RESOURCE PRODUCTIVITY. COMPARATIVE ANALYSIS ROMANIA-EU

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Abstract
This paper presents a comparative analysis of the evolution of resource productivity in the EU27 and Romania based on EUROSTAT statistical data. The period covered was 2000-2023. The results of the analysis revealed an upward trend in the EU27 average of resource productivity representing a decoupling between economic growth and resource consumption. This was not the case for Romania, which experienced a fluctuating evolution without a clear upward trend. There is a gap between Romania and the EU27. At the same time, the simple panel regression analysis at EU level showed a moderately strong and positive link between the rate of circular material use and resource productivity. In the case of Romania, however, the correlation was strongly positive even though circular material use rates were much lower than the EU average. This difference between the EU and Romania can be explained by structural variations between Member States (level of economic development, economic structure, environmental policies, technological level, etc.), which may weaken the strength of the relationship observed at the aggregate (EU) level. Such differences may attenuate the consistency of the relationship at the EU level.

Key words: *resource productivity, regression analysis, domestic material consumption, gap, circular material utilization rate.*

JEL Classification: O13, Q01, Q53

I. INTRODUCTION

According to the Global Material Resources Outlook to 2060: Economic Drivers and Environmental (OECD, 2019), global material consumption tripled between 1970-2017 to 89 billion tons, with a possible doubling by 2060.

Overall, resource consumption depends on two, diametrically opposed, categories of drivers. On the one hand, we are talking about those factors that increase consumption and, on the other, those that reduce it.

The first category includes population growth, rising living standards and economic expansion (NAS, NAE & IM, 1993; Stundziene, 2016; UNEP, 2024). With continued growth in population and living standards on a global scale, there is an intensification of aggregate demand, and thus an increased use of material resources (Bringezu, 2011). At the same time, any economic development requires more and more investment in infrastructure and construction, thus further amplifying the pressure on resources (OECD, 2019).

The second category of factors is made up of technological progress, rising household incomes and the restructuring of economies. Thus, the increase in household income leads to a shift in consumption preferences towards goods produced by less resource-intensive sectors - services and recreation (Jänicke et al., 1993). At the same time, technological progress plays an important role in reducing the material intensity of production processes, thereby reducing the amount of resources needed to produce goods and improving resource productivity (Hollen et al., 2013). In the same direction of reducing material intensity, the reconfiguration of the economic structure in favour of less resource-intensive economic sectors also contributes to this reduction in material intensity. Moreover, technological advances and structural transformations of an economy contribute significantly to countering the growth in demand for resources by ensuring that their use is decoupled from the rate of economic growth (OECD, 2019). Technological progress, income levels and economic structure can all contribute to resource productivity growth (Ghan et al., 2013).

The volume of material resources extracted globally has also increased significantly. Thus, according to the report The Circularity Gap (2023), the increase was from 28.6 billion tons (Gt) in 1972 to 101.4 Gt in 2021. The same report shows that maintaining a linear economic model could increase global extraction of material resources to 170-184 billion tons (Gt) by 2050, increasing pressure on natural resources and the capacity of ecosystems to regenerate.

It is not only the volume of materials extracted that puts pressure on natural resources, but also the way they are used within national economies. In this respect, domestic material consumption (DMC), which measures the total quantity of materials used in production and consumption, should be taken into account. In Romania, according to INS statistical data, between 1994 and 2022 the domestic consumption of materials has experienced

an oscillating evolution, reflecting major economic transitions. The post-communist economic restructuring in the 1990s led to a significant decrease in DMC and then, after 2000, economic development and intense investment led to a steady increase in consumption.

Analyzing the domestic consumption of materials is particularly important when assessing the sustainability of an economic system as it provides valuable information on the pressure on the environment and the efficiency of the use of available resources. However, a sustainable economic model is not only based on monitoring this consumption, but also on increasing its productivity. The latter reflects an economy's ability to achieve economic value (GDP) with as few material resources as possible. In other words, resource productivity is about achieving greater and greater economic output with less and less material consumption. Reducing environmental impact, maintaining economic competitiveness and achieving sustainable development goals can only be achieved through resource efficiency. Resource productivity is the sustainable development indicator for policy assessment (https://ec.europa.eu/). It covers economic and environmental aspects at the same time (Lee et al., 2014), and is an indicator that reflects the economic efficiency and maturity of an economy from a sustainable development perspective. As such, economic growth and environmental protection are possible under conditions of higher resource productivity determined by a limited amount of resources. Moreover, increasing resource productivity is the way to resolve the contradiction between the future development of economies and the resource problem (Ghan et al., 2013).

