvTaxRev), expressed as a percentage of gross domestic product, have an average of 2.653%, with a standard deviation of 0.791. The values range from a low of 0.85 to a high of 5.6, indicating that some Member States are applying green tax instruments more intensively to discourage polluting behaviour and stimulate the transition to a green economy. However, the relatively low levels of environmental taxes in some countries suggest an uneven application of environmentally oriented fiscal policies across the EU.

The analysis of descriptive statistics reveals that there is considerable variability across EU Member States in selected indicators, reflecting differences in the adoption and implementation of public policies for environmental protection and sustainable economic development. This diversity suggests that the transition to a green economy is not a uniform process, but one that depends on national specificities, both in terms of available economic and natural resources and in terms of political commitment and implementation of sustainability measures.

Table 4 presents the matrix of correlations between the variables included in the econometric panel data fixed effects model used to analyse the impact of public policies and economic and environmental factors on resource productivity in the European Union. The correlation coefficients are calculated using the Pearson method, and the corresponding p-values are indicated in parentheses, thus allowing the assessment of the statistical significance of the relationships identified.

Table no. 4. Pairwise correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) ResProd	1.000						
(2) RecyRWast	0.555 (0.000)	1.000					
(3) CircMatUseR	0.659 (0.000)	0.465 (0.000)	1.000				
(4) GenPackWast	0.680 (0.000)	0.594 (0.000)	0.453 (0.000)	1.000			
(5) FinEnCons	0.164 (0.005)	0.530 (0.000)	0.198 (0.001)	0.308 (0.000)	1.000		
(6) RealGDP	0.743 (0.000)	0.507 (0.000)	0.261 (0.000)	0.658 (0.000)	0.502 (0.000)	1.000	
(7) EnvTaxRev	-0.203 (0.000)	-0.150 (0.010)	0.032 (0.585)	-0.411 (0.000)	-0.039 (0.500)	-0.355 (0.000)	1.000

Source: Elaborated by the authors using Stata 18 program

The correlation matrix indicates that most of the independent variables analysed show statistically significant correlations with resource productivity, highlighting the role of public policies and economic factors in determining resource use efficiency in the European Union. The strong relationships identified between variables such as real GDP per capita, the rate of circular materials use, and the rate of municipal waste recycling suggest that the transition to a green economy depends to a large extent on the ability of Member States to implement effective sustainable development policies.

Table 5 provides an analysis of the Variance Inflation Factor (VIF) for each independent variable included in the panel data econometric model with fixed effects.

Table no. 5. Variance inflation factor

Variable	VIF	1/VIF
GenPackWast	2.646	0.378
RealGDP	2.215	0.451
RecyRWast	2.100	0.476
FinEnCons	1.647	0.607
CircMatUseR	1.462	0.684
EnvTaxRev	1.350	0.741
Mean VIF	1.903	.

Source: Elaborated by the authors using Stata 18 program

According to Table 5 the VIF test performed indicates a good specification of the model in terms of multicollinearity. The low VIF values suggest that the selected variables can be used without compromising the accuracy of the regression coefficient estimates, thus providing a solid support for further analysis of the relationship between public policies and resource productivity in the European Union.

Table no. 6. Regression results

ResProd	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
RecyRWast	0.005	0.002	2.39	0.018	0.001	0.009	**
CircMatUseR	0.035	0.006	5.85	0	0.023	0.047	***
GenPackWast	0	0.001	0.47	0.637	-0.002	0.003	
FinEnCons	-0.002	0	-7.88	0	-0.003	-0.002	***
RealGDP	0	0	9.61	0	0	0	***
EnvTaxRev	-0.064	0.039	-1.66	0.099	-0.14	0.012	*
Constant	1.59	0.259	6.14	0	1.08	2.099	***
Mean dependent var		1.867	SD dependent var				1.136
R-squared		0.610	Number of obs				296
F-test		68.620	Prob > F				0.000
Akaike crit. (AIC)		-181.547	Bayesian crit. (BIC)				-155.715

