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SUSTAINABLE DEVELOPMENT THROUGH ECO-INNOVATION. EMPIRICAL EVIDENCE FROM THE EU-27 MEMBER STATES

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Abstract. Increasing concerns for ensuring a sustainable future generated an imperative need to shift toward a circular economy and sustainable innovations. In this framework, eco-innovation becomes essential for achieving sustainable development. The main purpose of this paper is to focus on a more in-depth, original revealing of the influence of eco-innovation on countries' sustainable development. Thus, five eco-innovation dimensions, components of the Eco-Innovation Index, are considered for a complete approach. This paper first explores the interaction of the five dimensions within the Eco-Innovation Index. Further, the paper analyses the cumulative effects of the five Eco-Innovation Index dimensions on the 17 Sustainable Development Goals components defined by the United Nations. Considering a panel data set of 189 values for the EU-27 Member States for seven years and applying the Structural Equation Model (SEM), this paper emphasizes that only three out of five dimensions perform significantly in the Eco-Innovation Index. Moreover, it proved that the Eco-Innovation Index dimensions contribute to achieving 11 of the 17 sustainable development goals (SDGs). Also, the results highlight that significant relationships were revealed only between certain Eco-Innovation Index dimensions and some SDG components. This paper's conclusions contribute to a deeper understanding of gaining sustainable development through eco-innovation.

Keywords: circular economy, sustainable development, innovation, eco-innovation, Eco-Innovation Index, Sustainable Development Goals (SDGs).

JEL Classification: O30, O44, Q01.

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1. Introduction

Innovation is a key driver for enhancing corporate performance, raising human living standards and well-being, and powerfully influencing economic development (Curea-Pitorac, 2018). This idea is also supported by Ostraszewska and Tylec (2019) and Dima et al. (2020), which argue that innovation is a critical determinant of the corporate development potential and the European economies and, therefore, of societies' economic well-being.

The perception of the innovation process has evolved and shifted to a sustainable innovation approach. The issues regarding the relevance of environmentally friendly innovation (eco-innovation) in sustainable growth became a topic of interest to scientific researchers, practitioners, and public authorities (Kijek & Kasztelan, 2013).

Innovation is assumed by more and more companies focusing on gaining competitive advantages and contributing to economic growth (Herrera, 2016). Moreover, Schot and Steinmueller (2016) pointed out that innovation-driven growth is essential for social progress and human well-being. To ensure a sustainable future, companies should focus on reducing or eliminating the harmful impact of their activities on the natural environment, the economy and society (Li et al., 2022).

Stankevičienė and Nikanorova (2020) argued that due to the significant changes, there was a need to shift towards an economic model supporting sustainable development and the reorientation of companies towards innovation shaped to meet sustainable development goals. Thus, companies must shift towards an innovation trajectory to support countries gaining sustainable development by achieving sustainable development goals – a sustainable innovation. Sustainable innovations bring their input to a sustainable society and future and focus simultaneously on the three dimensions of sustainability: economic, environmental and social (Silvestre & Tirca, 2019).

Based on the relevant results presented in the literature, the lack of a complete understanding of how eco-innovation can influence sustainable development achievement in the context of intensifying concerns regarding ensuring a sustainable future stands up to this paper's opportunity. In line with increasing European countries' concerns regarding the need to focus on circular economy practices to support sustainable development, this paper explores the possible influence of eco-innovation on achieving the EU-27 Member States' sustainable development, highlighting its topicality and relevance.

In an original approach, this study considers the five dimensions of eco-innovation (Inputs, Activities, Outputs, Resource Efficiency Outcomes, Socio-Economic Outcomes) as components of the Eco-Innovation Index, which have been less addressed in the literature so far.

The research depth up to the level of the eco-innovation dimensions highlights the study's novelty and originality. Moreover, following the analysis of the influence of eco-innovation dimensions on sustainable development, the results cover two complementary perspectives, providing original, valuable findings. By considering five different dimensions of eco-innovation and structurally approaching them, the study allows the unveiling of various facets of eco-innovation and new perspectives on the relationship between eco-innovation and sustainable development. It contributes to revealing the impact of eco-innovation dimensions on the EU-27 Member States' sustainable development, adding consistent arguments to existing literature.

