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The Efficiency of Resource Utilization in EU-28 Countries through Eco-Innovation and Digital Inclusion

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Abstract: Innovation has been a historical driver for progress. The need for more effective resource utilization has ignited the presence of many innovations in the economic environment. Among others, digitalization and internet connectivity are important pillars of development. Our paper aims to provide a few insights related to the question "How can we increase the efficiency of resource utilization in EU-28 countries through Eco-Innovation and Digital Inclusion?" This paper examines the issue of innovation related to the use of natural resources (Eco-innovation) as a determining factor in resource consumption in societies with different levels of digital inclusion. Our analysis is based on clustering of EU-28 Member States using three variables: the degree of digital inclusion, the Eco-Innovation Index, and the degree of resource use. We expect digital inclusion to mediate the relationship between eco-innovation and resource utilization. Clustering might reveal how the Eco-Innovation Index, Digital Inclusion Level, and Resource Productivity Index differ among EU-28 Member States and provide relevant information for prioritization of resource allocation at the EU level. Our approach of clustering based on the three variables considered reveals that countries with a better economy present better performance from the point of view of Digital Inclusion in the context of Eco-Innovation and the use of resources.

Keywords: European Union Green Pact; eco-innovation; digital inclusion; resource productivity

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1. Introduction

The degree of digitalization has become important in today's society, where permanent challenges for the utilization of resources are modifying many parameters used in optimizing resource allocation. The European Union has been facing several climate and environmental concerns, the main one being the deterioration of the ecosystem. Climate and environmental issues are those that address the need to adopt complex solutions in economic activity (especially in agriculture, forestry and fishing), trade, e-commerce, and consumption of renewable resources, according to studies conducted by the European Commission [1]. As result, the European Commission had prepared the Green Pact.

An important aspect in the strategic management of the Green Pact of the European Union is the innovative use of resources, given that the degree of digitalization is inherently dynamic. The efficient use of resources is envisaged through digitalization in order to allow the transition to a circular economy, which is able to ensure extension of the life cycle of products [2,3].

The complexity of today's global phenomena and the Sustainable Development Goals (SDGs) require an integrated reform of society, the economy, and the environment (UN General Assembly). Education for sustainable development is crucial to this reform, dramatically influencing the speed of change and playing an essential role in environmental practices and policies that can promote ecosystem conservation and resource use. Thus, connecting education to the trends shaping the world in which we live has become a significant urgency [4].

Digital technologies have become an essential tool for achieving an economically efficient multidimensional world. They enable the rapid detection of pollution sources, improve energy efficiency, and provide support for reducing carbon emissions and greenhouse gases in the environment. Digital technologies strive to reduce or eliminate pollution and waste while increasing efficiency and production. These technologies have demonstrated a strong impact on the education system.

The recent COVID-19 pandemic has further institutionalized the applications of digital technologies. These digital technologies have made for a paradigm shift in the entire education system. It is not only a provider of knowledge, but a co-creator of information, a mentor, and an evaluator [5]. The introduction of new technology-assisted learning tools through mobile devices, tablets, laptops, simulations, dynamic visualizations, and virtual labs have transformed education in schools and institutions. Therefore, the Internet of Things (IoT) has proven to be a robust mechanism for integrating a world-class learning experience for everyone.

Another important objective of the Green Pact of the European Union is the more significant use of renewable energy. This objective is expected to generate an increase in the number of jobs in the electricity and construction sectors [4]. The "Get Ready for 55" package, part of the European Union's Green Pact, is a set of objectives included in the European Climate Legislation which take account of employment, stimulating investment capacity and innovation [6].

Bearing in mind all of the above-mentioned elements, our study addresses a current issue, namely, the link between innovation and use of resources in a society with a specific degree of digital inclusion. This paper aims to provide a few insights sparked by the question "How can we increase the efficiency of resource utilization in EU-28 countries through Eco-Innovation and Digital Inclusion?" by analyzing the following directions:

1. How can the EU-28 countries be effectively grouped into clusters based on the Eco-innovation Index, Digital Inclusion Index, and Resource productivity?
2. Does digital inclusion mediate the relationship between eco-innovation and resource utilization at the level of EU-28 countries?

The first question offers a perspective on the clustering of European countries according to the Eco-innovation Index, Digital Inclusion Index, and Resource productivity indicators. The clustering of countries according to this criterion can be used in analysis of efficiency and sustainability. Through the resulting clustering, our research can provide relevant information for the identification of successful policies in the most developed EU-28 countries as measures by the Eco-innovation Index and Digital Inclusion Index and the prioritization for resource allocation. This is important for policy setting in these fields and multi-annual budgeting for less-developed EU countries such as Romania. This approach is a novelty in the specialized literature, and is achieved using hierarchical cluster analysis (Ward's method with the squared Euclidian distance metric) and the K-Means clustering algorithm.

The second question supports the understanding of the mediating role of digital inclusion between eco-innovation and resource utilization. This study can be useful for policy prioritization in less-developed EU countries.

This paper presents a brief review of the literature, the research methodology, and conclusions, having as its specific objective the investigation of the direct and indirect relationship between eco-innovation (IV) and resource productivity (DV).