\*\*\*  $p < .01$ , \*\*  $p < .05$ , \*  $p < .1$

Source: Elaborated by the authors using Stata 18 program

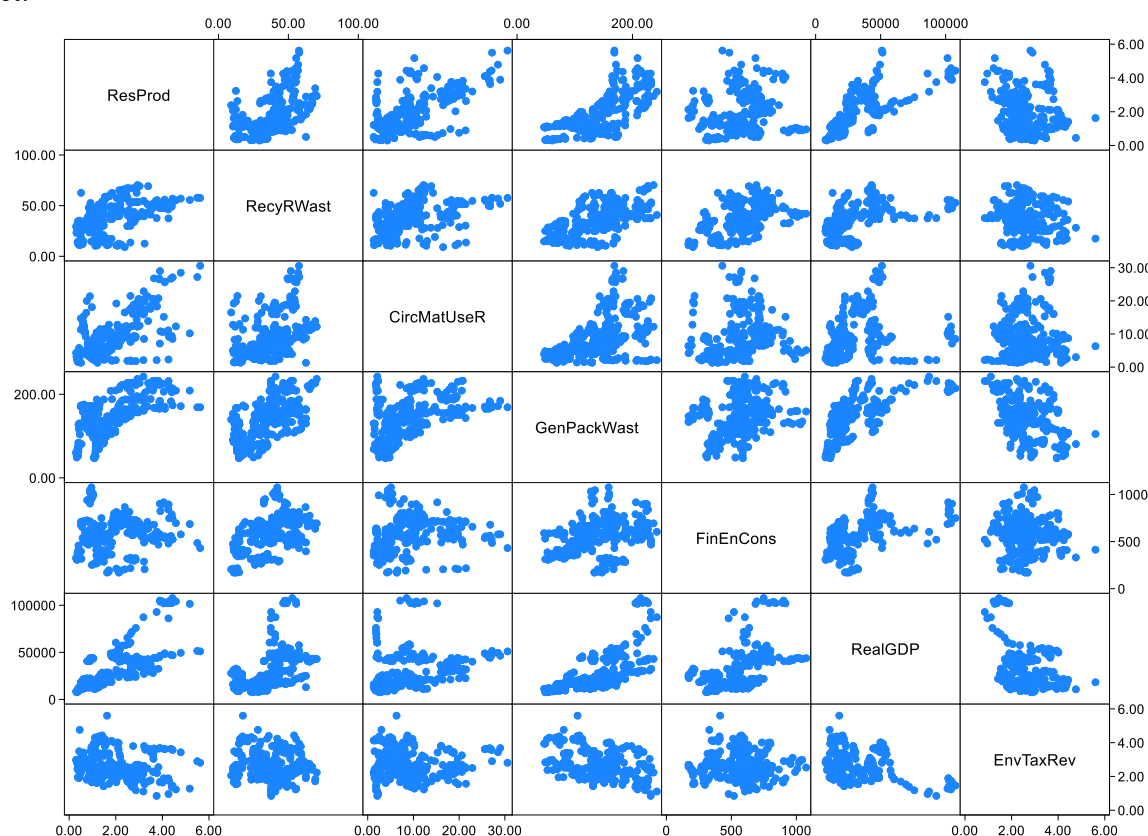
The analysis of the results presented in the regression table allows the validation of the hypotheses formulated in this study, providing a clear understanding of the relationships between the explanatory variables and resource productivity in the European Union. The positive and statistically significant relationship between municipal waste recycling rate and resource productivity is confirmed by the estimated positive coefficient of 0.005 and the p-value of 0.018, indicating high significance at the 5% level. This result suggests that policies that promote increased recycling rates contribute significantly to improving resource use efficiency, a key issue in the context of the transition to a green economy. Similarly, the hypothesis that a higher utilization rate of circular materials positively and significantly influences resource productivity is clearly validated by the positive coefficient of 0.035, accompanied by an extremely low p-value (0.000), suggesting a strong and consistent relationship at the 1% significance level. These results emphasize the importance of adopting circular economy practices to increase resource efficiency, which confirms the relevance of the objectives set at the European Union level on the transition towards a sustainable economic model.

On the other hand, the results on the effect of household final energy consumption on resource productivity show a clear negative relationship, as initially expected, confirming the hypothesis. The estimated negative coefficient of -0.002, accompanied by an extremely low p-value (0.000), reveals that high household energy consumption negatively affects resource use efficiency, a finding that suggests the need for more effective policies to reduce energy consumption and promote renewable sources. This significant negative relationship at the 1% level underlines that current policies aimed at increasing energy efficiency are not strong enough to counteract the negative impact of energy consumption on resource productivity.

For environmental tax revenues, the results suggest a negative relationship, but significant only at a lower confidence level (10%), as indicated by a p-value of 0.099. The estimated negative coefficient of -0.064 suggests that tax revenues from environmental taxes do not contribute significantly to resource productivity growth, and this result could reflect an ineffective implementation of environmentally oriented tax policies or a suboptimal use of the funds collected from these taxes. This result may also signal that the current structure of environmental taxes does not sufficiently incentivize the adoption of sustainable practices or investment in the green economy.

