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The Impact of Green Technologies on Transition to Circular Economy

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ABSTRACT

At the end of 2019, the European Commission presented its new long-term vision for the development of the EU. A strategy for growth, a fair environmental transition, a resource-efficient and low-carbon economy are the key highlights of this ambitious strategy for the next decade. Built on the Sustainable Development Goals (SDGs), this transformation goes through a complete change in the production and territorial infrastructure. It covers a whole set of activities, new practices and business models, interconnected and hierarchically ordered, according to their contribution to optimizing the use of raw materials and energy. The circular economy refers to the ability of an economy to grow while the use of resources decreases. The aim of this paper is to analyse the relationship between key indicators presenting the countries progress of transition to the circular economy, and a group of factors related to investment in R&D, green technologies and waste recovery and on this basis to outline the opportunities that the European Green Deal opens up for a faster and more efficient transformation of the economy from linear to circular. Comparative analysis between three clusters of EU countries is made. Time series analysis and correlation analysis along with comparative analysis are applied in the research. The conclusions reached point to the still existing connection with the linear model of development and the delay of the transition to a model of real circular economy. Efforts done till now have yielded results, but for the active "closure" of the circle active policies, synchronized actions by government, business and society are needed. This requires adequate measures taken by the public authorities and decisive reforms in the eco-innovation policy.

Keywords: *Circular Economy, Sustainable Development, Green Technologies, Ecological Transformation, Green Deal*

Introduction

The world of tomorrow will be digital and green, and it is important for the European economy to realize its full participation in it. The COVID crisis is a great challenge, but also a significant opportunity for the transformation of existing business models. With this motivation, the European Commission created "Next Generation EU" (COM 2019), with a budget of over 1

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trillion euros. The funds are not guaranteed but will be given if the principle “money against reforms” is followed and mainly for the green and digital transformation of the economy. The concept of the circular economy and the efficient, responsible, and environmentally friendly use of resources fits perfectly into this context.

It mobilizes the efforts not only of public authorities committed to sustainable development but also of companies aiming at better economic, social, and environmental development.

The first models of circularity that underlie the concept, came from the report of the Club of Rome "The Limits to Growth"(1972). A little later, Stahel and Reday (1976), in a report developed for the European Commission, set out the possibility of a circular model in the context of the need to create jobs and reduce energy consumption.

The theories of Lyle (1974) on regenerative economics and Stahel (2010) on performance economics, which emerged in the 1970s, can be seen as precursors to circular economics. The first mention of the term “circular economy” is from Pearce and Kerry Turner (1990). In the following years, the Cradle-to-Cradle concept introduced by McDonough and Braungart (2002) envisioned a shift from a linear to a circular business model.

This new vision for resources goes far beyond the need for recycling and waste management. It covers a whole set of activities, new practices, and business models, interconnected and hierarchical, according to their contribution to optimizing the use of raw materials and energy (Ivanova, 2020).

Among the many definitions of the concept and the various aspects of considering this notion, this report adopts the definition given by ADEME (2014), according to which “the circular economy is an economic system of exchange and production in which at each stage of the life cycle the product (good or service) aims to increase resource efficiency and reduce the harmful effects on the environment, ensuring the well-being of individuals.”¹

The circular economy refers to the ability of an economy to grow while the use of resources decreases (Martinez-Alier, 2012). The transition to a circular model aims to achieve "dematerialization"- an absolute or relative reduction in the number of materials used as well as the amount of waste with the aim to provide a better alternative to the dominant economic development model, so called “take, make and dispose” (Ness, 2008). However, the concept of a circular economy goes a step further. In it, the products not only are not discarded, but they are made in a manner that they can be easily repaired, turned into other products, or combined. Businesses are responsible for their products long after they sell them, and the key principle is a cooperation between different industries so that each of them can use waste materials from the others. The circular economy provides basic guidelines for what needs to be done to significantly and permanently reduce the resource dependence of the economy and move towards overcoming the scarcity of non-renewable natural resources. It is a new way of perceiving the existing links between markets and economic entities and it rethinks the perception of waste as a natural resource.

The transition to a circular economy aims to go beyond the limits of the linear model and to impose responsible and efficient use of natural resources and materials, new business models

¹ <http://www.ademe.fr/sites/default/files/assets/documents/fiche-technique-economie-circulaire-oct-2014.pdf> , accessed 24.01.2021

related to the production and consumption of products corresponding to the concept of eco-design, as well as prevention, recycling, and hierarchical waste management and use. In essence, the transition to a circular economy is an economic issue affecting access to (or sustainability of) raw materials, the reindustrialization and further digitalization of Europe, the creation of new jobs and the challenges of climate change, energy security and scarce resources. (Stahel, 2010)

The growing consumption of resources and the environmental consequences it causes require a change in the economic model (Ellen MacArthur Foundation, 2015). The concept of a circular economy is part of this change. It is a closed cycle covering each of the three areas: supply and responsible choice of producers, consumer demand and behaviour, and waste management.

