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Sustainable Consumption and Production: Exploring the Links with Resources Productivity in the EU-28

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Abstract: In the framework of the European Union's Sustainable Development Policy, the promotion of sustainable consumption and production patterns has been a key issue. The explanation is given by their capacity to address social and economic development within the carrying capacity of ecosystems and decoupling economic growth from environmental degradation. The EU has established an extensive range of proposals on sustainable consumption and production (SCP), which include an energy- and resource-efficient economy, circular economy, waste prevention and recycling, among others. This paper contributes, by using both factorial and regression analysis, to the identification of fundamental constructs that define SCP in the EU-28, their links with resource productivity and the role of governments and enterprises in its improvement by means of investment in research, development and innovation over the period 2001–2018. Some recommendations to policy-makers are proposed in the paper in order to take actions directly on SCP, such as promoting the use of recycled raw materials in public works, or imposing the need for Ecolabel certification to contract with public administration.

Keywords: sustainable consumption; sustainable production; research and development; factorial analysis; regression analysis

1. Introduction

1.1. Literature Review

The importance of developing both sustainable consumption and production (SCP) patterns has already been shown, within the framework of the European Roundtables for Cleaner Production, in the Oslo Symposium 1994. It defined SCP as "the use of services and related products, which respond to basic needs and bring a better quality of life while minimizing the use of natural resources and toxic materials as well as the emissions of waste and pollutants over the life cycle of the service or product so as not to jeopardize the needs of further generations" [1].

The concept of SCP was subsequently recognized in the Johannesburg Plan of Implementation, enacted in 2002, at the World Summit on Sustainable Development. On that occasion, the need for implementing important changes in the way societies consume and produce is emphasized in order to be able to achieve sustainable development. More specifically, it highlighted "the encouragement and promotion of a 10-year framework of programmes (10YFP) in support of regional and national initiatives to accelerate the shift towards sustainable consumption and production to promote social and economic development within the carrying capacity of ecosystems" [2] (p. 7). This 10 year framework of programs on sustainable consumption and production patterns was adopted at the Rio+20 Conference [3].

The 2030 Agenda for Sustainable Development was adopted in 2015, with 17 goals and 169 targets. Goal number 12 aims to ensure sustainable consumption and production patterns. For this, the document pointed out "We (Countries) commit to making fundamental changes in the way that our societies produce and consume goods and services" [4]. The objective was to achieve, among others, the following priority aimed by 2030: the sustainable management and efficient use of natural resources, the reduction of waste generation by means of prevention, reduction, recycling and reuse as well as the provision of relevant information for the sustainable development and the adoption of lifestyles in harmony with nature.

In order to carry out specific actions that promote SCP patterns, a better understanding of the factors that contribute to SCP is important. In this context, Bengtsson et al. [5] identified two approaches: efficiency and systemic. The efficiency approach is focused on technological improvement and informed consumer choice, in which the promotion of more efficient production methods and products is the basis. On the other hand, the systemic approach emphasizes overall volumes of consumption, distributional features, as well as, institutional and related social changes.

Haas et al. [6] pointed out the importance of increasing the circularity of the economy, with the aim of achieving SCP, by means of the following strategies: recycling and reuse, the switch from fossil fuels to renewable energies, and the reduction of the overall level of resource consumption. Recycling entails end-of-life waste reprocessing into products, materials or substances that can be reused in the chain of production and consumption. This contributes to the reduction of resources consumption in the economy, priority issue in the present environment of limited resources in the nature. On the other hand, fossil fuels are converted, in production processes, into greenhouse gas emissions and other residues which cannot be recycled into the economy, with the consequent environmental problems related to global warming and climate change. Hence, the importance of turning towards renewable sources characterized by being widely available, naturally replenished and involving a lower environmental impact. Finally, the resources consumption reduction is essential, as it has been established previously, in the present context of resources limitation.

Similarly, Nash [7] pointed out that resource use, available technologies, product design, and consumer demand as the main challenges in order to achieve SCP. In this context, smarter consumption, learner production, and global action were the main actions developed by the European Union (EU). Smarter consumption is related to promoting producers' and consumers' awareness of the environmental effects of their production and consumption choices (eco-design and labelling). In the case of learner production, it is based on life cycle thinking which requires the development of tools to promote resource efficiency (eco-management and audit schemes). Finally, global action makes reference to investment programs that support the global market for environmental outputs (for example, the International Partnership for Cooperation on Energy Efficiency).