In the current context of increasing efforts by countries to move away from the linear to the circular economy model, it can be said that DMC and resource productivity are essential tools for assessing sustainability and for formulating policies focused on more efficient use of resources. High resource productivity reflects resource efficient and also sustainable economies (Steinberg & Krausmann, 2011).

This paper focuses on the comparative analysis of resource productivity at the Romanian and EU level capturing the differences that exist in this respect. Given that one of the influencing factors of domestic resource consumption is the circular material utilization rate, we used simple panel regression analysis to establish the nature and intensity of the relationship between the two variables. The period analyzed was 2010-2023 and the statistical data used were downloaded from the EUROSTAT website.

II. COMPARATIVE ANALYSIS OF RESOURCE PRODUCTIVITY IN ROMANIA AND THE EU

Resource productivity is the ratio of GDP to domestic material consumption. This consumption is the total volume of materials used directly in the national economy and is calculated as the difference between direct material inputs (domestic extraction used and imports) and exports. The domestic extraction used is the solid, liquid and gaseous materials (excluding water and air, but including water contained in materials) extracted from the domestic environment and used in production and consumption.

The assessment of Romania's material resource use has to be carried out through a comparative approach with the EU27 average. The results show a positive development at EU27 level in contrast to the trend in Romania (see Figure 1). Thus, at EU27 level, there has been a continuous increase in average resource productivity, from 1.5 euro/kg CVL in 2000 to almost 2.4 euro/kg CVL in 2023. Such a development highlights a number of extremely important aspects. Thus, we can point to the fact that at EU27 level there has been a decoupling between economic growth and material consumption. At the same time, we can talk about efficiency gains in industries, logistics, recycling, innovation and services, as well as much better results in implementing the European Green Deal and the circular economy model that aims to slow resource depletion (https://www.europarl.europa.eu/topics/ro/).

