ИНСТИТУТ ЗА ИКОНОМИЧЕСКИ ИЗСЛЕДВАНИЯ НА БЪЛГАРСКАТА АКАДЕМИЯ НА НАУКИТЕ
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Sonia Chipeva[1]
Vania Ivanova[2]

THROUGH CIRCULAR TO LOW CARBON ECONOMY – CONCEPT AND EVIDENCES IN THE EU MEMBERS[3]

The aim of the study is to present an opportunity for the concept of circular economy to become a lever for the transition to a low-carbon and environmentally friendly economy. The correlation between key indicators for circular economy and change of GHG emissions in EU countries has been analysed, and a series of econometric models have been developed. An analysis has been conducted for 4 sets of countries – Bulgaria, the EU countries as a whole and the communities of old and new members separately. The existence of untapped opportunities related not only to more efficient use of resources, but also to the possibility of radical change in business models has been revealed in the analysis. The conclusions reached show that the concept needs to be extended so as to break the relation between economic growth and waste production, as well as the potential to reduce GHG emissions.
Keywords: circular economy; greenhouse gas emissions; sustainable production and consumption; recycling; EU
JEL: O13; O14; P28; Q01; Q52

1. Introduction

Targets agreed upon in the Paris Agreement to limit global temperature rise to below 2^0C (possibly 1.5^0C) by 2100 and to increase the effectiveness of the fight against climate change have made the EU's efforts in this direction priority. Challenges are complex and interconnected. They imply the development of a set of policies that lead to profound transformation. The European Green Pact (2019) is a response to these challenges. It is a new

[1] *Sonia Chipeva, Assoc.Prof., PhD, University of National and World Economy, +359 887926974, sonia.chipeva@hotmail.com.*
[2] *Vania Ivanova, Assoc.Prof., PhD, University of National and World Economy, +359887672031, vivanova@unwe.bg.*
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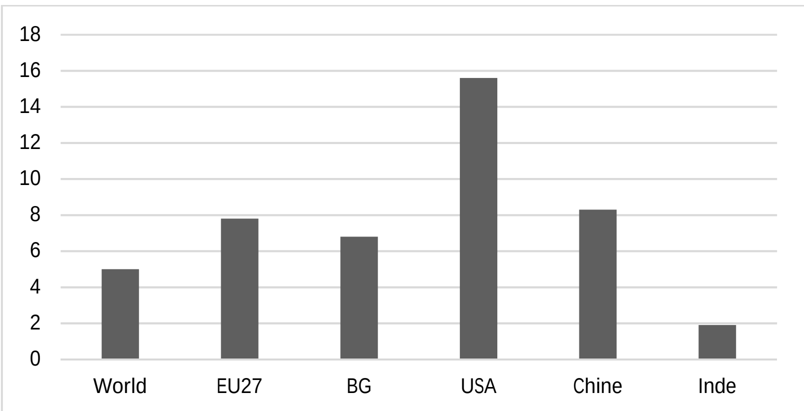
growth strategy that aims to transform the EU into a prosperous society with a modern, resource-efficient and competitive economy that should be decarbonised by 2050 and with economic growth not dependent on resource use. Building on the UN's new Sustainable Development Goals (SDGs), this transformation goes through a complete change in the business models of companies and households. Economic growth, just ecological transition, resource-efficient and low-carbon economy are key development focuses for the next decade in the newly adopted Green Pact. The ambitious goal that EU Member States have set themselves to play a decisive role in the process of ecological transformation of the economy in order to permanently address climate change requires radical, decisive and coherent action by all stakeholders. Investment Plan for a Sustainable Europe aims to mobilise at least €1 trillion of investment to achieve the objectives of the European Green Pact. To support action on environmental transformation and to ensure a rapid and sustainable recovery from the COVID-19 crisis and the transition to a green economy, the EC has created a new financial instrument, the New Generation EU. The fight against climate change and the need for a radical change not only in production methods but in the very concept of economic development have become the core of European economic policy in recent years. Making economic recovery a catalyst for the ecological transition and supporting efforts to achieve carbon neutrality by 2050 have become important priorities on the government agendas of the majority of European countries and of many NGOs. Most of the new Recovery and Sustainability Plans submitted by the member states to the European Commission to receive support for specific projects from the funds earmarked in the New Generation EU financial instrument, concern the transition to a low carbon economy and drive to further reduce greenhouse gas emissions. Up to now, CO_2 emissions remain too high despite the progress made in their limiting in recent years. According to the European Environment Agency (EEA), there was a 28% drop in emissions in the EU between 1990 and 2019 (EEA, 2021). Although the EU is a world leader in the fight to reduce greenhouse gas emissions (Figure 1), it is still far from achieving its targets of a 55% decline by 2030 and carbon neutrality by 2050. Based on 2019 data, the main emittents remain the sectors related to energy production (27%), transport (23%) and industrial production (including construction – 12%).

