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Sustainable Development According to Resource Productivity in the EU Environmental Policy Context

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Abstract: The constant rise in the consumption of resources puts the environment under pressure. Most resources are non-renewable in nature, which is why they must be utilized with great care. For this reason, the European Union devotes increasingly more attention to their efficient use. It deals with these aspects, making an effort to maintain the long-term competitiveness and to secure sustainable development in line with all of the related environmental impacts. In this context, several goals have been set out, to which the individual EU member states are bound. A method for monitoring resource efficiency was developed, consisting of indicators, the aim of which is to assess the efficiency of the use of soil, water, energy, with the most fundamental one being resource productivity. The results of the efficiency of use of the individual resources in the member states greatly differ, even without further investigating the links and correlations between the indicators. Research on the interrelationships of the individual indicators in terms of mutual influence has not yet been completed. The aim of our study was to define the correlation between the main indicator, resource productivity, and the other indicators at the level of the EU and its member states. For this purpose, we prepared a database with data which, for the sake of uniformity, were obtained from the publicly available Eurostat database. Subsequently, the data were analyzed and evaluated using the statistical software JMP 15 by a regression and correlation analysis. By using the multiple regression analysis, we created a model describing the significance of the impact of the observed variables on the resulting resource productivity of the EU member states. Generally, there is a positive correlation between the resource productivity and the Eco-Innovation index, as well as the utilization rate of recycled materials. For the sake of comparison, we developed a regression model at the level of the V4 countries, with the aim of evaluating the impact of the historical background of the countries on their contemporary ability to reach the goals set out by the environmental policy. The V4 countries are lagging far behind in meeting all of the environmental policy objectives, not only in tracking the main indicator (resource productivity) on which the multiple regression analysis is based. It was interesting to find that the multiple regression model at the V4 level does not include the indicators defined by the EU level model, the key ones, in this case, being water productivity, energy dependence, energy productivity, and environmental tax. This finding may also, after further analyses, be the key for other countries joining the EU in the future, in defining the weaknesses of the newly acceding states in terms of the EU's move towards a circular economy.

Keywords: sustainable development; environmental policy; resource productivity; data analysis; regression analysis; circular economy

Citation: Taušová, M.; Tauš, P.; Domaracká, L. Sustainable Development According to Resource Productivity in the EU Environmental Policy Context. *Energies* **2022**, *15*, 4291. https://doi.org/10.3390/en15124291

Academic Editor: Luigi Aldieri

Received: 5 May 2022
Accepted: 9 June 2022
Published: 11 June 2022

1. Introduction

The present-day global population and economic growth have a considerable impact on the environment. The incessant need for resources puts the environment under pressure, not only due to their depletion, but also as a result of the resource processing, which produces waste, emissions and immissions. Arguably, their amount greatly depends on the resource efficiency. In order to secure long-term sustainable development on a global scale, the resource efficiency must be as high as possible. Several legislative instruments have been approved on the EU and national level for this purpose.

The fundamental document we built upon is the "Europe 2020" strategy [1,2]. It is a strategy for delivering smart, sustainable and inclusive growth, and sustainable growth may be achieved by promoting a more resource-efficient, greener and more competitive economy. This strategy is related to the Seventh Environment Action Programme, entitled "Living well, within the limits of our planet" [3], which is a part of a long-term vision and strategy of the EU in the field of environmental protection until 2050 [4,5]. The goal of the EU is to live in line with the ecological limits of the planet until 2050. The Seventh Environment Action Program concerns the period until 2020, and its key objective is "to protect, conserve and enhance the European Union's natural capital, to safeguard the European Union's citizens from environment-related pressures and risks, to protect health and natural capital and to provide sound knowledge-base for the environment". Based on these documents, it may be assumed that the protection of the environment gains more awareness not only in the EU, but also all over the world. The "OECD Green Growth Strategy" addresses the quality of the environment, as well as the optimal use of natural resources, with the future generations in mind.

Nowadays, environmental policy is included in the economic policy of almost all countries. Its objective is to enter into the production and consumption decisions in the business area, as well as the decisions of consumers, with the aim to make changes in the consumer behavior which will benefit the environment. Before the environmental policy of a state can be formulated, it is necessary to identify the problems of the environment. The environmental policy must also take several economic factors into consideration, including the economic growth, its material and energy intensity, the structure of the economy and its structural changes, as well as the environmental legislation [6,7].

The following principles apply in the environmental policies of the developed countries:

- The "polluter pays" principle;
- The principle of support (of public burden);
- The precautionary principle;
- The principle of subsidiarity;
- The principle of economic efficiency;
- The principle of justice;
- The immediacy principle;
- The sustainability principle [8].

