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RESEARCH ARTICLE

# Environmental Policies as a Path to the Development of Circular Economy - the EU Perspective

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## Abstract

Although circular economy is a key pillar of the European sustainable development concept, under current global volatility the effectiveness of transition still remains under concern. This paper empirically assesses the impact the new Circular Economy Action Plan on circularity among the European countries during 2010-2023. The recycling rate of municipal waste is used as an indicator of circular economy, as waste management is central to circularity. Furthermore, the model includes other variables expected to influence circular economy adoption. The study uses an econometric approach based on a multiple linear regression model with fixed effects and tests for cross-sectional dependence, stationarity, and cointegration. The results indicate that the action plan substantially improved the circular economy and structured the transition process. R&D expenditure and all types of government ideology are found to have significant positive effects, whereas wealth and urbanization show no strong relationship. Overall, policies are found to have a positive impact, however, many other factors influence the process.

**Keywords** Circular Economy · Resource Management · Recycling · Environmental Law

**JEL classification codes** K32 · K33 · Q20 · Q53

## 1. Introduction

The economic model, the world is currently using, is based on extraction, usage, and disposal. Considering rapid population growth and finite resources, the traditional linear economic model is proven unsustainable. Environmental issues such as biodiversity loss, different types of pollution, and depletion of resources are increasingly threatening the earth's life-supporting systems (Rockström et al., 2009; Jackson, 2009; Martin et al, 2017). At this point, the issue of sustainable growth becomes an intensively discussed topic worldwide. Reducing the material footprint and facilitating a green (resource-efficient) economy is a key to achieving sustainable growth (Figure 1).

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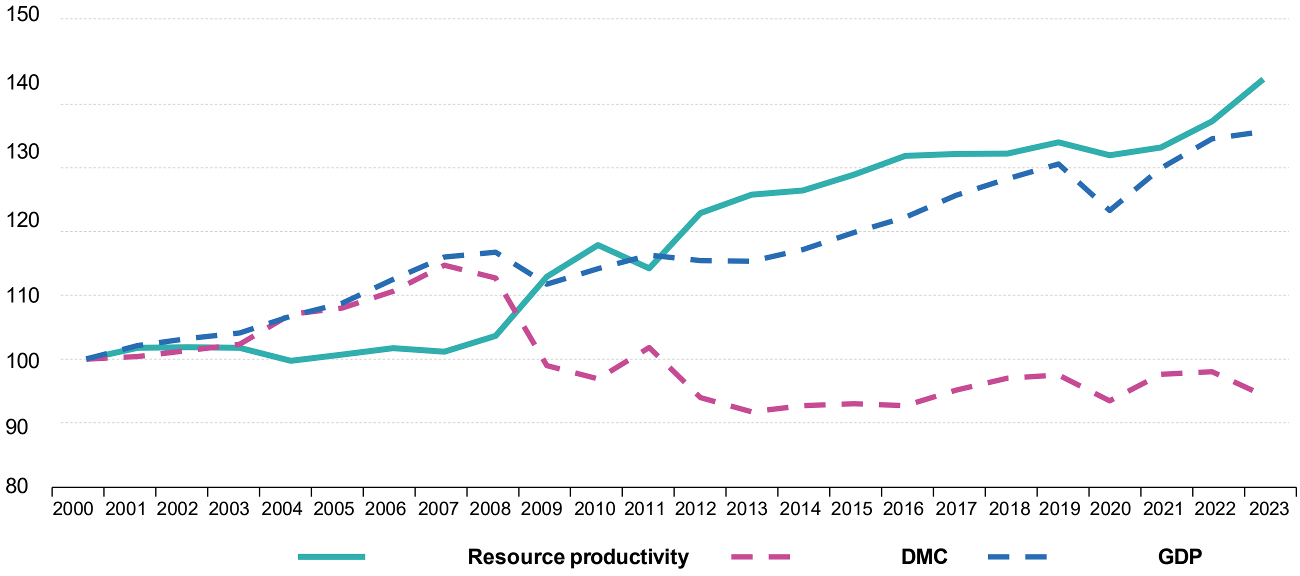


**Figure 1.** Resource productivity in comparison with GDP and DMC, EU, 2000-2023 (Index 2000 = 100) (Source: Eurostat (online data code: nama_10_gdp, env_ac_mfa; env_ac_rp))[2]

The concept of circular economy (CE) has been gaining importance during the last decades. Historically, the idea of limited inputs was first established in Kenneth E. Boulding's "The Economics of the Coming Spaceship Earth" (1966), which uses the concept of entropy, applied to understand the interaction of inputs and outputs in economic processes (Cardoso, 2018). Later the framework of circular economy was further advanced by Pearce and Turner (1990), who developed the notion of economic loops and explained the model where waste becomes a resource input. The most popular definition is framed by the Ellen MacArthur Foundation, which introduces circular economy as a framework that encompasses all pillars of sustainability in production and consumption patterns. The circular economy is a system where materials never become waste through maintenance, reuse, and recycling. A cyclical economy is associated with three principles: reduce, reuse, and recycle. These principles are called the 3Rs of circular economy; here reduction means a wide scope of actions in waste reduction at different levels of production and consumption. Reusing is another pillar that is related to extending product life if it can fulfill its original purpose. Particularly, recycling has become a fundamental part of CE over the years (Ellen MacArthur Foundation, 2015).

The shift towards a circular economy requires substantial changes across the entire economy, particularly, in the following interconnected pillars such as efficient material management, reducing toxic substances, efficient energy use, and offering economic incentives. Furthermore, member states must have harmonized definitions and a common measuring methodology to track the progress towards the shared objective of zero waste (European Commission, 2020b).

The development of the circular economy is an integral part of the European Union's (EU) efforts to address climate change, biodiversity loss, and pollution. The EU built a comprehensive framework to facilitate the transition to a closed-loop economy by implementing various policies on a supranational level. The first step towards the replacement of the linear economic model is the EU's 2014 proposal - "Towards a circular economy: A zero-waste program for Europe". Later the adoption of the first Circular Economy Action Plan (CEAP), namely "Closing the Loop – An EU Action Plan for the Circular Economy" in 2015, which resulted in a more systematic control of the process.

Next, the 2018 Circular Economy Package, which is a set of legislative acts, adopted by the European Union to accelerate the transition to a circular economy, includes four key directives that focus on waste management and resource efficiency. These comprised: Directive 2018/849 related to waste management for end-of-life vehicles, batteries, accumulators, and waste electrical and electronic equipment (WEEE); Directive 2018/850

[2] Resource productivity – measured as gross domestic product (GDP) over domestic material consumption (DMC) DMC measures the total amount of materials directly consumed in an economy by businesses for economic production and by households

targeting municipal waste landfilling regulation; Directive 2018/851 on waste; and Directive 2018/852 on packaging and packaging waste (European Parliament, 2018a; 2018b; 2018c; 2018d). European Green Deal, adopted in 2019, further strengthened the focus on waste reduction and decoupled economic growth. The framework sets clear targets in various areas of the economy through specific sector-based directives and regulations. And new CEAP, adopted in 2020, is one of the building blocks of the Green Deal, which makes the transition to circular economy an integral part of the overall sustainability framework established by the EU. In addition to introducing a new legislative measure to replace single-use packaging, tableware, and cutlery in the food service industry with reusable alternatives, the 2020 CEAP aims to expand the scope of the Eco-design Directive beyond energy consumption to include a broader range of products. The CEAP of 2015 was a general, broad policy for waste management and softer guidance compared with the 2020 action plan. The objectives of the CEAP 2020 are:[3]

- make sustainable products the norm in the EU
- empower consumers and public buyers
- focus on the sectors that use most resources and where the potential for circularity is high such as: electronics and ICT, batteries and vehicles, packaging, plastics, textiles, construction and buildings, food, water and nutrients
- ensure less waste
- make circularity work for people, regions and cities
- lead global efforts on circular economy

Furthermore, CEAP 2020 establishes 35 actions to be completed to achieve the objectives. Seven key areas are identified in the Commission's action plan to establish a circular economy: packaging; batteries and cars; buildings and construction; plastics, textiles, e-waste, food, water, and nutrients. The highest circularity rate was in the Netherlands (27.5%), followed by Belgium (22.2%) in 2022. In contrast, the lowest progress is reported by Finland (0.6%) and Romania (1.4%). In 2022, the main material type with the highest circularity rate was metal ores at 23.9%, followed by non-metallic minerals at 13.7% (Eurostat, 2023).

