The transition to circular economy in EU: An analysis of its impact on the economic growth.

by

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Abstract

This research paper's purpose is to elaborate a strategy that studies the sustainability of circular economy model according to environmental factors, and how it affects the European Union's economic growth. In open-end systems, waste is reintegrated to the economic system by implementing reusing and recycling processes which improves the efficiency of using finite resources thanks to a no-waste approach. The main objectives of this paper are the following: first to identify the principal indicators of circular economy that support sustainability; second is to analyze their impact on economic growth of the European union countries; and finally, to verify if the chosen indicators have a significant impact on the economic growth. A multilinear regression model with panel was used on the software Stata 16 according to two methos: fixed effects model to identify the suspected existing dependency between economic growth and the selected indicators and then a second model of Arellano-Bond dynamic panel data was performed to re estimate the data and verify its robustness.

Key words: circular economy; waste management; economic growth; sustainable development; panel data; reuse; raw materials; recycling.

Resumen

El objetivo de este trabajo de investigación es elaborar una estrategia que estudie la sostenibilidad del modelo de economía circular según los factores medioambientales y cómo afecta al crecimiento económico de la Unión Europea. En los sistemas abiertos, los residuos se reintegran al sistema económico mediante la implementación de procesos de reutilización y reciclaje que mejoran la eficiencia del uso de recursos finitos gracias a un enfoque sin residuos. Los principales objetivos de este trabajo son los siguientes: Primero, identificar los principales indicadores de economía circular que apoyan la sostenibilidad; en segundo lugar, analizar su impacto en el crecimiento económico de los países de la unión europea; y finalmente, verificar si los indicadores elegidos tienen un impacto significativo en el crecimiento económico. Se utilizó un modelo de regresión multilineal con datos de panel en el software Stata 16 según dos métodos: modelo de efectos fijos para identificar la supuesta dependencia existente entre el crecimiento económico y los indicadores seleccionados y luego se realizó un segundo modelo dinámico de Arellano-Bond.

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1 Introduction

In the standardized language of the European Commission (EC), “a circular economy is explained as an economy where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimized”.

Walter Stahel, a Swiss architect, was one of the leading promoters of the idea of the circular economy in the early 1980s, he defines the circular economy as follows: “A circular economy would turn goods that are at the end of their service life into resources for others, closing loops in industrial ecosystems and minimizing waste. It would change economic logic because it replaces production with sufficiency: reuse what you can, recycle what cannot be reused, repair what is broken, remanufacture what cannot be repaired”.

As a matter fact, the keen interest that the Scientifics have showed regarding the subject of circular economy has been increasing over the last year, mainly in the fields of economy and management. One can find in many publications of different authors from diverse nationalities the focus and attention given to this topic.

The economic literature of the past decades counts with an important number of econometric and economic studies that quantify the effects of environment management programs and waste on the economic development of nations, with the reference to a general equilibrium model.

Figure 1. From a Linear Economy

Source: Circular Economy Closing the loop-An EU Action Plan for the circular economy by the EC.

Figure 2. To a Circular Economy

- Maintaining the **value** of products, materials and resources in the economy for as long as possible
- Alleviating security of **supply** risks
- Boosting the **economy** by up to +7% GDP
- Increasing **competitiveness,** creating new business **opportunities**, and introducing **innovative** products and services
- Creating **jobs** in the EU
- Reducing **waste** generation, **GHG emissions** and other environmental impacts

Source: Circular Economy Closing the loop-An EU Action Plan for the circular economy by the EC.

In this context, the EC has suggested a new strategic approach in the field of circular CE, that enable to identify the risks generated by geopolitics and make recommendations that come in a list of objectives to be achieved, including the following:

- The sustainable products must be the norm in the EU
- Give more empowerment to consumers and public buyers
- Give more attention to fields the make use of most resources which implies that they have bigger circularity potential (Electronics, manufacturing of batteries and vehicles, Construction and buildings, nutrition industry, etc.).
- Lower the level of waste
- Lead global efforts on circular economy
- Adapt to the issue of climate change
- Ensure job growth in rural areas.

To achieve the objectives of the EC, a certain amount of knowledge and awareness of the CE functioning model must be acquired so that the transition to the circular economy happens smoothly. Mainly each individual concerned by this process must have the sufficient information about the recycling systems, economic goals, and governmental policy to determine the stage of the transition process.