Regarding sustainable consumption, it is considered as the main challenge in EU´s environmental policy. In this context, important advances in sustainable production have taken place, as several outputs have become more resource and energy efficient, whilst total resources consumption was increased [8]. In this context, Scholl et al. [9] and Mont and Dalhammar [10] showed the importance of national eco-labels in order to develop a more comprehensive approach that integrates social sustainability into sustainable consumption instruments, as well as the development of a user-friendly database that provides information about the life-cycle-related environmental, social and economic impacts of products. Mont and Plepys [11] suggested that government intervention was required to change the present framework in order to encourage producers to seek business opportunities based on less resource-intensive product-service offers. Hale [12] showed consumers´ environmental awareness as the main driver to create sustainable consumption and pointed out the need to strengthen policies related to this issue.

In addition to the aforementioned aspects, multiple studies have pointed out the importance and need for investment in research, development and innovation, both from the governmental point of view and from the business point of view, for the effective development of measures aimed at the achievement of SCP. Thus, Adedoyin et al. [13] showed that expenditures on research and development (R&D), especially those destined to the enhancement of renewable energies, improve environmental sustainability, while Stevens [14] denoted the relevance of the government's role in the development of SCP patterns through investment and incentives for R&D. Similarly, private investment in R&D can make a significant contribution to sustainable economic growth [15,16].

In this context, it can be concluded that there is not unanimity about the main drivers of sustainability in the EU-28. Factors related to specific actions were identified in previous literature (for example, circular economy in Haas et al. [6], Figge et al. [17], Di Maio et al. [18]; smarter consumption and learner production in Nash [7]; and governmental intervention in Hale [12] and Mont and Plepys [11]) but there is still not a global framework.

As explained in the next section, as a novelty this paper provides an empirical study, from a global point of view, of the relationship between the factors previously identified as drivers of sustainability and resource productivity, one of the main indicators used by the EU to measure sustainability.

1.2. Objective of the Paper

The objective of this paper is to deepen this research field from a global point of view, due to the previous literature been mainly focused on specific sectors. Thus, we can find several studies related to sustainable production and consumption in sectors such as energy [19,20], textiles [21,22], food [23,24], urban planning [25], construction [26], service sector [27], etc., as well as analyses focused on consumer behavior and attitude towards sustainability [28–30]. By considering the literature review, and the identification of resources productivity as one of the main traditional indicators for achieving SDG 12: Responsible Consumption and Production in the EU, according to the Statistical Office of the European Union (Eurostat), Figure 1 shows the proposed model to study the factors that impact sustainability. It is based on three pillars: circular economy, sustainable consumption patterns and sustainable production patterns.

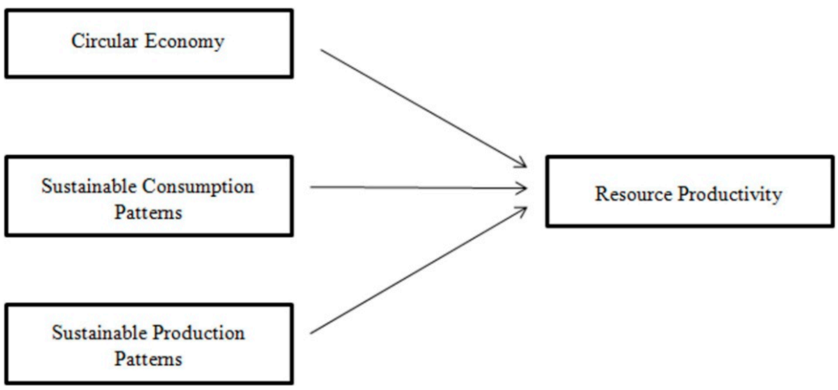

Figure 1. Proposed model in sustainability.

1.3. Hypotheses Proposed

The establishment of the hypotheses is based on previous literature, on those factors that previous research has identified as possible drivers of sustainability.