There are some barriers to the implementation of CEAP 2020. Economic growth and current price levels might provide limited incentives for businesses to switch towards circular solutions. This can be improved by policy solutions that monetize the positive externalities created by sustainable methods and government support for startups in this sector (OECD, 2025). Finetuning all related legislature by consolidating and aligning them towards the interests of stakeholders is another crucial aspect for the smooth transition towards a circular economy (World Business Council for Sustainable Development, 2020).

The graph below illustrates the dynamics of municipal waste recycling rate among the Eurozone countries (Figure 2). It can be noticed that all countries showed a general increase in recycling rates between 2010 and 2022. Leading countries are Germany, Ireland, Slovenia, Austria, Italy, and Latvia, which contribute a significant amount of municipal waste recycled. However, the difference in municipal waste recycling performance between the leading and laggard countries remains dramatic. This indicates that unequal investment and political or socio-economic variation between member states prevent uniform development of a circular economy, even if all are subject to CEAP.

[3] European Commission (2020). Circular economy action plan (webpage)

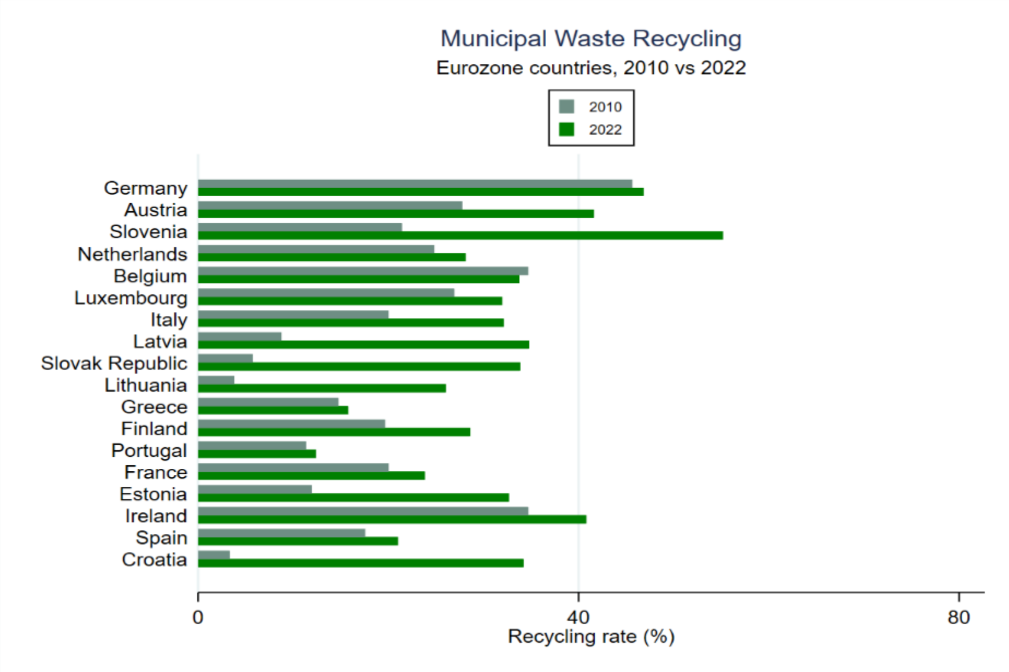


**Figure 2.** Municipal Waste Recycling in Eurozone countries, 2010 vs 2022 (Source: Elaborated by author using STATA program based on EuroStat (2025), Malta and Cyprus excluded)

The concept of circular economy has been widely explored within the academic literature. Earlier papers mainly focused on the definition and theoretical foundations of circular economy while later, theoretical analysis of circular economy implementation process and related challenges in different country cases proliferated. Others explore the individual or firm-level factors that shape circular behavior. Although the research provides a strong theoretical foundation for circular economy, empirical evidence of the effectiveness of certain policies targeting circular economy is limited. While the importance of estimating the effectiveness of the policies is increasingly recognized, the literature lacks quantitative evidence.

This paper contributes to the present literature by analyzing the effectiveness of the EU CEAP 2020 in terms of an increase in recycling rates, which is one of the main indicators of the circular economy. The article will provide empirical evidence for the Euro-area member countries' circularity rate changes and offer solid, consistent policy analysis. The main objective of the paper is to quantify the impact of adopting CEAP 2020 on recycling rates while including the potential impact of other factors, to provide the beneficial foundation for future policies targeting sustainability.

The rest of the article is structured as follows: In the following section, I discuss the relevant literature and develop the hypothesis. After which the methodology of the paper, including data collection method and processing, is described. The next part presents the results of the econometric analysis and the overall relationship between the variables. Finally, the paper concludes with a summary of the findings and policy implications, as well as potential limitations of the research and recommendations for future research.

## 2. Literature review

Research on the topic of circular economy has been growing exponentially over the last decade. Papers provide an analysis of factors determining the development of various elements of circular economy in different sectors of the economy and material types. However, to establish a proper relationship between circular economy and other factors such as economic growth, price failure, and competitiveness it is important to carefully measure CE (Moraga et al., 2019).

According to Tantau et al. (2018), recycling is considered a key instrument in the circular economy for efficient waste management. Particularly, the recycling rate of municipal waste is stated to be important as it includes waste generated by households, small businesses, and public institutions. If we consider two main goals of the circular economy, particularly waste reduction and reduced raw material consumption, it is apparent that the recycling rate is the main CE metric publicly available for a long period of time (Fellner and Lederer, 2020). Although the recycling rate contains some weaknesses in addressing the whole concept of circular economy, we assume that higher recycling rates mean lower demand for primary raw materials. However, due to the low availability of data and the complexity of the concept, the recycling rate is usually used for research purposes.

Additionally, it should be noted that almost all other CE indicators are derived from the recycling rate or represent ratios between the recycling rate and other factors. Therefore, the OECD selected the recycling rate of municipal waste as a core indicator that captures key elements of the CE based on policy relevance, analytical soundness and measurability principles (OECD, 2024). The new European CEAP gives importance to high-quality recycling and sets sector-specific recycling targets reinforcing its integral role (European Parliament, 2020). Furthermore, the recycling rate is one of ten indicators of circular economy established by the European Commission monitoring framework and detailed in Eurostat (Banjerdpaiboon and Limleamthong, 2023). Eurostat groups the indicators into the following categories: production and consumption, waste management, secondary raw materials, competitiveness and innovation, global sustainability and resilience. D'Adamo et al. (2024) found that recycling rate of municipal waste is the main criteria within waste management category.

Past literature mainly focuses on income, urbanization, R&D expenditure, political factors, age, population growth, and behavioral aspects of the circular economy.