Such an approach should include a global, systemic and integrated vision (Costanza, 1991), changing the model with a new one and adopting the principle of systematicity and connectivity of individual systems (figure 1).

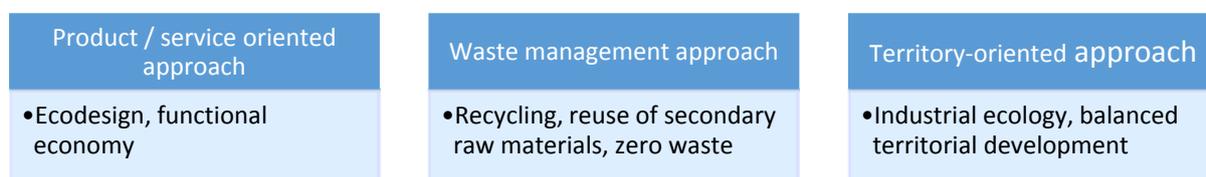


Figure 1. Scope of the circular economy model

In order to meet successfully the EU's resource efficiency targets by 2030, the transition to a circular economy model should become a national priority. This implies extending the concept not only to reducing waste and recycling (EC, 2014) it but to breaking the link between economic growth and waste production, as well as resource consumption (Capozza & Samson, 2019).

Most of the business practices so far come down to achieving more with less. In contrast, the circular economy relies on reuse. Its essence goes far beyond just waste management or environmental protection. At the heart of this concept is the effort to maximize the benefits of an already created product throughout its life cycle.

In 35 years, the volume of extracted resources has increased by 65% and about 50% of this volume are non-reproducible resources (OECD, 2010).

To date, the EU imports about six times more materials than it exports (EEA, 2018). While maintaining the current consumption pattern in the EU, the environmental footprint will triple by 2050 (Global Resources Outlook, 2019).

Rare metals (such as yttrium, indium, gallium) are becoming increasingly scarce and highly concentrated in a small number of countries, while their application in industries related to the production of equipment for green energy production is becoming more widespread.

Growth in consumption and depletion of natural resources have serious economic consequences, including rising commodity prices. Faced with this challenge, the need to change the model seems undeniable. The goal of the ecological transition to a circular economy has the immediate task of optimizing the management of resources - materials and energy. However,

the effects of such a transformation go far beyond this task and are projected on the results of combating climate change, a new type of economic growth and a new quality of life.

Unlike the linear economy model (extraction, production, consumption, waste), the circular economy produces goods and services, limiting the use of raw materials and energy on the one hand and reducing waste generation on the other. In order to meet the modern challenges of the economy, related on the one hand to the scarce, exhaustible and increasingly expensive resources and on the other to the environmental needs, the circular economy is based on three fundamental principles - creation and development of natural capital, optimization of resource consumption and the creation of "closed systems" with minimal negative externalities.

This is a practice-oriented concept. Fundamental in this model is the production of products designed for long-term use, with the most efficient use of resources. They shall be designed in such a way that they can be repaired, including by ensuring the maintenance of the production of spare parts for them. Products must be suitable for re-use, for shared use and with the longest possible life. Last but not least, the circular economy requires the production of such products that can be decomposed and their elements or subsystems reused as components in the production of new products. Recycling (as far as possible) of those parts that cannot be reused or repaired is a key factor.

The EU's efforts to build a sustainable, low-carbon and competitive economy with efficient use of resources are closely linked to the concept of a circular economy. In December 2015, the European Commission (EC) adopted a package of measures "The Circular Economy Action Plan", which includes a Communication, Action Plan and Proposals for revision of waste legislation. (EC, 2015)

With the announcement of the European Green Deal (2019) and the ensuing in March 2020 EU Communication "A New Action Plan on the Circular Economy - for a cleaner and more competitive Europe"(EC, 2020), prioritizing the transition to a circular economy model takes on a new meaning.

The European Union has taken the lead market initiative and identified several market sectors that are future areas of high growth in Europe. Most of these sectors, such as sustainable construction, recycling, bio-products and renewable energy, are key markets for eco-innovation. Making such a transition is an opportunity to ecologize the economy and to create new competitive advantages. For this reason, action in the circular economy is directly linked to key EU priorities, including jobs and growth, the investment agenda, climate and energy, industrial innovation and the renewed EU industrial policy strategy (EC, 2017). At the same time, the implementation of this Green Deal will contribute to the achievement of the 2030 Sustainable Development Goals, and in particular the Goal 12 for the establishment of sustainable consumption and production patterns.

Technology and eco-innovation are the two most powerful pillars in the accelerated development of the green economy. Awareness of the fact that the demand for organic products is constantly growing and that the opportunities to serve the "green markets" must follow it is essential for successful future economic development. The EU Eco-Innovation Action Plan (EC, 2011) defines eco-innovation as any type of innovation that results from or aims at significant and visible progress towards sustainable growth, by reducing the harmful impact on the environment, enhancing the resilience of environmental impacts or achieving more efficient and responsible use of natural resources. The Eco-Innovation Observatory (2014) identifies

eco-innovation as the introduction of any new or significantly improved product (good or service), process, organizational change or marketing decision that reduces the use of natural resources (including materials, energy, water and land) and reduces the release of harmful substances throughout the life cycle. In other words, evolving products, techniques, services and processes that reduce carbon emissions, use natural resources efficiently, promote recycling, and so on.