As mentioned above, several authors ([6,17,18]) have identified the increase in the circularity of the economy as one of the key factors in achieving SCP. Given that a circular economy entails resources' reuse as well as recycling in the chain of production and consumption, and this entails a reduction in the consumption of raw materials, an improvement in resource productivity would be expected. The first hypothesis proposed is:

Hypotheses 1 (H1). *The greater circularity of the economy, the higher resource productivity.*

Secondly, previous research ([7,9–11,31]) has pointed out the importance of less resource-intensive production, of more efficient technologies and design, with a lower environmental impact throughout the product life cycle, in order to achieve sustainability objectives. In this sense, it was hypothesized that sustainable production patterns (cleaner technologies, more efficient in the use of resources) will result in improved resource productivity, with the consequent sustainability improvements:

Hypotheses 2 (H2). *Sustainable production patterns will lead to higher resource productivity.*

Finally, the importance of establishing sustainable consumption patterns for achieving sustainability goals has been raised ([11,12,31]). In this sense, it has been pointed out that the producers' and consumers' awareness of the environmental effects in their production and consumption choices is a key issue. This environmental awareness should lead to a more efficient use of resources, which would entail improvements in resource productivity and allow reducing resource scarcity risk, with the consequent lower environmental impact. The proposed hypothesis is therefore:

Hypotheses 3 (H3). *Sustainable consumption patterns will lead to higher resource productivity.*

2. Materials and Methods

2.1. Sample and Variables

This study was developed for the EU-28 over the period 2001–2018. The unit of analysis is the EU in global terms, without going into an in-depth analysis of the institutional differences between countries. Those cases for which there was no information on any of the variables were not considered in the study in order to avoid missing values in the estimates. In this sense, the analysis were performed taking the data as a pool instead of using panel data methodology due to the high number of missing values in the explanatory variables. As a result, instead of the possible 504 observations (28 countries, 18 years), we ended up with 99 observations that were extracted from Eurostat database.

The variables included in this study were chosen from a previous literature review, as well as from available data in Eurostat. They are based on a circular economy, sustainable consumption patterns and sustainable production patterns.

With regard to sustainable production, as pointed out by Krajnc and Glavič [32] or Azapagic and Perdan [33], there are a series of measurable factors or elements that we can consider as key, such as energy use, materials use, water consumption, products, wastes, and air emissions.

On the other hand, according to Caeiro et al. [34], there are significant environmental and sustainability aspects or pressures directly related to household sustainable consumption to be taken into account: water, materials and energy consumption, pollutant emissions, waste disposal or land use patterns produced by the household activities, products and services.

In order to analyze the circularity of the economy, previous studies such as the one developed by Horvath et al. [35] consider the variables circular material use rate, recycling rate, domestic material consumption and resource efficiency, all of them available in Eurostat, considered as relevant. Taking into account what was mentioned above, and the availability of data, the selected variables aim to collect these main aspects by measuring the consumption and use of energy, the share of energy from renewable sources, the consumption of materials, the reuse or recycling of waste (domestic and construction and demolition) and the emission of greenhouse gases.

Finally, in order to take into account the effect of the investment in R&D proposed by Adedoyin et al. [13], the expenditure data collected by Eurostat were included in the analysis. All the variables selected are shown in Table 1.

Table 1. Variables included in the model.

Variable	Code	Source
Circular material use rate	CIRC-MAT-USE	Eurostat (cei_srm030)
Recycling rate of municipal waste	RECRAT-MWAST	Eurostat (t2020_rt120)
Recovery rate of construction and demolition waste	RECOV-RAT-WAST	Eurostat (cei_wm040)
Primary energy consumption per capita	PRIM-ENER-CONS	Eurostat (sdg_07_10)
Final energy consumption per capita	FIN-ENERG-CONS	Eurostat(sdg_07_11)
Final energy consumption in households per capita	FIN-ENERG-CONS-HOUS	Eurostat(sdg_07_20)
Share of energy from renewable sources	QUOT-ENERG-RES-E	Eurostat(sdg_07_40)
Greenhouse gas emissions per capita	GHG	Eurostat(t2020_rd300)
Greenhouse gas emissions intensity of energy consumption	GHG-ENERG	Eurostat (sdg_13_20)
Domestic material consumption per capita	DMC	Eurostat(t2020_rl110)
Intramural R&D expenditure (GERD—Government	RDEXP-GOV-D	Eurostat(rd_e_gerdtot)
Intramural R&D expenditure (GERD)—business	RDEXP-BUS-D	Eurostat(rd_e_gerdtot)
Resource productivity	RES-PROD-DMC	Eurostat(t2020_rl100)

