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Circular economy indicators – multiple linear regression

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Abstract. *The aim of this work is to compare EU countries in their efforts to implement the circular economy model and to indicate the EU's strategic objectives in this area, by analyzing circular economy indicators within the member states. To achieve this, a qualitative and quantitative analysis of the following indicators in THE EUROSTAT database has been carried out: total waste recycling rate, recycling rate of construction and demolition waste, recycling rate of electronic waste, and contribution of recyclable materials to the demand for raw materials in 2019 within the EU. A linear multiple regression was achieved through the SRSS program, which showed that the dependent variable of gross domestic product (GDP) is explained by 69%, and 68% respectively of the recycling rate of construction waste and the recycling rate of electronic waste. The analysis has shown significant correlation between the recycling rate of construction waste and the recycling rate of electronic waste.*

Keywords: circular economy, circularity indicators, gross domestic product, waste recycling rate, recyclable materials

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Introduction
According to UN projections, if current consumption trends continue to increase, the population would need the resources of two Earths by 2030, and three by 2050 to operate under optimum conditions. (Lakatos et al, 2017, 193)

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Overall material consumption is expected to double over the next forty years, while the amount of waste generated each year is expected to increase by 70% by 2050. (European Parliament, 2021)

The trend towards a global population growth, the intensification of urbanization, the increase in quality of life, the development of information technology and the reduction in product life cycles contribute to the diversification of waste streams and to increasing the volume of waste streams. The population has been estimated to grow to 9 billion in 2050; against this background, global demand for resources should triple, which requires a much greater use of natural resources, including materials, water, energy and fertile land. In this context, the concept of a circular economy has emerged, which is based on the principles of sustainable development, with the aim of extending the useful life of products, components and materials in circulation, without loss of value and, as much as possible, without disposal of waste. (MACHADO&Merioka, 2021)

Given that the natural environment is a vital factor of production, but at the same time, its resources are limited being evident in areas such as: resource exploitation, the economic added value of a unit of resource consumed, as well as the labor market, it is necessary implementation of the circular economy model, which offers feasible solutions for all these areas.

The circular economy has become a strategic objective within the EU both in the context of environmental restrictions, and because of its economic potential. Some EU countries have previously recognized the need and benefits of developing their own national circular economy strategies. As a result, circularity indicators show great diversity in the implementation of the circular economy model among EU member states. The pioneers in the process of economic transformation are represented by countries such as Belgium, Germany, France, Italy, the Netherlands, Austria, Sweden, Denmark and Finland. (Baran, 2019, 31-51)

The European Commission's report on environmental policy points to increasing rates of resource re-use across the Community. However, the level of implementation of the circular economy model requires significant investment in environmental infrastructure in order for the countries of the European Union to evolve and meet the environmental objectives set by the European Union in the new policies and strategies for implementing the circular economy model. (Busu, 2019, 159)

The European Commission has adopted an ambitious circular economy package, which includes revised legislative proposals on waste to stimulate the transition of european countries to a circular economy that will boost global competitiveness and sustainable economic growth and create new jobs. Within Europe, there is a broad legislative framework dedicated to the circular economy developed through a number of steps, including: The Circular economy Package, the European Green Pact and the Circular economy Action Plan. (Barandika El Al, 2017, 8236-8241)

Literature review

The literature contains many definitions of the concept of the circular economy, which are grouped around key concepts such as sustainable development, the systemic approach (micro, meso, macro), the 4R framework (Reduce, Reuse, Recycle, Recover) and the waste hierarchy. (Kirchherr et al., 2017, 211-232; Târgu et al, 2019, 22).

One of the most well-known definitions argues that the circular economy is a restorationand a regeneration system through design. It is based on three basic principles: Preserving and improving natural capital, optimizing resource yields and promoting system efficiency (Baran, 2019, 31-51)

The European Commission states that „In a circular economy, the value of products and materials is maintained as long as possible; Waste and resource use are minimized and when a product reaches the end of its life, it is used again to create additional value; this can bring major economic benefits contributing to innovation, growth and job creation.” (Târt et al., 2019, 22)

Florin Bonciu, (2021) defines the circular economy as a renewable system in which resource inputs, waste, emissions and energy losses are minimized by slowing down, closing and narrowing material and energy circuits. This system is based on the design of durable products, maintenance, repair, reuse, refurbishment, better recycling and recovery. In the context of the creative economy and the knowledge-based society, creativity and innovation can be highly appreciated in any sector of the economy, leading to productivity gains. (Suciu, 2008)

Alonso-Almeida et al (2021, 281) state that the circular economy requires a transformational process of changing from a linear to a circular economic model, where each production phase represents a systematic change at all levels.