Sidique et al. (2010) found that an increase in income marginally reduces the recycling rate, which is due to the assumption that rich people tend to consume more, generate more waste, and the opportunity cost of recycling goes up. The study applied a utility maximization and pooled ordinary least squares (OLS) models. Similarly, Önder (2018) established that higher income significantly reduces recycling, which might be explained by the fact that rich countries can obtain raw materials they need and do not care about recycling. A systematic literature review by Castro et al. (2022), studied the potential mechanisms of the rebound effect of circular economy. Discussions about the potential creation of new markets and products aligned with CE principles that will increase consumption, as well as the fact that sometimes innovative products do not completely replace old products and are introduced before the end-of-life of older generation products leading to waste are considered as potential rebound mechanisms. In contrast, Georgescu et al. (2021) revealed a positive bidirectional relationship between GDP per capita and recycling of municipal waste. And suggest that governments can achieve both high GDP and recycling rates through increasing R&D expenditure. A paper by Chen and Pao (2022) analyzed the relationship between CE indicators and economic growth, the results of the panel vector error correction model revealed the presence of short-run causality – economic growth leads to circular economy growth, but not vice versa. In the long run, a causal loop between the variables is identified, even though CE is still in its infancy. Additionally, a study of the EU countries by Kostakis and Tsagarikis (2021) revealed a positive significant influence of GDP per capita on recycling rate, which is supported by the findings of other studies,[4] as wealthier citizens require a cleaner environment to live. Panel data analysis of the EU member states shows that wealthier and more developed countries generate higher amounts of waste, however, they tend to report better circular economy indicators too (Grdic et al., 2020). Furthermore, Mazzanti et al. (2008) explore the inverted U-shape or so-called environmental Kuznets curve hypothesis within the framework of CE and indicators of economic development. A study of 103 Italian provinces showed that richer provinces in the north tend to be more innovative in waste reduction but they produce more waste per capita, indicating weak Kuznets curve evidence. Research shows that in advanced countries such as Germany and the Netherlands, which possess sophisticated recycling systems, cohesive public policies, and a strong understanding of the advantages of the circular economy, there is a positive relationship between circular economy and sustainable economic growth. In contrast, emerging economies such as Romania and Bulgaria face substantial challenges, including inadequate waste management infrastructure, limited access to advanced recycling

technology, and insufficient investment in the circular economy. Recent research indicates that these countries often experience institutional and behavioral difficulties, such as inconsistent legislation and a lack of appropriate financial support systems. These insights highlight the necessity for targeted interventions, such as European funding programs aimed at developing circular infrastructures (Horizon Europe, LIFE), harmonizing national regulations, and establishing effective markets for recyclables, to bridge disparities and ease the transition to a circular economy. Thus, the contrasts between developed and emerging economies

[4] Afroz et al. (2011); Guerin, Crete and Mercier (2001)

within the European Union underscore the significance of a flexible and customized policy framework bolstered by cross-sector collaboration and supranational initiatives (Georgescu, 2024).

According to the empirical results of a study on the determinants of recycling rates in the EU by Kostakis and Tsagarakis (2021), the urbanization level of the community might positively impact recycling because it can be used as a proxy for waste collection and recycling costs and recycling is well established in urban areas. Sufficient waste storage space, bin availability, and the proximity of recycling centers and waste collection services increase the recycling rate, especially in high-density urban areas (Oluwadipe et al., 2021; Guerin, Crete, and Mercier, 2001). Szabó et al. (2024) studied urban CE practices in cities of Italy, Hungary, and Germany, the findings suggest that the circular offers and initiatives provided by a wide range of stakeholders (public or private businesses, NGOs, active groups of people), which enable consumers to implement CE lifestyles are more widespread in urban environment. However, Sidique et al. (2010) identified that lack of space in highly urbanized cities discourages citizens from recycling and reduces recycling rates.

Research and Development that may result in higher value-added products and prolong the lifecycle of goods is expected to have a positive relation with pro-environmental behavior. In a study of barriers to the circular economy in the EU through interviews and a literature review, Kirchherr et al. (2018) revealed that the lack of advanced technologies to deliver high-quality recycling and remanufacturing processes is one the main barriers to implementing CE, which can be improved through R&D. According to Suchek et al. (2021) innovation focused on 3D printing, the Internet of Things, automatization and digitalization might be useful in waste management. Circular Economy Action Plan 2020 stresses the importance of research, innovation, and digitalization for circular economy transition. Specifically, the European Regional Development Fund, through smart specialization, LIFE, and Horizon Europe, is expected to supplement private innovation financing and assist the whole innovation cycle with the goal of bringing ideas to market. To summarize, it can be concluded that previous studies provide mixed results in terms of the effect of income and urbanization on the circular economy, while R&D is expected to be beneficial.

Another perspective on the determinants of circularity particularly recycling is a political ideology that is widely discussed in the literature. According to Arslan et al. (2024), the increased power of right-wing parties in the government is associated with lower e-waste recycling rates based on the analysis of 30 European countries. The results are robust with different indicators of government ideology. Right-wing governments are considered to be in favor of market-based solutions and voluntary contributions rather than strict regulations. While left-wing governments are more inclined to advocate for Extended Producer Responsibility programs and promote recycling (Wen et al., 2016). This behavior is explained by the fact that left-wing countries are mostly supported by the working class, they are less reluctant about higher environmental costs on private entrepreneurs.

Moreover, demographic changes are considered to alter the view about recycling and circular economy. The fertility rate, which is used as a proxy for population growth and number of young people in the country, can harm recycling if the proportion of the elderly, who can promote recycling, declines (Kostakis and Tsagarakis, 2021). A paper by Zhang et al. (2023) reviews existing publications to understand the relationship between space (population density) and CE environment. It has been concluded that high recycling activities usually occur in densely populated areas, while highly urbanized areas have reduced negative impact on circularity. Berglund and Soderholm (2003) in the study of paper recycling rate determinants, based on pooled time series data among 49 countries worldwide, found that population density increases land price and the cost of landfilling. Consequently, small but densely populated places should have higher recycling rates. Overall, previous papers provide mixed findings regarding the impact of urbanization and government ideology on CE.

The country-specific factors such as cultural norms and beliefs are indicated as another important factor influencing people's recycling behavior (Kumar, 2019; De Morais, Pinto, and Cruz-Jesus, 2021). A seminal contribution to the analysis of cultural differences among countries was laid by Hofstede (2001), who recognized five dimensions of culture: individualism, uncertainty avoidance, masculinity, long-term orientation, and power distance. Le and Kieu (2019) revealed the positive influence of collectivism, long-term orientation, and subjective norms on consumer disposal behavior in Vietnam. Social norms and beliefs refer to the formation of individual-level ethical consumption behavior and the extent to which the consumer perceives the social pressure when making a choice. The results of a comparative study of Indian and US consumers by Gaur et al. (2019) revealed that social actors such as family, friends, peers, and other stakeholders influence individual behavior. Similarly, the importance of leadership figures in communities is stated to be another interesting factor to consider. Tebernero et al. (2015) investigated individual and collective factors influencing the recycling behavior of 1,501 individuals selected from 55 Spanish localities and concluded that the recycling rate can be explained by age, recycling service satisfaction among people, education, income, and average community size. However, the relationship is found to be modest and that might indicate that policies should focus on promoting environmentally responsible culture.

According to Mies and Gold (2021), the social dimension of the circular economy is huge and it cannot be explained only through government involvement, education, employment, and health but all other social sustainability concerns should be analyzed at micro, meso, and macro levels. The study also concluded that customers, being a main influencing domain on the circular economy. However, this awareness is not directly translated into consumers' behavior, as end-of-life responsibility and consumption patterns are influenced by so-called 'culturally acceptable behavior', which depends largely on the country's culture (Corral-Verdugo, 2003).