Figure 1

Greenhouse gas emissions units of CO_2 equivalents per capita



Source: EEA.

Achieving these goals requires a shift to a more circular economy and is a vital contribution to the development of an economic model that is not only about profit but also about protecting the environment. In this context, our current linear economic system – resource extraction, production, consumption, disposal – is not sustainable and must be changed. The Circular Economy (CE) can be defined as a closed loop, covering each of the three areas: supply and responsible choice of producers, demand and consumer behaviour and waste management. According to the definition of the French State Agency for Sustainable Development (ADEME), which is adopted as a working definition in this study, "The circular economy is an economic system of exchange and production in which, at each stage of the life cycle of a product (good or service), the aim is to increase efficiency in the use of resources and reduce the harmful impact on the environment, ensuring the well-being of individuals" (ADEME, 2014, p. 4). Transition to CE aims to go beyond the limits of the linear model and to impose responsible and efficient consumption of natural resources and materials, new business models related to the production and consumption of products that meet the concept of eco-design, as well as prevention, recycling and hierarchical management and use of waste (Esposito et al., 2016, Aurez and Georgeault, 2019). It can be seen as an integral part of the concept of sustainable development as it is closely correlated with each of the dimensions – economic, social and environmental (Hours, Lapierre, 2013).

In order to meet today's economic challenges related to scarce, finite and increasingly costly resources on the one hand and the environmental needs on the other, CE is based on three fundamental principles (Figure 2).

Figure 2

Principles of the circular economy

Source: author's systematisation.

New vision covers a range of activities, new practices, and business models, interlinked, and hierarchised according to their contribution to optimising the use of raw materials and energy. Increasing consumption of resources and the negative environmental impact caused by it requires a change in the economic model (Pieroni et al., 2019). The concept of circular economy is part of this change. Ecological transition to CE has as its immediate task to optimise management of resources – both materials and energy. Moreover, the effects of the transformation go far beyond this task, and they are projected on the outcomes related to the fight against climate change, a new type of economic growth and new quality of life (Cavallo, 2018; Martinez-Alier, 2012; Pottier, 2016). Such an approach should include a global, systemic, and integrated vision. The transition to a circular economy requires fundamental changes in production and consumption systems that go far beyond resource efficiency and waste recycling. The circular economy model is a closed loop, covering each of the three areas: supply and responsible choice of producers, demand and consumer behaviour and waste management. Unlike the linear economy model (extraction, production, consumption, waste), CE produces goods and services, limiting the use of raw materials and energy on the one hand and reducing waste generation on the other (Rogers, Hudson, 2011).

The circular economy model implies a resource-efficient economy (Fricker, 2003; Ellen MacArthur Foundation, 2012). It means that by limiting resource use at the input of the system, the CO_2 emissions associated with that extraction are also reduced. At the same time, CE is an energy-saving economy based on the use of alternative energy from renewable sources and the implementation of such a model could reduce emissions associated with fossil fuel extraction by energy-producing use of waste recovery methods. CE is a recycler and actively enforces the use of secondary materials, efficiently utilising residual resources on cascading basis (Seidl, 2007). This not only increases resource efficiency, reduces the economy's dependence on scarce resources, but could also reduce greenhouse gas emissions (GGE). However, in order to be easily recyclable, products must be adapted to this. CE builds on the concept of eco-design and through the development of repair, re-use and repair activities allow to extend the life cycle of products, save resources, reduces waste and, therefore CO_2 emissions. The circular economy model goes far beyond the idea of waste minimisation (Stahel, 2010, Clarkson et al., 2008). It is a sharing economy – it promotes sharing, especially the development of new business models related to mobility, responsible consumption and sharing. These models, applied especially in urban transport, have a synergistic effect, and have an impact not only on traffic, air cleanliness but also on emission volumes. Last but not least, CE is a functional economy (Ghisellinia et al., 2016). Dematerialisation and the use of services instead of products, in addition to opening up new niches, offers new jobs and incomes by changing existing business models, contributing to the reduction of resource consumption and hence promoting a transition to a low carbon economy.

The aim of the paper is to explore the possibility that the circular economy concept becomes a lever for transition to low carbon and green economy. The impact of key circular economy indicators adopted by EU on the change in greenhouse gas emissions in EU countries, has been analysed. Carbon removals can be nature-based, or based on increased circularity, for instance, through long term storage in wood construction, re-use and storage of carbon in products such as mineralisation in building material(COM/2020/98).

The research thesis of the study is that by building on the principles of the CE and applying its model, the economies of EU member states can successfully achieve their low carbon economy goals by 2050.