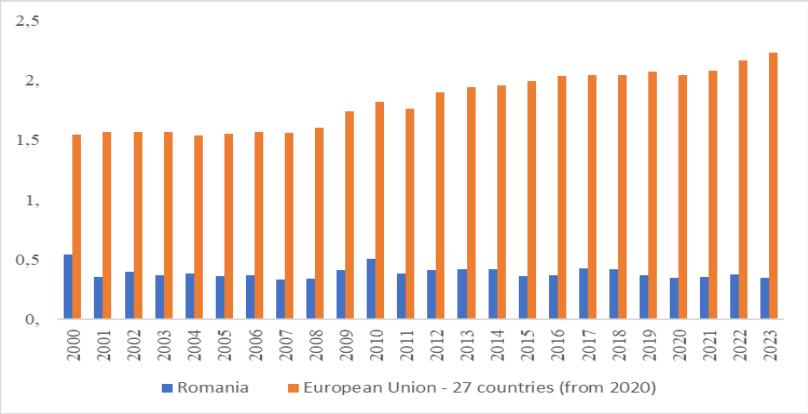
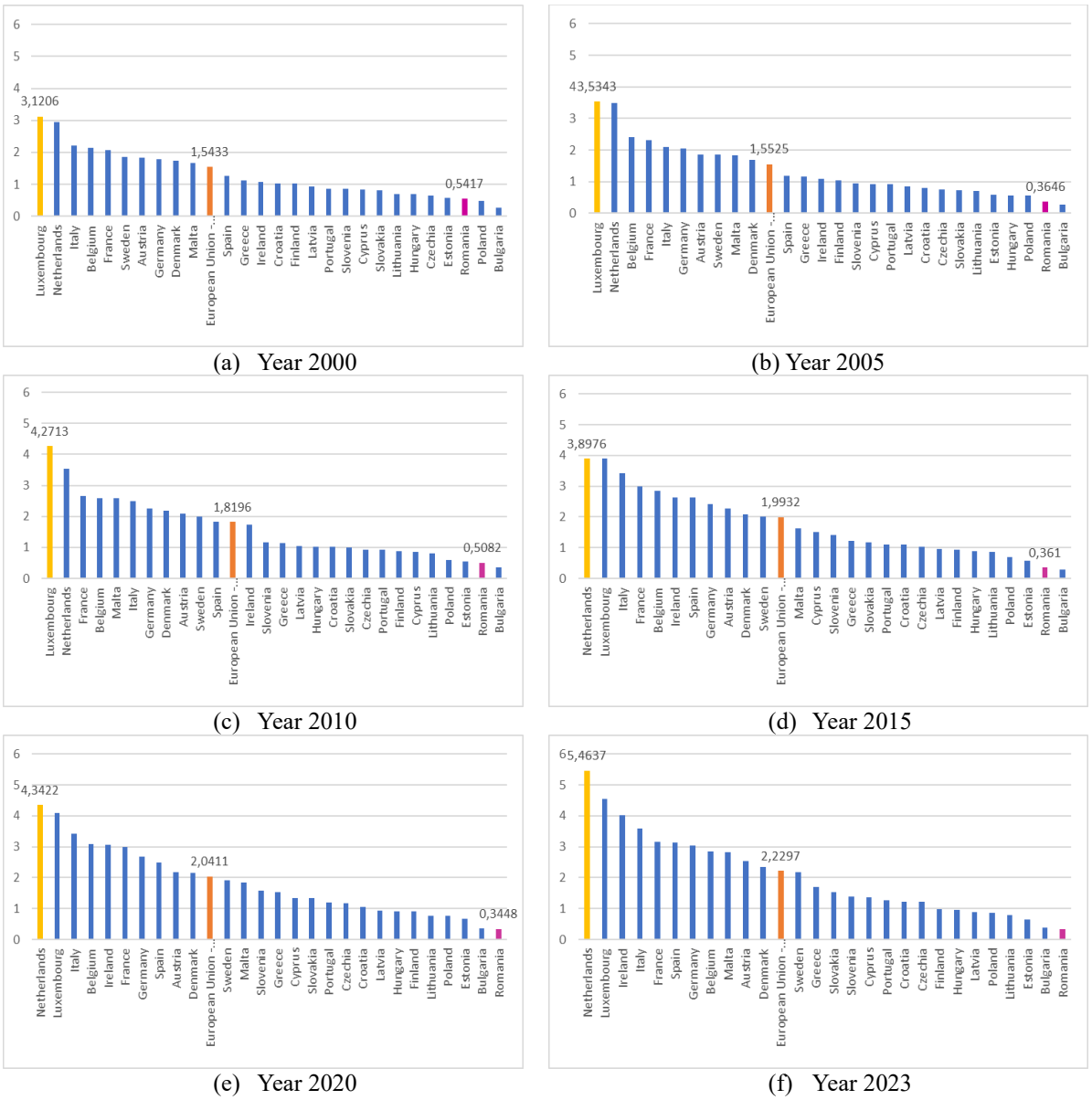


Figure 1. Evolution of resource productivity - EU27, Romania (2000-2023) - euro/kg, chain linked volumes (CVL) 2015

Source: compiled by author based on EUROSTAT data

On the contrary, Romania has not managed to follow an upward trend nor to decouple like many other EU Member States. The evolution of resource productivity has been oscillating throughout the period, between 0.3-0.5 euro/kg CVL, without a clear upward trend. This indicates a decrease in resource use efficiency. The explanations for this are: the development of economic activities in material-intensive sectors (construction, extensive agriculture, heavy industry); the technological gap with the EU due to low technological innovation capacity and thus the use of medium and low/low-tech/non-efficient technologies that imply higher resource consumption (Craiut et al, 2022; McKinsey & Company, 2022); the extremely low level of recycling and reuse of waste (see also Figure 3b); the weak development of high value-added services as a result of the low level of R&D spending, below 0.5% of GDP in 2021 according to Romania's Industrial Strategy 2024-2030.

If we consider all EU Member States, the year-by-year evolution of resource productivity is shown in Figure 2 (a-f). According to this figure, in the first years analyzed (2000, 2005 and 2010), Luxembourg ranked first in the ranking of Member States, but in 2015, 2020 and 2023 it is overtaken by the Netherlands. Romania has remained consistently at the bottom of the ranking, ranking higher than Bulgaria in 2010 and 2015, but in 2020 and 2023 it will be the lowest of all EU Member States.