Variables Explanation

Circular material use rate measures the share of material recovered and fed back into the economy in overall material use (in %) (CIRC-MAT-USE).

Recycling rate of municipal waste reflects the treatment of national waste. This measures the share of recycled municipal waste in the total municipal waste generation. Recycling includes material recycling, composting and anaerobic digestion. The ratio is expressed in percent (%) (RECRAT-MWAST).

Recovery rate of construction and demolition waste makes reference to the ratio that is related to construction and demolition waste (prepared for re-use, recycled or subject to material recovery, including through backfilling operations), and the construction and demolition waste treated (in %) (RECOV-RAT-WAST).

Primary energy consumption per capita considers the energy consumption by end users (such as industry, transport, households, services and agriculture), plus the energy consumption of the energy sector itself, losses taking place in energy transformation and distribution (in kg of oil equivalent per capita) (PRIM-ENERG-CONS), divided by the population of the country.

Final energy consumption per capita measures the energy consumed by end users (such as industry, transport, households, services and agriculture), although it excludes the energy consumption of the energy sector itself and the losses occurring during energy transformation and distribution. This variable is divided by the population (in kg of oil equivalent per capita) (FIN-ENERG-CONS).

Final energy consumption in households per capita measures how much electricity and heat (excluding the energy used for transportation) every citizen consumes at home. This variable considers only the energy used by end consumers (in kg of oil equivalent per capita) (FIN-ENERG-CONS-HOUS).

Share of energy from renewable sources measures the renewable energy consumption share in gross final energy consumption (in %) (QUOT-ENERG-RES-E).

Greenhouse gas emissions per capita makes reference to the total national emissions (including carbon dioxide, methane, nitrous oxide, and the F-gases (hydrofluorocarbons, perfluorocarbons, nitrogen triflouride and sulphur hexafluoride)), divided by the population (in kilograms per capita) (GHG).

Greenhouse gas emissions intensity of energy consumption is calculated as the ratio that relates to energy-related greenhouse gas emissions and gross inland energy consumption (index (2000 = 100)) (GHG-ENERG).

Domestic material consumption per capita makes reference to the total material amount directly used in an economy. It is calculated as direct material input minus exports, divided by the population (in kilograms per capita) (DMC).

Intramural R&D expenditure (GERD)—Government makes reference to all current expenditures for research and development performed by governments during a specific period (in Euro per inhabitant) (RDEXP-GOV-D).

Intramural R&D expenditure (GERD)—Business makes reference to all the current expenditures for research and development performed by enterprises during a specific period (in Euro per inhabitant) (RDEXP-BUS-D).

Finally, according to the Statistical Office of the European Union (Eurostat), the *resource productivity* variable is the lead indicator for measuring the resource efficiency, so it is used subsequently as the dependent variable of the regression analysis. The indicator is defined as the gross domestic product (GDP) divided by domestic material consumption (DMC) (in Euro per kilogram) (RESPROD-DMC).

2.2. Method

Principal component factorial analysis was the first method used in the present research. It is a multivariate analysis technique of data reduction. This method allows to transform and reduce the initial set of variables in a new set of variables (without losing any information), lineal combination of the original set of variables, called principal components (factors). Principal component factorial analysis seeks to find these components or factors, which are characterized by being uncorrelated with each other, which successively explains the greater part of the total variance. As Kline [36] explains, the meaning of these factors has to be deduced from the factor loadings, computed in the factor analysis. These factor loadings, correlations of the initial variables with the factors, are usually considered as high if they are greater than 0.6, and moderately high if they are above 0.3, ignoring other loadings [36]. This is the selection criterion that was applied in the present research.