From the perspective of Guerva and Deviatkova (2020, 156-169), the concept of the circular economy is a general approach to promoting green growth in the development of countries that can overcome global environmental problems and, as a result, achieve the sustainable state of the planet and save lives on Earth.

In the wider context of sustainable development, circular economy is becoming one of the important parts in the supply of resources to future generations, based on intra-and inter-generational solidarity, with the starting aims of the implementing the 3 R's (re-use, recirculation, recycling) and the extension of product lifecycle. (Aceleanu et al, 2019, 133602-133614)

A circular economy aims to close the flow of materials by means of appropriate technical-productive processes; this issue was addressed more recently when the integration of production and active circular processes were addressed. (Negrei & Istudor, 2018, 508)

Methodology

In order to carry out analyses of the concept of circular economy and how it is understood and applied within the Member States of the European Union, and in particular in Romania, at a macro level, indicators measuring the performance of the circular economy existing in the EUROSTAT database have been analysed.

The research method of choice consisted mainly of quantitative and qualitative analysis of statistical data. The linear multiple regression was achieved through the SPSS software, in which the dependent variable ”Gross domestic product” and two independent variables, ”the recycling rate of construction waste” and ”the recycling rate of electronic waste”. The Backward working method was employed for this analysis.

Results and discussions

Slovenia was at the top of the EU-wide waste recycling rate in 2018, with a rate of 82%, up by around 58% compared to the rate registered in 2010 (52%). The next positions are occupied by Belgium (81%), Lithuania (72%) and Luxembourg (70%). The countries with the highest increase in recycling rates in 2018 (compared to 2010), were Croatia with a 115% increase, followed by Slovenia with 58% and Lithuania with 44% (Table 1).

Table 1. Total waste recycling rate within the EU countries (%)

Country	2010	2012	2014	2016	2018	2018/2010 (%)
Slovenia	52	74	75	80	82	57.69
Belgium	75	80	81	78	81	8.00
Lithuania	50	51	57	68	72	44.00
Luxembourg	87	77	62	64	70	-19.54
Italy	60	64	67	68	67	11.67
Netherlands	71	71	72	72	66	-7.04
Austria	60	65	62	66	63	5.00
Czech Republic	50	58	60	60	61	22.00
Denmark	56	59	60	61	59	5.36
Poland	58	55	60	56	58	0.00
Croatia	26	35	47	52	56	115.38
Portugal	47	49	54	52	54	14.89
Germany	55	54	53	-	53	-3.64
France	50	51	53	54	52	4.00
Latvia	-	-	-	-	50	-
Slovakia	38	40	40	44	50	31.58
Sweden	51	53	51	49	50	-1.96
Hungary	36	35	40	43	49	36.11
Spain	44	46	46	46	47	6.82
Ireland	36	37	45	41	41	13.89
Finland	33	41	41	37	37	12.12
Cyprus	46	34	31	31	32	-30.43
Romania	26	28	27	30	29	11.54
Malta	24	28	27	43	28	16.67
Greece	-	-	-	-	27	-
Bulgaria	27	14	17	27	23	-14.81
Estonia	22	25	19	10	-	-

Source: Eurostat, accessed on 01.02.2022.

Countries showing a decrease in recycling rates are Cyprus (-30,43%), Luxembourg (20%), Bulgaria (-15%), the Netherlands (-7%), Germany (-4%) and Sweden (-2%).

Romania ranks 23rd out of the 27 EU countries with a total waste recycling rate of 29%, followed by countries such as Malta (28%), Greece (27%), and Bulgaria (23%). Romania shows an increase of over 11% in 2018 (29%) compared to the recycling rate registered in 2010 (26%) (Table 1).