2. Methodology and data

2.1. Methodology

Recently there have been plenty of studies dedicated to the green transformation. However, the usual focus of studies is put on the green growth in the EU (Sneideriene, Viederyte, 2020), the development of the circular economy in EU countries (Ivanova, Chipeva, 2019; Zielinska, 2019), new opportunities and challenges of transition to low-carbon and resource-efficient economy (Camilleri, 2021; Marin et al., 2014). Empirical studies concerning the effects of main indicators recommended by Eurostat for measuring circular economy (COM029) on GHG emissions within EU country members as a whole and defined subsets of them, including Bulgaria alone, were not published by now. The methodology applied in the study aims to explore how much the transition to the circular economy model leads to a reduction of GHG emissions in EU countries as a whole and in defined subsets, including in Bulgaria.

The relationship between greenhouse gas emissions and 6 adopted indicators of circular economy was analysed. Indicators of the circular economy under consideration in the analysis are presented in the table below (Table 1).

Table 1

Indicators and respective variables under consideration in the study

Variable	Indicator	Measure
Y	Greenhouse gas emissions – dependent	Tonnes per capita
X1	Circular material use rate	Percentage
X2	Energy productivity	Euro per kilogram of oil equivalent (KGOE)
X3	Resource productivity and domestic material consumption (DMC)	Euro per kilogram, chain-linked volumes (2015)
X4	Production, value-added and exports in the environmental goods and services sector	Million Euro
X5	Generation of waste, excluding major mineral wastes by hazardousness	Kilograms per capita
X6	Recycling rate of all waste excluding major mineral waste	Percentage

Source: own elaboration.

Selection of indicators was done among all the adopted by the European Commission in accordance with the principles and goals of the circular economy. To meet the purpose of the study, the indicators are selected to present different aspects of the circular economy. Relevance, acceptability, reliability, simplicity of use and sustainability of indicators were additional criteria taken into consideration for selection. Four sets of countries have been analysed in terms of the effects of indicators identified for circular economy and ecological production on the greenhouse gas emissions produced – (1) all EU members, including the UK (EU-28); (2) the old members, including UK (EU-15); (3) the new joined country members after 2004 (EU-13); and (4) Bulgaria alone (Table 2). The UK is included in the study since it is yet an EU member during the period under consideration. Variables for each indicator in the groups excluding Bulgaria have been calculated as means over countries in the respective group by years. Analysis for each of the 4 sets of countries has been conducted separately.

Table 2

Structure of country groups included in the study

EU-28	Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Hungary, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovenia, Slovakia Spain, Sweden, UK
EU-15	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Spain, Portugal, Sweden, UK
EU-13	Bulgaria, Czech, Croatia, Cyprus, Estonia, Latvia, Lithuania, Hungary, Malta, Poland, Romania, Slovenia, Slovakia
BU	Bulgaria

Source: own elaboration.

At the beginning of the analysis, all the variables considered have been tested for autocorrelation. The autocorrelation function of each of them has been explored and Q-test for the significance of the autocorrelation coefficients up to 9th order has been conducted. Correlation between Greenhouse gas emissions and each of the circular economy indicators considered as factors in the study has been explored first by respective single correlation coefficients calculation and their statistical significance has been tested. Correlation analysis outcomes have assisted factors selection in regression models after.

Multiple linear regression models of greenhouse gas emissions depending on the six nominated indicators for each pointed group of countries have been developed. This type of models has been applied due to the authors aim for exploring and presenting the partial effect of identified factors on GHG emissions. All the variables involved in the analysis have been tested for stationarity by applying the ADF test first, and Phillips-Perron test and the KPSS test then. Different unit root tests have been applied since the results showed abnormal high order integration (2nd or higher) for most of the variables (see Table A1 in Appendix).

The first trial for models specification was to use differences of respective orders for the integrated (or autocorrelated) series, but the models outcomes were not reliable. Moreover, using higher-order differences make models outcomes difficult for interpretation and more or less meaningless for the modelled correlations. Then, for models simplification, only the dependent variables were presented by 2nd and 3rd order differences, but results again were not satisfying. Taking into consideration all the above, we decided to build models including all the variables by their original values. It made the models more realistic and understandable on the one hand and allowed to apply Stepwise Least Square (SLS) method for factors selection on the other. Quality of models outcomes has been assessed and diagnostic of estimated models has been conducted. To overcome serial correlation, provoked by the nonstationary dependent variable, a specific approach for modelling the residuals correlated has been applied. Using this approach, the special models known as regARIMA models (or ARIMAX also) have been created in which autoregression (AR) and/or moving average (MA) components for the residuals were included where it was necessary. Thus the negative impact of autocorrelated and/or nonstationary series in the models was overcome and outcomes could be regarded as reliable.

All the analyses are applied with the econometric package Eviews, v.8.