The main aim of this paper is to study the impact the transition to a circular economy model on the economic growth of the countries states members of the EU, taking into account the independent variables, such as the circular material use rate, the recycling rate of municipal waste (RRMW), intra EU trade of selected waste categories, Gross Investment in tangible goods, persons and employed and value added at factor cost and how they affect and lastly the number of patents related to CE the dependent variable that will be represented by Gross Domestic Product per capita (GDP) growth. The process of selection of variables was based on profound research in related literature. Based on econometric modeling, the paper highlights that circular economy generates sustainable economic growth across the EU.

This paper has the following structure. Firstly, a statistical description of the independent variables used will be made. Then, the multiple regression model using panel data will be estimated by applying two methods: In a first place, the fixed model effects will be performed and then the Arellano-Bond dynamic panel data method will be used to verify the robustness of the first results. Finally, the research hypotheses should be validated. Further research, limitations of the study, and conclusions are summarized in the last section.

2 Literature review

2.1 Historical origins of the concept of the circular economy

The concept of circularity in how the economy works goes all the way back to the absolute starting point of the development of political economy that clarifies the connection between economic agents who produce and consume. The idea of circular flow was presented in the publications written during the eighteenth century, most quite underway by John Law, Richard Cantillon, and the French physiocrats (Schumpeter 1954, 223-243; and Murphy 1993). The portrayal made by François Quesnay in Tableau économique (1759), which shed the light on the expenditure between the classes sharing the space of economic relations in an agricultural kingdom, exhibits how the production made in a specific year is consumed and, all the while, how it ensures the continuous reproduction of a similar circuit in the next ayear, etc. in each resulting year.

A plan of economic reproduction that does not produce growth or an accumulation of the originally invested capital, since the point is to make a tool that helps analyze in order to clarify

the way in which wealth flows, and not how capital is accumulated. Through the development of a simple explanatory plan, a fundamental thought started to come to life for a better conceiving of the circular flow of income, which is used to represent any introductory economics textbook: the households that supply factors of production (land, labour, and capital) to the entities that use them to produce goods and services, and that generate the income (rents, wages, profits, and interest) that makes expenditure possible (consumption and investment). It was additionally this interpretive model, whose origin was founded by John Law (Money and Trade Considered, 1720) and Richard Cantillon (Essai sur la nature du commerce en général, 1755), that served as that filled in as the motivation for the advancement of insightful analytical instruments and ideas that were of highly crucial in the arrangement of current economic theory, namely input-output tables, national accounts tables, and general equilibrium approaches.

The concept of a circular economy is focused in this simple notion of the circular flow of income, yet additionally adds some other major fixings. One of these fixings is the one that relates the context of the shortage associated with the utilization of natural resources and production factors. In this specific area, the principal historical source of inspiration was the publication of Thomas R. Malthus, who, in his famous Essay on the Principle of Population (1798), illustrated the dangers innate in demographic development, whose mathematically progressive pace that threatens to exhaust available resources that grew only arithmetically. Despite the legitimacy or not of the disastrous projections made by Malthus (which overestimated the demographic tendencies that were to be noted in the more developed countries and underestimated the effects of technological progress on the exploration of natural resources), there is no question that his message worked as a sort of warning about the fast approaching consumption of resources, the uneven characters in the natural world brought about by mankind, and the weakening impacts of demographic development, particularly in metropolitan regions.

This cynical view was to be shared by numerous other nineteenth-century writers, frustrated with the accursed outcomes of industrial revolution and the economic advancement that had brought about social distortions, and which, most importantly, had brought about such bad unsettling influences to the climate. The development of an environmental and ecological mindfulness happened inside the setting of the scientific creativeness and the disclosures that fixated on the perception and information on the natural world, as Alexander von Humboldt showed so plainly

in his masterpiece Cosmos (1845). Be that as it may, it likewise occurred at the level of the philosophical imagination and the ethical and civic of Ralph Waldo Emerson, the author of Nature (1836) and Henry David Thoreau, the writer of Walden (1854). The instances of these writers, composing around the end of the main portion of the nineteenth century, were without a doubt significant for the progressive turn of events and fortifying of a mentality of cautiousness according to the deficiency of the circular balance and harmony of the natural world. This, thusly, prompted a developing worry for the protection of the climate that today finds intense sponsorship among the assailant allies of natural causes (Wulf 2015).