Table 2. Recycling rates of construction and demolition waste within the EU countries (%)

Country	2010	2012	2014	2016	2018	2018/2010(%)
Ireland	97	100	100	96	100	3.09
Malta	16	100	100	100	100	525.00
Netherlands	100	100	100	100	100	0.00
Lithuania	73	88	92	97	99	35.62
Hungary	61	75	86	99	99	62.30
Italy	97	97	97	98	98	1.03
Luxembourg	98	99	98	100	98	0.00
Slovenia	94	92	98	98	98	4.26
Belgium	17	18	32	95	97	470.59
Denmark	-	91	92	90	97	-
Greece	0	0	0	88	97	-
Latvia	-	-	92	98	97	-

Country	2010	2012	2014	2016	2018	2018/2010(%)
Estonia	96	96	98	97	95	-1.04
Germany	95	94	-	-	93	-2.11
Portugal	58	84	95	97	93	60.34
Austria	92	92	94	88	90	-2.17
Sweden	78	81	55	61	90	15.38
Poland	93	92	96	91	84	-9.68
Croatia	2	51	69	76	78	3800.00
Spain	65	84	70	79	75	15.38
Romania	47	67	65	85	74	57.45
Finland	5	12	83	87	74	1380.00
France	66	66	71	71	73	10.61
Cyprus	0	60	38	57	64	-
Slovakia	-	-	54	54	51	-
Bulgaria	62	12	96	90	24	-61.29
Czech Republic	91	91	90	92	-	-

Source: Eurostat, accessed on 01.02.2022.

Looking at the recycling rate of construction and demolition waste in the European Union countries, the top places are held by Ireland, Malta and the Netherlands, which have a recycling rate of 100%. It is noted that for Croatia, the recycling rate increased 39 times in 2018 (78%) compared to the rate registered in 2010 (2%). The same increase is seen in Finland, where the recycling rate increased 15,6 times in 2018 (74%) compared to 2010 (5%) (Table 2).

The recycling rate from construction decreased in Bulgaria by more than 61%, alongside Poland (-10%), Austria (-2%) and Estonia (-1%).

In 2018, Romania shows an increase in the recycling rate of construction and demolition waste of more than 57%, due to low amounts generated compared to the recycling capacity, which remained constant (Table 2).

Table 3. Recycling rate of electronic waste within EU countries (%)

Country	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2018/2014 (%)
Croatia	-	-	-	-	-	-	35.7	58.3	89.2	81.3	83.4	133.61
Denmark	-	39	41	50.1	46.5	37.6	42.3	43	41.4	38.5	67.5	59.57
Bulgaria	-		40.8	49.4	62.4	60.2	68.3	96.5	105.2	68.8	66.7	-2.34
Estonia	-	22.4	30.3	36.9	35.9	27.8	35.7	43.8	51.8	50.6	53.7	50.42
Ireland	-		30.9	32.5	36.1	38.6	43.1	46.1	49.5	47.7	53.5	24.13
Hungary	28.3	29.5	26	25.3	30.8	40	47.7	50.7	53.4	51.1	50.5	5.87
Finland	37.9	29.9	28.7	31	32.8	36.3	42.4	43.2	42.1	48.2	49.2	16.04
Austria	46	36.1	35.7	37.1	38.2	37.6	39.1	40.7	41	50.1	46	17.65
Slovakia	31.8	34.2	34.9	39.6	42.6	41.7	44.1	40.3	50.3	46.5	45.8	3.85
Sweden	62.4	52.2	55.3	64.9	62.6	64.9	52.7	51.6	55.4	47	45.4	-13.85
Luxembourg	36.6	38	33	30.6	27.6	29.3	35.4	42.5	45.6	45.5	44.1	24.58
Czechia			22.7	26	27.1	28.5	29.3	37.9	54	53.2	43.6	48.81
Latvia			14.5	19.9	26.5	27.8	26.4	23.1	23.2	40.6	43.3	64.02
Spain		12.6	14.7	16.7	19	26.1	26.2	35.6	37.4	41	43	64.12
Netherlands	22.5	22	27.8	33	33.2	31.3	38.1	39.3	40.4	43.3	41	7.61
Belgium	28.3	30.8	30.4	31.9	32	31.7	29.6	33.8	38.3	36.7	39.3	32.77
Poland		13.9	17.7	23.9	30.4	28.1	27.4	33.1	38.9	36.1	39.1	42.70
Germany		38.1	37.8	34.4	34.8	35.6	36.9	33.9	39	38.7	36.9	0.00
Lithuania	15.2	10.5	16.6	28.2	41.1	43.8	64.6	45.9	38.9	35.1	36.4	-43.65

Country	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2018/2014 (%)
Greece	21.6	29	19.4	19	18.6	22.1	29	32.7	34.2	32.9	35.8	23.45
France		19.2	21.8	22.6	22.6	23.6	26.3	32.2	37.1	36.6	34.2	30.04
Slovenia		17.6	22	26.4	26.9	16.7	27.5	47.7	39.3	32.5	33.6	22.18
Portugal	21.8	24	22.8	30.5	24.9	32.3	38.2	42.7	45.8	43.5	-	-
Italy			27.8	29.8	27.7	26.3	27.3	32.1	-	-	-	-
Cyprus		10.9	11.5	11.5	12.2	12.1	17	27	27.1	50.2	-	-
Romania		17	12	10.3	14.5	21	21.3	22.5	25	-	-	-
Malta		12.1	13.1	9.7	9.9	11	11.5	13.1	15.9	20.8	-	-

Source: Eurostat, accessed on 01.02.2022.