The analysis of municipal solid waste recycling rates revealed that local and national policies have a positive impact on recycling (Callan and Thomas, 1997). As circular economy implementation is a systematic approach, soft power policies with an ability to bring change in the willingness and culture of people through values and institutional practices are important in the process of transition to circular economy (Kirchherr et al., 2018). Sanz-Torro et al. (2025) assessed the EU country's national circular economy policies using Data Envelopment Analysis from 2010-2022. The findings support institutional theory, indicating that comprehensive CE policies result in considerable benefits in resource efficiency and sustainability. Productivity gains, particularly in nations with robust regulatory systems, support the theoretical assumptions made. It is highlighted that although the countries adopted policies with the same objective, the strategy used is different for each country. Overall, the study concludes that the differing rates of circular economy implementation are a clear reflection of the specific characteristics of the strategy each country implemented. Besides that, sufficient information regarding recycling and waste management should be available, for example, the usage of recycling centers and the return process of used products should be clear (Dururu et al., 2015). According to Hartley et al. (2023), targeted government intervention can provide much of the necessary push for a transition to a circular economy. A study based on the "stochastic impacts by regression on population, affluence, and technology" (STIRPAT) model and empirical techniques such as panel fixed-effects, random-effects, indicates that in OECD countries increase in regulatory efficiency positively effects environmental pollution (Hashmi and Alam, 2019). Overall, if policies result in the improvement of recycling convenience (provision of recycling services, waste bins) and reduce the opportunity cost, aggregate recycling rates are expected to rise.

Nogueira (2022) presents a legal analysis of the EU CEAP of 2015 and 2020, along with the type of policy instruments employed to reach the goal of sustainable transition. The author focuses on the regulatory instrument choice by the EU in terms of compliance and monitoring for CEAP. The study critically evaluates the content of circular economy action plans (2015 and 2020) from a legal point of view by stating that broad scope, vague terms, and certain voluntary implementation of circularity requirements make it difficult to measure progress. The reliance of the EU on nudges to make the shift in businesses' and consumers' mind, and only the informative nature of measures envisioned in regulations are considered to be weak. In essence, the development of strong pro-environmental culture and comprehensive policy framework on CE adoption can significantly improve the CE practices.

Overall, this paper will empirically analyze the effectiveness of CEAP adopted in 2020 and provide a general insight in the development of CE among the EU member states, considering other factors (besides policies) that influence CE transition. The main objective of current research is to identify whether the EU environmental policy (new CEAP) directed to accelerate the transition towards CE has a significant impact on the key CE indicators (e.g. recycling rate). Moreover, the following hypotheses are developed:

- $H_0$: $CEAP\ implementation\ has\ no\ significant\ effect\ on\ circular\ economy\ indicators.$
- $H_1$: $CEAP\ implementation\ significantly\ improves\ circular\ economy\ indicators.$

## 3. Methodology

To address the aforementioned research objective, the following econometric model has been established (1). The model includes the recycling rate as a measurement of CE and independent variables that try to explain changes in it including the categorical variable for CEAP adoption. Unbalanced country-level panel data for 18 Euro-area member states over the period of 2010-2023 is used for quantitative analysis. Malta and Cyprus were excluded from the analysis due to the small size of the economy, and specifications of economic activity.

Furthermore, in the context of EU law these countries often benefit from derogations, particularly for binding objectives because of structural and geographic reasons. Common areas of exemption are renewable energy, environment related regulations. The fixed effects model is applied as an analysis method. Although the fixed effects model is conventionally considered to be more appropriate than random effects by the literature, we have used the Hausman test in determining the choice between the random and fixed effects. The Hausman test checks whether the idiosyncratic errors are correlated with independent variables, and if the null hypothesis is rejected, the fixed effects model is accepted. However, the impact of time-invariant factors such as cultural norms cannot be analyzed through a fixed effects model. As the fixed effects model omits all variables constant over time. Therefore, the random effects regression model is used to account for the effects of cultural variables. Additional tests for cross-sectional dependence, unit root, and cointegration tests are applied to ensure the reliability and precision of the results.

This paper's main hypothesis is to determine whether the new CEAP aimed at promoting efficiency and implementing the circular economy has a significant impact on the important circularity indicators. The variable “Policy” included in the proposed model is built as a categorical variable that takes the value of one in years after a CEAP is implemented. The study aims to claim the efficacy of circular economy policies, namely the new CEAP, and provide additional policy insights for developing countries and anticipates finding a strong positive relationship between the policy and circular economy.

## 3.1. Model specification

Here, CE_indicator is the recycling rate of municipal waste, for country i and time period t. $\beta 0$ is the constant term, $X$ is the vector of other independent variables that were used in the empirical analysis, $\beta k$ k= 1…k - is the estimated coefficient for each variable, $\delta i$ - is the unobserved heterogeneity, and $\varepsilon i,t$ is the idiosyncratic term. Policy variable is specified separately because it is the variable of main interest for the paper.

$$CE\_indicator_{i,t} = \beta_0 + \beta_1 Policy_{i,t} + \beta_2 X_{i,t} + \delta_i + \varepsilon_{i,t} \quad (1)$$

Vector of variables that were used are the following: $GDPi,t$ is gross domestic product per capita, $urbi,t$ urbanization level, $gerdi,t$ government expenditure on R&D, political ideology variables $gov\_righti,t$; $gov\_centi,t$; $gov\_lefti,t$.

The model is based on the recycling rate of municipal waste, which is considered one of the direct measures of the circular economy. The dependent variable, the recycling rate of municipal waste is analyzed for the impact of financial, socio-economic, and policy variables. The impact of income level, measured by real GDP per capita, on circularity indicators such as recycling is ambiguous according to the research findings. In addition, urbanization level is included and used as a proxy for the cost of recycling and circular economy activities, and the availability of recycling centers. A higher level of urbanization is expected to increase the waste recycling rate (Kostakis and Tsagarakis, 2021; Robaina et al.,2020). Similarly, R&D expenditure is expected to enhance the circular capacity of countries and improve the recycling rate. While the influence of government ideology is expected to be positive for countries with dominant left-wing parties, and negative or zero for other government types. Cultural variables are expected to impact recycling negatively according to the past literature.

**Table 1.** Summary of variables

| Variable | Measurement type | Source | Expected relationship[5] |
|---|---|---|---|
| Recycling rate | Share of recycled municipal waste from total municipal waste treated (%) | OECD database | Dependent variable |
| Policy | Dummy variable taking values of zero before the year of CEAP adoption (2020) and one after | Author’s elaboration | + |
| GDP per capita | GDP per capita, PPP (constant 2021 international $) | World Development Indicators | +/- |

[5] The expected relationship is developed considering the findings of past literature

**Table 1 (Cont.).** Summary of variables

| Variable | Measurement type | Source | Expected relationship[6] |
|---|---|---|---|
| Urbanization | Urban population (% of total population) | World Development Indicators | +/- |
| R&D | Government expenditure on R&D in all sectors, in million euro | Eurostat | + |
| Government ideology | relative power position of right-wing, center and left-wing parties in government based on their seat share in parliament, measured in percentage of the total parliamentary seat share of all governing parties. Weighted by the number of days in office in a given year. | The „Comparative Political Data Set" (CPDS) - Armingeon et al. | +/- |
| Masculinity | Masculinity score, society's focus on material success and gender roles are clearly distinct | Hofstede (2001) | - |
| Individualism | Individualism score, the extent to which people put their personal beliefs over collective values (self-interest) | Hofstede (2001) | - |

First difference of urbanization level variables is used to avoid multicollinearity. Additionally, logarithmic transformation of GDP per capita is performed to reduce heteroscedasticity and make interpretations easier.

