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QUANTITATIVE APPROACH TO CIRCULAR ECONOMY IN THE OECD COUNTRIES

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Abstract

The circular economy, an evolving concept, is considered a necessary and pragmatic solution for reconciling the link between the growth rate and the pressure on the resources of the environment. Therefore, the purpose of the paper is the quantitative assessment of the circular economy in the OECD countries based on the indicators assembled by the authors. The goal set was achieved through both a theoretical and empirical objective. The theoretical objective is to combine and group indicators referring to the circular economy, as they are present in the literature. The empirical objective is to develop a model of causal analysis with significance for circular economy practice, based on indicators that measure economic growth, research-development, education, recycling. To achieve the empirical objective, cluster analysis, correlation analysis and path analysis were applied. The authors' contribution consists of adapting circular economy indicators to the 5 newly created classes and applying the statistical methods mentioned in the OECD circular economy analysis. The results of empirical research reflect, on the one hand, the classification of countries for a set of indicators of the circular economy and the significant links and dependencies between the indicators analysed on the other.

Keywords: circular economy, OECD countries, indicators, cluster analysis, correlation analysis, path analysis.

JEL Classification: O13, O44, C38, Q53

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Introduction

Economic development and social progress, seen as a permanent desideratum which reflects the evolution of society, have been approached both theoretically and practically in economic literature. The 90s brought new guidelines in terms of objectives and principles of sustainable development; in the past 10 years, the meaning of economic development has been redirected towards the circular economy. This involves reconsidering economic development and social progress in terms of a more practical attention simultaneously directed towards economic growth and environmental factors. Implicitly, an increased attention is directed to the resources needed to ensure the continuity of economic development. To put it briefly, we see circular economy as the linking element between economic growth and the solution to environmental issues. The concept of circular economy is a novel one and topical both in terms of its name and its applicability.

Another important aspect in supporting new forms of the economy, namely circular economy, is that related to waste management. Increasingly larger amounts of waste are the direct consequence of consumption higher than actual needs which also alters the environment as main supply resource. Thus natural waste management is closely and directly correlated to waste management. Moreover, it must be emphasized that the education and the creation of habits in agreement with the requirements to follow these circular processes are a fundamental element that allows the progress from theoretical to practical aspects.

The purpose of circular economy is to ensure the separation of resource use from GDP growth, in parallel with the proofs of limiting the negative impact on the environment.

Rethinking economic growth and development from the point of view of circular economy centres around three areas of interest:

- economic impact (GDP growth, employment rate, investment, etc.);
- environmental impact (use of resources, reduction of harmful emissions, decrease of pollution level);
- social impact (demographic changes, life quality, education, opportunities and/or social inequities, etc.).

Within this context, this paper seeks to highlight the causal relationships and the interdependencies between the directions in economic, social and environmental development. The quantitative analysis enables the developing of a model associated with the concept of the circular economy. For the quantitative evaluation of this type of economy, a number of indicators were considered in order to measure economic development, efficient use of the resources, environment, waste management, and human resources.

Starting from the fact that there is no consensus regarding the indicators of the circular economy, an original element in our research is the reconfiguration of the indicators groups in 5 main reference areas of the circular economy, as well as the adaptation of the indicators to the newly created areas. Another original element is the quantitative analysis of the circular economy performed for OECD countries, based on the following indicators: GDP/capita, R&D expenditures, mean years of education, renewable energy, municipal waste, and recycling rate of the municipal waste.

In order to create a classification of the OECD countries based on the selected indicators, cluster analysis was used. The significant relationships between the indicators of the circular economy considered in the research were identified using correlation analysis. Path analysis was applied in order to describe and identify the effects of a set of variables on a result variable. The statistic analyses were conducted using the SPSS program and the SPSS Amos package (IBM, 2011).

The paper continues with a literature review regarding the circular economy; in this section the authors summarized both theoretical aspects related to the concept, the benefits and indicators of the circular economy, and practical aspects regarding the evaluation of the circular economy. The next section includes the research methodology in which the indicators used in the analysis are presented, along with the research hypotheses and the statistical methods used. In this section the classification of the indicators in 5 areas is presented according to the common field of both circular economy and sustainable development. The results of quantitative analyses and their interpretations can be found in the next section. Finally, the conclusions present a summary of the study, the limitations of the analysis and future research directions.