The highest recycling rate for electronic waste in 2018 within the EU is 83,4% in Croatia, up by 133% compared to 2014 (35,7%).

The next places are held by Denmark, with a recycling rate of electrical appliances of 68%, Bulgaria (67%) and Estonia (54%). The highest increases in the recycling rate in 2018, compared to 2014, were recorded by Croatia (133%), Latvia (64%), Spain (64%).

The countries showing a decrease in the recycling rate in 2018 compared to 2014 are Lithuania (-43%), Sweden (-14%), and Bulgaria (-2%).

Romania is among the last countries in terms of the recycling rate of electrical appliances, with are cycling rate of 17% in 2009, reaching a recycling rate of 25% in 2016, rising by 47% (Table 3).

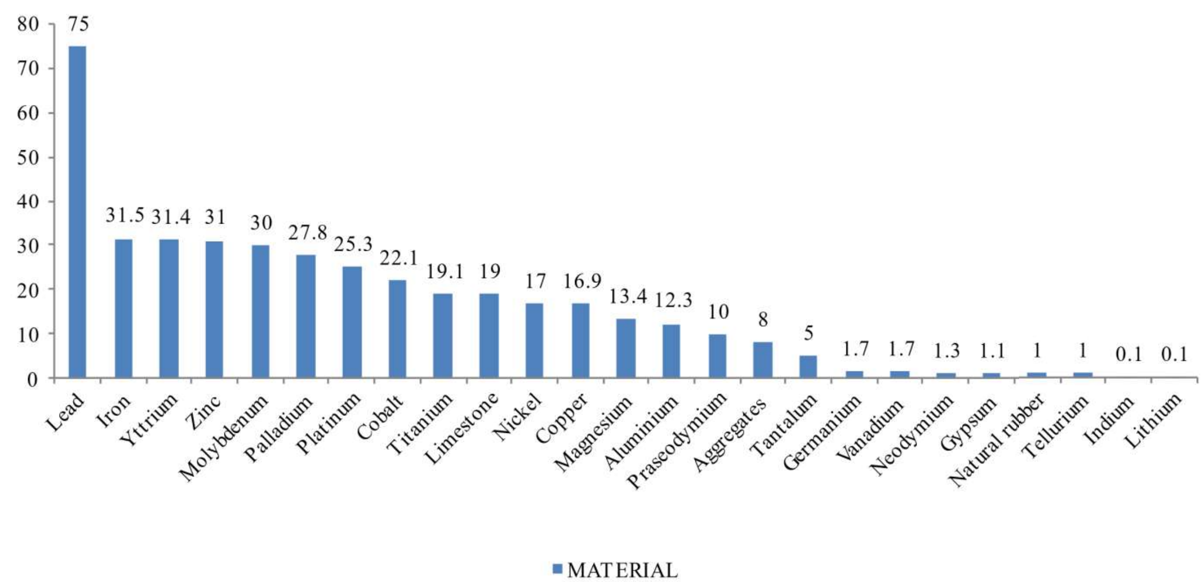

Figure 1. Contribution of recyclable materials to demand for raw materials within the EU in 2019 (%)

Source: Processing based on Eurostat data.

Looking at the contribution of recyclable materials to the demand for raw materials, in 2019, lead is ranked first with a contribution of 75%, followed by iron and yttrium with a contribution of 31,5% and 31,4% respectively. In the last place saretellurium with 1%, indium with 0,1% and lithium with 0,1% (Figure 1).

Through the SPSS application we achieved the linear multiple regression in which we used the dependent variable ”Gross domestic product” and two independent variables ”the recycling rate of construction waste” and “the recycling rate of electronic waste”. We employed the Backward working method, which will provide the correct statistical model, and try out all possible models, including all variables, one by one, from which it will remove the irrelevant variables. The variables that are not relevant are those variables that show multicoliniality, i.e. they are correlated with other variables in the model.