The EU environmental policy has several dimensions with economic, political and ethical aspects. The economic aspect is crucial, especially when adopting decisions on how to meet the environmental objectives with the efficient use of environmental resources. When evaluating the impacts on the environment, the EU considers ethical and moral principles to be an integral part of its decision-making processes. The political aspect of securing the environmental policy requires countries to implement the same procedures, which allows them to formulate their objectives in a transparent manner and to maximize the efficiency of the adopted measures [9].

The need to shape the environmental policy first appeared during the existence of the EEC, after the common consumer protection standards were defined with regard to several types of dangerous substances. Later, environmental action programs would be developed, formulating the principles and priorities of the EU environmental policy [10,11].

The first action program (1975–1977) put the emphasis on the need for a scientific evaluation of the impact of waste on the environment.

The second action program (1977–1981) defined four priority areas:

- reducing the environmental pollution;
- the rational use of natural resources;
- protecting and improving the quality of the environment;
- protecting the environment on an international scale.

The third action program (1982–1986) defined the need to integrate environmental problems into other economic policies and to implement the "polluter pays" principle.

The fourth action program (1987–1992) highlighted the need to comply with the environmental legislation, to regulate pollution and to raise awareness on the state of the environment.

The fifth action program (1992–1996) coined the term "sustainable development". Furthermore, it addressed the need to develop environmental and economic policy which would allow the meeting of the present-day needs, without reducing the ability to meet the needs of the future generations. The program specified problems, which required special attention, including:

– climate change;
– acidification and air quality;
– urban environment;
– coastal zones;
– waste management;
– management of water resources;
– protection of nature and biodiversity [12].

The sixth action program (2002–2012) set out the intent to reflect the protection of the environment into sector policies.

The priority areas of the program include:

– stabilization of greenhouse gases in the atmosphere;
– the protection and restoration of natural systems, bringing the loss of biodiversity to a halt;
– minimizing the environmental pollution produced by people;
– better resource efficiency, minimizing waste [12].

The seventh environment action program (2012–2020) set out three key objectives:

– to protect, preserve and enhance the natural capital of the European Union;
– to transform the European Union into a green and competitive, resource-efficient, low-carbon economy;
– to protect European Union citizens from environmental pressures and risks to health and well-being.

This long-term oriented program defines a vision beyond its application period and presents an idea of how the European Union might appear by 2050:

In 2050, we will live well, within the ecological limits of the planet. Our prosperity and healthy environment are based on an innovative circular economy in which nothing is wasted and in which the natural resources are managed sustainably and biodiversity is protected, enhanced and restored in a way that increases the resilience of our society. Our low-carbon growth has long been decoupled from resource use and sets the pace for a secure and sustainable global society [13].

The common characteristic of all of the environment action programs is the effort to use resources rationally and efficiently. Our survival depends on natural resources–metals, minerals, fuels, water, soil, wood, fertile land, clean air and biodiversity. All of these are vital for the functioning of the economies of all countries. At present, so-called critical raw materials are added to them. The European Commission has recently moved from policy concerns to its Critical Raw Materials Action Plan. The criticality of these materials requires their recycling and the improvement of technologies that do not rely on CRM, which are two pillars of a broad approach to the safety of minerals [14].

Resource efficiency means the sustainable use of the limited resources of the Earth, along with the minimization of the impacts on the environment. Enhancing resource efficiency is the key to ensuring growth and increasing the number of work opportunities in Europe, as well as in the whole world. It brings forward economic opportunities, reduces costs and improves competitiveness. This is why it is necessary to find new methods of managing production stocks, to reduce inputs, optimize production processes, management and business methods, to enhance the logistics, to change the consumption formulas and to minimize waste. It is equally important to develop new products and services, which are less input-demanding. This will allow us to produce more with a smaller volume of production factors and to provide added value with a smaller input. In connection with the above, the term 'The Material Metabolism' has also been introduced. The material metabolism indicators are most relevant to the current policy debate surrounding the European Green Deal–namely, material supply risk and the contribution of recycled materials to the total supply [15].

Resource efficiency will help to stimulate technological innovations, improve employability in the quickly developing sector of green technologies, open new export markets and bring benefits to consumers in the form of more sustainable products.

One of the parts of the Europe 2020 strategy, which is an EU strategy for the growth of the smart, inclusive and sustainable economy, is its main initiative "Resource-efficient Europe". It supports the transition to sustainable growth by means of a low-carbon, resource-efficient economy.

The plan for the resource-efficient Europe is one of the key documents of the main initiative for resource efficiency. It outlines the structural and technological changes that must take place by 2050, including the milestones to be reached by 2020.

The "Towards a Circular Economy" report advocates for the final transition of the EU from the linear economy to a circular economy. It identifies the measures leading to better resource efficiency and waste reduction. It changes the usual method of the use of resources, which, after extraction, use in production, consumption and end of life as a product, return back to the loop as a production factor [14].