2.2. Data

Empirical data used in the analysis is publicised on the Eurostat website for each country EU member for period from 2010 to 2019. For most of the indicators under consideration in the study annual data for each year is available, but for 2 of them (Generation of waste excluding mineral wastes by hazardousness and the Recycling rate of all waste excluding mineral waste) Eurostat provides data for each second year. To make the time series for these indicators comparable to the rest ones, the missing data for intermediate years have been fulfilled by interpolation using averaging the neighboured members. Data for 2019 for these time series have been obtained by extrapolation of the respective trend lines.

3. Results and Discussion

Most of the variables in the analysis, including all the series of GHG emissions, have been proven to be non-autocorrelated and the rest ones are 1st order autocorrelated. First-order Autocorrelation coefficients are presented in Table A2 in the Appendix. Since the autocorrelation is identified in only some of the factor series and the trends of these series and the series of GHG emissions for the respective countries' sets are not identical, there is no basis to expect a significant overestimation of the correlation between emissions and autocorrelated factors (Velichkova, 1981). Thereafter, serial correlation caused by autocorrelation in the initial series was controlled when it was necessary.

Correlation coefficients between Greenhouse gas emissions and circular economy indicators are presented in Table 3. Values in brackets are p-values of the tests for statistical significance of respective correlation coefficients at 5% significance level.

Table 3

Correlation coefficients between Greenhouse gas emissions and circular economy indicators

Circular Economy Indicators	Groups of countries			
	EU-28	EU-15	EU-13	Bulgaria
Circular material use rate	-0,6447* [0,0442]	-0,2562 [0,4748]	0,0595 [0,8702]	0,1628 [0,6532]
Energy productivity	-0,8200* [0,0037]	-0,9185* [0,0002]	0,1881 [0,6028]	-0,1902 [0,5987]
Resource productivity and domestic material consumption (DMC)	-0,8264* [0.0032]	-0,9190* [0,0002]	-0,1377 [0,7045]	-0,4099 [0,2394]
Production, value added and exports in the environmental goods and services sector	0,4795 [0,1607]	-0,4949 [0,1459]	0,5503 [0,0993]	0,0871 [0,8107]
Generation of waste excluding major mineral wastes by hazardousness	0,0292 [0,9361	0,8243* [0,0034]	0,3986 [0,2538]	0,1098 [0,7627]
Recycling rate of all waste, excluding major mineral waste	-0,8302* [0,0029]	0,1924 0,5943	0,4131 [0,2354]	0,1634 [0,6520]

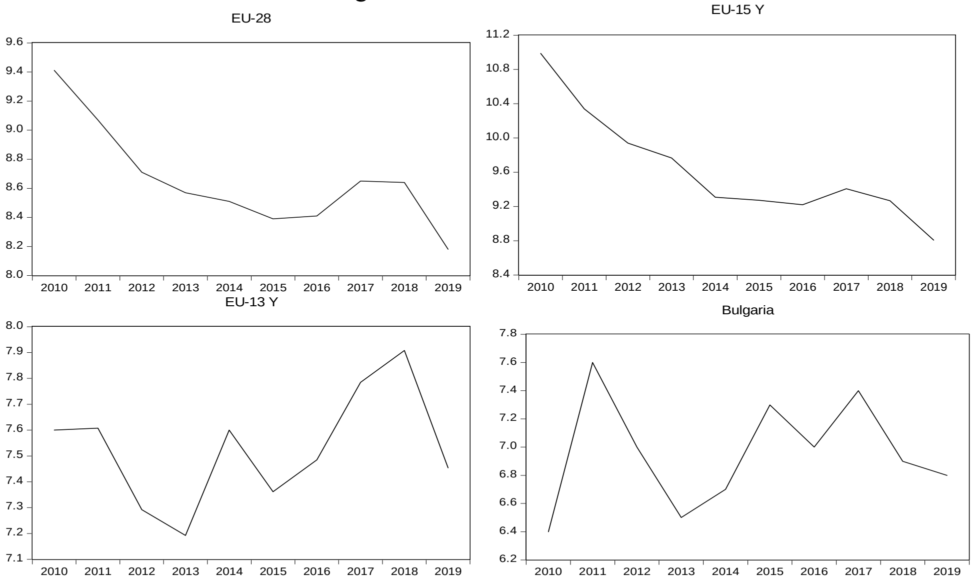
** Statistical significance proven at 5% significance level*