Thus, the paper's first goal is to explore the interaction of these five dimensions within the Eco-Innovation Index structure for the EU-27 Member States for the analysed period. Further, pursuing its second goal, the paper explores the cumulative effects of the five Eco-Innovation Index dimensions on the 17 Sustainable Development Goals for the EU-27 Member States. The SDGs outline the central core of sustainable development.

To reveal the impact of eco-innovation on achieving the European countries' sustainable development, this research study uses a panel dataset of 189 values for the current EU-27 Member States (including Croatia and excluding the UK) for seven years. It applies the Structural Equation Model (SEM).

The study's research hypotheses were mainly confirmed, the results bringing valid arguments regarding the essential role of eco-innovation dimensions in achieving EU-27 Member States' sustainable development outlined by SDGs.

Firstly, it reveals that, for the seven-year analysis period, in the EU-27 countries, only three out of five dimensions perform significantly within the Eco-Innovation Index, respectively Outputs, Inputs, and Activities.

Further, it highlights the cumulative effects of the five Eco-Innovation Index dimensions on 11 of 17 sustainable development goals, proving that eco-innovation mainly supports EU-27 Member States' sustainable development achievement and covers its economic, environmental, and social dimensions. The arguments brought by this study's results highlight that up to now, based on the influence of eco-innovation dimensions, only part of the 17 United Nations' sustainable development goals is on the way to being achieved for the EU-27 Member States.

Based on these research findings, there is considerable potential for future improvement in the EU-27 Member States' eco-innovation dimensions performance within the Eco-Innovation Index structure and, further, for these countries' sustainable development achievement.

The paper is structured as follows: First, a theoretical background section related to the topic is presented. Then, the paper'' aim is defined, and the data and methodology applied in this research study are explained. The third section illustrates the empirical results. Finally, discussion, implications and conclusions are presented.

2. Theoretical background

As an alternative economic model to the linear economy, the circular economy supports sustainable development with its three pillars: economic, social and environmental (Georgescu et al., 2022; Lamba et al., 2023). Although clear explanations of the circular economy-sustainability linkage have yet to emerge in the literature, a few aspects have been highlighted.

As evidenced by Stankevičienė and Nikanorova (2020), the circular economy is based on economic, environmental, and social pillars in line with the sustainability approach. It supports sustainable development by achieving sustainable development goals. In their study, the authors claim that eco-innovation is a key factor for a faster and more efficient transition toward the circular economy, arguing that the shift towards a circular economy may be reinforced by eco-innovation.

As Geissdoerfer et al. (2017) pointed out, the circular economy is a critical factor for sustainability, addressed in the literature as either a supporting factor or a trade-off in supporting sustainability. Furthermore, circular economy practices cannot provide solutions for all the problems defined by the SDGs, but they contribute directly or indirectly to achieving many of the SDGs' targets. The SDGs encourage circular economy practices (Schroeder et al., 2019).

Sustainable development focuses on the efficient and sustainable use of resources to improve the economy's competitiveness. It is one of the European Union's priorities for further evolution, smart development, and inclusive growth. In this framework, sustainable development aims to increase the European economies' competitiveness, orienting them towards a greener and more resource-efficient approach.

Sustainable development was first defined in 1987, and most researchers highlighted its complex and multidimensional nature based on its three pillars: economic, environmental, and social (Costanza et al., 2016; Biermann et al., 2017).

Initially, sustainable development was approached as involving a process of changes aimed at development consistent with both current and future needs and goals (WCED, 1987). As Hák et al. (2016) highlighted, the concept of sustainable development has emerged in the pressing need to harmonise long-term economic growth with responsible resource exploitation and environmental protection.

Subsequently, as developed countries become increasingly aware of the imperative of changing production and consumption patterns, the concerns about understanding and shaping the concept of sustainability intensified. Focusing on human needs accomplishment while respecting environmental boundaries, strong sustainable development is rare and hardly fulfilled because of trade-offs favouring economic sustainability over social and environmental sustainability (Lorek & Spangenberg, 2014; Gupta & Vegelin, 2016).

