

Disparities in the EU-27 Regarding Pollution and Generated Waste

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Abstract. *The paper explores the transition to a circular economy within the European Union, focusing on maintaining the value of products and resources in the economic cycle and reducing waste production (pollution and generated waste). EU environmental policy emphasizes ecologically sound waste management and responsible use of secondary materials, forming the basis for a circular economy. While viewing waste as future resources remains challenging, the concept of "waste management, prevention, and utilization" is the cornerstone of this approach, requiring significant investments in innovation, research, and economic development. The article underscores the impact of pollution as a barrier to socio-economic development and highlights the importance of efficient waste management for environmental protection. The economic analysis, based on simple linear regression, reveals disparities among EU member states regarding pollution levels and waste generation. The increasing quantities and diverse nature of waste generated in the EU pose growing challenges. Municipal waste, representing a substantial proportion, exhibits significant variations in management practices among member states. To achieve sustainability, an integrated approach within the EU is essential, requiring substantial efforts from member states to accelerate the transition to a circular economy. The conclusions highlight the importance of efficient waste management and the need for concrete measures to reduce pollution and promote a sustainable economy.*

Keywords: pollution, waste, environment, regression, disparities

Introduction

The attention devoted to the transition towards a circular economy, aimed at preserving the value of products, materials, and resources in the economic cycle for as long as possible, while minimizing waste production, has significantly increased (Blomsma & Tennant, 2020; Mazur-Wierzbicka, 2021). This concern is evident in the agendas of public authorities, the business environment, research institutions, and non-governmental organizations (Alexandrescu et al, 2019).

During the European Council meeting in Paris in 1972, the foundations of the European Union's environmental policy were established. This pivotal moment followed the first United Nations conference on environmental issues in June 1972, where heads of state or government recognized the need for a common environmental policy to accompany economic policies. They also called for the development of an action plan (Stockholm Declaration and Action Plan for the Human Environment, 1972). The Single European Act of 1987 introduced a new title,

DOI: 10.2478/picbe-2024-0127

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"Environment," providing the first legal framework for a common environmental policy. This aimed at conserving environmental quality, protecting human health, and ensuring the rational use of natural resources.

Subsequent treaty revisions reinforced the EU's commitment to environmental protection, emphasizing the role of the European Parliament in its development. Through the Maastricht Treaty in 1993, the environment officially became a policy area of the EU, introducing the co-decision procedure and making qualified majority voting in the Council a general rule. The Amsterdam Treaty in 1999 imposed the obligation to integrate environmental protection into all sectoral policies of the EU, with the goal of promoting sustainable development. Ten years later, in the Lisbon Treaty of 2009, "combating climate change" was recognized as a distinct objective, along with sustainable development in relations with third countries. This treaty granted legal personality to the EU, allowing it to conclude international agreements. These developments strengthened the EU's role as a key player in global environmental matters, facilitating significant initiatives such as the European Green Deal and the European Climate Law (European Parliament, 2023).

In the context of climate change, population growth, and the adoption of resource-intensive lifestyles, analyzing the correlation between the amount of waste generated and environmental pollution can provide informative insights into the current situation in the European Union. This knowledge can serve as a foundation for enhancing future efforts toward positive changes.

Within the EU's environmental policy, ecologically sound waste management and the responsible use of secondary materials they contain are crucial aspects (Chirescu, 2022). It is challenging to consider waste as potential future resources to be reintegrated into the production system, rather than viewing them as mere "waste" to be eliminated. However, the concept of "waste management, prevention, and utilization" forms the foundation of a circular economy. Nevertheless, its implementation requires significant investments in innovation, research, and economic development (Fatimah et al., 2020; Popa, 2021).

Literature review

Environmental care gained momentum in the 20th century, following the economic boom after World War II, with a more intense focus emerging after the Stockholm Conference on the Urban Environment when the international community began addressing global environmental issues.