As a part of monitoring resource efficiency, an assessment chart was prepared, summarizing indicators, which are progressively counted and reported for the individual EU member states and subsequently published in the Eurostat databases. It includes a set of indicators related to water, soil, materials, coal, as well as the main indicator in the form of resource productivity. Further indicators were added into the monitoring, depending on the thematic areas based on the EU priorities.

Our ambition was to assess to what extent the individual states meet the objectives and how the results influence the whole progress of the European Union, based on eight basic indicators contributing to the evaluation of resource efficiency and seven indicators from thematic areas reflecting other possible impacts. Part of the research was the assessment of the impact of the fulfillment of individual indicators on the fulfillment of the other indicators, and at the same time on the fulfillment of the main indicator–the resource productivity (Table 1).

Table 1. Selected indicators of the Assessment chart of resource efficiency (processed by the authors based on the Eurostat data).

Name of the Indicator	Objective
Resource productivity	Increase
Domestic material consumption per capita	Decrease
Water exploitation index	Decrease
Water productivity	Increase
Greenhouse gas emissions per capita	Decrease
Energy productivity	Increase
Energy dependence	Decrease
Share of renewable energy in gross final energy consumption	Increase
Circular material use rate	Increase
Eco-Innovation index	Increase
Recycling rate	Increase
Generation of waste excluding major mineral waste per GDP	Decrease
Landfill rate	Decrease
Environmental tax % of GDP	
Energy tax % of GDP	

The aim of the paper is to use multiple regression to identify the indicators with the strongest impact on the key indicator, resource productivity, which is one of the main objectives of the EU environmental policy. By also repeating the methodology at the level of the V4 countries—Slovakia, Czech Republic, Poland, Hungary—we want to show the influence of the historical background of a country on the overall level of environmental performance and the related impacts.

2. Materials and Methods

The aim of this paper was to evaluate resource efficiency at the level of the EU member states, with regard to the EU environmental policy, as well as to develop a multiple linear regression model for estimating the resource productivity parameters at the level of the EU. The analysis was repeated at the level of the V4 countries—Czech Republic, Slovakia, Hungary, Poland, former Eastern bloc countries—as these are countries with lower values of resource productivity. Our aim was to verify the influence of historical background on the direction of these countries towards achieving the environmental policy goals.

The resource productivity indicator is included in the table of resource efficiency indicators. It is used for monitoring the progress towards the resource-efficient Europe. Resource productivity is the main indicator of the assessment chart.

It is expressed as the ratio of gross domestic product (GDP) and domestic material consumption (DMC). The DMC measures the total amount of materials that are directly consumed in the economy. It is defined as the annual quantity of raw materials extracted from the domestic territory plus all of the physical imports minus all of the physical exports. It should be noted that the term "consumption", as used in the DMC, denotes the apparent consumption and not the final consumption. DMC does not include the upstream flows related to the imports and exports of raw materials and products which originate outside of the local economy.

$$\text{RESOURCE PRODUCTIVITY} = \frac{\text{GDP}}{\text{DMC}}\ [\text{PPS}\cdot\text{kg}^{-1}] \tag{1}$$

$$\text{DMC} = \text{EXTRACTION} + \text{IMPORT} - \text{EXPORT}\ [\text{kg}] \tag{2}$$

$$\text{Resource productivity} = \frac{\text{GDP}}{\text{EXTRACTION} + \text{IMPORT} - \text{EXPORT}}\ [\text{PPS}\cdot\text{kg}^{-1}] \tag{3}$$

PPS—Purchasing power standards are artificial "currency" units, which remove the differences in the purchasing power; thus, eliminating the differences between the price levels in the individual countries, and are used for making comparisons between countries.

Multiple linear regression allows us to examine the correlation between response (Y) and several independent variables at the same time. It is a suitable tool for a prediction analysis, the result of which will be a model for estimating future mean response values (Y) based on its correlations with other prediction variables (Xs), where β parameters are unknown parameters of the regression model and ε is a random observational error.

$$\text{Y} = \beta_0 + \beta_1\text{X}_1 + \ldots + \beta_\text{k}\text{X}_\text{k} + \varepsilon \tag{4}$$

At the same time, it has an analytical function explaining the relations between the response variable and the predictor variable. In our case, the response (Y) is the "resource productivity" indicator, which is, at the same time, a summarizing indicator reflecting the total resource efficiency of the individual countries as well as the EU as a whole. All of the other indicators were considered as prediction variables. By using the multiple regression, we derived a linear regression model for predicting the resource productivity of the whole EU. We then examined the strength of the impact of individual predictors on the response itself, which allowed us to define the key factors affecting resource productivity in the EU. We repeated this methodology in the analysis of the V4 countries, in an effort to verify the influence of the historical background of the countries on the low values of resource productivity and to compare which factors are key for productivity growth in the former

Eastern bloc countries—Czech Republic, Slovakia, Poland, Hungary. These models were then analyzed and we studied the differences in the significance of the individual input parameters and their effect on the resource productivity.