Sustainable development was promoted as a concept in 2015 in the 2030 Agenda for Sustainable Development (United Nations, 2015). In the new, expanded approach, sustainable innovation becomes a key enabler for most – if not all – sustainable development goals (United Nations, 2017).

The 17 Sustainable Development Goals (SDGs) outline the central core of sustainable development and cover its three dimensions: economic, environmental, and social. The importance and complexity of the sustainable development goals are strongly highlighted by the 169 targets that support the 17 SDGs. The achievement of 21 of these SDGs targets is directly supported by moving towards the circular economy. For another 28 SDGs targets, the achievement is indirectly influenced by adopting circular economy practices (Schroeder et al., 2019).

Relevant research highlights several attempts to cluster the 17 SDGs under the three dimensions of sustainable development without succeeding in a generally agreed mapping. Thus, some results stated that each of the 17 SDGs is linked with one of the three pillars (Costanza et al., 2016). Reference authors in the field argued that 15 of 17 SDGs proved their multidimensionality, addressing two or all three dimensions of sustainable development (Dalampira & Nastis, 2020). However, the United Nations (United Nations, 2015) claims that each goal interlinks all three pillars of sustainable development.

The lack of a generally agreed mapping of the 17 SDGs under the three pillars of sustainable development makes understanding and implementing them even more challenging. It implies a more detailed study and clarification of the SDGs and their link to the sustainable development dimensions.

In the new circular economy model context, a new type of sustainable innovation has emerged: eco-innovation. Both circular economy and eco-innovation are geared towards environmental protection and increasing resource efficiency to create a sustainable society (Council of the European Union, 2017; Gente & Pattanaro, 2019).

The concept of eco-innovation has emerged as a response to the modern economy's needs, based on the imperative of linking innovation with increasing concerns for the quality of the natural environment. Thus, eco-innovation has emerged both as a necessity and an opportunity for development (Carvalho et al., 2018; Ostraszewska & Tylec, 2019).

Eco-innovation is the main topic of relevant research studies, which alternatively refer to it as sustainable development innovation, green, environmental, or ecology innovation (Ostraszewska & Tylec, 2019; Kanda et al., 2019; Zhang et al., 2022).

As a category of sustainable innovation, the concept of eco-innovation seeks to reconcile the objectives of corporate profit growth and accelerating development with the protection of the natural environment quality and to explain in a different light the connection between economy, environment, and society (Carrillo-Hermosilla et al., 2009; Nowak & Szewczyk, 2016; Carvalho et al., 2018). Also, a very recent paper counting on the results of the most relevant research studies in the field argues the positive impact of eco-innovation on corporate financial and environmental performance (Borsatto & Bazani, 2023).

The European Commission (2012) addresses eco-innovation as any innovation focusing on achieving sustainable development. As pointed out by Wielgórka and Szczepaniak (2019), in the context of approaching sustainable development as aiming at creating a more environmentally friendly and competitive economy, one of the priorities, both for the present and future, summarised in the Europe 2020 Strategy, is achieving sustainable development through eco-innovation.

In their extensive study highlighting the evolution of eco-innovation theories, Hazarika and Zhang (2019) address eco-innovation as a main concept for greening the economy. In this framework, they highlight the relevance of the resource-based view, the institutional theory, the stakeholders' theory, and the evolutionary theory relative to eco-innovation. Krakowiak-Bal and Burg (2019) pointed out the positive effect of eco-innovation activities on gaining competitive advantages at the corporate level and the essential role of eco-innovation in achieving sustainable development. Therefore, eco-innovation is a company opportunity and key to countries' competitiveness.

Eco-innovation refers to improving natural resource use efficiency and changing the production and consumption models. It is a critical pillar reinforcing the transition towards a circular economy. In their attempt to reveal the significance of the eco-innovation concept and its relevant dimensions, Carrillo-Hermosilla et al. (2010) bring strong arguments supporting the idea that eco-innovation must be approached as a powerful tool that may renew the whole innovation system based on economic, social and environmental perspectives.

Moreover, Reid and Miedzinski (2008) showed that eco-innovation's importance is highlighted by its systemically identified implications at the micro, meso, and macro levels.