Source: own elaboration

There is a strongly presented negative correlation between *Greenhouse gas emissions* and 4 of circular economy indicators – *Circular material use rate*, *Energy productivity*, *Resource productivity and DMC* and *Recycling rate of all waste, excluding major mineral waste*, for the group of all EU countries. A very strong negative correlation is also presented between *Greenhouse gas emissions* and *Energy productivity* and *Resource productivity and DMC* for the old EU members. It shows concerning EU countries as a whole and the group of old members that both latter indicators are closely related to *Greenhouse gas emissions* like the indicators increase causes emissions decrease. The empirical result confirms the initial research hypothesis that accelerating ecological transformation, transition to a circular economy model, increase resource efficiency and resource re-use based on the 3Rs (reduce, re-use, recycle) rule can have a positive impact on emissions reduction and support efforts in the fight of climate change. On the other hand, there is a strong positive correlation between *Greenhouse gas emissions* and *Generation of waste excluding major mineral wastes by hazardousness* for the group of the old EU members. Closing the circle and striving for zero waste is at the heart of the circular economy concept. Introducing new production technologies with zero-waste or producing products with an eco-design that allows them to be more easily disassembled, using the useful components, and thus reducing waste, has a double dividend. In purely economic terms, it reduces production costs and in terms of environmental effects, it leads to a drop in greenhouse gas emissions. An important outcome here shows that the correlation between *Greenhouse gas emissions* and the indicators analysed cannot be proven for the new EU members, including Bulgaria. One of the reasons could be looked for in yet weak development of circular economy in these countries and thus, in lower levels of the respective indicators.

Figure 3

Greenhouse gas emissions time series in 2010-2019



Source: own elaboration

Results of all the applied Unit Root tests showed almost the same results, that is why only the results of ADF tests are presented in Table A1 in the Appendix. *Greenhouse gas emissions* time series for EU-28, EU-15 and EU-13 are integrated at a high level (3rd and above) and only this one for Bulgaria is not. Also, most of the factor variables turned to be integrated of a different order – I (1), I (2) or I(3). Analysing the results and taking into account the limited size of time series used, we supposed that it is likely outcomes of unit root tests not to be reliably enough. Moreover, models created using series differences could not fit well with empirical data, most of the models' parameters are not statistically significant and the explanatory capability of the models (presented by R-square) is very weak. The outcomes are not presented in the paper, but they are available in request from the authors. The outcomes of the last estimated models created using regARIMA approach and the Stepwise LS method for factors selection are presented below.

3.1. Model for the group of all EU members, including the UK (EU-28)

Taking under consideration correlations proven between the dependent variable and the initially specified factors and after running the Stepwise Least Square Method, the final (best) view of the model of *Greenhouse gas emissions* estimated for the group of all the EU members (EU-28) is:

$$\hat{Y} = c(0) + c(1)*X6 + c(2)*MA(1) \quad (1)$$

where: $\hat{Y}$ is *Greenhouse gas emissions* estimated; X6 is the *Recycling rate of all waste excluding major mineral waste;* c(0), c(1) and (2) are model parameters; MA(1) is the moving average term of residuals

Model fit well empirical data and the diagnostic tests provide evidences for normally distributed residuals with 0 mean, lack of serial correlation and heteroscedasticity. The explanatory capability of the model is 89.9%. Estimates of model parameters with important statistics for their quality are presented in Table 4. There is only one factor with a statistically significant effect on the *Greenhouse gas emissions* in the model – *The recycling rate of all waste, excluding major mineral waste*. The main reason for removing the rest of the initially specified factors from the model is the strong multicollinearity between them that yield unstable parameter estimates and conservative tests for their statistical significance. The effect of the factor is negative and shows that the average reduction of *Greenhouse gas emissions* for 1% increase in the *Recycling rate of all waste* will expect to be 0.162 tonnes per capita.

Table 4

Model estimation outcomes for EU-28

Variable	Coefficient	Std. Error	t-Statistic	Prob.(t)
X6	-0.1616	0.0468	-3.447	0.0107
C	16.7756	2.3829	7.039	0.0002
MA(1)	0.9322	0.0652	14.286	0.0000

Source: own elaboration

3.2. Model for the group of old EU members, including the UK (EU-15)

The Final (best) model of *Greenhouse gas emissions* estimated for the group of the old EU members (EU-15) is:

$$\hat{Y} = c(0) + c(1)*X2 + c(2)*X5 \quad (2)$$

where: $\hat{Y}$ is *Greenhouse gas emissions* estimated; X2 is *Energy productivity;* X5 is the *Generation of waste excluding major mineral wastes by hazardousness*; c(0), c(1) and (2) are model parameters

Four of the initially specified factors are removed from the model since they show statistically insignificant effects on GHG emissions. One of the reasons could be strong multicollinearity existed between them. Estimates of model parameters and main statistics that prove their quality are presented in Table 5. Parameters of factors included in the model are statistically significant. Model fit well empirical data and all the diagnostic tests provide evidences that the assumptions about the residuals are met. The explanatory capability of the model is 97.4%. The effect of *Energy productivity* is negative and shows that the average reduce of *Greenhouse gas emissions* will expect to be 0.6062 tonnes per capita for 1 Euro per KGOE increase in *Energy Productivity*. Effect of *Generation of waste excluding major mineral wastes by hazardousness* is positive and means that *Greenhouse gas emissions* will expect to increase by 0.0029 tonnes per capita for 1 Kg increase of *waste generated*.