The data were collected by continuously noting the published values of selected variables from the portal at https://ec.europa.eu/eurostat/data/database (accessed on 9 March 2022) for all of the years and the member states available. We compiled the records of the collected data, which we sorted out and modified in a database created in the sheet editor MS Excel, based on the requirements of the statistical software JMP; the modified data were transferred into the software and analyzed. The collected data present the results of 15 indicators for the period of 1990–2020 (Table 2). The final database comprises 21,033 pieces of data, with each indicator defined for a specific EU member state and a specific year. As shown in Table 2, the quantity of the published data differs between the individual indicators, and the differences in the volume of data result from the fact that some of the countries provided incomplete records or published data for certain indicators only every other year, such as in the case of the waste recycling rate, waste production rate and landfill rate. The analyses were selected and the conclusions were formulated based on the extent and the structure of the data obtained.

Table 2. Structure of the collected data (Source: processed by the authors in the Excel interface) [16–26].

Name of the Indicator	Number of Data	Reported Period
Resource productivity	742	2000–2020
Domestic material consumption per capita	832	1990–2020
Water exploitation index	1381	1990–2019
Water productivity	1092	1990–2019
Greenhouse gas emissions per capita	680	2000–2019
Energy productivity	1546	1990–2020
Energy dependence	4636	1990–2020
Share of renewable energy in gross final energy consumption	643	2004–2020
Circular material use rate	340	2004–2020
Eco-Innovation index	287	2010–2019
Recycling rate	138	2010, 2012, 2014, 2016, 2018
Generation of waste excluding major mineral waste per GDP	286	2004, 2006, 2008, 2010, 2012, 2014, 2016, 2018
Landfill rate	138	2010, 2012, 2014, 2016, 2018
Environmental tax % of GDP	4146	1995–2020
Energy tax % of GDP	4146	1995–2020
Total	21,033	1990–2020

3. Results

3.1. Multiple Linear Regression Analysis on the EU Level

By analyzing the 14 input parameters and the effect on the output variable "resource productivity" for all of the EU member states, we discovered that the Domestic material consumption per capita, the utilization rate of recycled materials, the Eco-Innovation index, water productivity and greenhouse gas emissions per capita contributed the most to the total resource productivity (Table 3).

The insignificant parameters were gradually excluded from the models, and the process of developing the model was repeated until only the significant parameters remained, ordered by their statistical significance (Table 4). The most significant parameters of the model were the Domestic material consumption per capita, Circular material use rate and Eco-Innovation index.

Table 3. Estimation of the parameters of the model, ordered by their statistical significance—EU (analyzed by the authors based on the EC data in the JMP software).

Sorted Parameter Estimates				
Term	**Estimate**	**Std Error**	**t Ratio**	**Prob > |t|**
Domestic material consumption per capita (t)	−0.099866	0.012525	−7.97	<0.0001
Circular material use rate (%)	0.0513418	0.007887	6.51	<0.0001
Eco-Innovation index (%)	0.0091188	0.001677	5.44	<0.0001
Water productivity	0.0011489	0.000476	2.42	0.0189
Greenhouse gas emissions per capita	0.0517565	0.023188	2.23	0.0295
Energy dependence (%)	0.0033335	0.001939	1.72	0.0910
Energy productivity	0.044695	0.026082	1.71	0.0919
Environmental tax % of GDP	0.0468744	0.028507	1.64	0.1055
Energy tax % of GDP	−14.7891	11.15977	−1.33	0.1903
Share of renewable energy in gross final energy consumption (%)	0.0059617	0.006944	0.86	0.3941
Recycling rate (%)	−0.004629	0.006708	−0.69	0.4929
Landfill rate (%)	0.0013956	0.005941	0.23	0.8151
Water exploitation index	0.0007942	0.003618	0.22	0.8270
Generation of waste excluding major mineral waste per GDP (kg/1000€)	−0.000023	0.000458	−0.05	0.9602

Table 4. Significant parameters of the model for the EU (analyzed by the authors based on the EC data in the JMP software).

Source	**Logworth**	***p* Value**
Domestic material consumption per capita (t)	17.020	0.00000
Circular material use rate (%)	11.327	0.00000
Eco-Innovation index (%)	9.397	0.00000
Water productivity	3.429	0.00037
Recycling rate (%)	3.199	0.00063
Energy productivity	2.679	0.00210
Energy dependence (%)	2.547	0.00283
Greenhouse gas emissions per capita	2.333	0.00465

The following figure describes the impact of the individual parameters on the resulting resource productivity, and the angle of the line clearly shows that two variables have a negative effect, namely, the Domestic material consumption and the Recycling rate, with the remaining parameters having a positive effect on the resulting resource productivity value (Figure 1), which is equally reflected in the prediction model itself.