Specialized literature abounds with works discussing environmental concerns. "Le Grand Larousse" in 1972 characterized the natural environment as the "totality of natural and artificial factors influencing human existence." As ecological problems grew and intensified, particularly in the latter half of the last century, a holistic perspective on the environment as a subject of interest and public action emerged. This perspective significantly manifested in the terms of regulatory acts adopted in some countries in the late 1960s (such as the United States Environmental Policy Act adopted in 1969) and the documents of the first United Nations Conference on the Environment held in Stockholm in June 1972 (M. Duțu, 2014).

The right to a healthy environment can be interpreted at both individual and collective levels. Regarding the individual dimension, it pertains to each person's right to prevent pollution, halt activities generating harmful pollution, restore the affected environment, and seek compensation for pollution-induced damages. Concerning the collective dimension, this right implies the responsibility of states to ensure its exercise and cooperate in preventing pollution and protecting the natural environment at both national and international levels (A. Diaconescu, 2017; Baste & Watson, 2022).

Lupan (1996) viewed environmental protection as conscious, scientifically grounded human action directed toward a well-defined goal: preventing pollution and maintaining or improving living conditions on Earth. This definition focuses on the tripartite organization of environmental protection activities, indicating three distinct elements: environmental protection, conservation, and the development or improvement of its conditions.

The word "pollution" has Latin roots coming from "polluero-ere" which means to dirty, defile, or profane, according to the dictionary. Pollution can result from both natural phenomena and human activity and it is a consequence of the existence and activities of any living being that generates waste, hindering or even making life impossible in that environment. In short, pollution represents the action of intoxication caused by pollutants, becoming more severe as the difference between the pollutant concentration in the environment and the tolerance limit increases.

Whether considered a natural or artificial phenomenon, pollution acts as a barrier to socio-economic development and serves as a warning, drawing attention to the fact that natural riches cannot be exploited in the long term in a ruthless and irrational manner. Material and energy natural resources are not infinite and must be used rationally and efficiently for the benefit of humans, avoiding waste and planning judiciously (Rațiu, 2008).

Dumitraș (2008) divides the sources of pollution into: natural and human, from agricultural, livestock, and forestry activities, radioactive and noise pollution. This study will focus on anthropogenic sources of pollution generated by waste per capita.

The pollution impact generated by waste affects both the quality of the environment and the health of the population (Siddiqua et al., 2022; Panaite, 2023). Along pollution, waste management is another major challenges facing the European Union in its efforts to protect the environment. Currently, the issue of waste is becoming more acute due to the growth in both quantity and diversity, alongside their increasingly evident negative impact on the environment. Urban and industrial development in communities, as well as the overall increase in the standard of living, generate increasingly larger quantities of waste within the European Union (Rios & Picazo-Tadeo; Iordachi et al, 2022).

According to the European Parliament in 2023, member states of the European Union generate 2.2 billion tons of waste annually. More than a quarter of this (27%) consists of municipal waste, i.e., waste collected and treated daily by municipalities, predominantly originating from households. The data highlight significant variations among EU member states regarding the quantity and waste management practices, but there is a general trend towards increasing recycling activities and reducing the use of landfills (D'Adamo et al., 2020; Martí & Puertas Medina, 2021).

The European Union aims to encourage waste prevention and product reuse to the greatest extent possible. In cases where these options are not feasible, recycling (including composting) takes priority, followed by using waste for energy production. Simple disposal of waste, such as in landfills, is considered the most harmful option for the environment and human health, even if it represents a less costly solution. While the per capita waste generation has increased, waste management has improved, with a notable rise in recycling and composting activities, while landfill use has decreased (European Parliament, 2023). The focus of the issue needs to be redirected from an integrative approach to agricultural trade policies and sustainable development, thereby forming a strategic plan for promoting a framework regulation aimed at consolidating the transition towards more sustainable consumption and production (Deaconu et al, 2023).