2. Materials and Methods

2.1. Review of Scientific Literature

The Juncker strategy led to the revision of the European energy legislation through the "winter" package for 2016. The revised legislation mentioned the need to integrate the renewable energy system, which is necessary to streamline the actions taken to reduce the negative impact on the European ecosystem in the medium and long terms [7].

As result, there were efforts in the following directions: (1) reform of the renewable energy system; (2) updating the energy efficiency of buildings; and (3) a new strategic governance package responsible for implementing tougher governance restrictions in order to coordinate the energy system through policies of the National Energy and Climate Plans [8].

The social effects of environmental policy were examined in order to determine opportunities for possible new jobs. As long as economic growth is strongly correlated with resource usage, experts emphasize that the strategy of the European Union's Green Pact has various expected benefits such as efficiency in the competitive allocation of resources and a significant reduction in net greenhouse gas emissions by 2050, while securing the conversion of European Union into a nondiscriminatory and prosperous society [9].

Implementing the ecological transition is not an easy process due to the vision underlying it, namely, a complex transformation into alliances between governments and industry representatives for climate neutrality that is not always positively correlated with the business objectives of the companies [10].

On the other hand, in many economically developed states of the European Union innovative technologies are promoted only when they are on the market and their use determines a significant reduction in costs. This approach does not take into consideration that the European Clean Energy Package is a valuable incentive to increase competition and the number of technological innovations as well as to develop the market for specific green technologies [11].

Strategies based on the digitalization processes provide a few obvious benefits, such as a significant reduction of waste, help in streamlining processes in companies, inducing longer product life cycles, and a meaningfully reduction in information transaction costs [12]. As a consequence, there is an inverse correlation between flows of materials used in the production of goods and services and the increase in the efficiency of resource consumption.

However, parsimoniously, there remain technological challenges that are difficult to solve and that require obstacles in implementing business models to be overcome. Therefore, the need for implementation of a solution such as circular economy based on digital technology becomes obvious [13].

For setting goals in the process of transition to circular economy, the EU-28 Member States started to analyze the relationship between eco-innovation and digitalization. Digital eco-innovation is an indispensable component of the transition to a circular economy; thus, we review the literature on this concept as well as that on digitalization.

The last several years have pushed many transformations of the business environment. Beyond the pledges of authorities and companies around increasing the resource usage through technological innovations, the COVID-19 pandemic stimulated a radical increase in the degree of digitalization of society at the global level. In addition, the strategies of the European Green Pact have aimed to improve European living conditions in the medium and long terms based on a series of measures and tools that encompass an integrative process based on digitalization.

Digitization is a term with multiple meanings specific to different fields; in recent years, several studies have been carried out on this topic. Digitization is relevant to a wide range of industries, being defined by terms such as digital connectivity, internet use, e-business, e-commerce, and e-services. Digitalization is at the core of transformation of society through its presence in all areas of daily life, such as communication, media, and workplaces.

Digitization provides access to an integrated network of information that can be beneficial for society. It can contribute to the development of the relationship between suppliers and consumers. Digitization can stimulate the commitment of internal resources to maximize the advantages determined by the innovation of business processes [14].

One of the facets of digitization, digital inclusion, has become increasingly important, referring to the process of ensuring universal access and effective use of information and communication technologies (ICT) by the population.

In accordance with the sustainable development goals established by the United Nations, digital inclusion can play a vital role in transforming localities and the people who live there into sustainable and inclusive environments, helping to reduce intra- and inter-nation inequity [15]. Thus, Neagu, Berige and Lendzhova (2021) highlighted the fact that the more virtual mobility is emphasized within a society, the greater its degree of digital inclusion. Furthermore, the higher the degree of digital inclusion, the more people become mobile [16]

Xiang et al. (2023) provided evidence that digital inclusion and supply chains can alter consumption patterns due to the heterogeneous impact of digital inclusion on consumption category shares. They emphasized that digital inclusion significantly affects household decision-making and consumer behavior [17].

On the other hand, companies can reduce their environmental impact and greatly improve their performance if they have effective collaborative capabilities, eco-technological innovation, and environmental strategies [18].

However, there is a gap between digital access and digital use (consumption and production), which is deeply related to the cultural, economic, and social conditions of individuals. The lack of digital access represents a determining factor against sustainable development, especially in the post-COVID-19 context [19].

In addition, the digital governance model that consider the environmental, social, and corporate elements has a significant direct positive effect on customer attitudes and product brand equity [20].

Another study on the Eco-Innovation Index specific to the European Union brought to the fore significant fluctuations in terms of the performance of the innovation process in the use of natural resources as well as of the components of the product life cycle. The conclusion was that the fundamental element of the transition to a circular economy is the "circularization" of the technology sector itself. Pichlak and Szromek (2021) highlighted the fact that the most eco-innovative companies are those that develop technologies for the protection of biodiversity [21].

Nowadays, society assumes new commitments in the field of climate, stimulating the expansion of responsible activities. We live in a new era of business in which the implementation of eco-innovation is key to maintaining competitive advantages through the sustainable transformation of business models [22].