A surprising finding is the fact that increasing the recycling rate of materials has a negative impact on the overall productivity of the country 's resources. Of course, it is necessary to take into account the mutual influence of other indicators. As can be seen from Figure 1, domestic per capita material consumption has a concurrent effect on the resulting resource productivity. It is clear that, in the case of these two parameters, it is necessary to examine in more detail the extent of the impact of the Domestic consumption of materials on the intensity of the slope of the line representing the Recycling rate. To this end, we are conducting further research. The Recycling rate should have a positive effect on the resource productivity rate. On the contrary, we consider the negative impact of the consumption growth on the overall resource productivity to be the correct result of the analysis.

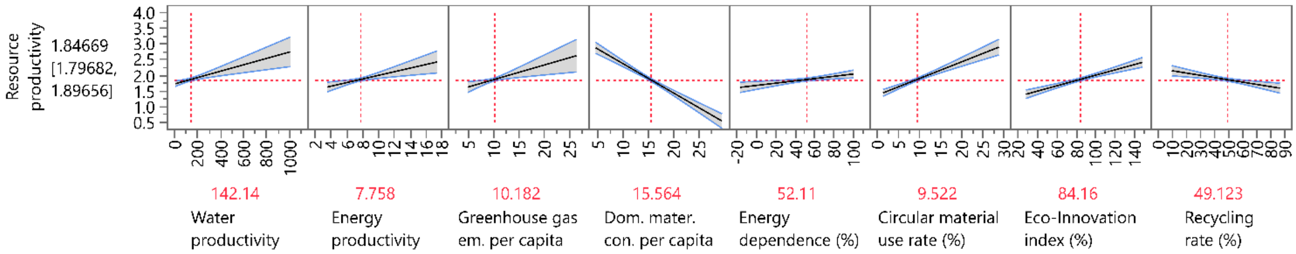


Figure 1. Impact of the individual parameters on the resource productivity value—EU (analyzed by the authors based on the EC data in the JMP software).

The model interprets the statistically significant part of variability (Table 5). The *p*-value is <0.05, which means that the zero hypothesis H0 is valid (H0 = the model interprets the statistically significant part of variability (*p*-value = 0.0001 *)).

Table 5. Test of the statistically significant parameters of the model—EU (analyzed by the authors based on the EC data in the JMP software).

Analysis of Variance				
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Ratio**
Model	8	49.851085	6.23139	133.4926
Error	66	3.080855	0.04668	Prob > F
C. Total	74	52.931940		<0.0001

By including all of the statistically significant parameters (indicators), the model will describe 94% of the variability (Rsquare = 0.94) in Table 6, which means that the model delivers reliable predictions.

Table 6. Descriptive ability of the model—% of the variability described by the model for the EU (analyzed by the authors based on the EC data in the JMP software).

Summary of Fit	
RSquare	0.941796
RSquare Adj	0.934741
Root Mean Square Error	0.216055
Mean of Response	1.848779
Observations (or Sum Wgts.)	75

The resulting model (Figure 2) represents a mathematical relation between the inputs and the response. The analysis defined 8 out of the 14 indicators significantly contributing to the resource productivity results, analyzed on the Pan-European level. The inputs with a statistically significant impact on the resource productivity include: Domestic material consumption per capita; Circular material use rate; Energy productivity; Greenhouse gas emissions per capita; Eco-Innovation index; Recycling rate and Water productivity.

1.1816724679

+ 0.0010168417 • Water productivity

+ 0.0575477259 • Energy productivity

+ 0.0466357543 • Greenhouse gas emissions per capita

+ − 0.093487664 • Domestic material consumption per capita (t)

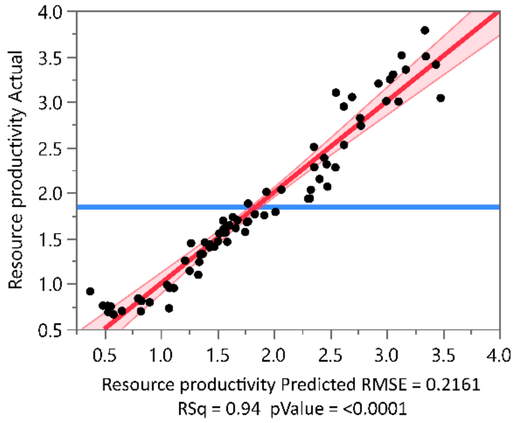
+ 0.0036446635 • Energy dependence (%)

+ 0.0530911558 • Circular material use rate (%)

+ 0.0084889557 • Eco-Inovarion index (%)

+ − 0.007240245 • Recycling rate (%)

(**a**) Prediction Expression



(**b**) Actual by Predicted Plot

Figure 2. Multiple linear regression model of resource productivity for the EU (analyzed by the authors based on the EC data in the JMP software).