## 4. Results and Discussion

The graph below illustrates the dynamics of the recycling rate of municipal waste among the Eurozone countries over the period of analysis (Figure 3). It can be observed that the recycling rate plateaued and declined after 2020, which can be expected by several factors. First of all, despite improvements in policies, recycling rates stagnated or declined as a result of the COVID-19 pandemic's significant disruption of municipal waste recycling systems throughout the EU between 2020 and 2021. Lockdowns and online work policies reduced commercial and industrial recyclable streams, while increasing household waste volumes, especially single-use plastics and packaging from online shopping (Yousefi et al., 2021). Furthermore, concerns about viral transmission deterred the use of reusable packaging and caused an increased use of disposable materials, health and safety regulations caused some municipalities to temporarily suspend separate waste collection and recycling operations (Zambrano-Monserrate et al., 2020).

Secondly, the new Directive (EU) 2018/851, which became mandatory in July 2020, as a part of the circular economy package amending Directive 2008/98/EC, affected the reported recycling rates of municipal waste. Paragraph 46 of the directive establishes a new recycling rate calculation method, according to which member states need to report the effective recycling rates (what is effectively recycled). It should be based on the weight of municipal waste that enters the recycling process, and not the weight of municipal waste collected for recycling as prior revision. Any losses during sorting and preparation for the recycling stage should be excluded from the recycled amount. The directive demands traceable and auditable recycling data that are counted towards the recycling targets (European Parliament, 2018). This transition towards stricter and precise regulation has improved the reliability and availability of circular economy-related data, however, resulted in distortion of the reported recycling rate trend. While the impact of policies designed to enhance the recycling rate, specifically the new CEAP, is long-term oriented and gradual.

[6] The expected relationship is developed considering the findings of past literature

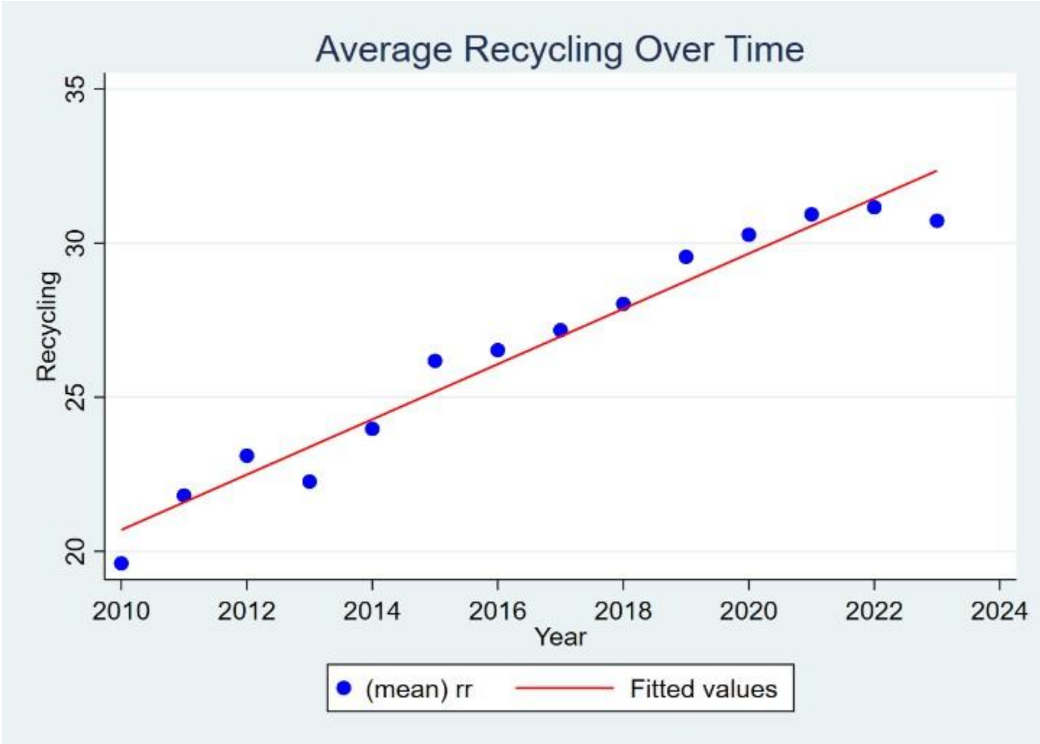


**Figure 3.** Average recycling of municipal waste overtime (Source: Author's elaboration)

In addition, some factors over the last couple of years changed the context of the circular economy transition in the EU. The global economic system is vulnerable to various risks, specifically related to the security of raw materials and supply chains of certain materials. The Russia-Ukraine conflict significantly impacted the prices of commodities, food, and energy due to the unequal distribution of resources, which has revealed the fragility of the global politico-economic system. Therefore, it can be concluded that circular economy initiatives gained more importance as they can contribute towards the greater resource and economic resilience of the EU (Institute for European Environmental Policy, 2022). However, keeping a substantial commitment to circular economy targets during the period of crisis is extremely demanding, therefore we might observe a slight plateau during this period. Similarly, a stagnating pattern can be noticed in a broader context of the EU waste dynamics. The increased generation of packaging waste and e-waste, coupled with slower overall recycling rate, demonstrates that the circular economy is a complex framework influenced by numerous factors (EEA, 2024b).

The results of preliminary analytics and a summary of statistics are presented in Tables B and C. From the correlation matrix, it can be observed that the recycling rate of municipal waste shows significant positive correlations with GDP, and government expenditure on R&D, followed by benefits from policy adoption, centrist government ideology, and individualistic society. Furthermore, we can notice that correlations between government ideology variables (gov_right2; gov_cent2; gov_left2) are strong because of the calculation method of the variables.

Additionally, the multicollinearity of the variables has been tested using the variance inflation factor (VIF) test. When independent variables have a high degree of correlation with one another, multicollinearity causes the variance (instability) of a regression coefficient to increase, which is measured by the VIF. In this context we use the threshold of VIF>10 to assess the multicollinearity of variables (Georgescu et al., 2025). According to the values in Table D, none of the independent variables exceed the threshold of VIF=10, which means there is no multicollinearity issue in the model specified.

Although the fixed effects model is generally preferred among the researchers, the Hausman test has been performed. The Hausman specification test indicates whether the regressors and unique errors of the model are correlated. The null hypothesis of the test assumes that the random effects model is consistent, while the alternative is that the fixed effects model is preferred. If the null hypothesis is rejected, the fixed effects model is accepted. Based on the results of the Hausman test (Table 2), the p-value is less than 0.05 showing that we reject the null hypothesis and the fixed effects model provides more consistent results.

**Table 2.** Hausman (1978) specification test

| | Coef. |
|---|---|
| Chi-square test value | 23.471 |
| P-value | .001 |

The table below presents the results of fixed effects regression (Table 3). The model shows a strong level of statistical confidence due to the representation of errors below the threshold of 5% (Prob > F below 0.05). It can be observed that policy adoption has a significantly positive effect on the recycling rate, which validates the hypothesis and increases recycling by approximately 4%. Additionally, when the same model is tested with the first lag of policy variable to take into account the gradual (non-immediate) impact of the new CEAP, the variable becomes insignificant. This may show that the influence of the circular economy action plan on the recycling rate is immediate rather than lagged. However, the coefficient is still substantial. A similar relationship was identified among European countries by Camilleri (2020), Callan and Thomas (1997), and most of the literature.