1. Review of the scientific literature

The end of the 20th century represented the period when the environmental problems reflected in the economic growth and development were recognized. In this period the foundation for the reassessment of natural resources in terms of the risk of their being depleted was laid. Thus, within the framework of the Club of Rome, the Report "Limits of Growth" (Meadows et al., 1972) the foundations of the models of a circular economy were laid and the alarm was raised on how the resources provided by the environment were managed. The circular economy is defined with a view to saving resources – to avoiding their depletion – and waste recycling – to avoiding the inability to manage them (De Perthuis, 2014).

The concept of circular economy appears to have been first used in an economic model by Pearce and Turner (1990), who remark that the traditional or linear economic model lacks the idea of recycling; this absence is prejudicial to the functional relation between environment and economy.

One of the best known definitions is given by the Ellen MacArthur Foundation: "an industrial system that is restorative or regenerative by intention and design" (2013a, p.7). The main focus of the circular economy is the decrease of resources consumption, of pollution and waste at each stage of products life cycle. (Sauvé, S., S. Bernard and P. Sloan, 2016). Other authors have identified opinions that were relevant to waste management, in the approach of the circular economy. Moreover, it is considered that the benefits of recycling cannot be quantified effectively by the traditional *laissez-faire* economy (Åkerman, 2016), and it supports interventions in the productive waste management. According to Tejasri, G. (2015), the concept of *green engineering* associated with the idea of the "second life of waste" is important for actual recycling. Green engineering is design of products and the process that conserve natural resources and decrease the impact on the environment to a minimum.

According to Steffen et al. (2015), the circular economy represents a fundamental alternative to the linear economic model which is implemented in most countries nowadays.

The authors emphasize the fact that the linear model is not sustainable because it is based on the assumption that natural resources are available without any restrictions and they are easy to access. Waste recycling represents one of the main aspects of the circular economy and involves feeding materials back into the economy and avoiding waste being sent to landfill or incinerated. In other words, waste recycling captures the value of the materials for as long as possible and reduces the losses.

The transition of a country from the linear economy to the circular economy involves high restructuring costs, followed by stranded assets, but, it creates benefits in four areas: resource use, environment, economy and society. Regarding the benefits of circular economy on the use of the resources, Nilsson et al. (2007) wrote about the importance of the cleaner production concept which involves two aspects: the fair use of the resources and the replacement of short life span or hazardous resources.

In a study conducted at the level of the United States of America, Esposito, et al. (2015) presents the main benefits the circular economy can bring. One of the benefits would be to have economic growth based on the use of existing materials in the system and on a lower use of natural resources. In order to have economic growth based on the principles of the circular economy, it is necessary to make investments to create and develop new technologies to ensure efficient collection and waste management.

Gallagher, et al. (2017) indicates another benefit of the circular economy: the efficient use of natural resources to create renewable energy. Thus, the authors of the study highlighted the importance of technologies that collect solar energy, water and wind to create electricity at a minimum cost and a very low level of environmental pollution. The main results of the study of Gallagher, et al. have pointed to the fact that the use of renewable energy technologies over a period of 100 years causes significant reductions in greenhouse gas emissions and the amount of depleted natural resources.

According to a report by ThreeC (2016), in order to take full advantage of the benefits of the circular economy as compared to those of the linear economy, education needs to be prioritized. Education can accelerate the transition to a circular economy as it has the role of changing the way of thinking of individuals and, implicitly, of society. Thus, the vision of a future economy where the 7R principles prevail and the efficient use of natural resources can become a reality, given that there will be a change in the way of thinking about the relations between the economy and society on the one hand and the environment, on the other hand.

Asian literature presents empirical concerns about circular economy measurement, case studies, and complex analyses (Geng, et al., 2012; 2013). Given that China's economic miracle was at the expense of its natural capital, the circular economy has been a national policy of sustainable development (Geng, et al., 2012).

The study by Banaité (2016) highlighted the fact that in China, measuring the impact of circular economy implementation is done at micro, meso and macroeconomic level. The author points out that the circular economy has emerged as a solution to the problems faced by the linear economy: production limited by lower access to natural resources, increased levels of pollution and increased energy consumption. At the same time, the application of the 7R principles of the circular economy can underpin sustainable development. The main results of the Banaité study are that most of the indicators used in the assessment of the circular economy aimed at reducing the use of natural resources and at waste recycling. The components of the sustainable development considered were the economic and

environmental ones. The indicators analysed include: the amount of waste resulting from industrial production processes, the degree of pollution from the production activities, the economic benefits of the industrial sector, and GDP/capita.