3.2. Multiple Linear Regression Analysis on the V4 Level

In this case, we only repeated the multiple linear regression analysis for the V4 countries, in order to examine whether there is any substantial deviation from the existing multiple linear regression analysis model for the whole of the EU. Just as in the previous chapter, the resource productivity was the dependent variable, and the independent variables were the same 14 input parameters. We analyzed the statistical significance of the impact of the input variables, and we discovered that the Domestic material consumption per capita and Energy productivity (Table 7) contributed the most significantly to the total resource productivity in the V4 countries.

Table 7. Estimation of the regression model parameters, ordered by their statistical significance—V4. (analyzed by the authors based on the EC data in the JMP software).

Sorted Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob > |t|
Domestic material consumption per capita (t)	−0.16252	0.034653	−4.69	0.0054
Energy productivity	0.1823476	0.057589	3.17	0.0249
Recycling rate (%)	−0.020496	0.012463	−1.64	0.1610
Water productivity	0.0020457	0.001334	1.53	0.1857
Landfill rate (%)	−0.016602	0.011076	−1.50	0.1942
Greenhouse gas emissions per capita	0.0823471	0.055796	1.48	0.2000
Energy dependence (%)	−0.007355	0.005851	−1.26	0.2643
Eco-Innovation index (%)	0.004104	0.003467	−1.18	0.2898
Water exploitation index	−0.016119	0.023417	−0.69	0.5218
Energy tax % of GDP	10.80975	22.8625	0.47	0.6563
Environmental tax % of GDP	−0.035776	0.089371	−0.40	0.7055
Share of renewable energy in gross final energy consumption (%)	0.0061848	0.020578	0.30	0.7758
Generation of waste excluding major mineral waste per GDP (kg/1000 €)	0.0005548	0.002442	0.23	0.8293
Circular material use rate (%)	0.0049976	0.038754	0.13	0.9024

Using the same method of increasing the significance of parameters, as described in the previous section, we ordered the significant parameters by their statistical significance (Table 8) The most significant parameters of the model are: Domestic material consumption per capita; Water productivity; Energy dependence; Energy productivity and Environmental tax.

Table 8. Statistically significant parameters of the model—V4 (analyzed by the authors based on the EC data in the JMP software).

Source	Logworth	*p* Value
Domestic material consumption per capita (t)	11.530	0.00000
Water productivity	8.400	0.00000
Energy dependence (%)	7.544	0.00000
Energy productivity	4.943	0.00001
Environmental tax % of GDP	4.068	0.00009

The impact of the individual parameters on the resulting resource productivity is described in Figure 3, and the angle of the line clearly suggests that three variables have a negative impact—the Domestic material consumption per capita, Energy dependence and Environmental tax, with the remaining parameters having a positive impact on the resulting value of the resource productivity. As in the case of the EU analysis, the Domestic consumption of materials per capita has the greatest negative impact on overall resource productivity. It is followed by Energy dependence, which is also confirmed historically. It is also interesting to note that while within the EU, the environmental taxes have a statistically insignificant impact on the overall resource productivity, within the V4 countries, increasing the environmental taxes has a clear negative impact on the resulting indicator. In this case, the reason may also be the aforementioned Energy dependence and the efforts of the V4 countries to maximize the use of their own energy resources, which are mostly non-ecological.

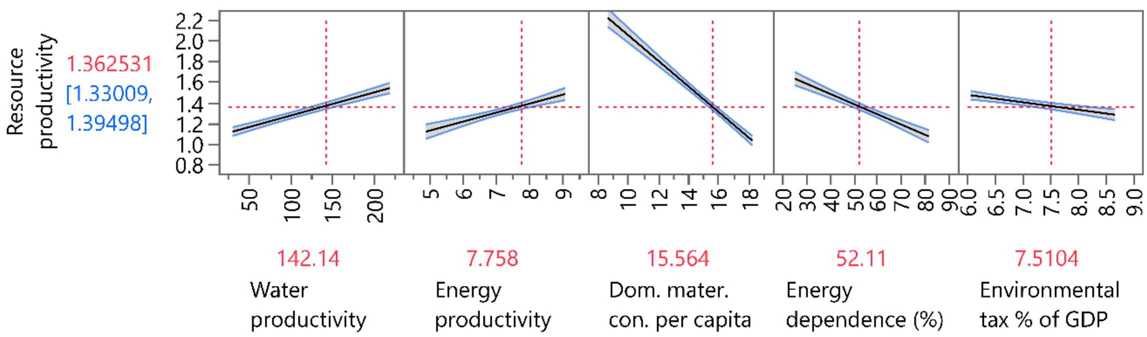


Figure 3. Impact of the individual parameters on the resource productivity value—V4 (analyzed by the authors based on the EC data in the JMP software).