Regarding the relationship between GDP per capita and the recycling rate of municipal waste, the results show a positive relation consistent with past literature. It can be inferred that the increase in wealth of the population leads to a higher demand for a clean and sustainable environment. Articles by Georgescu et al. (2021), Chen and Pao (2022), Kostakis and Tsagarikis (2021) determined that high-income countries tend to show better recycling indicators. However, some papers revealed a negative relationship between income and recycling practices. Specifically, Sidique et al. (2010) expect that richer people generate more waste and the opportunity cost of recycling is too high. Önder (2018) concludes similarly by stating that rich societies often lose interest in recycling as they tend to be more inelastic to changes in raw material prices. Along with technology and human capital, raw materials and other natural resources are necessary for economic growth. However, the results indicate that the EU governments take action against waste as the production level rises. Another variable that insignificant positive relationship is urbanization level. Past literature provides inconsistent results regarding the impact of urbanization on the recycling rate, while the majority consider that urbanization results in increased convenience for recycling.

Government expenditure on research and development is found to have a negative relationship with the recycling rate in model (1), which is opposite to the findings of previous research, while in the model (2) it is insignificant which indicates a marginal indirect effect on the outcome variable. However, the magnitude of the effect is extremely low. It can be due to the broad environmental and technological scope of R&D expenditure, rather than specific investments in waste management solutions. In general, recycling tends to be popular among countries with high R&D expenditure. Due to the development of new recycling techniques, sustainable material types, and innovation, R&D is crucial for circular economy development (Kostakis and Tsagarakis, 2021; Georgesku et al., 2021). Such initiatives as Circular Economy for Flexible Packaging (CEFLEX), recycling of rare earth elements (REE4EU) project, and ECOSYSTEX & Resyntex framework form the EU R&D network for developing new and enhanced circular economy techniques.

Government ideology is another variable that influences the recycling rate of municipal waste. From the results, it can be stated that a specific partisan viewpoint does not affect the recycling rate. Actions to develop a circular economy are performed on the same level in countries with various political party structures. Specifically, governments with a dominant share of right, center, or left parties in the parliament show a positive statistically significant relationship with the recycling rate. This finding is contrary to Arslan et al. (2024), which stated that the increased power of right-wing parties in the government is associated with lower recycling rates based on the findings of the panel data analysis of 30 European countries. Here the importance of cultural beliefs is evident because the notion of right, center party is different for various countries. For example, Sweden and Finland have dominant center-right/conservative parties, however, are some of the EU leaders in waste management and recycling.

**Table 3.** Regression results of recycling rate[7]

| Variables | (1) Fixed Effects Recycling Rate | (2) Fixed Effects Recycling Rate |
|---|---|---|
| pol | 3.793*** | |
| | (1.249) | |
| 1L.pol | | 3.060 |
| | | (1.816) |
| lngdp | 22.71 | 24.67 |
| | (15.25) | (16.58) |
| urbd[8] | 11.73 | 12.05 |
| | (9.212) | (9.884) |
| gerd | -0.000118** | -0.0000698 |
| | (0.0000553) | (0.0000415) |
| gov_right2 | 0.0613** | 0.0647** |
| | (0.0284) | (0.0286) |
| gov_cent2 | 0.0584*** | 0.0614*** |
| | (0.0142) | (0.0179) |
| gov_left2 | 0.0340*** | 0.0349*** |
| | (0.00965) | (0.0112) |
| _cons | -225.0 | -246.7 |
| | (164.3) | (178.2) |
| *N* | 213 | 213 |

Standard errors in parentheses (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

These results show the important dynamics of the implementation of the new CEAP. While institutional, economic, and political variables tend to show a profound impact on the recycling rate, the adoption of a circular economy action plan emerges as a robust determinant of the municipal waste recycling rate.

As the fixed effects model does not allow to analyze the cultural variables, specifically masculinity and individualism scores adopted from Hofstede's cultural dimensions, random effects regression is applied. Random effects model assumes strict exogeneity, while it allows to analyze the effect of time-invariant variables such as cultural variables. The empirical results obtained through random effects model are presented in the Table 4. It can be noticed that the implementation of the policy has a statistically significant positive effect on recycling rate of municipal waste. In the period after the adoption of the new CEAP, countries experienced around 4% higher recycling rates compared with "NO" policy period. The policy variable has a strong effect until the second lag of the variable. The other variables show approximately the same relationship pattern as for the fixed effects model.

Regarding the impact of the cultural variables, the results show a negative insignificant relationship between masculinity, individualism, and recycling rates. The result is aligned with the theoretical background. As individualism (where individual interests prevail over collective benefit) and masculinity (capitalistic beliefs) rise, people become less conscious of environmental consequences. According to Hofstede's cultural dimensions, individualistic societies prioritize personal success and independence more than collective endeavors like recycling (Hofstede, 2001). Pro-environmental behavior is also less common in societies with high masculinity scores, which tend to value economic growth and assertiveness over ecological responsibility

[7] All of the regression results are presented with robust standard errors
[8] Due to non-stationarity and multicollinearity issues, first difference of the variable is used

(Milfont and Schultz, 2018). Countries with higher individualism scores also reported lower participation in recycling and other environmental protection activities, according to research by Cho and Jung (2023). Furthermore, Jackson (2005) contends that sustainable consumption practices have a negative correlation with materialistic and self-enhancing values, which are frequently linked to cultures that are masculine. Together, these results lend credence to the idea that cultural orientations based on masculinity and individualism could serve as obstacles to the broad adoption of recycling practices.

**Table 4.** Regression results of recycling rate (random effects model)

| Variables | (1) Random Effects Recycling Rate | (2) Random Effects Recycling Rate | (3) Random Effects Recycling Rate |
|---|---|---|---|
| pol | $3.737^{***}$ | | |
| | (1.156) | | |
| L.pol | | $3.241^{**}$ | |
| | | (1.352) | |
| L2.pol | | | $2.332^{*}$ |
| | | | (1.303) |
| lngdp | $17.46^{*}$ | $18.40^{*}$ | $18.31^{*}$ |
| | (9.591) | (9.950) | (9.919) |
| urbd | 8.850 | 9.007 | 9.351 |
| | (8.036) | (8.567) | (11.50) |
| gerd | 0.0000411 | 0.0000653 | $0.0000841^{*}$ |
| | (0.0000538) | (0.0000482) | (0.0000452) |
| gov_right2 | $0.0577^{**}$ | $0.0611^{**}$ | $0.0531^{*}$ |
| | (0.0288) | (0.0298) | (0.0290) |
| gov_cent2 | $0.0627^{***}$ | $0.0663^{***}$ | $0.0659^{***}$ |
| | (0.0151) | (0.0174) | (0.0234) |
| gov_left2 | $0.0284^{***}$ | $0.0296^{**}$ | 0.0158 |
| | (0.0104) | (0.0121) | (0.0131) |
| indv | -0.0476 | -0.0695 | -0.0917 |
| | (0.222) | (0.228) | (0.231) |
| masc | -0.0119 | -0.0171 | -0.0252 |
| | (0.0721) | (0.0756) | (0.0824) |
| _cons | $-166.4^{*}$ | $-175.3^{*}$ | $-171.6^{*}$ |
| | (94.41) | (97.29) | (97.37) |
| *N* | 213 | 213 | 195 |

Standard errors in parentheses ($^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$)

Breusch and Pagan (1980) Lagrange multiplier (LM) test of cross-sectional dependence in the panel data is used to analyze the presence of inter-dependent observations. Cross-sectional dependence may happen due to common shocks and unobserved factors that contribute to the error term. In the case of cross-sectional dependence, the results of the standard fixed- and random-effects models will be consistent but they will not be efficient, namely, standard errors will be biased (De Hoyos and Sarafidis, 2006). The results based on 10 complete observations show Chi-square (153) = 339.522, Pr = 0 which means there is cross-sectional dependence. Furthermore, an increasing number of econometric literature concludes that a longer time dimension leads to the problem of stationarity and cointegration (Baltagi, 2001). Therefore, a Fisher-type augmented Dickey-Fuller unit root test is applied (Table G). The null hypothesis of the test assumes that the panels have unit roots. The results show that all the variables apart from recycling rate, urbanization level, and right government party variables are non-stationary. Consequently, in order to analyze the homogenous cointegration among non-stationary panels Pedroni cointegration test is applied. Due to the built-in limits of Pedroni cointegration test, we have tested only the variables that have a significant relationship with the recycling rate, namely pol; GERD; gov_right2; gov_cent2; gov_left2. According to the results in Table E, there is a long-run cointegrating relationship between the variables. This shows that variables have stable, long-run relationships and strengthens the reliability of findings.