2. Research methodology

In the specialized literature, there are mainly theoretical concerns about the circular economy and its benefits. Given that it is a relatively new concept, the interest in measuring the circular economy through specific macroeconomic indicators as well as the quantitative analysis of the circular economy is not sufficiently reflected in scientific articles. Therefore, the authors first proposed to develop a systematization of the indicators that can measure the circular economy; they achieved this objective by selecting the indicators to measure the circular economy and reordering and adapting them in 5 classes. In order to select the indicators to use in the model in the present research, we took into account two key issues:

- the indicators that suggest the content of circular economy are the indicators of sustainable development, since both circular economy and sustainable development aim at simultaneously achieving the three categories of objectives: economic, social and environmental, and also focus on resources and waste management;

- the indicators that can characterize the functionality of the circular economy rely on six basic principles that should be known and observed (Circle Economy, 2015a): *the infinite nature of matter and materials cycle, the use of renewable energy, supporting ecosystemic services and natural capital, supporting healthcare and human activity, supporting society and culture, the generation of value - both financial and of other types.*

So far, no set of indicators has been developed to describe the circular economy and to provide very clear information on the functionality of the circular economy model. The lack of indicators that can explicitly characterize the degree of development of circular economy, as well as the subordination of the concepts of circular development to the concepts of sustainable development, made us choose a number of classes of indicators that would allow us to describe the circular economy in OCDE countries. Thus, UN Environment has developed 10 indicators for sustainable development, and UNDP has developed 17 indicators for the same topic; the World Bank has developed over 50 specific environment and sustainable development related indicators; the OECD has developed 25-30 indicators to measure green growth; Eurostat has developed 32 indicators to measure the efficiency of resource use.

Since information in the literature is varied and sometimes contradictory, we have grouped indicators that can be used in the analysis, considering the three directions of development - economic, social and environmental. The processes covered are: collecting municipal waste, recycling, investment in research and development as well as in new technologies, innovation and creativity, education.

Given the very large number indicators in the analysis, the main point of reference in their selection is the identification of the five common areas that identify both the problems in the circular economy, and sustainable development: resource productivity, environment related issues, economic opportunities, social aspects, waste management (Åkerman, 2016; p. 23). In brief, we have developed our own reference system of indicators for the circular economy (Table no. 1).

Table no. 1: Reference indicators for the circular economy

Indicators Classes	Indicator sub-classes	Indicators
Resource efficiency	<i>Energy consumption</i> <i>Consumption of resources</i> <i>Ecological efficiency</i> <i>Ecological footprint</i> <i>Consumption patterns</i> <i>Organic farming</i> <i>Land use</i>	<ul style="list-style-type: none"> - Consumption of natural resources - The consumption of timber - Energy consumption - The use of renewable energy - The proportion of renewable energy by sources - Domestic material consumption, calculated by material types - The rate of the surfaces occupied by organic farms / total area used in agriculture - Energy consumption calculated in terms of type of transportation - Investment in road infrastructure by types - Annual energy consumption / per capita - The rate of energy consumption covered from renewable sources
Environment and components	<i>Climate change</i> <i>Biodiversity</i> <i>Ecosystemic services</i>	<ul style="list-style-type: none"> - Artificial land - Energy consumption - Natural capital - The level of CO₂ emissions - The ratio of forests affected by deforestation - The ratio of total area running the risk of soil erosion
Economic development	<i>Investment</i> <i>Competitiveness</i> <i>Profitability</i> <i>Returns</i> <i>Economic value</i> <i>Market diversity</i>	<ul style="list-style-type: none"> - GDP/capita - The rate of GDP growth - The rate of inflation - Net national income (% of GDP) - Total expenditure on research development (% of GDP) - Public expenditure on education (% of GDP)
Population	<i>Access to the labour market</i> <i>Poverty</i> <i>Consumption behaviour</i> <i>The protection of human health</i> <i>Food safety</i> <i>Society and culture</i> <i>Education</i>	<ul style="list-style-type: none"> - Sanitation services - Indicators referring to human health - The unemployment rate - The poverty rate - healthy life expectancy by gender - Expenditure on healthcare (% of GDP) - The number and size of households - Mean years of schooling
Waste Management	<i>Recycling</i> <i>3R</i> <i>7R</i>	<ul style="list-style-type: none"> - The amount of waste collected/capita - The production of hazardous waste /economic activities - The population connected to the waste water treatment system - Solid waste derived from industrial and household consumption - Radioactive waste management - Waste recycling and reuse