(a) Year 2000 (b) Year 2005

(c) Year 2010 (d) Year 2015

(e) Year 2020 (f) Year 2023

Figure 2. EU resource productivity - euro/kg, chain linked volumes 2015

Source: compiled by author based on EUROSTAT data

The data in Table 1 complete the picture of the low level of resource productivity in Romania. It highlights the gap expressed as a ratio, both with respect to the EU27 average and to the best performing country. Thus, compared to the EU leader, the gap has increased from 5.76 times in 2000 to 15.79 times in 2023 (Romania being approx. 16 times less resource-efficient than the Netherlands in 2023). This is also explained by

the fact that the leading countries (Luxembourg and the Netherlands) are post-industrial economies, focused on services, technology and the circular economy. They therefore consume fewer resources and produce much higher GDP.

The gap with the EU27 average has also increased steadily from 2.85 times in 2000 to 6.44 times in 2023, showing that Romania is not only not catching up, but is losing ground compared to the European average. The widening gap indicates, in fact, the relative worsening of Romania's position in the EU27 in terms of resource productivity.

Table 1. Gap between best performing country, EU average and Romania

Years	Gap between first place in EU27 and Romania (no. of times)		Gap between EU27 average and Romania (no. times)
	Number of times	Country	
2000	5.76	Luxemburg	2.85
2005	9.69	Luxemburg	4.26
2010	8.40	Luxemburg	3.58
2015	10.80	Olanda	5.52
2020	12.59	Olanda	5.92
2023	15.79	Olanda	6.44

Source: compiled by author based on EUROSTAT data

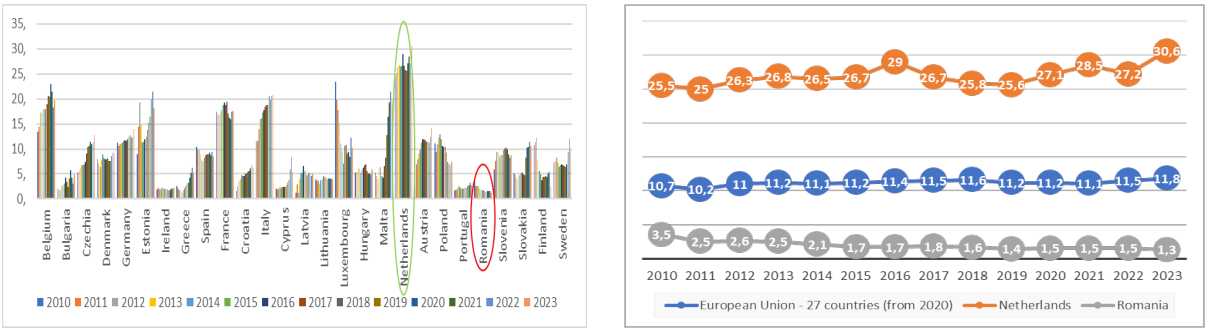
As mentioned above, one of the reasons for the inefficient use of materials in relation to GDP is also related to the economic structure. In the Romanian economy, resource-intensive sectors (extractive industry, agriculture and construction) have a low level of value added. They generate a modest value added in relation to the amount of material resources used (around 40% in 2023). In order to support these ideas, we have summarized in Table 2 the contribution of the four sectors (agriculture, industry, construction and services) to GDP creation.

Table 2. Contribution of sectors to GDP contribution- Romania (2008-2021)

Years	Agriculture, forestry and fishing	Industry	Construction	Services
2012	4.7%	25.0%	7.5%	50.5%
2013	5.4%	25.2%	7.0%	50.4%
2014	4.7%	25.3%	6.2%	52.3%
2015	4.2%	24.1%	5.9%	53.7%
2016	4.1%	24.1%	6.1%	55.4%
2017	4.4%	24.2%	5.9%	56.1%
2018	4.3%	22.7%	5.5%	57.9%
2019	4.1%	21.1%	5.9%	59.3%
2020	4.0%	20.3%	6.6%	59.8%
2021	4.3%	21.2%	6.6%	58.2%
2022	4.5%	22.5%	6.3%	57.7%
2023	3.9%*	19.6%*	8.0%*	59.8%*

Note: * - provisional dates
Source: NSI, Romania in figures (2015-2024)

Also, another determinant of resource productivity in Romania is the relatively low level of technological endowment of industry (Niță, 2012) which contributes to high material intensity. The outdated logistical and industrial infrastructure, together with the limited implementation of circular economy principles, accentuates this inefficiency. Low waste recycling rates further contribute to Romania's unfavorable position in European resource productivity rankings. To understand this situation even better, it suffices to look at Figure 3(a & b).