One more source of impacts that are verifiable in the way to deal with the circular economy is the one identifying with the analysis of the point of accomplishing steady and persistent development. Truth be told, by doubting the benefits of development for the wellbeing of development, the circular economy recuperates a custom throughout the entire existence of economic idea that had probably its best model in crafted by John Stuart Mill. In one of his most popular books, Principles of Political Economy: With Some of Their Applications to Social Philosophy (1848), Mill varies from the old style economists of his age by expressing that the chance of entrepreneur economies achieving the fixed state – at the end of the day, a second in their reformist development when the accumulation of capital and the further development of the product would stop to be conceivable – ought not be viewed as a negative certainty or as an undermining ghost.

As indicated by Mill, it would even be alluring if such a circumstance were to happen, to the extent that it would make it workable for need to be given to the issues of the distribution of wealth and property, rather than to the steady development of yearly production. This would be a chance for individuals to dedicate themselves to their own good and social turn of events and to working on their personal satisfaction, incorporating their relationship with their surrounding environment. Also, this advantageous fixed state was viewed by John Stuart Mill as an ideal model of society that could be moved nearer to, or even made conceivable, through political changes that would step by step change capitalism into a more attractive and more compassionate economic system.

The critical analysis of economic development with no human cutoff points was a consistent component in the publications of economic thinkers and common philosophers that opposed the

dominating vision of an economic science dependent on the standards of the alleged rationality of producers and consumers who are fulfilling limitless requirements. This judgment of the acquisitive spirit and the inefficient wasting of wealth was the principle worry in the methodology that Thorstein Veblen embraced to the wonder of prominent utilization in his renowned Theory of the Leisure Class (1899). Among the different writers illustrative of the institutionalist school in economics matters, it was John Kenneth Galbraith who best deciphered and fostered Veblen's heritage in destroying the components that meddle in the inspirations and inclinations of individuals for utilization, regardless of whether it be as exhibitionism or mimicry, as they continued looking for an ideal societal position, or because of exogenous conclusions and burdens that instigate conduct that doesn't compare to free individual decisions.

This gets rid of the legend of the sovereign customer, the holder of freedom of choice on the market. Such a consumer is just a passive economic agent, a casualty of misleadingly created needs, who is dependent upon the interests of an economy of badly shared wealth. Why develop, why create and consume when such activities carry with them waste and the exhaustion of natural resources? Communicated along these lines, this is likewise the inquiry that the protectors of the circular economy challenge us to reply. They have acquired a long practice of basic pondered the chance of the breakdown of the frameworks of natural equilibrium brought about by human activity, about the deficiency and unacceptability of available resources, about the accommodation of the natural world to the business power, and about the inadequacy of consumers to declare their own will.

Kenneth Boulding study – The Economics of the Coming Spaceship Earth - focusing on the need to think about the economic system as a shut system, implying that the economy and the climate is a circular pattern (not one pillar), where everything is a contribution for some other thing. In this view, the linear model of economy - climate communication can be transformed into a round design (put figures of linear versus circular economy).

3 Hypothesis

Table 1. Statistical hypothesis

Hypothesis number	Hypothesis
H1	The impact of recycling rate of municipal waste (RRMW) on economic growth is positive and significant.
H2	The environmental tax revenue is strongly correlated with economic growth.
H3	Intra EU trade is highly correlated with economic growth
H4	Private Investment, Jobs, Gross Value Added related to CE combined with the number of patents related to recycling secondary raw materials, is a significant factor of economic growth

4 Data and research methodology

4.1 Statistical sources of the data

All the data that is used in this study was extracted from the official page of Eurostata dedicated to the subject of circular economy and that provides all the necessary information and statistical figures about the indicators that can help conduct a proper empirical study on the matter.

4.2 Dependent variable

To conduct the current study of the implementation of a circular economic system in the European Union and how it impacts its economic growth, the dependent variable that was selected to measure the growth of the economy of the EU is the gross domestic production growth (GDP per capita) of each country member of the union. The selection of this variable was

based on literature. There are studies that demonstrate that the environmental taxes are significant drivers of economic growth. Others, such argue the importance of rates and environmental innovation in sustainable development and economic growth. The other variable, intra EU trade, is found to have positive effect on economic growth and sustainable development.