Source: authors' summary and adaptation of sustainable development indicators and proposal of indicators for the circular economy (apud. Akerman, 2016)

Among the indicators grouped in the first part of the paper, 6 indicators were included in 4 of the 5 established classes for the quantitative analysis of the OECD circular economy in 2015. Thus, the economic growth of the OECD countries was quantified by the GDP/capita indicator (US dollars / inhabitant). At the same time, in order to quantify the level of investments for the development of new technologies, we used the research and development expenditure (% of GDP) as indicator. Regarding the use of renewable resources at the level of each country included in the study, we used as an indicator the percentage of renewable energy in each country's primary energy reserve. To measure the amount of waste collected and recycled by each of the OECD countries, we considered the following indicators: municipal waste (kilograms / person), municipal waste recycling rate (% of municipal waste). Finally, as an indicator of the level of education in each of the countries included in the study, we used the average of the school years. Since the environmental and component class factors were not updated, they could not be considered in the analysis.

In the paper, the following notations of the indicators were used: GDP_CAP (GDP/capita), R&D_GDP (R&D expenditures), RENEW_ENERGY (renewable energy), MUNICIPAL_WASTE (municipal waste), RECYCLING_M (municipal waste recycling rate) and SCH_MEAN (average school years). Data sources for these indicators are Eurostat (Eurostat, 2017) and World Bank (World Bank, 2017).

The quantitative analysis of the OECD's circular economy was conducted along two directions. On the one hand, exploratory analysis is found in cluster analysis, where OECD countries have been grouped in homogeneous classes after each of the selected indicators. On the other hand, in order to identify significant links between the indicators considered, correlation analysis and path analysis were applied.

Cluster analysis involves grouping similar cases by organizing them according to one or more indicators. In the paper, the hierarchical classification was used to obtain an optimal number of clusters for each of the indicators used in the analysis. The similarity between countries in the same cluster was measured by the Euclidean distance, and the algorithm used was average linkage between groups as a hierarchical classification technique.

Using correlation analysis, a series of hypotheses on the significant links between the circular economy indicators for OECD countries were tested. These assumptions are:

- There is a significant correlation between economic growth and each of the following indicators: R&D investment, population education, waste quantity and recycling rate
- There is a significant relation between investment in R&D and each of the following indicators: population education, waste quantity, and recycling rate.
- There is a significant relation between the level of population education and each of the following indicators: the amount of waste and the level of recycling.

However, this type of analysis does not provide information on the nature of the correlation between the indicators. The relation can be divided into several types of effects: the direct effect of one variable on the other, the indirect effect of a variable on the other by means of a mediating variable, a common effect (a variable is in a causal relation with several variables simultaneously), a correlated effect (a variable is in a causal relationship with one or more variables simultaneously but is correlated with other variables) and a reciprocal

effect (2 variables cause each other) (Williams, 2015). The path analysis is intended to indicate the type of linkage between two variables both by graphical representation and by estimating path coefficients.

Path analysis was used to estimate the intensity of causal relations between sets of indicators. This analysis implies the existence of a scheme of a relation between the indicators. Thus, based on the literature, a set of hypotheses were formulated on the basis of which a path diagram was developed. Following the conceptualization of the causal structure for the indicators considered in the analysis, the assumptions are: GDP/capita and the average of the school years have a direct effect on the R&D expenditures; there is a direct reciprocal effect between average school years and R&D expenditure; R&D expenditure has an indirect effect on the municipal waste recycling rate, averaged by the average of the school year.

Path analysis is an extended multiple regression based on a system of relationships between variables represented by regression equations of the form:

$$Y = \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_j x_j + e \quad (1)$$

where: β_j represents the path coefficients,

Y is the endogenous variable,

x_j are exogenous variables,

and e represents the influence of the variables that are not included in the model.