In an extensive study covering 49 European and Asian countries, Jo et al. (2015) showed that eco-innovation is a critical key concept for achieving worldwide sustainable development goals. Based on that, they argued that eco-innovation became a hotly debated topic, especially in European countries. Moreover, a study regarding EU Member States proved that eco-innovation becomes essential for the achievement of sustainable development by these countries (Mačiulytė-Šniukienė & Sekhniashvili, 2021).

Even though a vast body of literature addresses the role of eco-innovation in sustainable development, pointing out different perspectives, it still has not focused on the influence of eco-innovation dimensions on the SDGs of the EU-27 member states.

Previous research has not paid any attention to eco-innovation's different dimensions. Instead, it has highlighted the role of eco-innovation in sustainable development in a more general approach, without an analytical approach to its five dimensions. Based on this, the following research hypotheses result:

Hypothesis 1 (H1): The interaction between the five eco-innovation dimensions increases the 27 EU member states eco-innovation performance.

Hypothesis 2 (H2): Eco-innovation, through its five dimensions, significantly affects most SDG dimensions, contributing to EU 27 member states' sustainable development.

3. Data and methodology

Aiming to reveal the possible influence of eco-innovation on countries' sustainable development, this paper relies on the above two research hypotheses.

Thus, the paper's first research hypothesis is to analyse the interaction of the five dimensions of eco-innovation within the Eco-Innovation Index. The Eco-Innovation Index is a relevant composite indicator measuring the environmental innovation performance of European Union Member States, presented annually in the Eco-Innovation Scoreboard by the European Commission.

The Eco-Innovation Index comprises five dimensions (as five sub-indexes), as follows (European Commission, 2022a):

- EII – "Eco-Innovation Inputs",
- EIA – "Eco-Innovation Activities",
- EIO – "Eco-Innovation Outputs",
- REO – "Eco-Innovation Resource Efficiency Outcomes",
- SEO – "Eco-Innovation Socio-Economic Outcomes".

Further, the paper's purpose for the second research hypothesis is to analyse the cumulative effects of the five Eco-Innovation Index dimensions on the 17 Sustainable Development Goals components, supporting sustainable development achievement. The 17 Sustainable Development Goals (SDGs) are defined by the United Nations (2015), as presented in Table 1.

Table 1. The 17 Sustainable Development Goals

Symbol	Definition	Symbol	Definition
SDG 1	"No poverty"	SDG 10	"Reduce inequalities"
SDG 2	"Zero hunger"	SDG 11	"Sustainable cities and communities"
SDG 3	"Good health and well-being"	SDG 12	"Responsible consumption and production"
SDG 4	"Quality education"	SDG 13	"Climate action"
SDG 5	"Gender Equality"	SDG 14	"Life below water"
SDG 6	"Clean water and sanitation"	SDG 15	"Life on land"
SDG 7	"Affordable and clean energy"	SDG 16	"Peace, justice and strong institutions"
SDG 8	"Decent work and economic growth"	SDG 17	"Partnerships for the goals"
SDG 9	"Industry, innovation and infrastructure"		

The research uses panel data for the current EU-27 Member States (including Croatia and excluding the UK) for seven years (2013–2019). The data set was chosen to ensure the indicators' relevance, the data homogeneity, and an appropriate sample size. The panel dataset of 189 values for the EU-27 Member States for seven years was collected from data provided by the European Commission for the Eco-Innovation Index dimensions (European Commission, 2022a, 2022b) and by Eurostat for the 17 SDGs components (European Commission, 2021).

Panel data represents a database containing information collected through observations of individuals or organisations representing a significant and consistent population, which allows regular monitoring of specific variables in different periods, usually using interviews, surveys, or observations. Many variables are often observed and collected to extend the data size, establish trends, make analysis, or reveal significant correlations.

Thus, the utility of panel data is varied, and it is used for economic, financial, and statistical research.

Instead of using pooled data, which offers information on different subjects at specific time intervals, the panel data involves information related to the same subjects or units at specific periods. Thus, while cross-sectional data involves observing multiple subjects and related variables at a specific time, time-series data contains one repetitive issue over time. The significant advantage of panel data is compressing features of both dimensions into a single model.