Subsequently, once the factorial analysis allowed us to compute the factors, the correlation between each of the three mentioned factors and the dependent variable was analyzed, evaluating the Spearman correlation coefficient. Later, a stepway regression analysis was used to assess the relationships between the selected factors and the dependent variable, namely the resource productivity. In order to check the robustness of the results obtained, several additional analyses were carried out, whose results were mentioned in the following sections.

Both analyses were performed using IBM® SPSS® Statistics (v 25.0).

3. Results

3.1. Factorial Analysis

The results obtained from principal component factorial analysis, summarized in Table 2, shows three factors that explain 74.609% of the variance. These factors were called: resource consumption (RESO-COMPS), sustainable use of resources (RESO-SUST-USE) and recycling-circular economy (REC-CIRC-ECO).

Table 2 shows factorial loadings that represent the correlation coefficients among the variables (rows) and factors (columns). Factorial loadings with values greater than 0.6 can be considered high, according to Kline [36] and Hair et al. [37]. These values allow confirming that independent variables, which were identified a priori, belong to a specific factor.

Previously, the Kaiser–Meyer–Olkin measure of sampling adequacy (KMO) was calculated in order to verify the suitability of the analysis. This should have a value of 0.6 or above. The KMO for this study was 0.744 which fit within acceptable limits. The Bartlett's Test of Sphericity should be significant (less than 0.05) and in this study met this criterion as the test showed a significant p value ($p = 0.000$). According to Hair et al. [37], in the study field of social sciences, a solution that explains more than 60% of the variance is valid. In this study, this variable has a value of 74.609%. Therefore, as the prerequisite values for model fit were achieved, the factor model can be considered reasonably fit.

Table 2. Results of principal component factorial analysis.

Variable Code	RESO-COMPS	RESO-SUST-USE	RESO-CIRC-ECO
PRIM-ENERG-CONS	0.960		
FIN-ENERG-CONS	0.947		
FIN-ENERG-CONS-HOUS	0.805		
DMC	0.610		−0.509
RECOV-RAT-WAST			0.554
CIRC-MAT-US			0.741
RECRAT-MWAST	0.480		0.666
GHG	0.819	−0.434	
GHG-ENERG		−0.626	
QUOT-ENERG-ERS-E		0.857	
RDEXP-BUS-D	0.699	0.518	
RDEXP-GOV-D	0.793		

Convergence in 6 interactions. Analysis of principal component analysis. Varimax with Kaiser normalization, 74.609% of the variance explained. Test KMO = 0.744, statistical significance $p = 0.000$, acceptable if $p < 0.05$. Barlett´s sphericity test: chi-square = 1036.34.

The estimates of the variables, as well as the overall adjusted assessment were developed by means of the principal component analysis. According to Kline [36] and Hair et al. [37], this method is suitable to summarize the original information of the factors in future analysis.

The results of Varimax rotation suggest that it is especially the variables that make reference to sustainable consumption patterns (PRIM-ENERG-CONS, FIN-ENERG-CONS, FIN-ENERG-CONS-HOUS, DMC) expenditure on research and development (RDEXP-BUS-D, RDEXP-GOV-D), and to a lesser degree, sustainable production patterns (GHG) and circular economy (RECRAT-MWAST), are combined by creating the first factor, which was called resource consumption (RESO-COMPS).

On the other hand, the results reinforce the expected pattern: circular material use rate (CIRC-MAT-USE), recycling rate of municipal waste (RECRAT-MWAST), recovery rate of construction and demolition waste (RECOV-RAT-WAST), and to a lesser degree and reverse direction, domestic material consumption (DMC), are all variables that make reference to the circular economy factor (REC-CIRCECO).

Finally, the variables that make reference to sustainable production patterns, especially in terms of energy (QUOT-ENERG-RES-E, GHG and GHG-ENERG), and to a lesser degree, expenditure on research and development (RDEXP-BUS-D, RDEXP-GOV-D) are combined by creating the third factor, which was called the sustainable use of resources (RESO-SUST-USE).