(a) UE27 (%) **(b) UE27, Romania, Netherlands (%)**

Figure 3. Circular material use rate

Source: compiled by author based on EUROSTAT data

According to Figure 3(a & b), while in many EU Member States the rate of circular use of materials has generally been on an upward trend, this has not been the case in Romania. Romania started in 2010 with a circularity rate of 3.5%, which is quite low anyway, and reached an even lower rate of 1.3% in 2023. On the other hand, the Netherlands has maintained its leading position with values generally above 25%, reaching more than 30% in 2023 (which is about 30 times higher than Romania).

Unlike Romania, the Member States with the highest levels of resource productivity (the Netherlands, Luxembourg, Belgium or France) have economies with a different structure, dominated by services, high value-added industries and technological sectors (OECD, 2025; Kolodziejczak, 2025). These countries have a relatively low consumption of material resources per unit of GDP generated, due to high levels of innovation, digitalization and operational efficiency. Sustainability-oriented public policies, mainstreaming of the circular economy and investments in the green transition have also contributed to enhancing the material efficiency of these countries.

III. CORRELATION BETWEEN CIRCULAR MATERIAL UTILIZATION RATE AND RESOURCE PRODUCTIVITY

Recycling waste contributes to reducing resource consumption (Abbott et al, 2011; Velis & Bruner, 2013; Qiang et al., 2024; NIH; WasteTrade) while conserving natural resources and protecting the environment (Chertow, 2009; Wang, 2025; NASEM, 2025).

A positive relationship exists between the rate of circular material use and resource productivity, meaning that an increase in the rate of circular material use leads to an increase in resource productivity (Velis & Bruner, 2013, Pineiro-Villaverde & García-Álvarez, 2020).

l) *at the EU level*

In order to verify the existence of a link between the rate of circular material use (the independent variable) and resource productivity (the dependent variable), we conducted a simple regression analysis on a panel dataset covering the 27 EU member countries over the period 2010-2023. The regression analysis was also performed at the Romanian level, over the same period. The statistical data used were taken from the EUROSTAT website. The analysis was performed in Microsoft Excel without using a specific econometric model for panel data. Therefore, the results obtained express an average relationship, at aggregate level, between the variables analyzed.

The regression analysis tested two statistical hypotheses, formulated for a significance level $\alpha = 0.05$:

- Null hypothesis (H_0): the coefficient of the independent variable is equal to zero, which implies that there is no significant relationship between the variables.
- Alternative hypothesis (H_1): the coefficient of the independent variable is non-zero, which implies that there is a statistically significant relationship between the variables.

The distribution of observation points and the regression equation for EU27 are shown in Figure 4

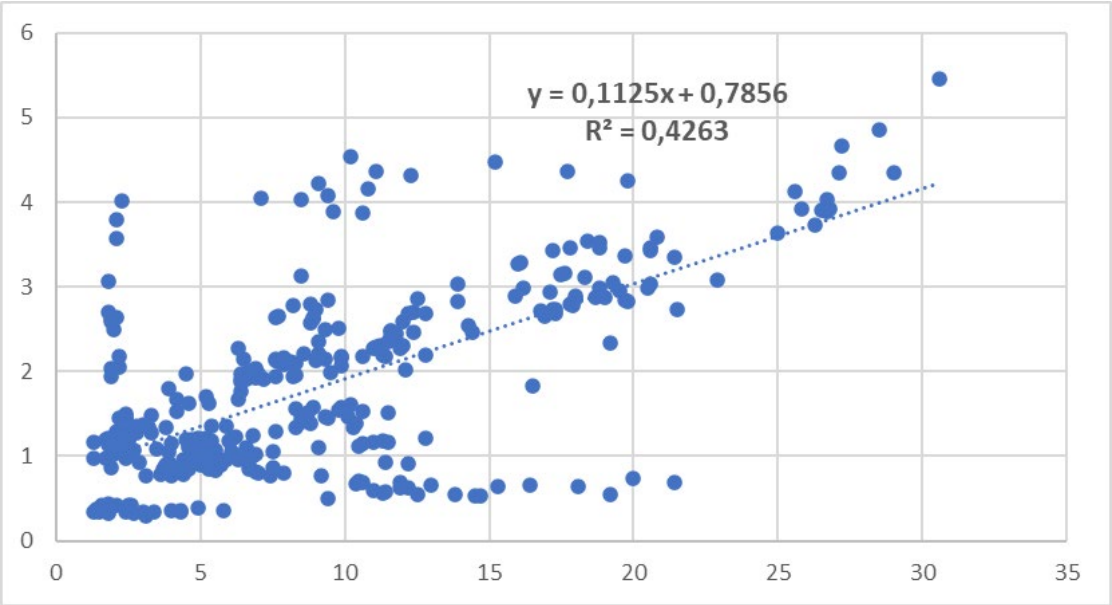


Figure 4. Point cloud and linear regression function - EU27

Source: compiled by author based on EUROSTAT data

The results of the regression analysis performed in Excel are presented below:

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0,65294015
R Square	0,42633084
Adjusted R Square	0,42468709
Standard Error	0,83158894
Observations	351

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	179,3610255	179,361	259,3646	5,01333E-44
Residual	349	241,3475177	0,69154		
Total	350	420,7085433			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95,0%*
Intercept	0,78564107	0,076755225	10,23567	1,12E-21	0,634680078	0,93660206	0,634680078
Circular material use rate	0,11247947	0,00698422	16,1048	5,01E-44	0,098743011	0,12621592	0,098743011

According to these results, there is a positive and significant relationship between circular material utilization rate and resource productivity.

The correlation coefficient is 0.65 which signifies a moderately strong and positive correlation. According to the coefficient of determination, 42.6% of the variation in resource productivity is explained by the circular material utilization rate. The P-value is below the significance threshold of 0.05, which indicates that the relationship between the two variables is statistically significant. Therefore, the null hypothesis that there is no relationship between the variables is rejected.

The coefficient of the independent variable (circular material utilization rate) shows that for a 1% increase in the circular material utilization rate, resource productivity increases by 0.112 euro/kg.

2) at Romanian level

The distribution of observation points and the linear regression function are displayed in Figure 5.

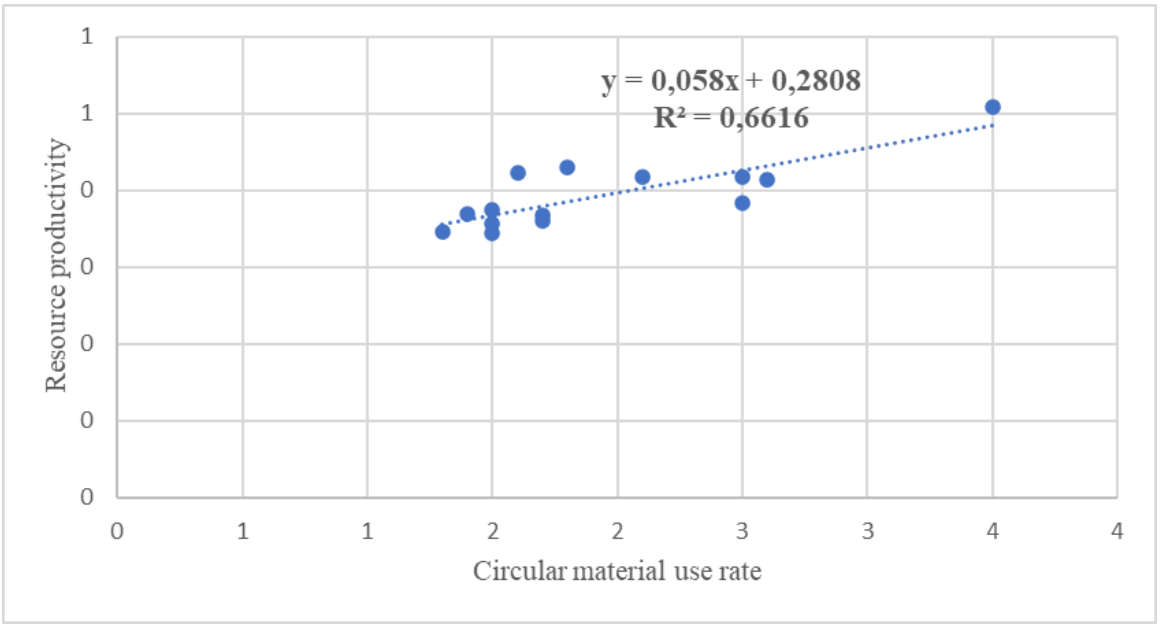


Figure 5. The point cloud and the linear regression function - Romania
Source: compiled by author based on EUROSTAT data

The results of the regression analysis are below:

Regression Statistics	
Multiple R	0,81339619
R Square	0,66161336
Adjusted R Square	0,63341447
Standard Error	0,02693737
Observations	14

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0,01702483	0,017025	23,46239	0,00040245
Residual	12	0,008707465	0,000726		
Total	13	0,025732295			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0,2807907	0,024366919	11,52344	7,59E-08	0,227699746	0,33388166
Circular material rate use	0,05803787	0,011981891	4,843799	0,000402	0,031931578	0,08414417

The correlation coefficient is 0.81 which signifies a strong and positive correlation. 66.16% of the variation in resource productivity is explained by the circular material utilization rate. The P-value is less than 0.05 which means that the relationship between the two variables is statistically significant.