In order to meet these challenges, profound structural transformations are required, both in the technologies used so far and to a very large extent in the use of new technologies, innovations and the creation of new products and services relevant to the needs of the 21st century, guaranteeing the possibility of sustainable development.

Such a transition cannot happen quickly, easily and automatically. EU countries have different traditions, implement different policies supporting the environmental transition. They also have very different production structures that require different adaptation times.

In the transition to a more circular economy, monitoring key trends and patterns is a key tool for understanding how the various elements of the circular economy evolve over time, for identifying success factors in the Member States, and for assessing whether sufficient action has been taken. The results of the monitoring should provide a basis for setting new priorities towards the long-term goal of a circular economy (Bourg, & Arnsperger, 2016).

Methodology

The aim is to analyse the relationship between the 3 key indicators presenting the countries progress of transition to the circular economy and a group of factors related to investment in R&D, green technologies and waste recovery and on this basis to outline the opportunities that the European Green Deal opens up for a faster and more efficient transformation of the economy from linear to circular.

The working hypothesis of the study states: countries, including business and public authorities, that invest actively in green technologies are making more serious progress in transforming the economy into circular one, which is reflected in the dynamics of monitored indicators.

In the transition to more circular economy, monitoring key trends and patterns is a key tool for understanding how the different elements of the circular economy evolve over time, for identifying success factors in the Member States and for assessing whether sufficient action has been taken. There is currently no “universally recognized method for measuring the efficiency of a country or company in the transition to circular economy, nor holistic tools for monitoring and supporting this process” (EEA, 2019).

The methodology adopted by Eurostat for monitoring the progress of transition to a circular economy model identifies four groups of indicators (EC, 2018). These encompass a set of ten key indicators which cover each phase, i.e., production, consumption, waste management and secondary raw materials, as well as economic aspects – investments and jobs, and innovation.

To fulfil the purpose of this study, it is important to capture various aspects of circular economy. Impact of Green Technologies on Transition to Circular Economy has been investigated based on a set of key indicators that are monitored by Eurostat. For the purpose of this study, three of indicators for circular economy were selected - *Resource productivity and domestic material consumption (SDG_12)*, *Recycling rate of municipal waste (CEI_WM011)*

and Circular material use rate (CEI_SMR030). Each of them reflects a corresponding aspect of the transformation of the economy into a circular one. Resource productivity and domestic material consumption and Circular material use rate are associated with change in the production model, and Recycling rate of municipal waste shows changes in consumer behavior.

The selection of indicators is made in accordance with the principles and goals of circular economy, on the one hand, and the framework of indicators adopted by the European Commission, on the other. Since waste management and recovery is crucial, Recycling rate of municipal waste (CEI_WM011) is used. The EC definition is as follows: Recycling rate of municipal waste gives an indication of how waste from final consumers is used as a resource in the circular economy. Municipal waste reflects mainly waste generated by the final consumers as it includes waste from households and waste from other sources that is similar in nature and composition to household waste (EU, Eurostat, https://ec.europa.eu/eurostat/cache/metadata/EN/cei_wm011_esmsip2.htm)

The Circular Material Use Rate (CEI_SMR030) is an indicator, which the EC perceived as one of the indicators for a circular economy, shows the ratio between the re-used resources in the country and the total consumption of resources (in %). According to Eurostat, this indicator expresses the relative share for a given raw material, how much of its input into the production system comes from recycling of "old scrap" i.e. scrap from end-of-life products (EU, Eurostat, https://ec.europa.eu/eurostat/cache/metadata/EN/cei_srm010_esmsip2.htm).

The Resource productivity and domestic material consumption (DMC) indicator was added, being a part of the indicators monitored under Goal 12 (Responsible production and consumption) from the SDGs, as it gives an indication of resource efficiency, which is one of the immediate tasks under a circular economy.

Correlation between each of the 3 key indicators mentioned above and set of factors for encourage the transition to circular economy has been studied. The factors are related to the domestic expenditures for R&D (public and businesses), Environmental protection investments, related to new, green, environmentally friendly technologies and resource efficiency. The study group of factors includes:

<i>sdg_09_10</i>	<i>Gross domestic expenditures for R&D – all expenditures (% of GDP)</i>
<i>sdg_09_101</i>	<i>Gross domestic expenditures for R&D – business enterprise sector (% of GDP)</i>
<i>cei_cie010</i>	<i>Gross investments in tangible goods (% of GDP)</i>
<i>env_pat</i>	<i>Patents related to environmental protection (% of all new technologies)</i>
<i>env_ac_epigg</i>	<i>Environmental protection investments of general government – total (in millions euro)</i>
<i>env_ac_epigg_w</i>	<i>Environmental protection investments of general government – waste management (in millions euro)</i>
<i>env_ac_epigg_ww</i>	<i>Environmental protection investments of general government – wastewater management (in millions euro)</i>
<i>env_ac_epissp</i>	<i>Environmental protection investments of corporations – total (in million euro)</i>
<i>env_ac_epissp_w</i>	<i>Environmental protection investments of corporations – waste management (share of total %)</i>
<i>env_ac_epissp_ww</i>	<i>Environmental protection investments of corporations – wastewater management (share of total %)</i>

Pearson's correlation coefficients have been applied and tests for their statistical significance at 5% significance level have been conducted.