3.2. Correlations between Factors and Dependent Variable

Once the new variables were obtained from the aggrupation of homogeneous criteria by means of the factorial analysis, a study of bivariate correlations between these factors and the dependent variable were carried out. An analysis of the Spearman correlation coefficient, given that the factors obtained do not respond sufficiently to a normal distribution, was used. Table 3 shows the results obtained in this analysis.

The study of Spearman's correlation allows us to extract some relevant ideas for further analysis. Thus, we can already see that there is an important and significant correlation between the factor linked to the circular economy (REC-CIRC-ECO) and resources productivity (RES PROD-DMC) (Spearman's Rho = 0.741; Sig. = 0.000 < 0.01). To a lesser extent, there is a certain correlation between the factor related to resources consumption (RESO-COMPS) and their productivity (Spearman's Rho = 0.242; Sig. = 0.016 < 0.05). On the contrary, there does not seem to be a significant correlation between the factor linked to a sustainable use of resources (RESO-SUST-USE), especially in terms of energy production, and its productivity in economic terms (Spearman's Rho = −0.155; Sig. = 0.127 > 0.05). For this reason, for the subsequent regression analysis, factors 1 (RESO-COMPS) and 3 (REC-CIRC-ECO) will be used. These results will be analyzed later.

Table 3. Correlation analysis.

		RESO-COMPS	RESO-SUST-USE	REC-CIRC-ECO
RES PROD-DMC	Spearman's Rho	0.242 *	−0.155	0.741 **
	Sig. (bilateral)	0.016	0.127	0.000
	N	99	99	99

* correlation is significant at 0.05 level (bilateral), ** correlation is significant at the 0.01 level (bilateral).

3.3. Regresion Analysis

Once the factorial analysis allowed us to compute the factors and the correlation analysis allowed us to select them in relation to their significance, a stepway regression analysis was applied. As it is well known, in the multiple linear regression model we look for a relationship like the following:

$$Y_i = \beta_0 + \beta_1 \cdot X_{i1} + \beta_2 \cdot X_{i2} + \cdots + \beta_n \cdot X_{in} + \varepsilon_i$$

where:

Y_i is the observed value of the dependent variable;
β_0 represents the effects due to constant factors;
$\beta_1, \beta_2, \ldots \beta_{\mathrm{n}}$ are the weights of each of the n independent variables in the model;
ε_i are errors due to uncontrolled factors.

The construction of the equation was done by selecting the variables step by step, as explained by Rodríguez-Jaume and Mora-Catalá [38]. The aim of this methodology was to find, among all the possible explanatory variables, those that best explain the dependent variable without any of them being a linear combination of the others. In each step is introduced only that variable that meets the input criteria, analyzing the p-value associated with the statistic t (if $p < 0.05$ the variable is introduced). Once introduced, it was assessed if any of the variables met the output criteria, also analyzing the p-value. Finally, in each step in which a variable was introduced or eliminated, the regression goodness-of-fit statistics, the analysis of variance (ANOVA) and the estimation of parameters were performed, considering the variables introduced in each model. For obtaining the regression coefficients $\beta_1, \beta_2, \ldots \beta_{\mathrm{n}}$, the criterion of the least squares is used.

Regarding the goodness of the linear regression model, as pointed out by Rodríguez-Jaume and Mora-Catalá [38], the analysis of variance allows us to assess if this model is adequate to estimate the values of the dependent variable. The ANOVA table provides the F statistic from which we can formulate the null hypothesis that the two variables are unrelated. If the p-value associated with the F statistic is less than the level of significance (0.05), we will reject the null hypothesis. In our case of multiple regression analysis, the analysis of the variance table (Table 4) indicates the p-values associated with the F statistic in each of the two models generated.

Since the p-value associated with the F statistic is lower than the significance level ($p < 0.05$), it indicates that the model proposed is adequate for estimating the values of the dependent variable.

In the same way, the goodness of the adjustment can be verified by the values of R and the coefficient of determination (R^2 and adjusted R^2). According to Abuín [39], with a value of the coefficient of determination R^2 between 0.5 and 0.85, it was considered that the adjustment was good.

Table 4. Analysis of variance (ANOVA) of the two models.