The coefficient of the circular material utilization rate shows that for a 1% increase in the circular material utilization rate, resource productivity increases by 0.058 €/kg. Compared to the EU27 situation, the value is significantly lower.

III. CONCLUSION

The analysis highlights gaps in resource productivity between Romania and the EU. While the European average for this indicator has been on an upward trend, Romania has failed to follow such a path. The gap between Romania and the EU in general, and between Romania and the best-performing European countries in particular, reflects both economic and technological structural differences and the level of maturity of national policies in the field of sustainable development. Closing this gap means accelerating the transition to a sustainable economy based on innovation, material efficiency and decoupling economic growth from the consumption of physical resources.

This requires: more investment in green technologies and industrial efficiency; changing the economic model based on intensive material consumption; integrating more actively into European circular economy and digitalization policies. The lack of major reforms and investments in clean technologies, recycling and reuse, in the modernization of production chains, in the development of high value-added services, makes Romania remain stuck in an inefficient economic model and vulnerable to future environmental policies and carbon costs.

Although the circular material utilization rate in Romania has been relatively low (ranging between 1.3-3.5%) compared to the EU average (ranging between 10.2%-11.8%), the correlation with resource productivity has remained positive and strong. This suggests that, despite the low values, the two variables have evolved in a consistent manner over time.

In contrast, the results of the regression analysis at the EU level revealed a moderately strong and positive relationship between the rate of circular material use and resource productivity. The slightly weaker strength of this relationship compared to Romania is explained by structural variations between Member States (level of economic development, structure of industry, environmental policies or degree of public involvement, etc.). In other words, the more homogeneous characteristics within the Romanian economy made the same relationship clearer and stronger.

IV. REFERENCES

1. Abbott, A, Nandeibam, S & O'Shea, L. (2011), *Explaining the variation in household recycling rates across the UK*, Ecological Economics, vol. 70, no. 11, pp. 2214-2223. https://doi.org/10.1016/j.ecolecon.2011.06.028