4.3 Independent variables

Table 2. Description of statistical variables

Indicators	**Definition**	**Unit**	**Variables**
Recycling rate of municipal waste	The indicator measures the share of recycled municipal waste in the total municipal waste generation.	Percentage	X1
Environmental tax revenue	An environmental tax is a tax whose tax base is a physical unit (or a proxy of it) of something that has a proven, specific negative impact on the environment and which is defined in the European system of accounts (ESA 2010) as a tax	Million euro	X2
Intra EU trade	Intra EU trade measures the quantities of selected waste categories and by-products imported by EU Member States from another Member State.	Thousands of Tons	X3

Gross investment in tangible goods, Jobs, Gross Value Added related to CE	The indicator includes "Gross investment in tangible goods", "Number of persons employed" and "Value added at factor costs" in the following three sectors: the recycling sector, repair and reuse sector and rental and leasing sector.	Million euro	X4
Number of patents related to recycling and secondary raw materials	The indicator measures the number of patents related to recycling and secondary raw materials. The attribution to recycling and secondary raw materials was done using the relevant codes in the Cooperative Patent Classification (CPC).	Number	X5

4.4 Methodology

As mentioned before, the main aim of circular economy, in opposition to linear economy, is to develop economic models so that the resources can be used in a more efficient way. In this study, five indicators are used to describe CE, and their impact on economic growth. Concretely in this model, the five macroeconomic factors will be the independent variables of the linear regression model with panel data that is going to be applied on the indicators of the countries of the EU, so that they can be classified according to their degree of commitment to the issue of sustainability and implementation of the model of CE and how it impacts the economic growth of each country individually and generally of the EU.

The first step was to generate the Table 1 that represents a statistics summary of all the variables that will be use in the regression process. When comparing the mean and median of each variable, it comes to the attention that their values are very close, which proves the fact that the selected data follows a normal distribution.