In February 2021, the European Parliament adopted a resolution on the new Circular Economy Action Plan. This imposes additional requirements to achieve a carbon-neutral, sustainable, non-toxic, and fully circular economy by 2050. Among these requirements are stricter

recycling standards and mandatory targets for the use and consumption of materials by 2030. One year later, the same institution endorsed a revision of rules concerning Persistent Organic Pollutants (POPs) to reduce the presence of hazardous chemicals in waste and production processes. The new regulations will establish stricter limits, ban certain chemicals, and exclude polluting materials from recycling processes. Moreover, the Commission proposed new regulations at the European Union level regarding packaging. These include proposals to improve packaging design, such as clear labeling to promote reuse and recycling. Additionally, a transition to biologically sourced, biodegradable, and compostable plastics is proposed.

Environmental pollution resulting from the level of waste generated by human activity is a global issue. Predominant waste treatment and disposal systems involve landfilling and incineration. In this context, this article analyzes differences in pollution levels within the EU-27, with a focus on their environmental impact.

Methodology

The present research employs a simple linear regression model with cross-sectional data, utilizing the least squares method. Key motivations for adopting this research approach include two main ideas: (a) facilitating the determination of the variance degree of the selected exogenous variable (specific to waste generation activity) that explains the variance of the endogenous variable (pollution); (b) simplifying the focus on each observation individually, for each of the 27 EU member states, highlighting their deviations from the linear model and thus revealing disparities in pollution levels. This econometric analysis method is commonly encountered in specialized literature (Baltagi, 2021) and well-grounded, with numerous cross-sectional studies addressing pollution from various perspectives such as economic growth (Ordas et al, 2011), income inequality (Michieka et al, 2022), sustainable development, innovation, and research (Constantin et al., 2021), among others.

Continuing with the cross-sectional regression methodology, this quantitative investigation addresses the issue of pollution from the perspective of disparities within the EU-27, focusing on the waste generation factor per capita.

To develop the econometric model, two distinct sets of data were extracted from the same source namely the Eurostat platform (2020). To determine the pollution level it was used the dataset named "Pollution, grime, or other environmental problems" (indicator code: ilc_mddw02) and for determining the quantity of generated waste, it was extracted the dataset named "Waste generation per capita" (indicator code: cei_pc034).

Results and discussions

To conduct a comparative analysis of disparities in sustainable development within the European Union with its 27 member states, we first examined the descriptive statistics of pollution and waste. This information is presented in Table 1.

Both series exhibit similar distributions regarding the Skewness indicator, showing a positive skewness for both values, with the pollution-related value being more pronounced at 0.84 and the waste generation-related value at 0.46. Regarding the Kurtosis indicator, there is a slight leptokurtic distribution for pollution (4.3) and a platykurtic distribution for the indicator reflecting waste generation per capita (1.68).

Table 1. Descriptive statistics of the analyzed indicators

	Pollution, grime or other environmental problems	Waste generation per capita
Mean	12,3	7.306
Median	11,8	5694
Maximum	27	16847
Minimum	5,5	1483
Standard Deviation	4,91	5,09
Skewness	0,84	0,46
Kurtosis	4,3	1,68
Jarque-Bera	5,12	2,91

Source: Authors' own research.

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According to Eurostat, in 2017, approximately 14% of the European Union (EU) population reported being exposed to pollution, dirt, and other environmental issues in their local area. The proportion has remained close to 14% since 2012.

The EU figure conceals significant variations among different member states. In 2017, Malta recorded by far the highest proportion of its population (26.5%) reporting exposure to pollution, dirt, or other environmental issues, while the next highest proportions were observed in Germany (24.5%) and Greece (20.3%). Exposure rates to pollution, dirt, or other environmental issues were also above the EU average in Luxembourg, Latvia, Slovenia, Lithuania, Bulgaria, and Romania.