Eco-innovation ensures a competitive advantage and has a positive effect on financial performance. Thus, the adoption of eco-innovation has effects both in terms of economic aspects (market share, sales, profitability, quality, launch of new products on the market before competitors) and cost performance (cost of energy and materials per production unit, compliance with environmental performance standards, penalties for non-compliance with environmental laws) [23].

Technological heterogeneity and absorptive capacity are factors that cause productivity differences in the EU as well as globally [24]. Therefore, the transition to sustainability could be enhanced by boosting any of the thematic areas or indicators included in the eco-innovation index, especially in lower performing countries. In terms of innovation, EU-28 Member States are pursuing policies and practices to achieve the goals of the circular economy and sustainability [12].

Therefore, it becomes obvious that there is a need for a forecast study with a higher degree of accuracy on strategic parameters that can be used for policy decisions in EU countries. Thus, our endeavor aims to analyze the relationship between eco-innovation, digital inclusion, and resource productivity indexes, aiming to identify the successful policies of the most developed EU-28 countries in the fields of eco-innovation and digital inclusion in order to disseminate them and decrease the development gaps among EU-28 countries.

The results of our work can be meaningful for policy-makers and practitioners. Through the Digital Europe Program, the European Union wants to promote the implementation of innovative digital technologies at the economic and social levels, investing an estimated 15% of the total multiannual financial proposal for the years 2021–2027 [25].

2.2. Research Items

The current economic and social context presents challenges such as reducing the degradation of European ecosystems and improving various economic and social parameters [26]. Therefore, implementing innovative measures represents an obvious strategy for growth. The continuously increasing digitalization rate motivated us to conduct a study on the role of digitalization in the relationship between innovation and the use of resources in today's European society.

Eco-innovation and ecological technology are essential for the future of Europe, being an important theme of EU policies. To take a step towards sustainable economic growth, more green innovation is needed [27]. Eco-innovation is considered a tool for increasing the competitiveness of producers, reducing their costs and offering new solutions for customers whose environmental awareness is constantly growing [28]. As processes, eco-innovations represent optimization through the selection of appropriate materials, flows, and distribution methods which can be used with lower consumption of energy and natural resources and with as little overall pollution as possible [29].

The Eco-Innovation Index provides a high-level assessment of the state of the economy, society, and the environment [30]. Eco-innovation involves resource efficiency and aggregate socio-economic characteristics [31].

The Eco-Innovation Index was created by aggregating sixteen metrics for the five components [32], as presented in Figure 1. Its constituents are Inputs of Eco-innovation (revealed through Government loans and expenditures for environment and energy, research, and development and Total number of research and development staff and researchers), Eco-innovation activities (exposed by the Number of enterprises that have introduced an innovation with environmental benefits obtained within the enterprise, Number of companies with environmental innovations, and Number of ISO 14001 [33] registered organizations), Eco-innovation results (revealed through Number of patents related to eco-innovation, Number of academic publications related to eco-innovation, and Number of accesses in all electronic media related to eco-innovation), Results on resource efficiency (from Productivity of materials, Water productivity, Energy productivity, and Intensity of GHG emissions), and Socio-economic results (measured through Exports of products from Eco-industries, Employment in eco-industries, and Turnover in eco-industries).

Another component included in our study was the Digital Inclusion Index. It summarizes all activities of access to information and communication technologies, including reliable access to the internet, digital devices, technical and content support, applications, and software [34].

The Digital Inclusion Index reflects access, accessibility, and digital ability specific to each country through indicators such as digitalization, internet connectivity (access, technology, etc.), and digital skills [35].

In recent years, the focus of digital inclusion has shifted from digital access to digital results [36]. This highlights that the existence of attitudes and basic skills does not automatically determine digital inclusion, this being determined by the level to which individuals with the right attitudes and skills participate and engage in various activities on the internet [37].

Last but not least, the third integral component of this study is the yield of the use of resource within EU Member States [38]. Resource productivity refers to the productivity of using digital technologies in everyday life.