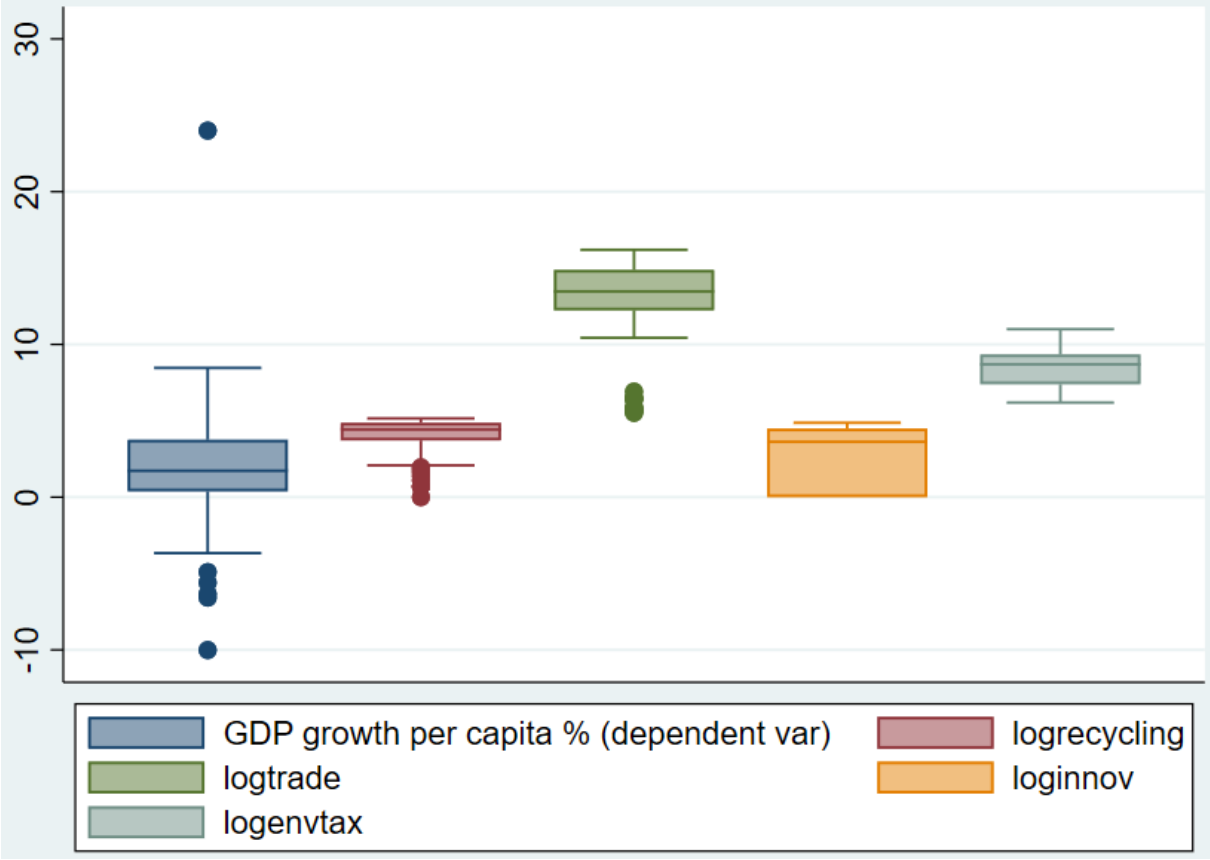
Table 3. Descriptive Statistics

stats	GDPgro~e	logrec~g	logtrade	logenv~x	loginnov
mean	1.941788	4.145306	13.29002	8.577996	2.693244
max	23.99925	5.153292	16.19437	10.99761	4.867535
min	-10.01628	0	5.521461	6.194406	0
p50	1.723478	4.430817	13.46834	8.692323	3.624252
sd	3.049467	.9589935	2.076898	1.364968	2.00859
N	207	207	207	207	206

Source: Stata 16

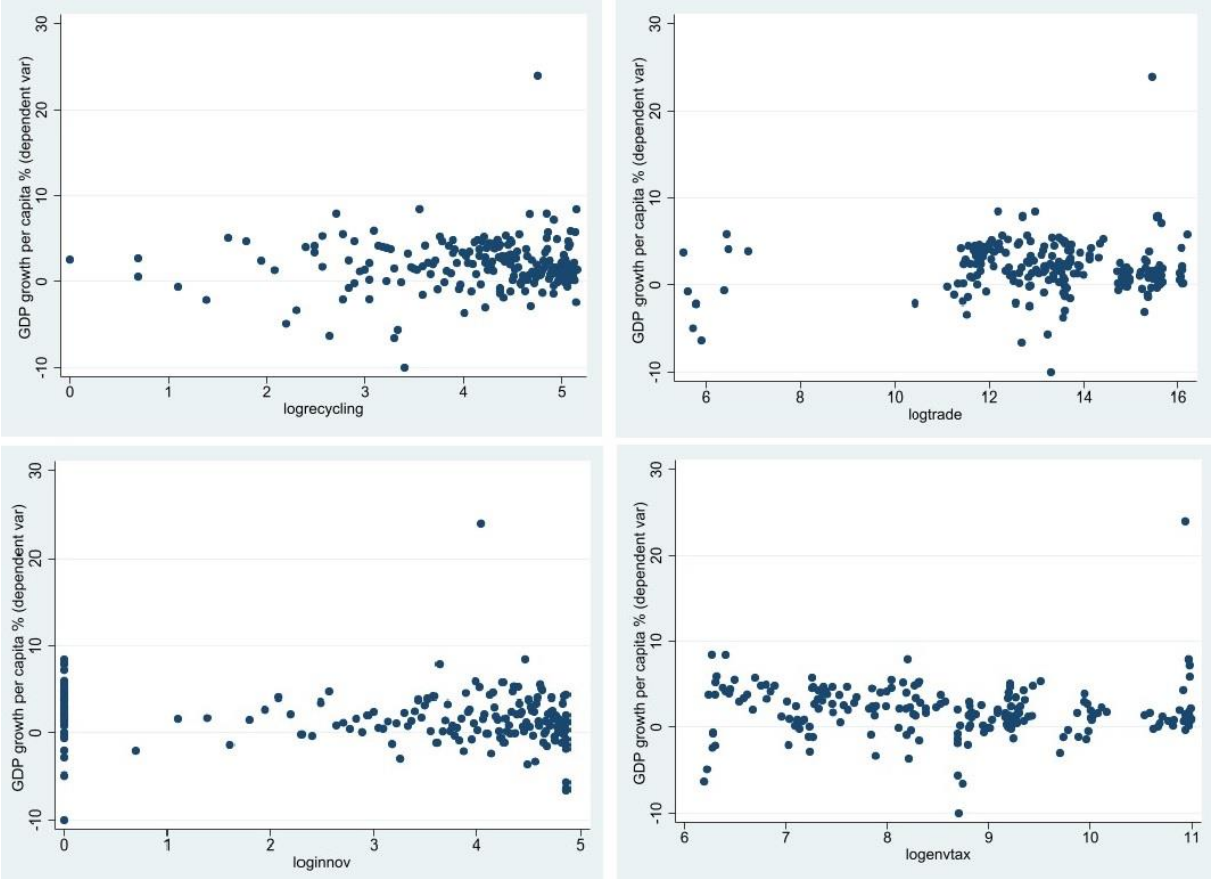
Then we have put all the data in a boxplot graph as shown in the Figure () in order to determine whether there are significant outliers or not. The variables representing tax revenues and recycling rate of municipal waste did have some outliers value, as well as the GDP which could be related to not using the logarithmic value of the independent variable.