The variables used in path analysis are either exogenous (with variance that does not depend on any variable in the model) or endogenous (with the variance determined by other variables in the model). In the model of the present paper, the exogenous variable is GDP/capita, and the endogenous variables are: renewable energy, R&D expenditures, municipal waste, municipal waste recycling rate and average school years.

Through path analysis, the effects between the observed variables in the theoretical model on which the pathway is drawn are specified (Shuemacker, et al., 2016). This analysis contains several types of effects: direct effects, indirect effects and total effects. The direct effect indicates a direct link between the two variables. This type of effect is quantified by path coefficients and can be significant for a certain significance threshold established by the researcher (Alwin & Hauser, 1975). The indirect effect implies the existence of a mediator variable through which the two variables are linked. Thus, a variable has a direct effect on the mediator variable and it has a direct effect on another variable. The total effect refers to the sum of the direct and indirect effects of two variables (Finney, 1972).

3. Results and discussion

Presentation of the analyses results was done in two stages. First, the hierarchical classification of OECD countries is presented according to the indicators considered in the research. Then, the significant linkages and dependencies between the circular economy indicators for the OECD countries are analysed.

3 clusters were obtained by grouping the OECD countries by renewable energy. The countries in cluster 1 create renewable energy in a percentage of up to 25% of their own

stock of primary energy, while countries in cluster 2 produce renewable energy in a percentage between 25% and 46% of their stock of primary energy. Iceland presents an extreme situation in comparison with the rest of the countries; more than 88% of the energy this country produces comes from reserves of primary renewable energy.

Depending on GDP/capita, OECD countries fall into 4 clusters. The first cluster refers to the countries with an average level of GDP/capita of 42.161 \$ and includes countries from Europe, Asia and America. The second cluster is characterized by a low average of GDP/capita (25.878 \$) and includes countries that are characterized by less prosperous economic situation (ex. Greece, Portugal, etc.). The third cluster includes countries with a higher average level of GDP/capita (62.974 \$) and most belong to the North-West area of Europe. The fourth cluster is represented by Luxembourg, whose value of the variable GDP/capita is much higher than its values for the rest of the countries (103.770 \$).

Cluster analysis developed for R&D expenditures as % of GDP shows that OECD countries have grouped in 5 clusters. The first cluster includes countries which invest an average low level of the GDP/capita (1,3%) for R&D. Many of the countries in this cluster are located in Central and South-East. The second cluster includes the countries which, on average, invest the lowest percentage of GDP for R&D: no more than 0.5%. In the third cluster, the average percentage of GDP allocated to investment in R&D is higher than those in countries in clusters 1 and 2 (2,13%). Most countries in cluster 3 are from the West of Europe. Cluster 4 is formed largely of countries in Northern Europe, that allocate a percentage of GDP between 2,5 and 3,5% for R&D. Two countries are included in cluster 5: Korea and Israel. They invest over 4.2% of GDP for R&D.

Grouping the OECD countries according to education revealed that the first cluster includes countries where the mean years of schooling is between 11.9 and 13.4 years. Most countries in cluster 1 are part of Central and Northern Europe and in America. Cluster 2 includes countries with a mean years of schooling between 9.8 and 11,7 years. Most of these countries are located in Western and Southern Europe. The countries that have the lowest mean years of schooling are included in cluster 3. Thus, Turkey, Mexico and Portugal have a mean years of schooling lower than 9 years.

Grouping the countries according to the municipal waste indicator resulted in 4 clusters. The first cluster includes countries that produce, on average, 452 kg per capita of municipal waste, most of which are located in Western and South-Western Europe. Cluster 2 includes countries that produce the lowest amounts of municipal waste per capita (an average of 337 kg per capita). At the other end are countries from clusters 3 and 4 that produce, on average, 595 kg of municipal waste per capita, and 744 kg per capita, respectively. The countries that produce the largest amount of municipal waste are: New Zealand, United States, Switzerland and Denmark.

The cluster analysis shows 3 clusters for the recycling municipal waste. The first cluster comprises the OCDE countries with the highest average rate of municipal waste recycling (49%). The countries in the first cluster are the following: Australia, Slovenia, Germany and Korea. At the opposite end are the statistical units in the cluster 2. They present the lowest average rate of municipal waste recycling: 4.2%. The countries in cluster 2 are: Turkey, Mexico and Slovak Republic. Cluster 3 includes countries with an average rate of municipal waste recycling by 25,25%.