Based on the outcomes for year under study, three clusters are drawn with different number of countries within each one, corresponding to three models of transition to circular economy. Cluster 1 includes Bulgaria and Estonia, Cluster 2 includes 12 countries which, with few exceptions (Belgium, Finland, Sweden, Portugal), are the majority of the new Member States, and Cluster 3, comprising 14 countries, covers mainly old Member States and three new Member States (Czech, Slovenia, Cyprus) that joined EU after 2004. (see Ivanova & Chipeva, 2019).

Data used in the research has been summarized for the separate clusters using mean value of each indicator included in the analysis respectively. Dynamics of 3 key indicators presenting the countries progress of transition to the circular economy, namely *Circular material use rate*, *Resource productivity and domestic material consumption* and *Recycling rate of municipal waste*, has been explored over 9-years period – from 2010 to 2018. Average annual Growth Rate (AAGR) of indicators for each cluster has been calculated. Significant problems related to the lack of data over the years for some of indicators monitored and used for assessing countries progress of transition to circular economy have been encountered. One of the reason is likely due to serious delay of data supplying regarding some countries. Due to lack of data rather short time series used in the analysis cause problem on some of the statistical tests applied for proving statistical significance of correlation coefficients as making the Null hypothesis much conservative. Thus, statistical significance of most correlation coefficients cannot be proven, though their high value.

Results and discussion

Over the past 9 years, the EU's countries have been increasing its resource productivity and recycling rate of municipal waste. This trend is observed in all three clusters, although the results differ substantially in separate aspects. The explanation can be found in measures applied by the EU in the field of waste, new rules for plastics, rising prices of resources on international markets and the gradual change in the behaviour of economic operators.

The observed trends, however, need to be interpreted with caution, as they might not be entirely due to the success of environmental policies.

The most insignificant is the progress in terms of *Circular material use rate*. The reason can be found in the yet poorly developed market of secondary raw materials in some of the countries, the lack of clear regulation of this market and insufficient quantity of materials for recycling, especially in cluster 1.

Charts of average annual growth rate of all three indicators follow a positive trend, but it is too weak, the differences between the clusters remain and in general the transition to a circular economy is slow.

Three key indicators are presented on fig.2. All the indicators show slight positive trend over time. Growth of *Resource productivity and domestic material consumption* is slowest compared to the rest two indicators – average annual growth rate (AAGR) of the indicator is only 0,2%. AAGR of *Circular material use rate* is 4,8% and *Recycling rate of municipal waste* annual average increase is 4,2%

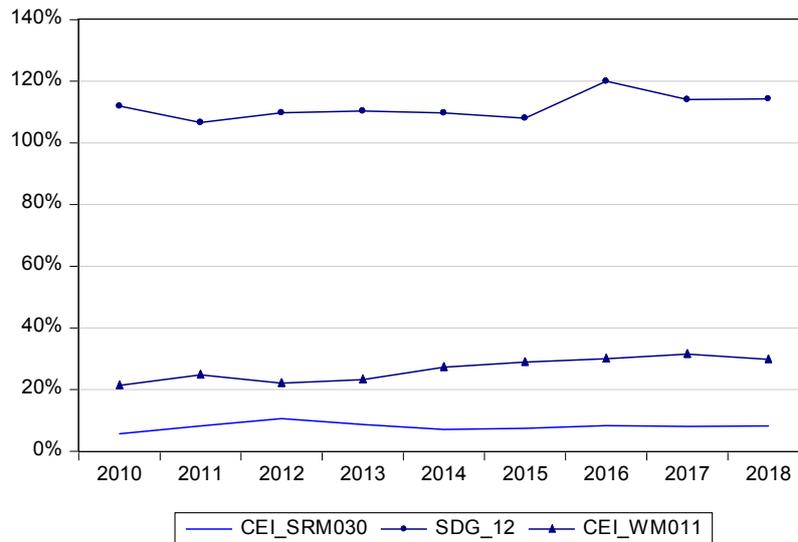


Figure 2. Trend lines of Circular material use rate, Resource productivity and domestic material consumption and Recycling rate of municipal waste for Cluster 1 for period 2010-2018
 Source: Eurostat and author’s calculations

For the countries of Cluster 2 only the indicator *Recycling rate of municipal waste* shows a bit higher increase over time – AAGR is 6,95% (fig.3). The rest two indicators have slight positive increase – AAGR of *Circular material use rate* is 1,64% and AAGR of *Resource productivity and domestic material consumption* is only 0,24%.