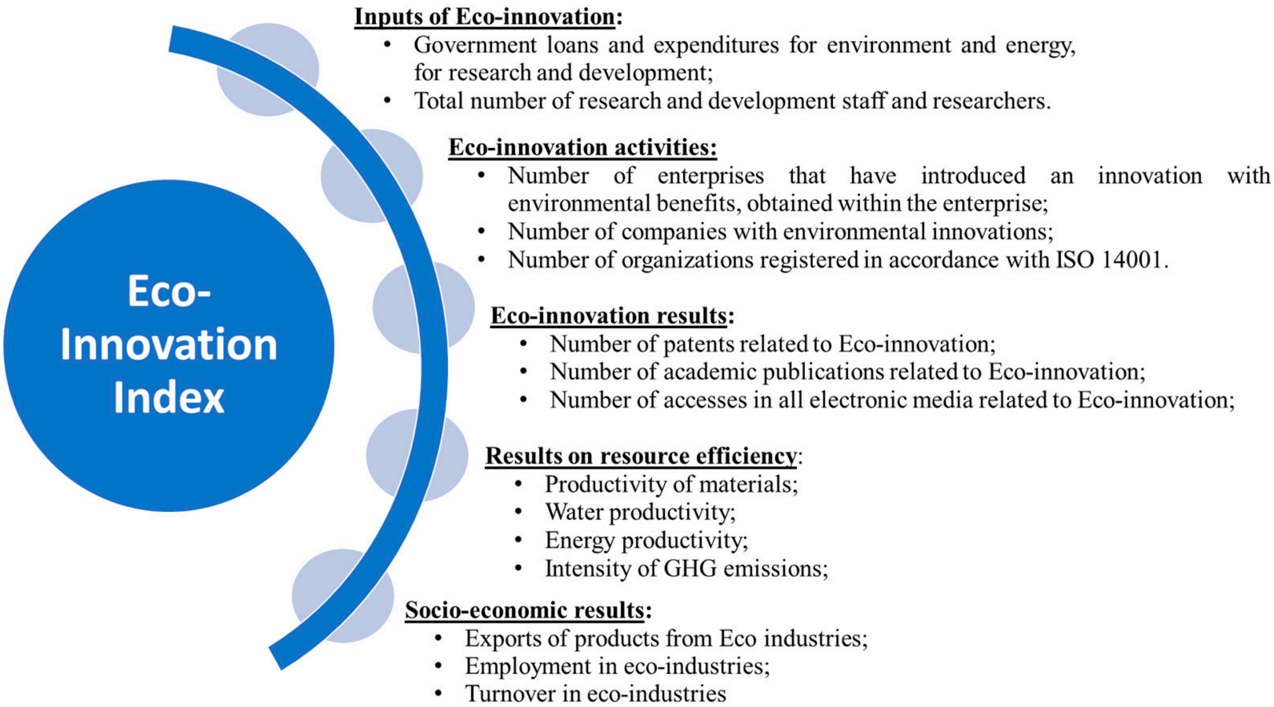


Figure 1. Components of the Eco-Innovation Index. (Authors' representation based on Al-Ajlani et al., 2021 [32]).

Among many changes, the recent COVID-19 pandemic has determined the development of digital financial services, especially through its digital financial inclusion component. This inclusion is essential in order to ensure everyone's access to digital financial services, thereby actively contributing to sustainable economic growth. Economic development and activities that promote digital financial inclusion must be aligned in order to contribute to the achievement of the Sustainable Development Goals for 2030 [5].

2.3. Research Methodology

Our research is based on eco-innovation, digital inclusion, and resource productivity indexes provided by Eurostat, the EEA, and the Organisation for Economic Co-operation and Development (OECD)

The analysis was conducted focusing on all EU-28 Member States for the period 2010–2020 using data about digital inclusion, eco-innovation, and resource productivity available on EUROSTAT, the statistical website of the European Commission, which includes the economic and statistical data of European countries.

Based on our literature review, we considered the following hypotheses for testing to be validated/invalidated:

H1. *Eco-innovation significantly influences digital inclusion.*

H2. *There is a significant direct and positive relationship between digital inclusion and resource productivity.*

H3. *Eco-innovation contributes to increasing resource productivity.*

H4. *Digital inclusion mediates the relationship between Eco-innovation and digital inclusion.*

For the validation/invalidation of hypotheses H1, H2, and H3, we used SPSS to estimate several types of models (Linear, Quadratic, Compound, Growth, Logarithmic, Cubic, Exponential, Inverse, and Power) in order to find the best fit for our data.

Mediation focuses on the relationships between two variables, X and Y, when X can be considered a possible cause of Y. When a third variable, Z, is incorporated, many relationships may exist. Z may cause both X and Y, making it a confounding variable [39]. Moreover, Z may enhance X's prediction of Y without modifying the relationship between X and Y.

It is often of great interest to identify and study the mechanisms through which a mediating variable intervenes in determining the dependent variable [40]. It can influence the outcome in two different ways. First, it can act as a moderator, causing the focal process to deviate from its natural free-running state; thus, at an experimentally-settled level of the IV, the DV functions differently when moderation occurs versus when it does not.

In addition, we can compare the effect of X on Y between the condition in which the hypothesized process operates freely and naturally and the condition in which the hypothesized process is "bound" by another variable. Mediation is the adding of a third variable (M) to the relationship $X \rightarrow Y$, whereby X causes the mediator M ($X \rightarrow M$) and M causes Y ($M \rightarrow Y$), meaning that $X \rightarrow M \rightarrow Y$. Researchers use three equations to represent the relationships among X, M, and Y, as follows: $Y = cX + e1$; $M = aX + e2$; $Y = c'X + bM + e3$. Statistical mediation analyses test whether c and c′ differ from each other. Because $c = c' + ab$, researchers usually directly test the point estimate of the indirect effect (ab) against zero using a bootstrapping approach. If the difference is significant, then the hypothesized process serves as a mediating process linking X to Y. Statistical mediation analyses have been questioned due to the limitation of causal inference between M and Y [41].

The mediation process that depicts our fourth hypothesis, namely, the intervention of digitalization in the relationship between the Eco-Innovation Index and the degree of use of resources, is presented in Figure 2.