Nevertheless, the standard error component can represent a significant restrictive supposition in many panel data frameworks, which presumes that the disturbances involve a homoskedastic variance and the absence of spatial correlation. However, compared with time-series or cross-sectional data, the panel data are more complex, able to analyse dynamic linkages and model the differences between the subjects.

The database offered by the European Commission provides normalized values of the Eco-Innovation Index and its five dimensions. To ensure data compatibility, the authors normalized the available data provided by Eurostat for SDGs components, so there is no issue of data stationarity.

Figure 1 explains the conceptual model that relies on the Eco-Innovation Index's five dimensions, significantly impacting the 17 SDG components. This influence is intended to highlight the role of eco-innovation's dimensions in achieving sustainable development for the EU-27 Member States.

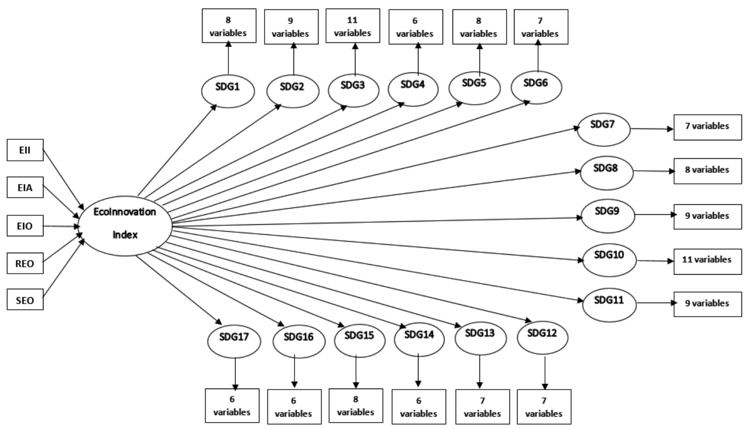

Figure 1. The conceptual model designed to assess the Eco-Innovation Index dimensions' impact on achieving the Sustainable Development Goals for the EU-27 Member States (source: authors' process in STATA 16.1 – using Structural Equation Model)

The data were processed in STATA 16.1, using the Structural Equation Model (SEM), Maximum likelihood (ML) estimation method, and Observed Information Matrix (OIM) as Standard Error type.

4. Results

Applying the Structural Equation Model (SEM) in the framework presented in Data and Methodology, a series of relevant information regarding the complex interdependencies between the Eco-Innovation Index dimensions and the 11 SDGs components with reliable data resulted. Synthetically, the results are presented in Figure 2.

The exogenous (observed) variables are EII, EIA, EIO, REO, and SEO.

The latent variables are EIIndx, SDG1, SDG7, SDG12.

The model's endogenous variables, consisting of SDGs subdimensions, according to the United Nations codifying, are presented in Table 2.

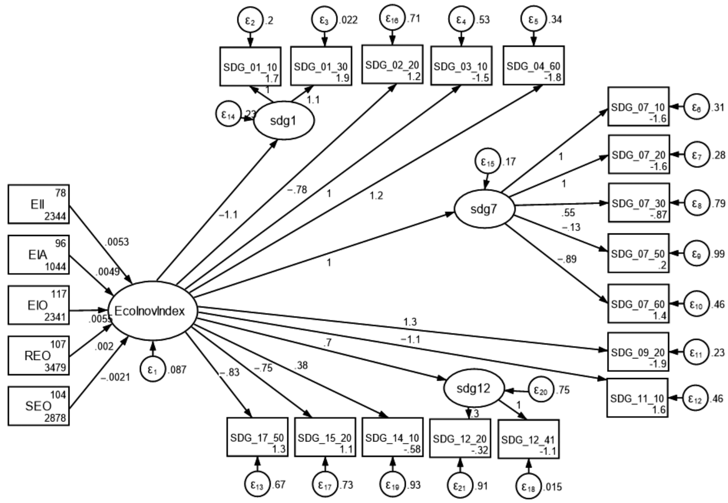

Figure 2. The results of the empirical model designed to assess the Eco-Innovation Index dimensions' impact on achieving the Sustainable Development Goals for the EU-27 Member States in the 2013–2019 period (source: authors' process in STATA 16.1 using Structural Equation Model)