Table 5

Model estimation outcomes for EU-15

Variable	Coefficient	Std. Error	t-Statistic	Prob.
X2	-0.6062	0.0682	-8.888	0.0000
X5	0.0029	0.0004	5.912	0.0006
C	9.2072	1.4367	6.408	0.0004

Source: own elaboration

3.3. Model for the group of new EU members (EU-13)

Final (best) specification of the model of *Greenhouse gas emissions* estimated for the group of the new EU members (EU-13) is:

$$\hat{Y} = c(0) + c(1)*X2 + c(2)*X4 + c(3)*X5 \quad (3)$$

where: $\hat{Y}$ is *Greenhouse gas emissions* estimated; X2 is *Energy productivity*; X4 is *Production, value added and exports in the environmental goods and services sector*; X5 is *Generation of waste excluding major mineral wastes by hazardousness*; c(0), c(1), c(2) and c(3) are model parameters

Three of the initially specified factors are included in the model. Due to the strong multicollinearity between factors, three of them, X1, X3 and X6, are removed from the model. Thus, in the final specification, all the parameters are statistically significant and the model fits well empirical data. All the diagnostic tests provide evidences that the assumptions about the residuals are met. The explanatory capability of the model is 88.4%. Estimates of model parameters with important statistics for their quality are presented in Table 6.

Table 6

Model estimation outcomes for EU-13

Variable	Coefficient	Std. Error	t-Statistic	Prob.
X2	-1.583368	0.293319	-5.398109	0.0017
X4	6.19E-05	1.40E-05	4.424038	0.0045
X5	0.004710	0.000873	5.393367	0.0017
C	5.200979	0.658178	7.902087	0.0002

Source: own elaboration

There is a negative effect of *Energy productivity* on the *Greenhouse gas emissions*. The average reduce of emissions will expect to be 1.675 tonnes per capita for 1 Euro per KGOE increase in *Energy Productivity*. On the other hand, there is a positive effect of *Generation of waste excluding major mineral wastes by hazardousness* on the *Greenhouse gas emissions* and an average increase of emissions will expect to be 0.0047 tonnes per capita for 1 Kg increase of *waste generated*. The effect of *Production, value added and exports in the environmental goods and services sector* on the *Greenhouse gas emissions* is positive but almost zero. Actually, this economic sector is yet too weakly developed, particularly in most new EU members. Likely it is the reason for such a weak effect presented in the model.

3.4. Model for Bulgaria alone (BU)

Final (best) specification of the model of *Greenhouse gas emissions* estimated for the group of the new EU members (EU-13) is:

$$\hat{Y} = c(0) + c(1)*X2 + c(2)*X4 \quad (4)$$

where: $\hat{Y}$ is *Greenhouse gas emissions* estimated; X2 is *Energy productivity*; X4 is *Production, value added and exports in the environmental goods and services sector*; c(0), c(1) and c(2) are model parameters

There are only 2 of initially specified factors that are selected in the model of *Greenhouse gas emissions* for Bulgaria. The main reason here is again strong multicollinearity between factors but another reason could be looked for in insufficient development of sectors that are related to the circular economy and promote a low-carbon economy. All the parameters in the final model specification are statistically significant and the model fits well with empirical data. All the diagnostic tests provide evidences that the assumptions about the residuals are met. The explanatory capability of the model is 88.4%. Estimates of model parameters with important statistics for their quality are presented in Table 7.

Table 7

Model estimation outcomes for EU-13

Variable	Coefficient	Std. Error	t-Statistic	Prob.
X2	-61.32133	12.94908	-4.735576	0.0021
X4	0.011672	0.002899	4.026236	0.0050
C	180.7251	24.77203	7.295529	0.0002

Source: own elaboration

Factors with a significant effect on *Greenhouse gas emissions* in Bulgaria are *Energy productivity* and *Production, value added and exports in the environmental goods and services sector*. The first factor has a rather strong negative effect on the emissions and the expected average reduction of emissions is 61.321 tonnes per capita for 1 Euro per KGOE increase in *Energy Productivity*. The effect of the second factor is rather smaller and positive, that means 0.0116 tonnes per capita expected average increase of emissions for 1 Million Euro increase of *production, value added and exports in the environmental goods and services sector*.

4. Conclusions

In this study, we aim to identify the components of the circular economy that support sustainability with a positive impact on greenhouse gas emissions reduce. The circular economy is defined as an economic system applicable at both micro and macro levels, with a focus on the 3Rs – reduce, re-use, recycle and recover – of materials in production and consumption activities to achieve sustainable development. Analysing the results of the four developed models for the respective defined groups of EU countries, it can be stated that the original research hypothesis is proven, and all the selected indicators have a more or less significant impact on the reduction of emissions, but their effects are expressed in different degree for the EU Member States. Production, value added and exports in the environmental goods and services sector seems to cause the smallest effect on the Greenhouse gas emissions. Energy Productivity is one of the most important factors for reducing Greenhouse gas emissions and transition to a low-carbon economy in all the EU countries.