2. Bringezu, S. (2011) *Key elements of economy-wide sustainable resource management*. Annales de Mines, Serie Responsabilite & Environnement, 61, pp. 78–87
3. Chertow, M. (2009, August 1), *The Ecology of Recycling,* disponibil online: https://www.un.org/en/chronicle/article/ecology-recycling/?utm_source=chatgpt.com, accessed July 4, 2025
4. Circle Economy & Deloitte (2023) *Circularity Gap*, https://www.circularity-gap.world/2023. accessed June 18, 2025
5. Craiut, L., Bungau, C., Bungau, T., Grava, C., Otrisal, P. și Radu, A.-F. (2022). Transfer de tehnologie, sustenabilitate și dezvoltare, la nivel mondial și în România. *Sustenabilitate* , *14* (23), 15728. https://doi.org/10.3390/su142315728
6. Ghan, Y., Zhang, T., Linag, S., Zhao, Z., Li, N. (2013) *How to Deal with Resource Productivity Relationships Between Socioeconomic Factors and Resource Productivity*, Journal of Industrial Ecology, vol. 1793), pp. 440-451, DOI: 10.1111/j.1530-9290.2012.00547.x
7. Hollen, R.M.A., Van Den Bosch, F.A.J., Volberda, H.W. (2013) *The Role of Management Innovation in Enabling Technological Process Innovation: An Inter-Organizational Perspective*, European Management Review, vol. 10, pp. 35–50, DOI: 10.1111/emre.12003
8. Jänicke, M., Mönch, H., Binde, M. (1993) *Ecological Aspects of Structural Change*, Intereconomics: Review of European Economic Policy, vol. 28(4), pp. 159-169
9. Kołodziejczak, M. (2025). Analiză comparativă a servitizării în țările Uniunii Europene utilizând măsura sintetică a dezvoltării a lui Hellwig. *Sustainability* , *17* (4), 1683, https://doi.org/10.3390/su17041683k
10. Lee, I.S., Kang, H.I., Kim, K.H., Kwak, I.H., Park, K.H., Jo, H.J., An, S. (2014) *A suggestion for Korean resource productivity management policy with calculating and analyzing its national resource productivity*, Resources, Conservation and Recycling, vol. 91, pp. 40-51, https://doi.org/10.1016/j.resconrec.2014.07.012
11. McKinsey & Company (2022), *Bridging the gap: Transversal technologies to boost Romania's resilience*, disponibil online https://www.mckinsey.com/featured-insights/europe/bridging-the-gap-transversal-technologies-to-boost-romanias-resilience, accessed June 26, 2025
12. Ministerul Economiei, Antreprenorialului și Turismului (f.a.), *Strategia industrială a României 2024-2030*, disponibil online: https://sgg.gov.ro/1/wp-content/uploads/2024/11/ANEXA-22.pdf, accessed June 26, 2025
13. NAS, NAE & IM (1993) *Population Summit of the World's Scientific Academies*. Washington, DC: The National Academies Press, https://doi.org/10.17226/9148
14. National Academies of Science, Engineering, and Medicine (NASEM), (2025), *Municipal Solid Waste Recycling in United States: Analysis of Current and Alternative Approaches*, Washington DC: National Academies Press, https://doi.org/10.17226/27978
15. National Institute of Health (NIH), (f.a.), *Benefits of Recycling*, https://nems.nih.gov/environmental-programs/pages/benefits-of-recycling.aspx?utm_source=chatgpt.com, accessed July 4, 2025
16. Niță, V. (2012), *A Threefold Assessment of the Romanian Economy's Eco-efficiency*, Romanian Journal Of European Affairs, vol. 12(4), pp. 59-77
17. OECD (2019) *Global Material Resources Outlook to 2060: Economic Drivers and Environmental Consequences*, OECD Publishing, Paris, https://dx.doi.org/10.1787/9789264307452-en. accessed June 18, 2025
18. OECD (2025), *OECD Economic Surveys: Luxembourg 2025*, OECD Publishing, Paris, https://doi.org/10.1787/803b3ea1-en.
19. Pineiro-Villaverde, G. & García-Álvarez, M.T. (2020). *Sustainable Consumption and Production: Exploring the Links with Resources Productivity in the EU-28*. Sustainability, *12* (21), 8760. https://doi.org/10.3390/su12218760
20. Qiang, Z., Nan, Q., Chi, W., Qin, W., Yang, S., Zhu, W., Wu, W., (2024), *Recycling packaging waste from residual waste reduces greenhouse gas emissions, J. of Environmental management, vol. 371, 1230128,* https://doi.org/10.1016/j.jenvman.2024.123028
21. Steinberg, J.K., Krausmann, F. (2011) *Material and Energy Productivity*, Environmental Science & Technology, vol 45(4), pp. 1169-1176, https://doi.org/10.1021/es1028537
22. Stundziene, A. (2016) *Key Indicators for Improving the Resource Productivity in the Baltic States*, BE-CI 2016: 3RD International Conference On Business And Economics, vol.17, pp.339-354, http://dx.doi.org/10.15405/epsbs.2016.11.02.31
23. UNEP (2024) *Global Resources Outlook 2024 Summary for Policymakers: Bend the Trend – Pathways to a liveable planet as resource use spikes*. International Resource Panel. Nairobi. https://wedocs.unep.org/20.500.11822/44902
24. Velis C.A., Brunner, P,H. (2013), *Recycling and resource efficiency: it is time for a change from quantity to quality,* Waste Management & Research, 31(6), pp.539-540, https://doi.org/10.1177/0734242X13489782
25. Wang, Z. (2025), *Resource Recycling and Eco-Efficiency Improvement from the Perspective of a Sustainable Economy*, SHS Web Conf. 213, International Conference on Management, Economic and Sustainable Social Development, 01014, https://doi.org/10.1051/shsconf/202521301014
26. WasteTrade, (f.a.), *How Recycling Conserves Natural Resources,* https://www.wastetrade.com/ro/resources/environmental/how-recycling-conserves-natural-resources/?utm_source=chatgpt.com, accessed July 4, 2025
27. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Resource_productivity
28. https://www.europarl.europa.eu/topics/ro/article/20151201STO05603/economia-circulara-definitie-importanta-si-beneficii, accessed June 19, 2025