Table 2. The endogenous variables of the empirical model

Symbol	Definition	Symbol	Definition
SDG_01_10	"People at risk of poverty or social exclusion"	SDG_07_60	"Population unable to keep home adequately warm by poverty status"
SDG_01_30	"Severally material deprived people"	SDG_09_20	"Employment in high and medium-high technology manufacturing and knowledge-intensive services"
SDG_02_20	"Agricultural factor income per annual work unit"	SDG_11_10	"Overcrowding rate by poverty status"
SDG_03_10	"Life expectancy at birth"	SDG_12_20	"Resource productivity and domestic material consumption"
SDG_04_60	"Adult participation in learning"	SDG_12_41	"Circular material use rate"
SDG_07_10	"Primary energy consumption"	SDG_14_10	"Surface of marine sites designated under Natura 2000"
SDG_07_20	"Final energy consumption in households per capita"	SDG_15_20	"Surface of terrestrial sites designated under Natura 2000"
SDG_07_30	"Energy productivity"	SDG_17_50	"Share of environmental taxes in total tax revenues"
SDG_07_50	"Energy import dependency by products"		

Firstly, as seen in Figure 2 and Table 3, analysing the Eco-Innovation Index based on the interaction of its five dimensions reveals some essential characteristics.

Further, following the structural analysis of the Eco-Innovation Index, we study its impact on 11 of the 17 SDGs components. The results are presented in Figure 2 and Table 4.

Table 3. The Structural Equation Model (SEM) results for the first research hypothesis (H1)

Structural equation model (SEM) Estimation method: maximum likelihood (ml) Log-likelihood: –8442.3012			Number of observations = 189 p = 0.95	
Structural EIIndx	OIM		z	P>|z|
	Coef.	Std. Err.		
EII	.0053	.0010	5.05	0.000
EIA	.0048	.0011	4.19	0.000
EIO	.0054	.0011	4.91	0.000
REO	.0020	.0005	3.74	0.000
SEO	–.0020	.0006	–3.14	0.002

Table 4. The Structural Equation Model (SEM) results for the second research hypothesis (H2)

Structural equation model (SEM) Estimation method: Maximum likelihood (ml) Log-likelihood: –8442.3012			Number of observations = 189 p = 0.95	
	OIM		z	P>|z|
	Coef	Std. Err.		
SDG 1				
EIIndx	–1.0991	.1141	–9.63	0.000
SDG_01_10				
SDG 1	1 (constrained)			
const.	1.6767	.1544	10.86	0.000
SDG_01_30				
SDG 1	1.1055	.0516	21.39	0.000
const.	1.8536	.1500	12.36	0.000
SDG_02_20				
EIIndx	–.7794	.1103	–7.06	0.000
const.	1.1890	.1699	7.00	0.000
SDG_03_10				
EIIndx	1 (constrained)			
const.	–1.5254	.1598	–9.55	0.000
SDG_04_60				
EIIndx	1.1768	.1156	10.17	0.000
const.	–1.7952	.1538	–11.67	0.000
SDG 7				
EIIndx	1.0390	.1152	9.02	0.000
SDG_07_10				
SDG 7	1 (constrained)			
const.	–1.5850	.1629	– 9.72	0.000
SDG_07_20			13.56	
SDG 7	1.0217	.0753		0.000
const.	–1.6194	.1567	–10.33	0.000
SDG_07_30				
SDG 7	.5485	.0962	5.70	0.000
const.	–.8695	.1806	–4.81	0.000