Croatia recorded the lowest rate at 5.5%, having undertaken numerous legislative measures for environmental protection over time. The Environmental Protection Act (EPA) was enacted in 1994 and amended in 1999. However, in 2007, the Croatian Parliament adopted a new version of the EPA, which included obligations to improve air quality, implement environmental impact assessments (EIA), introduce strategic environmental assessments (SEA), enhance public participation in environmental matters, ensure access to environmental information, and strengthen the prevention and control of integrated industrial pollution (IPPC). The act also introduced the decentralization of administrative responsibilities for environmental protection. To date, the EPA is complemented by 17 implementing regulations, one decision, and 25 ordinances (United Nations, 2014).

Regarding the waste generation index per capita, Finland ranks first with a value of 16,847, followed by Sweden and Luxembourg. At the other end of the spectrum, Croatia has the lowest value at 1,484 kg/capita, followed by Lithuania (1,501 kg/capita) and Portugal (1,612 kg/capita).

Table 2. Results of the Cross-Sectional Linear Regression Model

Method Formula				
$\text{LS WASTE_GENERATION_PER_CAPITA} \\ \text{POLLUTION_GRIME_OR_OTHER_ENVIRONMENTAL_PROBLEMS} = C$				
The Formula of the Model Equation				
$\text{WASTE_GENERATION_PER_CAPITA} = \\ C(1)*\text{POLLUTION_GRIME_OR_OTHER_ENVIRONMENTAL_PROBLEMS} + C(2)$				
The Model Equation and the Obtained Coefficients				
$\text{WASTE_GENERATION_PER_CAPITA} = \\ 429.147862894*\text{POLLUTION_GRIME_OR_OTHER_ENVIRONMENTAL_PROBLEMS} + 2028.37017529$				
Variable	Coefficient	Standard Error	t-Statistic	Prob.*
C	2028,37	2492,003	0,813952	0,4234
Pollution, grime or other environmental problems	429,1479	188,6124	2,27529	0,0317
R2	0,571553	Mean dependent var		7306,889
Ajusted R	0,538415	S.D. Dependent Var.		5093,851
S.E. of regression	4728,194	Akaike info criterion		19,83166
Sum squared resid	5,59	Schwarz Criterion		19,92765
Log likelihood	-265,7274	Hannan-Quinn criter.		19,8602
F-Statistic	5,176943	Durbin-Watson stat		1,908079
Prob(F-statistic)	0,031723			

Note: All variable coefficients have an associated probability below the threshold of 0.05, validating the results

Source: Authors' own research.

Regression model based on cross-sectional least squares method was developed considering pollution as the endogenous variable, while waste generation per capita was considered the exogenous variable. The econometric results obtained from the quantitative analysis in the statistical software Eviews 12 are presented in Table 2. The coefficient of determination shows that 57.15% of the endogenous variable is influenced by the exogenous variable. The adjusted R validates the model, as there is only a difference of 3.31%. As calculated in the t-Statistic column in Table 2, the Student-t parameter values validate the econometric model, given that the Prob values are close to zero (0.03). These should be minimized, allowing significant variability of variable parameters from zero, as observed in the econometric model developed in this study. The model confirms that if EU-27 member countries were to implement policies discouraging waste generation, encouraging reuse, and applying circular economy practices, all these would be reflected in the level of pollution, dirt, or other environmental issues. Validating the econometric model presented in this paper is an important step; therefore, the White test of residual homoscedasticity was conducted, and the results are presented in Table 3.

Table 3. The White test for homoscedasticity of the residuals

F-statistic	0,058	Prob.F(2,24)	0,9437
Obs*R-squared	0,1299	Prob. Chi-Square(2)	0,9371
Scaled explained SS	0,0672	Prob. Chi-Square(2)	0,9669

Source: Authors' own research.