Furthermore, to mitigate the correlation of observations within a specific country and country specific effects, regression absorbing the country effect with clustered standard errors has been performed (Table F). According to the results, it can be observed that the policy adoption still has a significant positive impact on recycling rates. In addition, government ideology and R&D expenditure are found to be important for recycling trends.

## 5. Conclusion

Overall, the paper studied the development of a circular economy in Europe, specifically focusing on the role of legislation in this process and based on other economic, social, and institutional factors. The findings of the study confirm the hypotheses and offer a deep understanding of the dynamics in the transition to a circular economy within the European Union. The econometric analysis reveals that the circular economy action plan has a significant positive effect on the circular economy and fosters a shift towards a more resource-efficient economy. It is demonstrated that wealth, infrastructure, and innovations are complementary factors to achieve the policy objectives. Particularly, recycling rate of municipal rate increased by around 4% following the implementation of CEAP, ceteris paribus. While increase in income and urbanization result in 23% and 12% respective growth in recycling rate, however, the relationship is not statistically significant. Similarly, government expenditure on R&D showed insignificant negative association. Finally, variable representing government ideology showed significant positive link (approximately 0.1%) to recycling rates. This paper aims to contribute to the academic literature on the circular economy by analyzing circular economy action plans effectiveness quantitatively and trying to pinpoint factors that need to be targeted by policies. The study also highlights the main obstacles in reaching the circular economy targets such as differences in recycling infrastructure, technological development, behavioral barriers, and disparities in funding of the circular economy projects. Overcoming these barriers is important to improve the circularity rate it requires an integrated approach through better regulation, uniform standards, and investment.

The following policy recommendations can upgrade the current framework and raise the circularity rate among the EU member states. Firstly, the proposition is the creation of a single market for recycled raw materials at the European level by eliminating trade barriers. This can improve the material flows between states and facilitate uniform recycling quality standards. Secondly, facilitation of the private investment in the circular economy can accelerate the transition and help to mitigate disparities in recycling rates among countries. Furthermore, as we identified R&D expenditure to be a significant contributor to a circular economy, better mobilization of funds from the EU-level institutions including Horizon Europe, the Cohesion Fund, LIFE, ERDF, ESIF, and RFCS can bring current expertise to another level. Another aspect is further increasing demand for recycled materials by incentive structure for businesses, such as tax benefits because still secondary raw materials remain expensive. The OECD 3Ps framework advises that people and firms, places, and policies are pillars of the territorial approach to the circular economy. Providing clear and easily accessible information about product recyclability, durability, and origin to customers may raise awareness and individual actions which is an important step. Furthermore, potential labor market disruptions are expected because the benefits of a circular economy will vary across sectors of the economy, and resource-intensive sectors will be disadvantaged. Policies tailored to the specific country cases, powered by granular disaggregated data, will be pivotal in achieving the next phase of the CE transition.

This study contains certain limitations that can be considered for future research. Although fixed-effects models are useful for analyzing longitudinal data, certain issues are present, such as low statistical power, measurement errors, time invariance, unobserved heterogeneity, and the inability to analyze data over extended periods of time. Furthermore, the study can be carried out based on the regional-level datasets to observe the variation of recycling levels depending on the region's specificities. An extended study of circular economy determinants among developing nations and, a more precise and consistent econometric methodology to address the endogeneity issue might be interesting. The methodology adopted in this study provides a valuable base and could be replicated among developing countries to assess the effectiveness of circular economy policies within different institutional and economic contexts. Such comparative analysis might lead to more precise and context-centered policymaking. However, data availability is a strong barrier for detailed and larger geographic scope studies.

In conclusion, circular economy is a concept that is a key to sustainable and resilient future for the EU and beyond. A full transition to a circular economy requires a systematic change in incentives of stakeholders, accessibility of circularity to stakeholders, and political support. Although some challenges remain at the EU level of policymaking, we found that the new CEAP adopted in 2020 is a significant driver of the circular economy.

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**Data availability** This study uses secondary data obtained from publicly accessible sources. The datasets used in this article are available from the OECD Data Explorer, World Development Indicators, Eurostat, Comparative Political Data Set and Geert Hofstedes' Dimension data matrix. These datasets are openly accessible subject to the providers' standard terms of use. No proprietary or confidential data were used. Any other data used in the analysis is available from the corresponding author upon reasonable request.

## Declarations

**Competing Interests** The author declare no competing interests.



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# Appendices

**Table A.** Country profiles (Source: Elaborated by author based on OECD data explorer (2025) and EEA (2024) circular economy country profiles)

| Country | Policy focus | Progress metrics (recycling rate of municipal waste 2022) |
|---|---|---|
| **Netherlands** | Government-wide programme for a Circular Dutch Economy by 2050<br>Target sectors: plastics, consumer goods, manufacturing, building and construction, biomass and food | 28.1% |
| **Italy** | National Circular Economy Strategy<br>Target sectors: waste electrical and electronic equipment (WEEE), plastics, textile, construction<br>and agrifood | 32.1% |
| **Germany** | The National Circular Economy Strategy<br>Target sectors: plastics, metals, vehicles, textile, electronics | 46.8% |
| **Belgium** | Vision 2050 long-term strategy for Flanders;[9] Circular Wallonia<br>Target sectors: food, water, plastics, construction | 33.8% |
| **Spain** | Spanish Circular Economy Strategy 2030<br>Target sectors: construction, farming, consumer goods, textile, tourism | 21% |
| **Finland** | Strategic program to promote a circular economy by 2035<br>Target sectors: carbon-neutrality, food, forest-based loops, biomass | 28.6% |
| **Austria** | The Austrian Circular Economy Strategy<br>Target sectors: microplastics, food waste, management of secondary materials | 41.6% |
| **Portugal** | The Portuguese National Action Plan for the Circular Economy<br>Target sectors: agri-food, construction, distribution and retail, electric and electronic, plastics, tourism, and textile | 12.4% |
| **Slovenia** | Roadmap towards the circular economy in Slovenia 2018<br>Target sectors: food system, forest-based value chains, manufacturing industry | 55.2% (Highest value) |
| **Ireland** | The Circular Economy and Miscellaneous Provisions Act 2022<br>Target sectors: construction, manufacturing, retail, households, services, hospitality | n/a |
| **Greece** | National circular economy Strategy 2018<br>Target sectors: plastics, food waste, packaging waste, municipal waste | 15.8% |
| **Slovakia** | Roadmap for circular economy of the Slovak Republic<br>Target sectors: construction, heavy industry, bio-waste | 33.9% |
| **Estonia** | - Circular economy white paper; Estonia 2035 strategy (no circular economy strategy)<br>- Target sectors: food waste, agricultural sector, vehicle, public procurement | 32.7% |
| **France** | Circular economy roadmap 2018; Anti waste law 2020<br>Target sectors: single-use plastics, textile products, computers and all other consumer goods | 23.8% |
| **Luxembourg** | National circular economy strategy 2021<br>Target sectors: municipal household waste, biowaste, packaging, WEEE, construction | 32% |

[9] Belgium does not have a dedicated national resource efficiency or circular economy strategy/action plan, mainly due to its constitutional set-up (EEA, 2024).