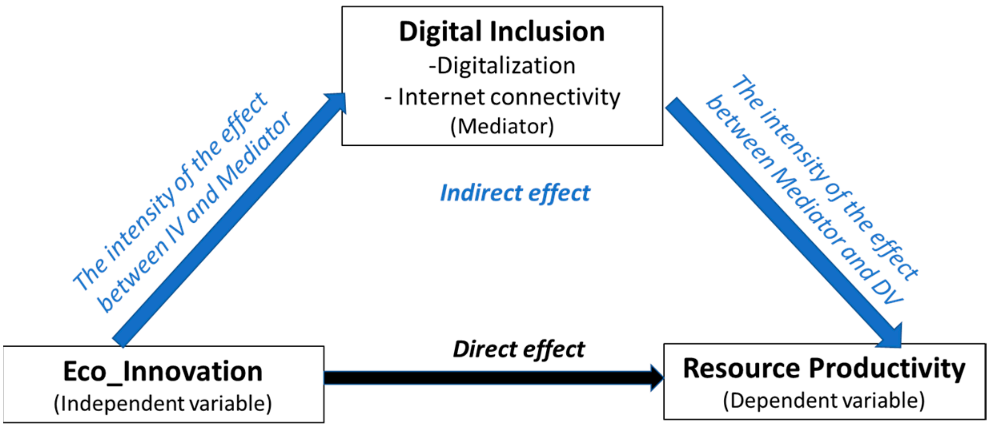


Figure 2. Digital inclusion as a mediating factor (research proposal).

Eco-innovation is the independent variable in Figure 2, and its "effect" on resource consumption is the dependent variable that is communicated via two channels.

The direct propagation effect represents only a part of the total propagation value, as in this case the independent variable influences the dependent variable through the variable acting as mediator: independent variable $\rightarrow$ variable mediation; mediator $\rightarrow$ dependent variable.

The propagating indirect effect depends on the mediator–independent variable relationship. This effect is the product of two indices: the independent variable–mediator intensity index and the mediator-dependent variable intensity index [42]. Rammer and Seidl emphasized that hierarchical learning-based neural networks and data mining methods are among the most appropriate prediction tools used by specialists when studying environmental problems [43].

However, in order to achieve the goal of our research, we used descriptive data analysis techniques (more precisely, data grouping techniques) generally applied to multivariate data sets to identify the structure present in the data. Clusters are formed by evaluating the similarities and dissimilarities of intrinsic characteristics between different cases, and the clustering of cases is based on emergent similarities [7].

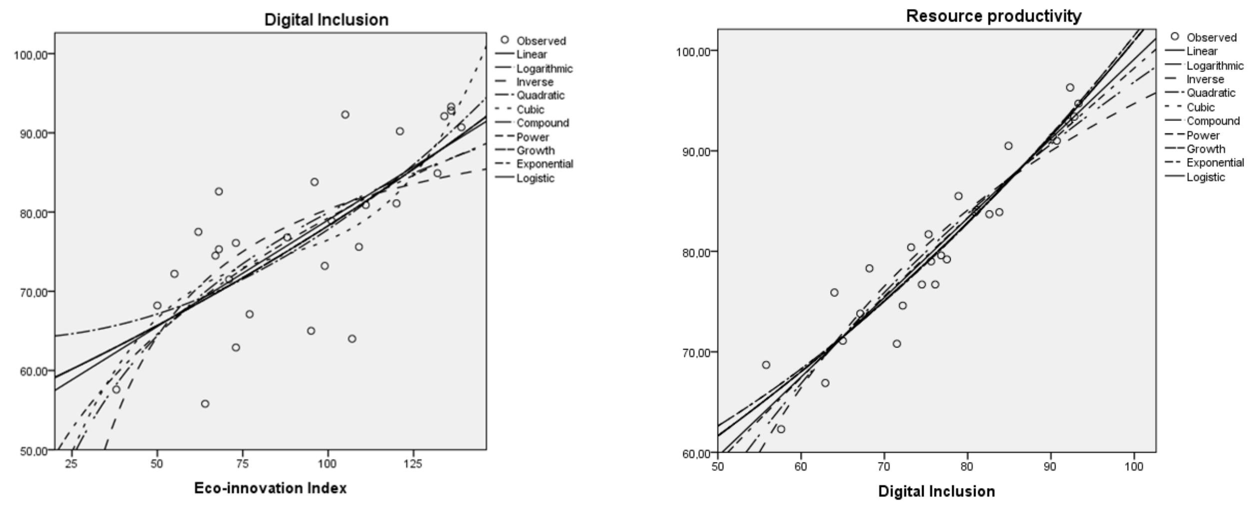
In order to identify the cluster that Romania belongs to, we a used a two-step approach in the clustering to identify those EU-28 member states which have similar characteristics. First, we identified the number of clusters within the EU-28 member states through a hierarchical clustering analysis. We used Ward's method and chose the squared Euclidian distance metric. All data were standardized before performing the data analysis.