The transformation from linear to a circular economy model causes a positive impact on the reduction of GHG emissions. This is particularly true for the EU-15 group, where some countries have had significant success and implemented new business models related to the transition to a more resource-efficient, less waste-generating and greener economy. In the EU-13 group, the indicators of the circular economy show a weaker effect on the GHG emission reduce. In these catching-up countries with not very well-developed circular economy infrastructure there is a lag and a slowdown in environmental transformation. Most of them have a per capita GHG emissions performance below the EU average, but still, above the 2050 net-zero emissions target, public policy reform to promote the transition to a circular economy needs to be accelerated in these countries. Research outcomes strongly support the fact that the circular economy should be promoted by key stakeholders (academia, government, business, and civil society) in order to promote a sustainable, green economy. The study highlights the need for more widespread implementation of CE models as an opportunity to accelerate the EU environmental transformation and achieve the ambitious 2050 targets. In order to successfully meet the EU's 2030 low carbon and resource efficiency targets, the transition to a circular economy model should become a governments priority. This implies extending the concept not only to waste reduction and recycling, but to break the dependency between economic growth and waste production as well as resource consumption.

For the transition to a clean, green, and environmentally friendly industry to be effective, more committed and adequate actions are needed from governments, especially in the newly acceded countries. This requires workable programs with clear purposes and tools to achieve them. Such strategy must necessarily cover measures as follows:

- Advance projects (including economic incentives) involving technological innovation of processes, new products and materials resulting in 'greening' industrial productions and lengthened life cycle of products. It is necessary to create more incentives for projects that favour the use of less resources, allow longer product life cycle, easier repair and recycling of the products as well as sustainable development of innovative start-up system and innovation clusters.

- Upgrading development of enterprises innovation activity. Grant support needs to focus on the risky part of investments in this area with a focus on creating new products and services, technologies transfer and commercialisation, strengthening collaboration with knowledge-generating units and businesses, and ensuring full participation in the development of the scientific and innovation ecosystem.
- Create a favourable environment for increasing involvement in a separate collection of waste by both consumers and producers. This would facilitate the supply of quality material for recycling and considerably enhance the efficiency of the process.

Authors regard this study as a first attempt to analyse empirically the correlation between the transition to the circular economy and the reduction of GHG emissions, using econometric models. Considering the short time series available up to now for most of the indicators included in the study and missing data for some of the countries, in addition, the models developed will be validated in future using data for the next years. Future confirmation of the research hypothesis and of the results obtained by now is a challenge for further authors' research. This will enhance arguments for promotion and imposing the circular economy concept, especially in EU countries, most of which yet underestimate potential impacts.

References

ADEME. (2014) Economie circulaire: notions, Fiche technique, ADEME Angers, 1-10 [online] Available at:<http://www.ademe.fr/sites/default/files/assets/documents/fiche-technique-economie-circulaire-oct-2014.pdf> (accessed: 20.09.2021).

Aurez, V., Georgeault, L. (2019). L'économie circulaire. Système économique et finitude des ressources. Paris, De Boeck supérieur.

Camilleri, M. A (2021) A circular economy strategy for sustainable value chains: A European perspective. – In: Vertigans, S., Idowu, S. O. (eds.). CSR, Sustainability, Ethics&Gouvernance, Springer, Cham, Zwitzerland.

Cavallo, M. (2018). Circular economy: benefits and good practices. Milan, Edizioni Ambiente.

Clarkson, P. M., Lie, Y., Richardson, G. D., Vasvari, F. P. (2008). Revisiting the relationship between environmental performance and environmental disclosure: An empirical analysis. – Accounting Organisations and Society, 33(4-5), pp. 303-327.

EEA. (2021). Trends and projections in Europe 2021. Report No 13/2021. [online] Available at:<https://www.eea.europa.eu//publications/trends-and-projections-in-europe-2021> (accessed: 20.09.2021).

Ellen MacArthur Foundation. (2012). Towards the Circular Economy (2012), Vol.1, [online] Available at: <https://emf.thirdlight.com/link/x8ay372a3r11-k6775n/@/preview/1?o> (accessed: 10.08.2021).

Esposito, M., Tse, T., Soufani, K. (2018). The circular economy: an opportunity for renewal, growth, and stability. – Thunderbird International Business Review, 60 (5), pp. 725-728. [online] Available at:<https://doi.org/10.1002/tie.21912>.

European Commission. (2018). COM 029 final European Commission Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. On a monitoring framework for the circular economyhttps://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1516265440535&uri =COM:2018:29:FIN(accessed: 6.08.2021).

European Commission. (2019). COM 640 final European Commission Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. The European Green Deal. [online] Available at: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2019%3A640%3AFIN>.