Figure 3. Visualized summary statistics with boxplot



The next step was to scatterplot the dependent variable GDP with each independent variable of the model, in order to visualize the relationship between the variables. As it can be seen on the next figure, the recycling rate and intra trade components seems to concentrated, while the remaining two variables, environmental tax revenues and innovation, look like they have a linear correlation with the dependent variable.

Figure 4. Scatterplot of GDP and the variables of the model



Source: Stata 16

At this stage, the correlation matrix was generated in order to test the multicollinearity. The Person correlation matrix showed the degree of correlation between the variables of the model. A high level of correlation, 0.90 or above, is a sign of substantial collinearity. As shown in the next table, there is no evidence of the presence of high degree of correlations, consequently it can be concluded the model does not represent a risk of multicollinearity within its variables.

Table 4. Pearson's correlation matrix

	GDPgro~e	logrec~g	logtrade	logenv~x	loginnov
GDPgrowthp~e	1.0000				
logrecycling	0.0746	1.0000			
logtrade	0.0667	0.5319	1.0000		
logenvtax	-0.0473	0.4394	0.7456	1.0000	
loginnov	-0.1864	-0.0190	0.1256	0.1699	1.0000

Source : Stata 16

The purpose of this paper is to study and analyze the impact that circular economy can potentially have economic growth, to estimate that initially the fixed effect model will be used after comparing it with the random effects model and then testing through the Hausman test which one is more suitable for the present panel of data without addressing the endogeneity issue. This first part of the estimation process will enable us to measure the strength and the sign of the impact that each independent variable has on the GDP growth. Then the system generalize method of moments (GMM) will be used to get rid of the endogeneity issue by instrumentalizing the dependent variable, GDP per capita, (lagged on one period).

In both models, the variable labelled innovation will represent the product of the two last variables mentioned in the independent variables section, "private investment, jobs, gross value added related to CE" and "Number of patents related to recycling". The reason behind this compilation is based on studies that demonstrate a strong relationship between labor force, investment, employability and innovation and also the patent system for promoting innovation in CE.

5 Results

5.1 Descriptive analysis

The starting point of the estimation process was running the panel data using fixed effects model and random effects one in order to apply the Hausman test that enables to identify the more suitable and appropriate model for the dataset. The null hypothesis, H0, is that the preferred model is random effects; The alternate hypothesis is that the model that must be used is fixed

effects. Essentially, the test aims to demonstrate if there is a correlation between the unique errors and the regressors in the model. The null hypothesis is that there is no correlation between the two. In the case of this research paper, the Hausman test confirmed that the suitable model is the fixed effects one.

When running the Hausman test, it was found that the Prob>chi2 =0.0002, which means that the null hypothesis must be rejected in favor of the alternative one. In consequence, the appropriate way for analyzing the data in this case is the fixed effects method, as shown below:

Table 5. Hausman test results for fixed effects vs random effects method

	Coefficients (b) efectos_fi~s	(B) efectos_al~s	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
logrecycling	.5053831	.42748	.0779031	.1330608
logenvtax	6.580983	-.3880629	6.969046	1.757623
logtrade	1.330461	.3084613	1.021999	.4983797
logX6	-.0740399	-.2930381	.2189982	.0455386

b = consistent under Ho and Ha; obtained from xtreg
B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= 22.45
Prob>chi2 = 0.0002
(V_b-V_B is not positive definite)

Fixed effects method equation:

$$gdp_{i,t} = \alpha_0 + \alpha_1 log_{tax_{i,t}} + \alpha_2 log_{rec_{i,t}} + \alpha_3 log_{innov_{i,t}} + \alpha_4 log_{trade_{i,t}} + \alpha_i + \epsilon$$

Where:

I= number of countries

t= time period of panel data

α_0 *= interception of the regression*

α_i = *individual specific effect*

ε = *error term*

GDP = gross domestic product

logtenvtax = environment tax revenues

logrecycling = recycling rate of municipal waste

loginnov = private investment, jobs, gross value added related to

*CE * number of patents related to CE*

logtrade = intra trade in recyclable raw materials

According to the equation above of the fixed effects method, logarithmic values of the independent variables were used for the present panel data analysis in order to make them compatible with the regression process.

The following table represents the details of the estimation that has been made by the fixed effects method. All the independent variables seem to positively impact the GDP growth, except for the last one (innovation). The Three first variables were found significant, especially environmental tax revenues, followed by intra EU trade in secondary raw materials and finally the recycling rate of municipal waste can be considered significant since it's close to the level of significance 0.1.