The model also interprets the statistically significant part of variability (Table 9) in this case. The *p*-value is <0.05, which means that the zero hypothesis H0 is valid (H0 = the model interprets the statistically significant part of variability (*p*-value = 0.0001 *)).

By including all of the statistically significant parameters (indicators), the model will describe 98% of the variability (Rsquare = 0.98) in Table 10, which in this case also means that the model delivers reliable predictions.

Table 9. Test of the statistically significant parameters of the model—V4 (analyzed by the authors based on the EC data in the JMP software).

Analysis of Variance				
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Ratio**
Model	5	1.3336638	0.266733	142.4866
Error	14	0.0262078	0.001872	**Prob > F**
C. Total	19	1.3598716		<0.0001

Table 10. Descriptive ability of the model—% of the variability described by the model for the V4 + Lithuania (analyzed by the authors based on the EC data in the JMP software).

Summary of Fit	
RSquare	0.980728
RSquare Adj	0.973845
Root Mean Square Error	0.043266
Mean of Response	1.44534
Observations (or Sum Wgts.)	20

The resulting model (Figure 4) represents a mathematical relationship between the input indicators and resource productivity at the level of the V4 countries. We analyzed 14 input indicators, and the model excluded 9 of the indicators which were statistically insignificant. The analysis defined five indicators with a statistically significant contribution to the resource productivity results analyzed at the level of the V4 countries—Water productivity; Energy productivity; Domestic material consumption per capita; Energy dependence; Environmental tax.

3.3691580108

+ 0.0022339717 • Water productivity

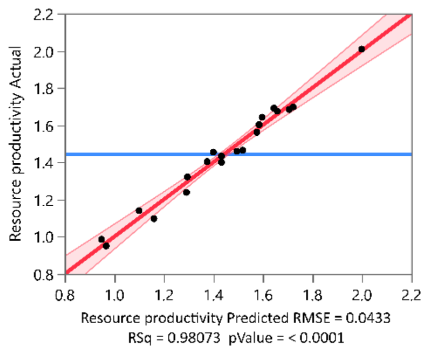
+ 0.0871064957 • Energy productivity

+ − 0.124484584 • Domestic material consumption per capita (t)

+ − 0.00992798 • Energy dependence (%)

+ − 0.072580735 • Environmental tax % of GDP

(**a**) Prediction Expression



(**b**) Actual by Predicted Plot

Figure 4. Multiple linear regression model of resource productivity for the V4 (analyzed by the authors based on the EC data in the JMP software).

After comparing both models, it may be concluded that a considerable difference was identified between these two models, with the historical background of the countries possibly having the most substantial influence. Major limitations in the progress of the V4 countries were detected. Europe has pursued the path of the circular economy by means of implementing green innovations or using waste as a secondary resource, but the V4 countries fall short in implementing these principles. This provides space for further research by the scientific community in the areas of eco-innovations and the ecologization of technologies.

4. Discussion and Conclusions

Haider and Bhat (2020) studied the link between the material and energy efficiency on the one side and the total factor productivity on the other and found out that not all of the countries have the same energy demands. Increasing the total factor productivity is associated with decreased energy levels per a unit of input [27,28]. This was also confirmed in our research, but the impact of energy productivity is more significant in the case of regression analysis at the level of the V4 countries.

Neither does the consumption of materials and energy have a causal link with the gross domestic product [29], which must be monitored due to sustainable development. The afore-mentioned finding was also validated by the study of Belke et al. (2011), who attempted to find a long-term relationship between the consumption of materials and energy and the GDP [30,31].

The findings of the research conducted for the presented paper point out to the need to focus not only on the final goal, but also on the associated factors which influence its achievement. This means that the correlations discovered may help the countries with major differences to redirect their funds to areas seemingly unrelated to a specific goal but which may ultimately accelerate its achievement. For instance, by increasing the recycling rate, the countries will contribute not only to achieving the goal of the decreased landfill rate, but they may also enable the decrease in the Domestic material consumption per capita or to increase the Energy productivity of the state.

It is also necessary to study the productivity in the field of recycling materials [32], which contributes to the improvements in the disposal of solid municipal waste. In addition, it is crucial to take into consideration the use of materials and their recycling, especially in the civil engineering [33], which is affected by factors such as the energy consumption, carbon footprint and the total construction productivity.