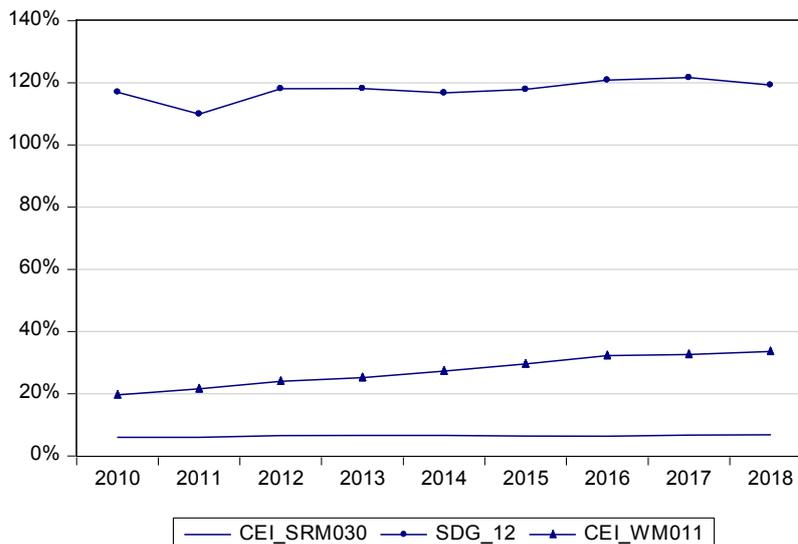


Figure 3. Trend lines of Circular material use rate, Resource productivity and domestic material consumption and Recycling rate of municipal waste for Cluster 2 for period 2010-2018
 Source: Eurostat and author’s calculations

The countries in the third cluster show very slight increase of the analyzed indicators (fig.4). *Circular material use rate* shows the smallest increase – AAGR is 1,24%. The rest two indicators show a little bit larger growth rate – AAGR of *Resource productivity and domestic material consumption* is 2,86% and AAGR of *Recycling rate of municipal waste* is 2,93%.

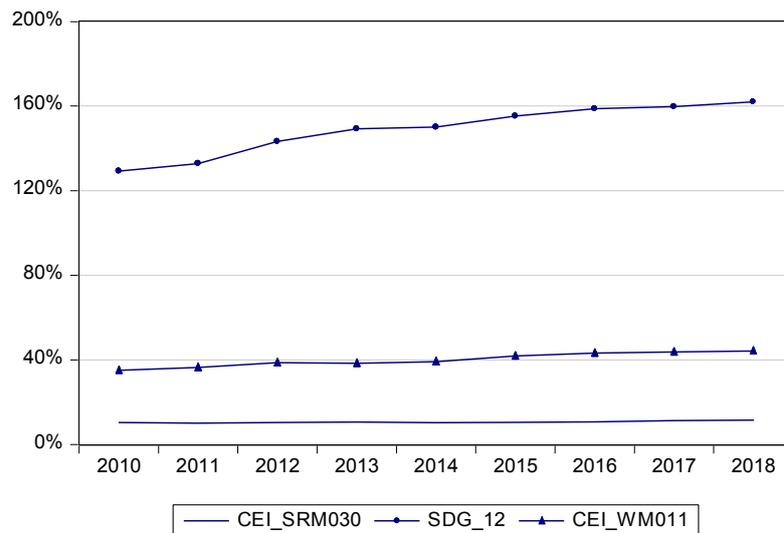


Figure 4. Trend lines of Circular material use rate, Resource productivity and domestic material consumption and Recycling rate of municipal waste for Cluster 3 for period 2010-2018

Source: Eurostat and author's calculations

It can be concluded that there is a positive trend of the indicators measuring the transformation of economy into circular one for all the EU countries. This tendency holds for all the clusters but the growth is too weak, the differences between the clusters remain and in general the transition to a circular economy goes slowly. The process becomes more tangible after 2015, that can be explained by introduction of the circular economy as leading priority in EU environmental policy.

Significant progress is established for the *Recycling rate of municipal waste* in all three clusters, but mostly in Cluster 2. The separate waste collection, the construction of adequate infrastructure in the sector, the application of new modern technologies in the separation of municipal waste, the awareness and increasing public sensitivity to the problem gives good results.

The results in terms of Growth of Resource productivity and domestic material consumption are worrying. Growth rate of this indicator is very low in all three clusters but there is a special lag in Cluster 1. Bulgaria and Estonia, which form this cluster, remain largely attached to a linear development model, with low Resource productivity, highly dependent on yield and consumption of primary resources.

Bivariate Pearson's Correlation Coefficients between indicators for country progress of transition to the circular economy, *Circular material use rate*, *Resource productivity and domestic material consumption* and *Recycling rate of municipal waste*, and set of selected factors are presented in the tables below (table1-3). Values in brackets are p-values of the *t*-tests for statistical significance of the correlation coefficients. There is considerable part of correlation coefficients that show moderate to strong correlation between indicators and some of factors ($R \geq 0,5$) but their statistical significance could not be proved due to insufficient longitude of time series used in the analysis.