Validation of the hypotheses suggests that recycling and circular material use policies have a significant positive impact on resource use efficiency within the EU, while high household energy consumption negatively affects resource productivity. At the same time, the results highlight that environmentally oriented fiscal policies have a limited impact on resource use efficiency, suggesting the need to reform these instruments to better support the transition to a green economy. These findings underline the relevance of implementing more coherent and better coordinated policies at European level that integrate economic, environmental and social objectives in a harmonious way.

Figure 1 illustrates the scatterplot matrix between all independent variables and the dependent variable (ResProd - Resource Productivity) used in the panel data econometric analysis for the 27 EU Member States. This matrix allows to visualize the two-way relationships between the variables and to identify possible patterns, correlations or non-linear relationships present in the dataset.



**Figure 1. Matrix of scatterplots for the variables used in the econometric panel data model**

Source: Elaborated by the authors using Stata 18 program

Figure 1 provides a clear visual picture of the possible correlations and relationships between the variables used in the model, partially supporting the regression results and highlighting that economic and environmental variables have a different impact on resource productivity within the European Union.

## 5. Conclusions and public policy recommendations

The study investigated the relationship between public policies for environmental protection, sustainable economic development and resource productivity in the context of the transition to a green economy in the European Union, using a panel econometric fixed effects panel data model for the period 2013-2023. The analysis included 27 European Union Member States and used a number of relevant variables such as municipal waste recycling rate, circular material use rate, packaging waste generation, household final energy consumption, real gross domestic product per capita and environmental tax revenues.

The results obtained indicate that resource productivity is positively and significantly influenced by the recycling rate of municipal waste and the utilization rate of circular materials, thus confirming the importance of implementing effective policies to promote the circular economy. Also, real GDP per capita shows a significant positive influence on resource productivity, suggesting that countries with a higher economic level have a greater capacity to adopt advanced technological measures and resource efficient practices.

In contrast, household final energy consumption has a significant negative effect on resource productivity, suggesting that current policies are not effective enough to reduce the negative impact of energy consumption on resource efficiency. Toegative impact of environmental tax revenues on resource productivity, although significant only at a lower confidence level (10%), suggests a potential ineffectiveness of environmentally oriented tax policies in their current form.

### *Public policy recommendations*

On the basis of the results obtained, the following public policy recommendations can be made that could contribute to increasing resource productivity and supporting the transition to a green economy at EU level:

1. Promote the circular economy by increasing recycling and the use of circular materials. Increased investment in recycling infrastructure and facilities that support the use of recycled materials is essential to improve resource productivity. Educational programs and awareness campaigns should be expanded to encourage active participation of citizens in separate waste collection.
2. Reform environmental tax policies. Revenues from environmental taxes do not contribute effectively to increasing resource productivity, suggesting the need to restructure these taxes. A possible solution would be to allocate the collected funds more efficiently to investments in energy efficiency projects, technological innovation and the promotion of the circular economy.
3. Increase household energy efficiency. Introducing financial incentives for the adoption of energy-efficient technologies, as well as stricter standards for the energy consumption of household appliances and residential buildings, could help to reduce overall energy consumption and thus improve resource productivity.
4. Integrating economic and environmental objectives. Public policies should be better coordinated at EU level to ensure an efficient and equitable transition to a green economy. Better harmonization of standards and regulations on resource efficiency, recycling and green taxation is needed.

### *Research limitations*

This research has several limitations that should be taken into account wheCiobanu, Ștefanhe results. First, the econometric model used did not explicitly control for possible external shocks or global factors that could influence resource productivity, such as economic crises, pandemics or energy price fluctuations. Second, the use of panel data for an 11-year period may not be extensive enough to fully capture the long-term effects of the public policies implemented. Also, the existence of heteroscedasticity and cross-sectional dependence identified by the diagnostic tests suggests that the results could be affected by the model specification. Third, the variables used do

not fully capture the complexity of the public policies implemented in each Member State, and institutional or cultural differences are not integrated in the analysis.

### **Future research directions**

In order to improve the accuracy and relevance of the results, future research could extend the analysis by using more advanced models, such as Driscoll-Kraay standard errors corrected for heteroscedasticity and cross-sectional dependence (Driscoll-Kraay standard errors) or dynamic panel data models (GMMs). It would also be useful to include additional variables that better capture the institutional, cultural and social dimensions that may influence the effectiveness of the public policies implemented. The integration of indicators on technological innovation, R&D investment and specific European policies such as the European Green Pact could provide a more comprehensive perspective on the transition to a green economy. A comparative analysis between EU Member States and other developed and developing economies could also help to draw more general conclusions and identify best practices.

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