Model		Sum of Squares	df	Mean Square	F	*p*-Value
1	Regression	55.537	1	55.537	121.572	0.000 *
	Residual	44.312	97	0.457		
	Total	99.848	98			
2	Regression	65.590	2	32.795	91.899	0.000 **
	Residual	34.258	96	0.357		
	Total	99.848	98			

Dependent variable: RES PROD-DMC, * Predictors: (constant), REC-CIRC-ECO, ** Predictors: (constant), REC-CIRC-ECO, RESO-COMPS.

The results obtained in the regression analysis are summarized in Table 5 for both models and show that the adjustment of model 2 can be considered good.

Table 5. Results of the regression analysis.

Coefficients [1]								
Model		Non Standardized		Standardized	t	p-Value		
		β	Dev. Error	β			R^2	Adjusted R^2
1 [2]	(Intercept)	1.695	0.068		24.956	0.000	0.556	0.552
	REC-CIRC-ECO	0.753	0.068	0.746	11.026	0.000		
2 [3]	(Intercept)	1.695	0.060		28.236	0.000		
	REC-CIRC-ECO	0.753	0.060	0.746	12.475	0.000	0.657	0.650
	RESO-COMPS	0.320	0.060	0.317	5.308	0.000		

[1] Dependent variable: RES-PROD-DMC. [2] Predictors: (intercept), REC-CIRC-ECO. [3] Predictors: (intercept), REC-CIRC-ECO, RESO-COMPS.

The following expression is obtained for the dependent variable (resource productivity):

$$\text{RES-PROD-DMC} = 1.695 + 0.753 * \text{REC-CIRC-ECO} + 0.320 * \text{RESO-COMPS}$$

The model with the best fit and that best explains the dependent variable (RES-PROD-DMC), as noted above, is model 2, in which both independent variables are introduced (REC-CIRC-ECO, RESO-COMPS). It can be observed that circular economy (REC-CIRC-ECO) (factor 3) and resource consumption (RESO-COMPS) (factor 1) have a positive and statistically significant impact on resource productivity (RES-PROD-DMC) ($\beta = 0.753$ $p = 0.000$ and $\beta = 0.320$ $p = 0.000$, respectively).

In order to check the results obtained in the Spearman correlation study, the factor linked to a sustainable use of resources (RESO-SUST-USE) was introduced in a model with the other two factors (REC-CIRC-ECO, RESO-COMPS), obtaining again that this factor is not significant ($\beta = -0.216$ $p = 0.117$), so it does not seem to be a good predictor of the dependent variable. On the other hand, to verify that, with the data used, there are no clear differences between countries that could affect the results, a pooled OLS regression using the cluster option at country level was developed, using STATA 13, obtaining similar results, with a very slight variation in the coefficients of the explanatory variables (intercept $\beta = 1.655$; REC-CIRC-ECO $\beta = 0.739$; RESO-COMPS $\beta = 0.323$).

4. Discussion

Environmental pollution prevention and reduction as well as SCP promotion have been set as essential issues in the framework of the European Union's Sustainable Development Strategy. These actions are especially relevant in order to secure, in the long-term, the physical basis of society and economy in a way that respects the tolerable limits of the planet's resources and improves environmental protection.

This paper provides an empirical analysis of the identification of fundamental constructs that define SCP in the EU-28 during the period 2001–2018. The results obtained from the principal component factorial analysis allowed us to identify three factors that explained 74.609% of the variance: resource consumption (RESO-COMPS), recycling-circular economy (REC-CIRC-ECO), and the sustainable use of resources (RESO-SUST-USE). Analyzing each of these factors separately we can conclude the following, in order of significance:

The study of the correlation and the regression analysis suggests that the factor called recycling-circular economy (REC-CIRC-ECO) has a positive and significant impact on resource productivity (RES-PROD-DMC), which validates Hypothesis 1. In this point, we must remember that this factor summarized the variables circular material use rate, recycling rate of municipal waste, recovery rate of construction and demolition waste, and in the opposite sense domestic material consumption per capita. Reuse and recycling convert waste into usable products and materials in the production chain or in the domestic sphere, which contributes to reducing the consumption of resources in the economy, which in turn increases its productivity. This result agrees with that stated by Hass et al. [6] and by Schroeder et al. [40]. Therefore, it is possible to move towards sustainable modes of production and consumption (SCP) and increase resource productivity by promoting practices related to circular economy and recycling. These practices, as defined by the European Environment Agency [41] can be: eco-design, repair, reuse, refurbishment, remanufacture, product sharing, waste prevention and waste recycling.