Regarding cluster 1, results are too contradictory. There is very strong positive correlation of *Recycling rate of municipal waste* with *Gross investments in tangible goods* ($R=0,9375$). It is due to the efforts of the States to build a new, modern infrastructure related to waste management.

The significant positive correlation of *Recycling rate of municipal waste* with *Environmental protection investments of general government – wastewater management*, as well as of *Recycling rate of municipal waste* with *Gross investments in tangible goods* ($R=0,9375$) is proven (table 2). At the same time there is weak relationship between expenditures for green technologies and the indicators. Since the positive trend of the indicators analyzed here it is possible some other factors (apart from green technologies) to have a more significant impact on the transformation in Bulgaria and Estonia.

Table 1. Pearson's Correlation Coefficients between indicators for progress of transition to the circular economy for countries in Cluster 1.

Factors	Indicators for country progress of transition to the circular economy		
	CEI_SMR030	SDG_12	CEI_WM011
SDG_09_101	0.4781 [0.3375]	-0.5739 [0.2337]	0.1477 [0.7800]
SDG_09_10	0.1854 [0.7250]	-0.8083* 0.0516	0.3783 [0.4596]
CEI_CIE010	-0.7296** [0.0998]	-0.4872 [0.3270]	0.9375* [0.0057]
ENV_PAT	-0.4946 [0.3185]	-0.5777 [0.2298]	-0.6888 [0.1301]
ENV_AC_EPIGG	-0.1247 [0.8139]	-0.4893 [0.3245]	0.1724 [0.7439]
ENV_AC_EPIGG_W	-0.4717 [0.3449]	-0.8000* [0.0560]	-0.7821** [0.0660]
ENV_AC_EPIGG_WW	0.3921 [0.2965]	0.3361 [0.5148]	0.5845 [0.2230]
ENV_AC_EPISSP	-0.3286 [0.3879]	-0.3775 [0.4606]	0.4913 [0.3223]
ENV_AC_EPISSP_W	0.3387 [0.3725]	-0.5196 [0.2906]	0.0957 [0.8568]
ENV_AC_EPISSP_WW	0.4819 [0.1889]	0.1911 [0.7167]	0.4153 [0.4128]

*Correlation coefficient is statistically significant at 5% significance level

**Correlation coefficient is statistically significant at 10% significance level

Source: Author's calculations

In the cluster 2 significant to strong correlation is detected of the *Circular material use rate* with the *Gross domestic expenditures for R&D – all expenditures* (0,7884), the *Patents related to environmental protection* (0,6740), the *Gross domestic expenditures for R&D – business enterprise sector* (0,6334) and the *Environmental protection investments of general government – total* (0,5213) (tabl.2). The *Resource productivity and domestic material consumption* correlates strongly positive with the *Environmental protection investments of general government – total* (0,7848) and significantly positive with the *Gross domestic expenditures for R&D – business enterprise sector* (0,5054). Strong correlation of the *Recycling rate of municipal waste* with the *Gross domestic expenditures for R&D – business enterprise sector* (0,7755), the *Environmental protection investments of general government – total* (0,8337) and the *Environmental protection investments of general government – wastewater management* (0,6966) is proven.

Table 2: Pearson's Correlation Coefficients between indicators for progress of transition to the circular economy for countries in Cluster 2.

Factors	Indicators for country progress of transition to the circular economy		
	CEI_SMR030	SDG_12	CEI_WM011
SDG_09_101	0.6334** [0.0670]	0.5054 [0.1651]	0.7755* [0.0141]
SDG_09_10	0.7884* [0.0116]	0.0080 [0.9836]	0.2884 [0.4516]
CEI_CIE010	0.2974 [0.4370]	0.2197 [0.5699]	0.1321 [0.7346]
ENV_PAT	0.6740** [0.0465]	0.0919 [0.8140]	0.4704 [0.2012]
ENV_AC_EPIGG	0.5213 [0.1500]	0.7848* [0.0122]	0.8337* [0.0052]
ENV_AC_EPIGG_W	0.0420 [0.9144]	0.3375 [0.3744]	0.2936 [0.4432]
ENV_AC_EPIGG_WW	0.3921 [0.2965]	0.4522 [0.2216]	0.6966** [0.0371]
ENV_AC_EPISSP	-0.3286 [0.3879]	0.1332 [0.7326]	0.3238 [0.3952]
ENV_AC_EPISSP_W	0.3387 [0.3725]	0.0494 [0.8995]	0.2327 [0.5466]
ENV_AC_EPISSP_WW	0.4819 [0.1889]	0.1275 [0.7436]	0.5519 [0.1233]

*Correlation coefficient is statistically significant at 5% significance level

**Correlation coefficient is statistically significant at 10% significance level

Source: Author's calculations

In the cluster 3 there is strong and very strong positive correlation of the Resource productivity and domestic material consumption correlates with the Gross domestic expenditures for R&D – business enterprise sector (0,9134), the Environmental protection investments of general government – wastewater management (0,9260), the Gross investments in tangible goods (0,8072), the Environmental protection investments of corporations – wastewater management (0,8113) and the Gross domestic expenditures for R&D – all expenditures (0,7953). Strong positive correlation of the Recycling rate of municipal waste with the Gross domestic expenditures for R&D – business enterprise sector (0,8187), the Environmental protection investments of corporations – wastewater management (0,8563) and the Gross domestic expenditures for R&D – business enterprise sector (0,7148) is proven. In addition, there is significant correlation of the Recycling rate of municipal waste with the Gross domestic expenditures for R&D – all expenditures (0,6198) and the Gross investments in tangible goods (0,6279).