End of Table 4

Structural equation model (SEM) Estimation method: Maximum likelihood (ml) Log-likelihood: –8442.3012			Number of observations = 189 p = 0.95	
	OIM		z	P>|z|
	Coef	Std. Err.		
SDG_07_50				
SDG 7	–.1261	.0973	–1.30	0.195
const.	.1999	.1689	1.18	0.237
SDG_07_60				
SDG 7	–.8906	.0849	–10.48	0.000
const.	1.4117	.1695	8.33	0.000
SDG_09_20				
EIIndx	1.2768	.1152	11.08	0.000
const.	–1.9477	.1405	–13.86	0.000
SDG_11_10				
EIIndx	–1.0677	.1103	–9.68	0.000
const.	1.6288	.1547	10.53	0.000
SDG 12				
EIIndx	.6995	.1103	6.34	0.000
SDG_12_41				
SDG 12	1 (constrained)			
const.	–1.0672	.1700	–6.28	0.000
SDG_12_20				
SDG 12	.3002	.1494	2.01	0.044
const.	–.3204	.1805	–1.78	0.076
SDG_14_10				
EIIndx	.3776	.1092	3.46	0.001
const.	–.5761	.1783	–3.23	0.001
SDG_15_20				
EIIndx	–.7501	.1121	–6.69	0.000
const.	1.1443	.1688	6.78	0.000
SDG_17_50				
EIIndx	–.8340	.1119	–7.45	0.000
const.	1.2723	.1671	7.61	0.000
LR test of model vs. saturated: chi-square = 2222.501, Prob. > chi-square = .0000 LR test of baseline vs. saturated: chi-square_bs = 4006.687, Prob. > chi-square_bs = .0000				
Equation – level goodness of fit: overall R-squared =.8166				

Both likelihood ratio (LR) tests show that these ratios are significantly different from one, and the associated probability is zero, which shows a good fit for the model. Also, the z values associated with the model coefficients are high. The probabilities associated with z are minimal and, in most cases, are equal to zero, meaning that the coefficients are consistent. Regarding equation-level goodness of fit, the overall R-squared value is close to 1, indicating a good fit for the model.

In addition, several methods were used to test the model's robustness. Thus, the OIM (Observed Information Matrix) method, the EIM (Expected Information Matrix) method and the Robust model were applied at 95% and 99% confidence levels for the same data. The results do not change significantly regardless of the chosen method, highlighting the research model's robustness.

5. Discussion

The empirical research results essentially confirmed the research hypotheses, highlighting exciting findings.

As seen in Figure 2 and Table 3, analysing the Eco-Innovation Index based on the interactions of its five dimensions within the Eco-Innovation Index structure for the EU-27 Member States for the analysed period reveals a series of interesting peculiarities, mainly confirming the assumption of the first research hypothesis H1.

Thus, we note that four dimensions positively correlate with the Eco-Innovation Index. In contrast, the SEO component negatively correlates with the Eco-Innovation Index. This fact can be explained to some extent by the elements that compose this dimension, based on employment, increasing profitability, and stimulating export policies through developing eco-innovation activities. The results show that, currently, the percentage of exports resulting from eco-activities, respectively, the rate of employees involved in eco-industries and the profit made from such activities are still low compared to other indicators of the impact of eco-innovation. Thus, the negative correlation between this component and the Eco-Innovation Index can be partially explained.

On the other hand, the EIO dimension has the strongest positive correlation with the Eco-Innovation Index, which shows the significant impact of the immediate results of the eco-innovation activities generated by the business and research environment. This dimension is based on the most visible effects of eco-innovation, with a direct impact on the economy, such as the number of invention patents, the number of scientific publications or the media coverage of the effects of eco-innovation. It follows with a positive correlation significantly equal to the first one, the EII dimension. That shows the significant influence of human and financial resources invested in enhancing eco-innovation development. Research and development expenses, environmental policies, and green energy investments are included here, respectively, as the percentage of employees in research and development out of total employees.

A significant positive impact is also observed in the case of the EIA dimension, which shows the importance of focusing on eco-innovation activities. This dimension is based on the efficient use of energy and the implementation of sustainable products, especially at the level of SMEs, respectively, on the degree of environmental management performance certification at the corporate level. Thus, it can be observed that the most significant dimensions of the Eco-Innovation Index are those of output, input and eco-innovation activities, whose immediate effects are the easiest to reveal.

The REO dimension has the lowest positive correlation with the Eco-Innovation Index, which unfortunately shows the relatively low impact of resource efficiency. Thus, the Eco-Innovation Index relies too little on increasing resource productivity. Critical natural resources are still extensively consumed during economic and social activities, harming and pressing on the natural environment.

Next, following the structural analysis of the Eco-Innovation Index, its impact on the SDG dimensions was highlighted. The results are presented in Figure 2 and Table 4, mainly confirming the second research hypothesis (H2): the five eco-innovation dimensions significantly affect most SDG dimensions, contributing to the sustainable development of EU 27 member states.