Furthermore, we performed K-Means cluster analysis to identify the cluster membership, taking into account the number of groups identified in the previous analysis [44]. The grouping was based on the following variables: the Digital Inclusion Index, the Eco-Innovation Index, and the degree of resource use.

The K-means technique was used to divide either the cases or the variables of a dataset into non-overlapping groups based on discovered features. Our objective was to produce clusters of cases/variables with a high degree of similarity within each group and a low degree of similarity between groups. The K-Means clustering technique is based on the calculation of a vector (which represents the mean) used to describe each cluster. This centroid technique has become widely used in the exploratory analysis of (large) datasets, which can be clustered/mined them in various research fields thanks to increases in computer processing power [45]. Therefore, the K-Means technique has become a favorite tool for use in such research. The data processing for this study was performed using the statistical tool SPSS (Statistical Package for the Social Sciences) version 23.

3. Results

We used SPSS to estimate several types of models (Linear, Quadratic, Compound, Growth, Logarithmic, Cubic, Exponential, Inverse, and Power), aiming for the best fit. The estimated models for the relationship between our variables are presented in Figures 3 and 4.



(**a**) (**b**)

Figure 3. Estimated models * for the relationship between (**a**) Eco-Innovation (IV) and Digital Inclusion (DV) indexes and (**b**) Digital Inclusion (IV) and Resource Productivity (DV). * Note: Some representations of the estimated models might be overlapping.

Figure 3 presents all the estimated models for the relationship between eco-innovation (IV) and digital inclusion (DV) (Figure 3a) as well as the relationship between digital inclusion (IV) and resource productivity (DV) (Figure 3b).

In the same way, Figure 4 presents the estimated models for the relationship between eco-innovation (IV) and resource productivity (DV).

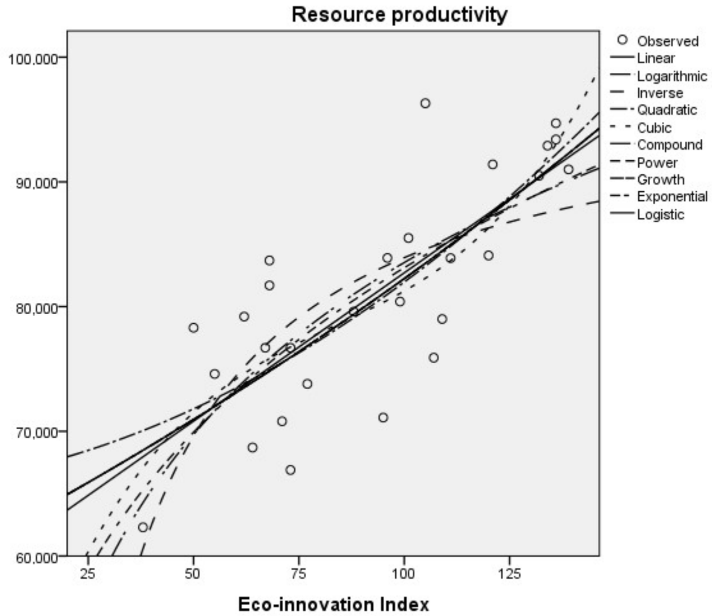


Figure 4. Representations * of the estimated model for the relationship between Eco-Innovation (IV) and Resource Productivity (DV). * Note: Some representations of the estimated models might be overlapping.

Each figure presents the possible estimated models, the "best model" being selected further, according to R square and *p* value for each relationship studied.

We assessed the correlations among our variables, which are presented in Table 1. All three variables are positively correlated and statistically significant, as highlighted by a *p* value < 0.01. Furthermore, digital inclusion and resource productivity are highly correlated, with a coefficient of 0.952.

Table 1. Correlations among variables.

	Eco-Innovation Index	Digital Inclusion	Resource Productivity
Eco-innovation Index		0.734 **	0.782 **
Digital Inclusion	0.734 **		0.952 **
Resource productivity	0.782 **	0.952 **	

**. All correlations are statistically significant (*p*-value < 0.01).

We used the Fischer test to identify the best estimation model for the relationship between the analyzed variables, obtaining the results presented in Table 2.

Table 2. Estimated models.

Independent Variable	Dependent Variable	The Most Effective Model Estimator	*p*-Value	R	Fisher Test
Eco-inovation	Digital Inclusion	Cubic	0.00 < 0.05	0.763	$11.12 > F_{tab}$
Digital Inclusion	Resource Productivity	Quadratic	0.00 < 0.05	0.954	$127.89 > F_{tab}$
Eco-inovation	Resource Productivity	Quadratic	0.00 < 0.05	0.786	$20.22 > F_{tab}$

The most effective estimator of the models presented in Figures 3 and 4 were identified following the analysis of the coefficient of determination (R), *p*-value, and the value of the Fisher test result. Thus, the resulting model for each relationship among variables was the one that had the highest R, a *p*-value below 0.05, and Val Fisher test > Tabular Fisher (F_{tab} = 3.5874 for alfa = 0.05), being presented in Table 2.

According to the results presented in Tables 1 and 2, Hypotheses 1–3 are accepted.