Based on the White test, the null hypothesis was rejected, confirming the homoscedasticity of residuals, as the p-value exceeds the threshold of 0.05. Given this result, the analysis of residual variance was continued by graphically representing them according to Table 3. Additionally, the proportion of residuals in absolute value from the total was calculated, and this result was included in Table 4 to highlight the most significant disparities identified regarding pollution among the EU-27 member states.

Table 4. The residual plot

obs	Actual	Fitted	Residual	Residual Plot
Belgium	11	12.5770...	-1.5770...	
Bulgaria	11.6	14.9755...	-3.3755...	
Czechia	3.8	10.7773...	-6.9773...	
Denmark	9.4	10.7593...	-1.3593...	
Germany	13.5	11.3074...	2.19254...	
Estonia	8.1	14.2412...	-6.1412...	
Ireland	8.2	10.6774...	-2.4774...	
Greece	20	14.4363...	5.56367...	
Spain	11.8	10.2705...	1.52949...	
France	18.6	15.2126...	3.38735...	
Croatia	5.5	9.97188...	-4.4718...	
Italy	15.4	14.5526...	0.84735...	
Cyprus	8.9	10.3748...	-1.4748...	
Latvia	15.7	9.97908...	5.72091...	
Lithuania	17	10.3368...	6.66314...	
Luxembourg	14.6	15.2226...	-0.6226...	
Hungary	11.7	14.0797...	-2.3797...	
Malta	27	16.1136...	10.8863...	
Netherlands	14	12.2472...	1.75272...	
Austria	7.9	12.4683...	-4.5683...	
Poland	13	11.1747...	1.82525...	
Portugal	13.2	10.0234...	3.17654...	
Romania	12.3	12.3124...	-0.0124...	
Slovenia	15	11.6552...	3.34475...	
Slovakia	9.8	10.5755...	-0.7755...	
Finland	9.2	10.5355...	-1.3355...	
Sweden	5.9	15.2410...	-9.3410...	

Source: Authors' own research.

As observed in both Table 4 and Figure 1, the most significant disparities in terms of pollution based on waste generation were noted in the following countries: Czech Republic, Estonia, Lithuania, Luxembourg, Netherlands, and Sweden. The Czech Republic ranked the lowest in the pollution, dirt, or other environmental problems ranking, with a score of 3.8%, compared to the EU

average of 12.3%. However, concerning the kilograms of waste generated, the Czech Republic ranked 10th among the 27 countries in the European Union. The residuals of the econometric model for each analyzed country are visually represented in column 5 of Table 4, according to the weights of residuals in absolute value from the total (EU27). If the sign in column 5 is oriented to the left, the deviation is below average, and if the sign is oriented to the right of the graph, the residual deviation is above the EU-27 residual average.