**Table A (cont.).** Country profiles (Source: Elaborated by author based on OECD data explorer (2025) and EEA (2024) circular economy country profiles)

| Country | Policy focus | Progress metrics (recycling rate of municipal waste 2022) |
|---|---|---|
| **Latvia** | Action Plan for the Transition to a Circular Economy 2020-2027<br>Target sectors: wood and wood-based materials, food waste, textile, furniture | 34.5% |
| **Lithuania** | Guidelines for the Lithuanian transition to a circular economy by 2035<br>Target sectors: agriculture (bioeconomy),<br>transport, construction, household consumption waste | 26% |
| **Croatia** | No single circular economy strategy in Croatia, however measures are specified in Waste Management Plan of the Republic of Croatia for the period 2023-2028<br>Target sectors: food waste, tourism, energy, construction | 32.4% |

**Table B.** Matrix of correlations

| Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| (1) rr | 1.000 | | | | | | | | | |
| (2) pol | 0.220 | 1.000 | | | | | | | | |
| (3) lngdp | 0.415 | 0.082 | 1.000 | | | | | | | |
| (4) urbd | -0.179 | 0.046 | 0.102 | 1.000 | | | | | | |
| (5) gerd | 0.410 | 0.070 | 0.224 | -0.116 | 1.000 | | | | | |
| (6) gov_right2 | -0.061 | 0.094 | -0.251 | 0.016 | -0.199 | 1.000 | | | | |
| (7) gov_cent2 | 0.271 | -0.050 | 0.257 | -0.142 | 0.184 | -0.405 | 1.000 | | | |
| (8) gov_left2 | -0.181 | -0.086 | 0.007 | 0.087 | 0.012 | -0.564 | -0.458 | 1.000 | | |
| (9) indv | 0.212 | -0.001 | 0.453 | -0.273 | 0.351 | -0.013 | 0.185 | -0.188 | 1.000 | |
| (10) masc | 0.015 | -0.013 | 0.153 | -0.346 | 0.202 | -0.298 | 0.162 | 0.098 | 0.045 | 1.000 |

**Table C.** Descriptive Statistics

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| rr | 243 | 26.363 | 10.729 | 3.331 | 58.812 |
| pol | 252 | .286 | .453 | 0 | 1 |
| gdp | 252 | 52713.621 | 24421.228 | 24098.054 | 135379.29 |
| urb | 252 | 72.486 | 12.953 | 52.658 | 98.189 |
| gerd | 250 | 13737.862 | 24163.972 | 108.65 | 129972 |
| gov right2 | 234 | 36.219 | 34.02 | 0 | 100 |
| gov cent2 | 234 | 27.375 | 31.304 | 0 | 100 |
| gov left2 | 234 | 34.641 | 34.866 | 0 | 100 |
| indv | 252 | 57.333 | 16.42 | 27 | 80 |
| masc | 252 | 45.944 | 25.479 | 9 | 110 |

**Table D.** Variance inflation factor

| | VIF | 1/VIF |
|---|---|---|
| 1.pol | 1.054 | .949 |
| lngdp | 1.604 | .623 |
| urbd | 1.454 | .688 |
| gerd | 1.236 | .809 |
| gov right2 | 8.643 | .116 |
| gov cent2 | 7.379 | .136 |
| gov left2 | 9.065 | .11 |
| indv | 1.752 | .571 |
| masc | 1.383 | .723 |
| Mean VIF | 3.73 | . |

**Table E.** Pedroni test for cointegration

| | |
|---|---|
| H0: No cointegration | Number of panels =18 |
| Ha: All panels are cointegrated | Avg. number of periods = 11.833 |

| | | | |
|---|---|---|---|
| Cointegrating vector: Panel specific | | | |
| Panel means: | Included | Kernel: | Bartlett |
| Time trend: | Not included | Lags: | 0.00 (Newey-West) |
| AR parameter: | Panel specific | Augmented lags: | 1 |

| | Statistic | p-value |
|---|---|---|
| **Modified Phillips-Perron t** | 5.4321 | 0.0000 |
| **Phillips-Perron t** | -3.8336 | 0.0001 |
| **Augmented Dickey-Fuller t** | -2.9028 | 0.0018 |

**Table F.** Regression results of recycling rate (with clustered standard errors)

| | (1)<br>Recycling rate |
|---|---|
| Pol (Yes) | 3.793** |
| | (2.91) |
| lngdp | 22.71 |
| | (1.43) |
| urbd | 11.73 |
| | (1.22) |
| gerd | -0.000118 |
| | (-2.05) |
| gov_right2 | 0.0613 |
| | (2.07) |
| gov_cent2 | 0.0584** |
| | (3.92) |
| gov_left2 | 0.0340** |
| | (3.37) |
| _cons | -225.0 |
| | (-1.31) |
| *N* | 213 |

Statistics in parentheses ($^{*}$ $p < 0.05$, $^{**}$ $p < 0.01$, $^{***}$ $p < 0.001$)

**Table G.** Fisher-type augmented Dickey-Fuller unit root test

| | | recycling rate | | policy | | GDP | | urb | | GERD | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Statistic* | *p_val* | *Statistic* | *p_val* | *Statistic* | *p_val* | *Statistic* | *p_val* | *Statistic* | *p_val* |
| Inversechi-squared (22) | P | 64.7694 | 0.0023 | 4.3652 | 1.0000 | 25.7299 | 0.8977 | 425.149 | 0.0000 | 0.5803 | 1.0000 |
| Inverse normal | Z | -0.7466 | 0.2276 | 5.1104 | 1.0000 | 1.7684 | 0.9615 | -11.8257 | 0.0000 | 8.7037 | 1.0000 |
| Inverse logit t (59) | L* | -1.7425 | 0.0423 | 4.8178 | 1.0000 | 1.8163 | 0.9637 | -31.4232 | 0.0000 | 9.7601 | 1.0000 |
| Modified inv. chi-squared | Pm | 3.3905 | 0.0003 | -3.7282 | 0.9999 | -1.2103 | 0.8869 | 45.8616 | 0.0000 | -4.1743 | 1.0000 |

| | | gov_right2 | | gov_cent2 | | gov_left2 | | masculinity | | individualism | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Statistic* | *p_val* | *Statistic* | *p_val* | *Statistic* | *p_val* | *Statistic* | *p_val* | *Statistic* | *p_val* |
| Inversechi-squared (22) | P | 84.9822 | 0.0000 | 31.2196 | 0.6953 | 18.446 | 0.9933 | 0.0000 | 1.0000 | 0.0000 | 1.0000 |
| Inverse normal | Z | -2.4527 | 0.0071 | 0.1005 | 0.5400 | 1.3204 | 0.9067 | | | | |
| Inverse logit t (59) | L* | -3.9355 | 0.0001 | 0.229 | 0.5903 | 1.1904 | 0.8815 | | | | |
| Modified inv. chi-squared | Pm | 5.7726 | 0.0000 | -0.5634 | 0.7134 | -2.0688 | 0.9807 | -4.2426 | 1.0000 | -4.2426 | 1.0000 |