We studied the correlations in Table 1 to determine whether or not the efficient use of resources can be supported only by the evolutionary trend of the eco-innovation index. It seems that the efficient use of resources within the EU-28 countries is supported by the complementarity between the eco-innovation index and the digital inclusion index. It should be mentioned that the micro-, meso-, and macroeconomic strategies of the EU-28 countries should be based on the propulsion of digital inclusion and eco-innovation in finding better and better solutions to provide a balance, both in the use of green resources as well as in the automation of the workforce.

Table 3 illustrates the digital inclusion mediation testing of eco-innovation and resource productivity. The data show that the *indirect effect of IV on DV through the mediator* has a higher value than *the direct effect of IV on DV*, demonstrating the validity of hypothesis H4, according to which the degree of digital inclusion (partially) mediates the relationship between the Eco-Innovation Index and the degree of use of resources. The performance of the analysed model, presented in Table 3, is revealed by the coefficient of determination, which has a significant value of 92.06% and *p*-value < 0.05.

Table 3. Relationship between Eco-Innovation (IV) and Resource Productivity (DV).

Mediator: Digital Inclusion	Coefficient	SE	*p*-Value	Bootstrap 95%CI
Direct effect of mediator on DV	0.68	0.07	<0.05	[0.54, 0.82]
Total effect of IV on DV	0.24	0.04	<0.05	[0.16, 0.31]
Direct effect of IV on DV	0.06	0.03	<0.05	[0.01, 0.11]
Indirect effect of IV on DV through the mediator	0.18	0.03	-	[0.12, 0.25]

Source: SPSS output.

In addition, the value of the coefficient of determination resulting from the analysis was used to carry out the clustering of the EU-28 countries. Table 4 displays the results of applying the K-Means clustering algorithm to the data.

The results of the division into clusters presented in Table 4 shows the evolutionary behavior of EU-28 Member States in terms of the Eco-Innovation Index, Resource Productivity Index, and degree of digital inclusion.

Table 4. The Eco-Innovation Index, Digital Inclusion Level, and Resource Productivity Index country clustering results.

Eco-Innovation Index			Digital Inclusion Level			Resource Productivity Index		
Cluster	**Country**	**Value ***	**Cluster**	**Country**	**Value ***	**Cluster**	**Country**	**Value ***
1	Austria	120	1	Austria	81	1	Denmark	93
1	Denmark	136	1	Belgium	84	1	Finland	91
1	Finland	139	1	Czechia	77	1	Germany	91
1	Germany	132	1	Estonia	83	1	Luxembourg	95
1	Sweden	134	1	France	81	1	Netherlands	96
1	United Kingdom **	121	1	Germany	85	1	Sweden	93
1	Luxembourg	136	1	Hungary	75	1	United Kingdom **	91
2	Belgium	96	1	Ireland	79	2	Austria	84
2	Czechia	88	1	Latvia	76	2	Belgium	84
2	France	111	1	Malta	75	2	Czechia	80
2	Ireland	101	1	Slovakia	78	2	Estonia	84
2	Italy	107	1	Spain	76	2	France	84
2	Netherlands	105	2	Denmark	93	2	Ireland	86
2	Portugal	95	2	Finland	91	2	Malta	82

Table 4. *Cont.*

Eco-Innovation Index			Digital Inclusion Level			Resource Productivity Index		
Cluster	**Country**	**Value ***	**Cluster**	**Country**	**Value ***	**Cluster**	**Country**	**Value ***
2	Slovenia	99	2	Luxembourg	93	2	Poland	78
2	Spain	109	2	Netherlands	92	2	Slovakia	79
3	Poland	50	2	Sweden	92	2	Slovenia	80
3	Bulgaria	38	2	United Kingdom **	90	2	Spain	79
3	Cyprus	55	3	Bulgaria	58	3	Bulgaria	62
4	Hungary	67	3	Romania	56	3	Greece	67
4	Greece	73	4	Croatia	67	3	Romania	69
4	Croatia	77	4	Cyprus	72	4	Croatia	74
4	Slovakia	62	4	Greece	63	4	Cyprus	75
4	Latvia	73	4	Italy	64	4	Hungary	77
4	Lithuania	71	4	Lithuania	72	4	Italy	76
4	Malta	68	4	Poland	68	4	Latvia	77
4	Romania	64	4	Portugal	65	4	Lithuania	71
4	Estonia	68	4	Slovenia	73	4	Portugal	71

Note: * The value of the coefficient of determination resulting from the analysis, on which basis the clustering was carried out; ** UK left the European Union in January 2020.

4. Discussion

Our study aims to evaluate the direct effect of Eco-Innovation Index (considered an independent variable) on resource productivity (the dependent variable) as well as the indirect effect manifested through the Digital Inclusion Index acting as a mediator.

In light of these effects, the mediation relationship is significant and is reproduced through the last hypothesis.