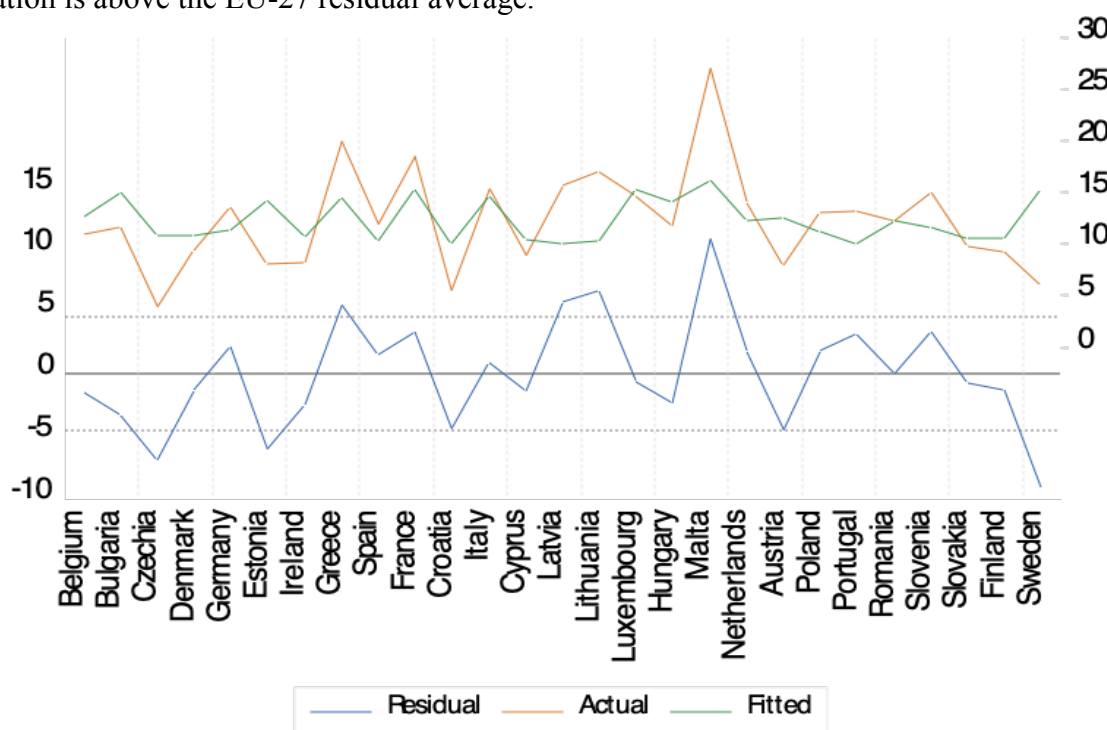


Figure 1. The residuals

Source: Authors' own research.

According to Figure 1, anything beyond the dashed line represents errors. For the model to be valid, residuals must be homoscedastic, nonlinear, and normally distributed.

Conclusion

To reduce pollution levels in the European Union, various measures are necessary, and each individual can contribute to these efforts. In addition to the significant impact that pollution, dirt, and other environmental issues have on both the economic and social sectors, effective waste generation practices can contribute to environmental protection. For the entire European Union to achieve full sustainability, each member state needs to exert significant efforts to accelerate the transition toward an equitable society that understands and pro-motes a circular economy.

This paper contributes to the scientific literature by examining the disparities in the EU-27 through the lens of two analyzed variables: (a) the level of pollution, dirt, and other environmental issues and (b) waste generation per capita. Moreover, this research is bringing new insights through the econometric analysis of disparities in pollution, the chosen variables, and the selected research method, which is a quantitative linear cross-sectional analysis. From a managerial perspective, the findings provide insights for decision-makers regarding the negative implications of pollution based on waste generation. Therefore, the study's results can assist decision-makers in finding

measures to promote responsible consumption, generating fewer wastes based on the identified disparities within the EU-27 through econometric means.

The results of the simple linear regression model based on the waste generation factor highlight that on the one hand, the most significant disparities were observed in countries such as Denmark, Spain, Italy, Luxembourg, Romania, and Slovakia (EU-27 member states with a good balance in waste generation and pollution) and on the other hand, Malta, Sweden, Czech Republic, Lithuania create a group of countries that will need to recover gaps in the future.

This study presents some limitations. The chosen methodology, the developed econometric model proves useful for identifying EU-27 member states that are most sensitive to pollution generated by waste. However, the model does not provide a detailed explanation of how pollution disparities occur in the EU-27. This gap represents a subject of interest for future investigations. To enhance the current results and further refine the econometric model, it is essential to test and incorporate a greater number of variables. This iterative process is crucial for robust analysis. Supporting the integration of the circular economy, based on sustainable development principles, represents one of these factors that can facilitate a successful transition to a prosperous economy. By continually refining our models and considering a broader range of variables, we contribute to a more comprehensive understanding of the dynamics involved in promoting economic prosperity through sustainable practices.

Acknowledgments

This research was conducted as a result of Simona Roxana Pătărlăgeanu's Erasmus+ mobility at the Department of Economics, Business and Marketing within the Catholic University of Valencia. The mobility took place between 03 March 2024 –10 March 2024.

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