In order to ameliorate the model, the countries that contain missing value were eliminated. Consequently, the Prob > F was found to be nearly 0 which implies that the overall model is significant and allows a good estimation.

The results show that the environmental tax revenues variable has a positive and significant effect on the model. According to the estimation made by Stata 16, The GDP growth would increase by 6.58 units whenever the environmental tax revenues grow by 1 unit. The intra EU trade in Recycled materials has also a positive and significant impact on the dependent variable in a way that when it increases by 1 unit, the GDP per capita would grow by 1.33 units. In a

same way, the recycling rate of municipal waste seems to have a positive impact on the GDP per capita, It should be mentioned that the level of significance in this study is set to 0.1 and since that variable represents a very close value to 1%, it could also be considered practically significant making the GDP increase by 0.5 units every time it grows by 1 unit.

All those independent variables that were found to positively and significantly impact the GDP growth, could be considered as crucial factors to the economic growth.

The remaining variable representing innovation capacities related to CE, seems to be insignificant to the GDP and has a negative effect on it.

Table 6. Fixed effect panel data method

```
Fixed-effects (within) regression               Number of obs      =       206
Group variable: Country                         Number of groups   =        23

R-sq:                                           Obs per group:
     within  = 0.1693                                         min =         8
     between = 0.0079                                         avg =       9.0
     overall = 0.0002                                         max =         9

                                                F(4,179)           =      9.12
corr(u_i, Xb)  = -0.9859                        Prob > F           =    0.0000
```

GDPgrowthp~e	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
logrecycling	.5053831	.3282251	1.54	0.125	-.1423053	1.153072
logtrade	1.330461	.5614293	2.37	0.019	.2225891	2.438332
logenvtax	6.580983	1.801383	3.65	0.000	3.026305	10.13566
loginnov	-.0740399	.1066232	-0.69	0.488	-.2844401	.1363603
_cons	-74.06009	16.69782	-4.44	0.000	-107.01	-41.11019
sigma_u	11.856597					
sigma_e	2.5209592					
rho	.95674772	(fraction of variance due to u_i)				

Source: Stata 16

In order to take a better consideration of the effects that independent variables have on the dependent one of this model, the GMM method, using the Arellano–Bond conditions, can be used to confirm that results found by fixed effects method. The GMM enables to estimate dynamic panel date models based on a model in first differences. This method also allows to

address the problem of endogeneity, heteroscedasticity and serial correlation issues. The GMM that will be used in this paper follows this form:

$$\Delta gdp_{i,t} = \Delta gdp_{i,t-1} + \alpha_1 \Delta log_{tax_{i,t}} + \alpha_2 \Delta log_{rec_{i,t}} + \alpha_3 \Delta log_{innov_{i,t}} + \alpha_4 \Delta log_{trade_{i,t}} + \Delta \epsilon_{i,t}$$

I = number of countries

T = period of time of the panel data

ε = error term

ΔGDP = gross domestic product

Δlogtenvtax = environment tax revenues

Δlogrecycling = recycling rate of municipal waste

Δloginnov = private investment, jobs, gross value added related to

*CE * number of patents related to CE*

Δlogtrade = intra trade in recyclable raw materials

When running the Arellano-Bond dynamic panel data estimation method, as shown in the bellow table, the results seem to be similar to the one we got using the FE model. In this model, the dependent variable is lagged by one period assuming that the independent variables show their effect only the following year. The environmental tax revenues and intra trade EU of recycled materials seem to be significant in the same way as they were in the previous model, meanwhile recycling rate of municipal waste could be considered significant to a level of 20%, and can be accepted as it has a positive impact on the GDP. Lastly, the variable innovation still doesn't show any sign of significance nor positiveness.

Globally, the model could be considered significant since the Prob > chi2 is nearly 0. The GMM method is a more robust model to estimate panel data, in this case it supports and confirm the results gotten by the fixed effects method applied previously, giving more proof that all the three variables have an important impact on the economic growth.