This paper aims to identify the efficient economic behavior of EU-28 countries according to the Eco-Innovation Index, Digital Inclusion Index, and resource productivity. Thus, four groups of EU-28 countries that show significant similarities in terms of digitization have been configured. They reveal that high Eco-Innovation Index countries such as Austria, Denmark, Finland, Germany, Luxembourg, Sweden, and the United Kingdom followed a similar path toward more effective eco-innovation policies and practices. The same level of openness has been applied to the implementation of eco-innovation policies in these nations. There has not been a large increase in the Eco-Innovation Index score for a number of countries in cluster 3 (including Poland, Cyprus, and Bulgaria). As Nikolova-Alexieva and others (2022) observed for Bulgaria, this might be the result of an undeveloped entrepreneurial innovation culture [46]. Therefore, these countries have to capitalize on their human capital and newly developed technology while concentrating efforts on research and development. Investments in research initiatives, particularly in the fields of ecology, energy, and agriculture, could be a useful tactic for these countries.

The second cluster, which includes countries such as Belgium, the Czech Republic, France, Ireland, Italy, the Netherlands, Portugal, Slovenia, and Spain, has average eco-innovation efficiency, as shown by the average Eco-Innovation Index values. There are certain European Union (EU) member states with Eco-Innovation Index scores above zero, while others, such as Croatia, Estonia, Greece, Hungary, Latvia, Lithuania, Malta, Romania, and Slovakia, have scores below zero. As EUROSTAT mentioned, a reason for these low scores might be the modest investment in R&D&I; thus, boosting the eco-innovation factors for these countries should be on the agenda of policy makers.

In terms of digital inclusion, the resulting first cluster reveals countries such as Austria, Belgium, Estonia, Czech Republic, France, Ireland, Germany, Hungary, Lithuania, Malta, Slovakia, and Spain that have followed the same evolutionary tendency in their degree of digital inclusion. They show an average level for the values associated with the degree of digital inclusion.

The leading EU-28 Member States, such as Finland, Denmark, Luxembourg, the Netherlands, Sweden, and the United Kingdom, have the highest degree of digital inclusion. Cyprus, Croatia, Greece, Italy, Lithuania, Poland, Portugal, and Slovenia are ranked at the average level for digital inclusion thanks to European economic development programs. Among the less-developed EU-28 countries, both Romania and Bulgaria, for example, tend to have the same behavior in terms of digital inclusion. They are in the last two places regarding their degree of digital inclusion due to a lack of digital education, mainly in rural environments [47,48], as well as fragmentation of digital public services both from a territorial point of view and at the decision-making level [49].

Last but not least, it should be mentioned that in terms of resource usage efficiency, countries such as Hungary, Portugal, Cyprus, Croatia, Italy, Lithuania, and Latvia have nevertheless succeeded in increasing their resource productivity over the last decade thanks to the European funds for financing economic sustainability projects. While Romania, Greece, and Bulgaria have reached an almost acceptable level of resource productivity yield, its annual growth is insignificant. Although Romania has seen a modest increase in the efficient use of resources, the main cause of slow growth remains poor resource management.

A conclusion of our study is that countries with better economies present better performance from the point of view of digital inclusion articulated in the context of eco-innovation and the use of resources. This conclusion is substantiated by our analysis of clusters of countries grouped based on the three variables considered in this study.

The results of this study can be useful for practitioners and policy-makers due to the fact that it reveals how digital inclusion acts as a mediator and can significantly facilitate the transfer of innovation. This phenomenon can further increase the value of the Eco-Innovation Index and generate an increase in the productivity of resources. Therefore, it is necessary for policy-makers to put in place legal frameworks and financial instruments for the development of digital inclusion and eco-innovation incentives.

Using the clusters determined in our research, policy-makers can initiate suitable socio-economic projects for each cluster to allow the efficient use of resources through digitization and the adoption of optimal eco-innovation strategies.

However, according to the 2030 Sustainable Development Agenda, household digital access and connectivity do not guarantee equal access and use of digital tools by all household members [12,50]. Resources may not be allocated equally within households, and one of the dimensions that reflects the way resources can be distributed is the gender of people [51]. Therefore, more comprehensive analysis using data disaggregated by gender and age is necessary.

Our approach reveals the importance of the relationships between the Eco-Innovation Index, Digital Inclusion Index, and resource productivity, highlighting the need to study the role of individual behaviors in increasing resources productivity. Among the successful tools for this, we can mention increasing the use of automation and digitization in all fields of activity and improving the digital literacy of the population. In addition, eco-innovation can increase the productivity of resources, ensuring a constant increase in the yield of the use of both human and material resources.

In another vein, the current economic context forces world economies to find solutions to reduce inefficient use of resources, emphasizing greening through eco-innovation and digitization.

The results in Table 1 show a statistically significant evolution of the three considered parameters in the same direction. In other words, it should be emphasized that resource productivity is vulnerable to the trend of eco-innovation mediated through digital inclusion.

Notably, our research is limited in scope and approach, and can be further developed. Thus far, we have not identified efforts regarding the division of countries into clusters related to the efficiency of strategies for green politics based on digital inclusion. Another limitation of the present work could be its failure to take into consideration the main macroeconomic variables and their correlation with digitization and innovation strategies, especially for developing countries.

This research can be extended by comparing the psycho-socio-economic approach of macro-, meso-, and microeconomic parameters to the quantitative approach of the subcomponents of the indicators under consideration.

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