In the second stage of the empirical research, we intended to identify significant causal linkages between the OECD circular economy indicators, by applying correlation analysis and path analysis.

Using the correlation analysis results (Table no. 2), we can identify several significant correlations. Therefore, there is a significant direct relation between GDP/capita and municipal waste for a confidence level of 99 % (Sig < 0,01). At the same time, a significant correlation was identified between GDP/capita and the municipal waste recycling rate. In an economy based on overconsumption, the higher the GDP/capita, a higher consumption results which, in turn, generates a greater amount of waste from consumption. The contribution of the circular economy can regulate this connection, in the sense of supporting the use of waste as a new resource included in the production process. In this case a high level of consumption will no longer represent a threat to resources and the environment.

Table no. 2: The results of correlation analysis

		RENEW_ ENERGY	GDP_ CAP	R&D_ GDP	SCH_ MEAN	MUNICIP_ WASTE	RECYCLI NG_M
RENEW_ ENERGY	Pearson Correlation	1	0,223	-0,006	0,046	0,241	0,031
	Sig		0,197	0,976	0,792	0,163	0,861
GDP_ CAP	Pearson Correlation	0,223	1	0,515	0,583	0,618	0,364
	Sig	0,197		0,002	0,000	0,000	0,032
R&D_ GDP	Pearson Correlation	-0,006	0,515	1	0,524	0,367	0,470
	Sig	0,976	0,002		0,001	0,030	0,004
SCH_ MEAN	Pearson Correlation	0,046	0,583	0,524	1	0,387	0,539
	Sig	0,792	0,000	0,001		0,022	0,001
MUNICIP_ WASTE	Pearson Correlation	0,241	0,618	0,367	0,387	1	0,192
	Sig	0,163	0,000	0,030	0,022		0,269
RECYCLI NG_M	Pearson Correlation	0,031	0,364	0,470	0,539	0,192	1
	Sig	0,861	0,032	0,004	0,001	0,269	

Source: authors' processing

R&D expenditures are significantly correlated to GDP/capita considering a risk of 1% (Sig < 0,01). In terms of joining the circular economy model, the higher the rate of investments in research-development, the more efficient, productive and profitable the adequate management of resources and processing of waste. At the same time, R&D expenditures are in a significant direct correlation with both the municipal waste indicator (Sig < 0,05) and with the municipal waste recycling rate (Sig < 0,01). The first significant direct correlation indicates that an important proportion of the GDP allocated to R&D is a pertinent solution that allows proper use of waste as resources, enables pragmatic consideration of the 7R concept, respectively. Therefore, innovation becomes a priority and produces important socio-economic effects. We believe that a meaningful allocation of the GDP for research and development allows countries to stimulate innovation, access to creative and/or green technology, and an increase in the rate of municipal waste recycling, respectively.

The level of education, measured by the mean years of schooling, is one of the most important indicators in the analysis of circular economy. This has been signalled by the significant direct correlations between both indicators characterizing the economic development (GDP/capita and research and development expenditures, $\text{Sig} < 0.01$) and indicators characterizing the circular economy (recycling municipal waste ($\text{Sig} < 0.05$) and municipal waste ($\text{Sig} < 0.01$)). Since efficient recycling involves the use of advanced technologies, the indicator R&D expenditures (% of GDP) is significant in the connections indicated by the analysis. As a common denominator, the level of education is the indicator of the social aspects group that creates a close and direct connection with the environmental and economic aspects. Thus, the level of education is influenced and supported by GDP/capita, but the relationship proves to be mutual as well. An increased level of education leads to progress in the direction of R&D, a field supported by the GDP allocation rate. An advanced technological level determines the use of modern and efficient municipal waste collection and recycling technologies, but in turn these actions are directly influenced by the level of education.

Furthermore, path analysis was used to investigate the relation between the circular economy indicators of the OECD countries in terms of exogenous and endogenous variables.

The circular economy involves waste management, so we highlight the route and linkages between economic, education and environmental aspects. Thus, considering the model in Figure no. 1, we are considering the transformation of the linear economy into a circular economy.