Secondly, the analysis carried out suggests that the factor called resource consumption (RESO-COMPS) has a positive and significant effect, although to a lesser extent, on their productivity (RES-PROD-DMC), which would validate Hypothesis 3. This result agrees with that stated by Hale [12] and Mont and Plepys [11], in the sense that an efficient use of resources will tend to increase resource productivity and allow reducing resource scarcity risk, with the consequent lower environmental impact. In the same way, it was observed that public and private investment in research and development, present in the factor in a relevant way with the variables *Intramural R&D expenditure (GERD)—Government* and *Intramural R&D expenditure (GERD)—Business*, allows us to face the uncertainty behind climate change in a manner consistent with sustainable economic growth, supporting the rapid technological change necessary as indicated by Baker and Solak [42].

Finally, the factor called the sustainable use of resources (RESO-SUST-USE) encompasses the variables related to sustainable production, especially those related to energy. According to Zafar et al. [15], a positive effect of the sustainable production on economic growth, and therefore, on the resource productivity variable, would be expected to validate Hypothesis 2. However, from the analysis carried out, no significant relationship emerges, since there is no correlation between the RESO-SUST-USE factor and resource productivity (RES-PROD-DMC). However, the factorial loadings clearly indicate the positive effect of the increase in the share of renewable energies in the decrease in greenhouse gases, and the investment from the private sphere in research and development to promote these clean energies, which does agree with the previous research of Zafar et al. [15].

The results obtained have a number of implications related to the orientation of the policies followed to achieve the objectives of sustainable development, both in the EU in general and in its member countries in particular. On the one hand, it seems clear that it is essential to make a decisive commitment to the development of practices of circular economy, recycling and reuse, both in the public administration itself (giving priority to the use of recycled raw materials in public works, for example), as in industry (for example, by promoting the visibility and recognition by consumers of Ecolabel certifications, so that companies are encouraged to obtain them, or by requiring them for contracting with the administration), as in homes (for example, by promoting school campaigns on responsible consumption, reuse and recycling). These practices result on the one hand in the reduction of the import of necessary raw materials, reducing dependence on developing countries, and on the other hand, in the reduction of waste generated that cannot be incorporated back into the production chain, reducing the impact on the environment. At the same time, it is necessary to maintain the commitment to the use of renewable energies, which allows the reduction of dependence on the import of fossil fuels and at the same time reduces the emission of greenhouse gases. All this should imply an increase in investment in research, development and innovation by the EU, but specifically focused on the practices of circular economy, since it is supported in part on the continuous technological improvement of processes, from design to manufacturing and the ultimate recovery of materials.

These ideas are in line with the approaches made by the European Commission in its European Green Deal, the plan to make the EU's economy sustainable. They fit in with what the Commission proposes in its Communication *A new Circular Economy Action Plan for a Cleaner and More Competitive Europe* [43], in terms of empowering consumers and public buyers, circularity in production processes, establishing requirements for the use of recycled materials in construction, or coordinating innovative initiatives in the circular economy through the European Institute of Innovation and Technology. Similarly, this study contributes to one of the objectives set by the Commission, which is to analyze how the impact of circularity on climate change mitigation and adaptation can be measured in a systematic way [43].

To conclude, we must mention some limitations of the study carried out, which will be analyzed in future research. The field of research is complex, with multiple interrelated factors. Although in order to obtain homogeneous measures of the initial data, it was decided to take into account the per capita values and not the absolute values of each of the member countries, the study does not include possible institutional, structural or policy differences between countries, which may have a particular influence on the results. On the other hand, given that the availability of data is limited, it was decided to consider the relationship between the variables without taking into account their evolution over time. One possible field for future research, depending on the availability of data, would be to carry out the analysis, even if it were qualitative, of the influence on the results of the country variable on the one hand, and the time variable on the other, in order to determine whether the relationship obtained is consistent.

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