Table 7. Arellano–Bond for dynamic panel data method

Arellano-Bond dynamic panel-data estimation — Number of obs = 160
Group variable: **Country** — Number of groups = 23
Time variable: **Year**

Obs per group:
min = 6
avg = 6.956522
max = 7

Number of instruments = 33 — Wald chi2(5) = 1318.74
Prob > chi2 = 0.0000

Two-step results

GDPgrowthpercapitadepende	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
GDPgrowthpercapitadepende L1.	.1818703	.0111198	16.36	0.000	.1600759	.2036647
logrecycling	.1892149	.1428827	1.32	0.185	-.09083	.4692599
logenvtax	2.77194	.7356379	3.77	0.000	1.330117	4.213764
logtrade	.8532074	.38576	2.21	0.027	.0971317	1.609283
loginnov	-.0011442	.0197162	-0.06	0.954	-.0397872	.0374988
_cons	-34.9256	8.314991	-4.20	0.000	-51.22268	-18.62852

Source: Stata 16

5.2 Discussion of the results

The present study aims to determine the impact that might have the CE indicators on the economic growth of the EU countries. As mentioned before, CE is defined as an economic system of closed loops in which raw materials, components and products lose their value as little as possible, and that mainly focuses on the 4R of reducing, reusing, recycling and recovering materials in order to ensure a better sustainable development and resolve the issue of precariousness of natural resources. The panel data of this paper was analyzed through two methods by using the software STATA 16: The first method was the fixed effects and the second one was the dynamic panel data estimation of Arellano-Bond. Both models were applied to study the relationship and impact that the four independent variables (environmental tax revenues, recycling rate of municipal waste, Intra EU trade of recyclable of raw material and the combined variable private investment, jobs, gross value added related to CE * number of patents related to CE), have on the dependent variable GDP per capita growth. When analyzing the results, it can be stated that all the variables have a positive and significant impact on the economic growth of the EU countries, except for the last variable that represents innovation in CE that seemed not to be sufficiently significant nor positive. The results of this study are confirmative of other

conducted studies on the same subject in which authors developed regression models to highlight the relationship between economic growth and circular economy indicators and which argue that sustainability and the circular economy impact on economic growth is not increased by a simple shift to renewable resources or materials. Another study, highlights the major impact that environmental tax revenues have on the economic growth, confirming the same result that was deduced from this paper.

The novelty of this research paper is the use of a combination of two panel data estimation methods to study the relationship between the CE indicators and the level of economic growth of EU countries on a period of nine years from 2010 to 2018, and there for the limitation of this study is related to the time length period used for the estimation models. Longer periods, with a wider range of countries that do not contain missing data as well as more control variables, can perhaps offer better results and a bigger picture of the econometric model to analyze this transition to CE and how committed the countries are in its implementation. Another suggestion for future research could be the implementation of such models in a larger number of countries and making some comparisons among EU and non-EU countries.

The present paper backs up the idea that CE must be encourage by the principal actors of sustainable economy supports (the quadruple helix model of innovation—academia, government, business, and civil society). Moreover, three of the four presumed hypotheses were validated by the estimation models, proving that the link between CE factors and the necessity of collaboration among the quadruple helix model is crucial to the implementation and the improvement of circularity, which affects significantly the economic growth.

6 Conclusions and avenues for further research

Researches led to the conclusion that developed economies have uncovered different assets of the civil society in the goal of environmental protection, parallelly with the investments in reusing and recycling infrastructure. The positive effects of the circular economy model can be empowered by expanding the level of municipalities' revenue, the solicited workforce, and the benefit got by the project workers providing the ecological framework. The econometric examination performed features the effect of exogenous factors, determining variables of the circular economy in the economic growth.

Economic growth and environmental performance must go in pair. The natural environment depends on economic activity and development, giving the fundamental resources needed in order to deliver products and services, as well as preparing and retaining undesirable side-effects as waste and contamination. Circular economy and environmental resources add to the economic growth and social activity, contributing to control flood risks, controlling the local climate (both temperature and air quality), and ensuring the supply of clean water and other assets. Correspondingly, economic growth adds to the investment and dynamism expected to convey and foster new innovation, which is basic to both managing ecological resources and productivity growth.

Maybe the main advantage is the one felt at the singular level. By making a similarity between the product life through reuse, which converts into life prolongation and the advantages of this natural cycle on the human being's existence, and considering that the essential asset is biomass, we can see how the nature of the ecological components is certainly spread, decidedly affecting the quality of the human life. The investigation can be additionally evolved using other macroeconomic factors comparable the characteristics of the CE and ecological difficulties, revealing insight into the most recent EC improvements in the field to carry out the circular economy in daily activities. Future research could be made for a longer period of time and use other economic indicators or econometric models.

Abbreviations

EU European Union

EC European Commission

GDP gross domestic product

CE circular economy

RRMW recycling rate of municipal waste

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