If strategies involving the best practices in waste collection were implemented, 18 mil. tons of waste could be collected in Europe on top of the present-day volumes, which would lead to a 13% decrease in the greenhouse gas emission production related to packaging and its waste. Although the high performance of the collection is decisive for resource efficiency, simply improving the systems of the collection of wastes separated from resources will not be sufficient for reaching recycling goals and the goals of decreased greenhouse gas emissions' production; the material losses must be decreased in the entire value chain, i.e., in the phase of the separation of the recycling [34,35].

The results of the analyses confirm the above-mentioned hypothesis and suggest that countries focusing solely on decreasing the production of emissions associated with fossil energy and transport may not attain the desired progress, if they fail to provide an equally intense support for the innovative processes and research and development activities aimed at the ecologization of processes.

Kuhl et al. [36] discuss business models for the circular economy (CE) with potential environmental benefits and resource productivity. The circular business models, based on refurbishing and reusing, promise significant savings in costs as well as major decreases of the negative impact on the environment [37–39]. Resource processing must change radically from the linear-use model based on the purpose to a more sustainable, circular model. In this context, Velenturf et al. (2020) developed a model that acknowledges the complex character of our resource flows [40–42]. The environmental sustainability must be interconnected with the concepts of the green economy, the circular economy and the bioeconomy [43,44].

The multiple linear regression model of resource productivity (Figure 2) suggests that if we intend to increase resource productivity, it is vital to develop and support other areas, such as water productivity, energy dependence, use of renewable energy sources and recycling. The results of the paper include mathematical models pointing out the significance of the individual factors, with the reliability of their impact within the created model being up to 94%.

However, according to Loiseau et al., the links with sustainability are not always clear since there are various degrees of substitutability, compromises between environmental and economic advantages are allowed, and they require more-or-less structural changes to our way of living [45–47]. In addition, the circular economy needs to be linked to the approach to human development (HD), as one of the discussions concerns the missing social and human dimension of the circular economy. Schroder et al. (2020) include the socio–economic elements of the transformation from linear to circulating economic models in combination with HD from social science and development studies [48,49].

This may be related to the application of the results of analyses in the area of the impact of taxes on citizens and entrepreneurs. Resource productivity in a country may also become more efficient if the energy and environmental taxes are set correctly. Such taxes also include a carbon tax. Implementing low-carbon operations across supply chains is vital for a cleaner, more sustainable world [50].

By means of a multiple regression model, we expressed the mathematical relation between the main indicator of "Resource productivity" and the other indicators, both at the level of the EU and at the level of the V4 countries, and we identified a substantial difference between these two models. Major constraints in the development of the V4 countries have been identified. Europe is moving towards a circular economy through the introduction of eco-innovations or the use of waste as a secondary resource. The model at the V4 level does not mention these factors or defines their impact as insignificant; here, the insufficient level of moving these countries towards a circular economy is reflected. It identifies water productivity, energy dependence, energy productivity and environmental tax as the most significant factors. These findings may also be valuable in terms of defining the key drivers of inadequacy of the newly acceding countries to the EU.

In order to reach the goals of the sustainable development with the focus on the circular economy, it is vital to scrutinize every possible sustainable alternative in various fields. This is important for the future development plans of policy-makers [51,52].

The results of the study suggest that setting out long-term goals in sustainable development is a complex process, which, apart from technical and economic knowledge, requires an understanding of the statistical data processing and evaluation, and ultimately the skill of their usable presentation. Within the presented analyses, it was proved that it is necessary to examine in detail, not only the influence of individual parameters on the resulting productivity of resources, but also the effects of the parameters between each other. Further research will focus on the analysis of such interrelationships, and on the determination of the methodology (behavior pattern) for their prediction. By setting out the correct determination of the indicators' plan, on the basis of knowledge of their interaction, it will be possible to optimize the overall resource productivity more effectively.

It is clear that, by scrutinizing the effects of all of the indicators based on the highest amount of highly detailed data possible, we are able to define models of their dependence affecting the achievement of goals, with a reliability of almost 100%. Individual countries, as well as organizations such as the European Union, should therefore expand the processes of data collection and evaluation to facilitate reaching goals in the field of the sustainable development for all of the stakeholders and to make it more realistic.

Author Contributions: Conceptualization, M.T. and P.T.; methodology, M.T.; software, M.T.; validation, L.D. and P.T.; formal analysis, M.T.; investigation, M.T.; resources, P.T.; data curation, L.D. and P.T.; writing—original draft preparation, M.T.; writing—review and editing, P.T.; visualization, M.T.; supervision, L.D.; project administration, L.D.; funding acquisition, L.D. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by VEGA, grant number 1/0797/20.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: Contribution presents the partial result of grant project VEGA 1/0797/20.

Conflicts of Interest: The authors declare no conflict of interest.

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