European Commission. (2020). COM/2020/98 final A new Circular Economy Action Plan for a Cleaner and More, Competitive Europe, [online] Available at: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2020:98:FIN&WT.mc_id=Twitter> (accessed: 12.08.2021).

Fricker, A. (2003). Waste Reduction in Focus. – Future, Vol. 35, N 5, pp. 509-519.

Ghisellinia, P., Cialanib, C., Ulgiaticd, S. (2016). A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. – Journal of Cleaner Production, 114 (2016), pp. 11-32

Hours, A., Lapierre, C. (2013) Economie ecologique et equitable:2-ses caracteristiques. – L'encyclopedie du developpement durable, N 186, pp. 1-9.

Ivanova, V., Chipeva, S. (2019), Transition to a Circular Economy Model in the European Union – State and Outlook. – International E-Journal of Advances in Social Sciences, Vol. V, N 14 , pp. 694-701, e-ISSN: 2411-183X.

Marin, G., Miceli, V., Nicolli, F., Zoboli, R. (2014). Recource-efficient green economy and EU policies. European Environment Agency, Luxembourg: Publications Office of the EU.

Martinez-Alier, J. (2012). Environmental justice and economic degrowth: an alliance between two movements. – Capitalism Nature Socialism, 23(1), pp. 51-73.

Pieroni, M., McAloone, T. C., Pigosso, D. (2019). Business model innovation for circular economy and sustainability: A review of approaches. – Journal of Cleaner Production, 215, pp. 198-216. DOI: 10.1016/j.jclepro.2019.01.036.

Pottier, A. (2016). Comment les économistes réchauffent la planète. Paris, Seuil.

Rogers, K., Hudson, B. (2011). The triple bottom line: The synergies of transformative perceptions and practices for sustainability. – OD Practitioner, 43(4), pp. 3-9.

Seidl, D. (2007). General strategy concepts and the ecology of strategy discourses: A systemic-discursive perspective. – Organisation Studies, 28(2), pp. 197-218.

Sneideriene, A., Viederyte, R. (2020) Green growth assessment discourse on evaluation indices in the European Union. – Entrepreneurship and sustainability issue, Vol. 8, N 2, pp. 360-369.

Stahel, W. R. (2010). The Performance Economy (2nd ed.). Palgrave-MacMillan, London.

Velichkova, N. (1981). Statistical methods for studying and forecast development of the social and economic phenomena. Sofia, Scince & Art.

Zielinska, A. (2019). Comparative Analysis of circular Economy Implemantation in Poland and other EU Countries. – Journal of International Studies, 12(4), pp. 337-347.

https://ec.europa.eu/eurostat/web/circular-economy.

https://ec.europa.eu/eurostat/web/sdi/climate-action.

APPENDIX

Table A1

Results of ADF tests for stationarity of the variables

Variables		Groups of countries			
		EU-28	EU-15	EU-13	Bulgaria
Y	Greenhouse gas (GHG) emissions	I(3)	I(3)	I(3)	I(0)
X1	Circular material use rate	I(3)	I(3)	I(0)	I(2)
X2	Energy productivity	I(2)	I(1)	I(0)	I(0)
X3	Resource productivity and domestic material consumption (DMC)	I(2)	I(0)	I(0)	I(3)
X4	Production, value added and exports in the environmental goods and services sector	I(2)	I(2)	I(3)	I(2)
X5	Generation of waste excluding major mineral wastes by hazardousness	I(1)	I(3)	I(2)	I(2)
X6	Recycling rate of all waste excluding major mineral waste	I(1)	I(3)	I(3)	I(2)

Table A2

First order Autocorrelation coefficients of the variables in the models

Variables		Groups of countries			
		EU-28	EU-15	EU-13	Bulgaria
Y	Greenhouse gas (GHG) emissions	0.4	0.51	0.22	0.22
		[0.141]	[0.060]	[0.419]	[0.406]
X1	Circular material use rate	0.46	0.4	0.52	0.59
		[0.087]	[0.135]	[0.056]	[0.031]
X2	Energy productivity	0.6	0.66	0.61	0.59
		[0.018]	[0.016]	[0.025]	[0.031]
X3	Resource productivity and domestic material consumption (DMC)	0.6	0.65	0.21	0.16
		[0.021]	[0.017]	[0.429]	[0.558]
X4	Production, value added and exports in the environmental goods and services sector	0.28	0.44	0.5	0.67
		[0.306]	[0.103]	[0.066]	[0.013]
X5	Generation of waste excluding major mineral wastes by hazardousness	0.52	0.53	0.67	0.6
		[0.054]	[0.052]	[0.014]	[0.028]
X6	Recycling rate of all waste excluding major mineral waste	0.65	0.55	0.73	0.35
		[0.016]	[0.044]	[0.007]	[0.199]