Table 3. Pearson's Correlation Coefficients between indicators for progress of transition to the circular economy for countries in Cluster 3.

Factors	Indicators for country progress of transition to the circular economy		
	CEI_SMR030	SDG_12	CEI_WM011
SDG_09_101	0.5402 [0.1668]	0.9134* [0.0015]	0.8187* [0.0129]
SDG_09_10	0.2860 [0.4922]	0.7953* [0.0183]	0.6198** [0.1012]
CEI_CIE010	-0.2918 [0.4831]	0.8072* [0.0154]	0.6279** [0.0955]
ENV_PAT	-0.7071* [0.0498]	-0.8596* [0.0062]	-0.8136* [0.0140]
ENV_AC_EPIGG	-0.4485 [0.2650]	0.6439** [0.0849]	0.7148* [0.0463]
ENV_AC_EPIGG_W	0.2032 [0.6292]	0.2959 [0.4767]	0.0499 [0.9066]
ENV_AC_EPIGG_WW	0.5928 [0.1214]	0.9260* [0.0010]	0.9271* [0.0009]
ENV_AC_EPISSP	0.0160 [0.9699]	-0.5984 [0.1171]	0.3770 [0.3571]
ENV_AC_EPISSP_W	0.3157 [0.4461]	0.2841 [0.4953]	0.2793 [0.5029]
ENV_AC_EPISSP_WW	0.6669** [0.0708]	0.8113* [0.0145]	0.8563* [0.0066]

*Correlation coefficient is statistically significant at 5% significance level

**Correlation coefficient is statistically significant at 10% significance level

Source: Author's calculations

As can be seen from the data in table 2 and 3 correlation analysis shows significant to strong positive correlation between the studied indicators and most of the selected factors for the second and third cluster. Considering that the 3rd cluster is closest to circular economy model (without a complete transformation), the analysis provides evidence that serious investments in science, green technologies and the environment, both on the part of the public and the private sector, lead to increase efficiency in the resources use, and hence to positive environmental effects.

The existing incompleteness in the macro data for some of indicators considered in this research rise difficulties for statistical analysis and more specifically for providing statistical evidence for significant relationship between investments in eco-technologies and the transition to a circular model of the economy. That in turns along with time lag in the introduction and adaptation of green technologies, the small relative share of the sector related to the production of eco-technologies in the national economy, the still weak effect of the accompanying productions raises a lot of scepticism and leads to an underestimation of the possibilities of the circular economy in the national strategies for economic recovery. It can be seen well in cluster 1 results.

Looking for analogies with digital and communication technologies, it can be assumed that new environmental technologies will be the engine of future growth and the core of the new development model, provided that their mass implementation is stimulated through green investments, accompanied by profound production and organizational changes to ensure the

effectiveness of the application of these new innovative technologies. This is best expressed in cluster 2 results.

Bulgaria stands in the cluster of the countries furthest from the circular economy model. Along with country-specific reasons, the low productivity and unsatisfactory performance of the research and innovation system have a serious contribution to this lag in the process of ecological transformation, both in terms of research organizations and business separately and in terms of the interaction between them.

Policy fragmentation, the need to continue the reforms, overcoming underfunding and developing a sustainable national ecosystem are actions that could help to overcome this serious backlog.

The country is in the group of “modest” innovators with an innovative performance of 38% of the European average². Insufficient financing of the sector – 27th in the EU in terms of the share of public expenditure on R&D (0.84% of GDP in 2019), as well as the weak innovation activity of companies, are a factor holding back the transformation. The data from 2018³ on the innovation activity of enterprises shows a decrease of 15% compared to 2011 of SMEs with their innovation; a 16% drop in SMEs with technological (product and / or process) innovations; a decrease of 5.6% of SMEs with non-technological (marketing and organizational) innovations; a decrease of 81% when selling new products for the market and new for the company as a share of turnover; and a 27% drop in enterprises with access to ICT training.