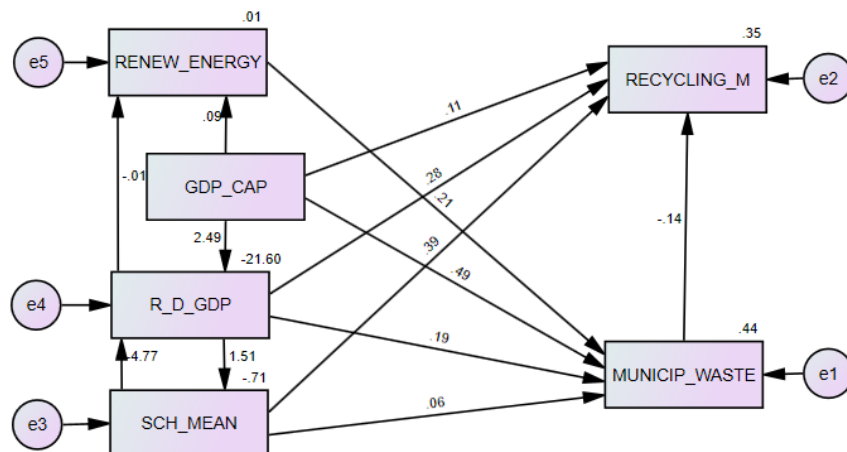


Figure no. 1: Path diagram

On examining the diagram, we can say that mean years of schooling, R&D expenditures, GDP/capita and renewable energy influence both municipal waste and recycling of municipal waste.

Thus, we obtained the estimates for all relationships in the measurement models (the path coefficients using regression analysis). The path coefficients are presented in Table no. 3.

Table no. 3: Standardized path coefficients

Predictor	Predictand	Estimate	Sig
GDP_CAP	R&D_GDP	2,487	0,000
R&D_GDP	RENEW_ENERGY	-,008	0,808
GDP_CAP	RENEW_ENERGY	0,095	0,758
RENEW_ENERGY	MUNICIPAL_WASTE	0,209	0,118
SCH_MEAN	MUNICIPAL_WASTE	0,061	0,444
R&D_GDP	MUNICIPAL_WASTE	0,186	0,282
GDP_CAP	MUNICIPAL_WASTE	0,488	0,018
R&D_GDP	RECYCLING_M	0,281	0,405
SCH_MEAN	RECYCLING_M	0,393	0,048
GDP_CAP	RECYCLING_M	0,115	0,462
MUNICIPAL_WASTE	RECYCLING_M	-0,139	0,368
SCH_MEAN	R&D_GDP	-4,774	0,000
R&D_GDP	SCH_MEAN	1,514	0,000

Source: authors' processing

In Table no. 3, the standardized values of the path coefficients and the probability values associated with the testing of the significance of the model parameters ($H_0: \beta_j = 0$; $H_1: \beta_j \neq 0$) are presented for each regression model. For a probability level of 5%, we have 5 significant coefficients, as follows: investments for R&D and the level of education are in a reciprocal dependency relation, economic growth significantly influences R&D investments and the amount of waste, while the recycling level depends on the population's level of education.

On the base of these estimates, we have the following equations:

$$R\&D_GDP = 2,515 * GDP_CAP - 4,824 * SCH_MEAN \quad (2)$$

$$SCH_MEAN = 1,516 * R\&D_GDP \quad (3)$$

$$MUNICIPAL_WASTE = 0,488 * GDP_CAP \quad (4)$$

$$RECYCLING_M = 0,402 * SCH_MEAN \quad (5)$$

Using path analysis, we can distinguish direct and indirect effects. Direct effects assume the association of one variable with another variable. Indirect effects are the association of one variable with another mediated through other variables in the model. For variables in the above equations, direct and indirect effects were studied. Table no. 4 presents a synthesis of the intensity of the direct and indirect effects between significant variables.

Table no. 4: Direct and Indirect Effect between variables

Type of effect	Predictor	Mediator	Predictand	Path value
Direct	GDP_CAP	-	R&D_GDP	0.000
	GDP_CAP	-	RECYCLING_M	0.462
	GDP_CAP	-	MUNICIPAL_WASTE	0.018
	R&D_GDP	-	SCH_MEAN	0.000
	R&D_GDP	-	RECYCLING_M	0.405
	R&D_GDP	-	MUNICIPAL_WASTE	0.282
	SCH_MEAN	-	R&D_GDP	0.000
	SCH_MEAN	-	RECYCLING_M	0.048
	SCH_MEAN	-	MUNICIPAL_WASTE	0.444
	MUNICIPAL_WASTE	-	RECYCLING_M	0.368