Table 4. Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	,831[a]	,690	,380	24,988	,690	2,228	2	2	,310
2	,827[b]	,685	,579	20,586	-,006	,036	1	2	,867
a. Predictors: (Constant), recycling rate C., recycling rate E.									
b. Predictors: (Constant), recycling rate E.									

Source: SPSS own representation.

Table 4 shows the summary of the model, where we focus on the value of R square. A higher value indicates a statistically better model. In the present case, R square has the value of 0,69 and 0,68, which means that the dependent variable, in this case gross domestic product (GDP), is explained 69% and 68% respectively by the recycling rate of construction waste and the recycling rate of electronic waste.

This table shows information about the regression coefficients. Thus, it can be seen that the two variables are included, the recycling rate of construction waste and the recycling rate of electronic waste, together with the constant (GDP).

Table 5. Regression equation coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95,0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	73,853	65,491		1,128	,377	-207,930	355,636
	rata reciclare E.	5,609	4,921	,971	1,140	,373	-15,566	26,783
	rata reciclare C.	-,369	1,943	-,162	-,190	,867	-8,728	7,990
2	(Constant)	64,828	37,121		1,746	,039	53,309	182,964
	rata reciclare E.	4,780	1,873	,827	2,552	,011	1,181	10,741
a. Dependent Variable: PIB								

Source: SPSS own representation.

It can be seen that the relevant model for the regression equation is the second one, which contains only the electronic waste recycling rate variable, because the value recorded for SGIs is 0,01 below the 5% threshold. The resulting equation is: **Y=c+bX1; Y=64,828+4.78X1**. In addition, the confidence interval is between 1,18 and 10,74, which indicates that the variable is statistically significant (Table 5).

Table 6. Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
2	**Recycling rate C.**	-,162[b]	-,190	,867	-,133	,213
a. Dependent Variable: PIB						
b. Predictors in the Model: (Constant), recycling rate E.						

Source: SPSS own representation.

Table 6 lists the variables excluded from the model. In order to explain why they have been deleted, a correlation analysis between the variables considered as independent (recycling rate of construction waste and recycling rate of electronic waste) needs to be performed. The exclusion of a variable from the regression model means that it is not independent of others and has a strong correlation. This is how a Pearson correlation was made, explained in table 7.

Table 7. Correlations between independent variables

		Recycling rate E.	Recycling rate C.
Recycling rate E.	Pearson Correlation	1	,887*
	Sig. (2-tailed)		,045
	N	5	5
Recycling rate C.	Pearson Correlation	,887*	1
	Sig. (2-tailed)	,045	
	N	5	5
*. Correlation is significant at the 0.05 level (2-tailed).			

Source: SPSS own representation.

According to the correlation table, we see significant correlation between the recycling rate of construction waste and the recycling rate of electronic waste, of which Pearson's coefficient is 0,887. (Table 7)

In conclusion, through this analysis we can claim that the recycling rate of electronic waste is important for economic growth in Romania, as there have been significant values for the examined coefficients.

Conclusion

The research found that the country with the highest rate of waste recycling in the European Union is Slovenia with 82%, followed by Belgium with 81% and Lithuania with 72%. Romania ranks 23rd out of the 27 EU countries with a total waste recycling rate of 29%, showing an increase of over 11% in 2018 (29%), compared to the recycling rate recorded in 2010 (26%).

In terms of the recycling rate of construction and demolition waste, the first places are occupied by Ireland, Malta and the Netherlands with a recycling rate of 100% in 2018. Within the analysed period, Romania showed an increase in the recycling rate of construction and demolition waste by more than 57%, with the highest percentage being reached in 2018(85%), thus placing 21st in the list of European countries.

Analysing the recycling rate of electronic waste, it was noted that Romania was among the last countries, with a rate of 25% in 2016. The highest recycling rate for electronic waste in 2018 in the European Union was recorded in Croatia with 83,4%, followed by Denmark (67,5%), Bulgaria (66,7%) and Estonia (53,7%).

Analysis of the multi-linear regression carried out in the SPSS software showed that the dependent variable, gross domestic product (GDP), is explained in proportion of 69% and 68% respectively by the recycling rate of construction waste and the recycling rate of electronic waste. Analysis of the regression equation coefficients has shown that the relevant model for the regression equation is the one containing only the electronic waste recycling rate variable, since the registered value for SGIs is 0,01 and is below the 5% threshold.. Significant correlations between the recycling rate of construction waste and the recycling rate of electronic waste have been noted at the end of the research, thus concluding that the recycling rate of electronic waste is of particular importance for economic growth in both Romania and EU countries.

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