In the field of **technological innovation** possible and necessary direction of actions by the State, is:

- to reorient existing national resources and to allocate additional funds to national research and practical programs related to the accelerated development of eco-technologies and technological renewal of “green industries”. It is important to focus on promising, competitive and exporting sectors, although they do not necessarily have the fastest and highest returns in the short or even medium term;
- the creation of a national program “Innovation in the future” to finance research projects and developments;
- the creation of a public investment fund supporting this type of innovative green investments. Its aim must be SMEs specializing in these new technologies, which, despite the urgent need for innovation, fail to obtain financing and increase their capital in order to develop, especially at the stage of transition to industrial production. Such a fund can be a direct minority shareholder in these companies, and after reaching their stable stage of development and sufficient profitability to withdraw.

SMEs in sectors with potential for a circular economy need clearly defined, concretely defined measures to facilitate their transition to environmentally friendly industries. This support should be aimed at improving resource efficiency, more competitiveness and easier market access for their green products.

Financial support for SMEs could be provided through three lines: innovation, guarantees and co-investment. Here, too, the variety of incentive measures is big – preferential interest

² Eco-innovation Observatory: eco-innovation index, 2019

³ Source: National Statistical Institute

rates, a relieved lending regime for “green investments”, financial assistance for innovative projects of environmental and social significance, export support, etc.

Conclusion and recommendations

The conclusions reached point to the still existing connection with the linear model of development and the delay of the transition to a model of a real circular economy. In all three clusters there is a positive trend in the dynamics of indicators measuring the transformation of the economies of EU countries into circular ones. The process is becoming more tangible after 2015, which can be explained by the introduction of the circular economy as a leading priority in EU environmental policy.

The efforts done till now have yielded results, but for the active „closure“ of the circle, are needed active policies, synchronized actions by government, business and society. This requires adequate measures taken by the public authorities and decisive reforms in the eco-innovation policy.

The degree of awareness of the importance and significance of the problems related to the ecological transformation of the economy and in particular the transition to a model of a circular economy varies from one EU country to another. The initial hypothesis about the importance of green technologies is confirmed by the values of the correlation coefficients, especially in cluster 3.

Business are interested in innovation and new technologies and are aware of the need for more and more investments in this direction.

That is why, it is more than necessary for the state to play a decisive role and to direct much more public resources to projects related to clean, resource-saving technologies, eco-design and new product that meet the standards of circularity.

Uptake of innovations in business can be supported using funding instruments, regulations and direct infrastructure investment.

Governments can stimulate knowledge diffusion by replicating projects and stimulating the circulation of insights, for example through standardization and workshops organized by intermediary actors. Governments can support societal adoption of innovations by developing positive narratives that promote social acceptance and by involving societal groups through public participation methods.

In order to build such a model and make it successful, it requires several consecutive steps:

- Importance of the environment for the development of innovation and research and the need for measures for the purposeful development of a national research and innovation ecosystem. Research and innovation policies and measures are fragmented and insufficiently coordinated, there are no sustainable and well-developed links and interactions between actors, which hampers the efficient use of resources, and the full participation in the European and global science and innovation space.
- Launching and imposing the idea of the eco-concept related to the creation of products with a longer life, suitable for reuse, repair or recycling. In this direction, the promotion of good practices will mobilize business and contribute to a more radical change in production models. The adoption of specific quantitative targets for the recycled materials used for different sectors is a pass in the right direction to mobilize producers.

- Promotion (including economic incentives) of projects related to the technological innovation of processes, new products and materials, leading to “greening” of industrial production. Intensifying the interaction between business, research organizations and universities and capitalizing on its results. The largest share of enterprises creates innovations independently or in partnership with other enterprises. The partnership with the scientific organizations has an informal character and is far from the full use of its potential for the innovative and R&D development of the Bulgarian enterprises and economy;
- It is necessary to create more incentives for projects that favor the use of few resources and allow a longer product life cycle and easier repair and recycling; Sustainable development of innovative start-up system and innovation clusters. The results and evaluation of the investments made so far in this area show the need to create conditions and prerequisites for sustainable development and viability of the supported so far innovative start-ups and innovation clusters, skills and conditions for technology transfer and marketing of products and services; Upgrading development of the innovation activity of the enterprises. Grant support needs to focus on the risky part of the investment in this area with a focus on creating new products and services, technology transfer and commercialization, strengthening collaboration with knowledge-generating units and businesses, and ensuring full participation in the development of the scientific and innovation ecosystem;
- Investments in key resources and natural capital, such as: water, renewable energy, marine resources, biodiversity and ecosystem services, sustainable agriculture, forests, waste and recycling. They could become areas of future economic growth and world markets (EC, 2020).
- Combining market and regulatory instruments: environmental taxes, elimination of environmentally harmful subsidies, mobilization of public and private financial resources, investment in skills and green jobs. It is necessary to develop indicators that reflect progress in a broader sense (environmental and social) and that can be applied alongside the GDP.

The change to a sustainable and circular economy needs to combine the ambitious environmental goals with stable social requirements and to create a coherent legal framework for sustainable production and consumption. This suggests that, in parallel with private sector initiatives, public authorities should coordinate, support and promote environmental, economic and social changes leading to accelerating this transition. The lesson learned from successful experiences is that the transition towards CE comes from the involvement of all actors of the society and their capacity to link and create suitable collaboration and exchange patterns.

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