Type of effect	Predictor	Mediator	Predictand	Path value
Indirect	GDP_CAP	R&D_GDP	SCH_MEAN	0.011
	GDP_CAP	R&D_GDP	RECYCLING_M	0.571
	GDP_CAP	R&D_GDP	MUNICIPAL_WASTE	0.229
	GDP_CAP	MUNICIPAL_WASTE	RECYCLING_M	0.571
	R&D_GDP	SCH_MEAN	RECYCLING_M	0.000
	R&D_GDP	MUNICIPAL_WASTE	RECYCLING_M	0.000
	R&D_GDP	SCH_MEAN	MUNICIPAL_WASTE	0.174
	SCH_MEAN	R&D_GDP	RECYCLING_M	0.001

Source: authors' processing

In Table no. 4, it can be seen that, with respect to the direct effects between variables, the relationships with the highest intensity are between GDP/capita and recycling municipal waste (0.462) and between mean years of schooling and municipal waste (0.444). Also, considering the indirect effects of the variables, the most intense linkages are between GDP/capita and recycling municipal waste (0.571) and between R&D expenditures and municipal waste (0.174).

Validation of path analysis results is based on several criteria: *Goodness-of-fit* (GFI), *Adjusted GFI* (AGFI), *Normed fit index* (NFI). The estimated models are statistically significant (GFI = 1,000; AGFI = 0,997; NFI = 0,999).

Conclusions

Considering the challenges of the present, to which the socio-economic world is called to respond, we believe that the issues of economic growth, sustainable development and the circular economy are reduced to two essential elements: resources and life with direct implications on the environment as the main resources generator. Circular economy is the basis for a healthy economic growth. It replaces the concept of „end of life” with that of „restoration”, promotes the use of renewable energy, eliminates the use of toxic chemicals, eliminates waste through superior design of materials, products, systems and business models. Ensuring the credibility and the pragmatism of the circular economy, viewed as a viable alternative to the linear economy and as an applicable facet of sustainable development, is accomplished through various forms of analysis. The basic support of the analysis is represented by groups of specific indicators, databases, information and a methodological framework adequate to the purpose for which the analysis is performed.

The study's purpose is the quantitative analysis of the circular economy of the OECD countries relying on a set of indicators selected from the areas created in the first section of the paper. The research objectives at both theoretical and empirical level were achieved by studying the literature review and by applying statistic methods on the circular economy indicators of the OECD countries, respectively.

The cluster analysis, as a descriptive method, provided information on the classification of OECD countries into groups of homogeneous countries and the characterization of these groups according to each of the 6 indicators considered. This method also allowed countries with extreme values to be identified, such as Luxembourg, which has the highest GDP / capita in 2015, or Korea and Israel, with the highest percentage of GDP invested in research and development. The results of the correlation analysis are complementary to those of the

path analysis as the significant linkages identified in the correlation analysis were deepened by the path analysis.

The correlation analysis indicated significant relationships between the indicators considered in the research. Thus, GDP/capita is significantly correlated with mean years of schooling and waste management. This reveals the fact that GDP/capita is at the basis of an increased level of education. A high level of education contributes to advances in R&D area, which, through modern technologies, ensure the effective municipal waste collection. Another group of significant correlations is that between R&D expenditures, waste management and recycling of municipal waste. Thus, an advanced technological level determines the use of modern technologies in order to ensure an efficient collection and recycling of municipal waste. Therefore, the hypotheses are confirmed.

In order to identify the types of effects that exist within the relationships between the indicators we used the path analysis. The main results of the analysis highlighted that GDP/capita and mean years of schooling have a direct effect on R&D expenditures. At the same time, a mutual effect could be identified between mean years of schooling and R&D expenditures. With respect to the indirect effects, R&D expenditures have an indirect effect on recycling municipal waste, which is mediated by mean years of schooling.

A limitation of the research is represented by the fact that a part of the circular economy indicators were not available, so our data were incomplete. With respect to the indicators, the circular economy is measured by a large number of sustainable development indicators, while there is an insufficient number of specific indicators, at least at a macroeconomic level. Another limitation is the insufficiently clear distinction between sustainable economy and circular economy in the literature review.

Future research directions imply an analysis of the evolution of circular economy indicators and their correlation with sustainable development indicators, as well as the application of other statistical methods to the analysis of these indicators.

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