Thus, starting with the first SDG, the Eco-Innovation Index's significant negative structural impact on SDG1 may be observed, with an above-unit regression coefficient. To explain this effect, it is necessary to analyse the SDG1 structure. It contains a series of variables that refer to the living conditions of disadvantaged people. By applying SEM, a significant impact of the Eco-Innovation Index could be highlighted on two variables of SDG1, namely SDG_01_10 and SDG_01_30. The first variable, SDG_01_10, refers to the percentage of people in the total population below the poverty line established in the EU-27 countries based on a mix of conditions. The second variable, SDG_01_30, refers to the percentage of people in the total population who are severely disadvantaged from a material perspective and whose living conditions are severely constrained by the lack of resources. Both variables are defined according to a series of specific criteria.

In the case of these two variables, the negative impact of the Eco-Innovation Index dimensions is expected since one of the main goals of eco-innovation is to increase the quality of life, including reducing poverty. Eco-innovation, proposing new practices to develop local communities and promote sustainable development, is fundamental in creating better-paid jobs and building a more caring society with limited natural resources. All these elements lead to an increase in the standard of living and, implicitly, the reduction of the poverty level in the analysed countries. The significant impact of eco-innovation in the improvement of various fields such as education, healthcare, transport, environmental protection, security, etc., as well as in the increase of energy production from renewable sources, must gradually lead to a rise in the quality of life and a reduction of the disadvantaged people share.

Regarding SDG2, it can be observed, similar to SDG1, a negative structural impact of the Eco-Innovation Index. This time, the negative effect with a below-unit regression coefficient is revealed only on a single variable, SDG_02_20. This variable is defined in classical terms as a partial measure of labour productivity in the agricultural field, as a ratio between income and resources based on annual work units (AWUs). As is known, traditional agriculture pursues productivity strictly by balancing the income obtained and the allocated resources. Unlike conventional agriculture, the main goal of ecological agriculture is not to maximise profit but to maximise biological productivity naturally, through predominantly consumption of renewable resources, for long-term assurance of the environment's quality. As a result, the effect of the Eco-Innovation Index on labour productivity in the agricultural field conventionally defined is currently negative. This negative correlation shows that a way must be found to complement conventional agricultural productivity with ecological and sustainable productivity.

In the case of SDG3, a positive structural impact of the Eco-Innovation Index can be observed. This positive effect, with a regression coefficient equal to one, is highlighted based on the variable SDG_03_10, defined as the average number of years a newborn can expect to live in a specific country. Eco-innovation is based on active ageing, which means extending life by improving the quality of life, smart health, consuming high-quality ecological products, and activities specific to each age. Based on these aspects, it is an expected positive effect. Eco-innovation leads to the development of an economic-social framework suitable for all ages, in which each person can play an active role in society, which must directly lead to an increase in life expectancy. A key issue in this regard is the acceleration of innovative processes in the medical field, such as the discovery of new therapeutic and curative solutions, which have a direct and immediate effect on increasing life expectancy and the quality of life in general.

From this point of view, enhancing the processes of transforming research and innovation results in the health field into concrete benefits for patients and society is desirable.

The effect of the Eco-Innovation Index on SDG4 materialises significantly through the variable SDG_04_60. This variable refers to people between 25 and 64 participating in various education and training programs, usually after initial education. The impact of the Eco-Innovation Index on the percentage of people involved in lifelong learning is strongly positive, with an above-unit regression coefficient. It shows that innovative forms of education, based on natural environment care and emphasising the use of renewable resources, determine the interest of a growing percentage of the EU-27 countries' population in accessing various forms of lifelong education. On the other hand, lifelong education is critical in the population's acquisition of new skills to be involved in sustainable economic growth and contribute to more orientation on environmental care. Education focused on durability and sustainability will create the skills needed to develop a more balanced, homogeneous, viable society and be better prepared to face future challenges.

The following strategic goal on which the Eco-Innovation Index has a significant effect is SDG7, based on five variables. As expected, this is the most complex effect revealed by SEM between the Eco-Innovation Index dimensions and the components of an SDG. The regression coefficient shows a slightly above-unit influence of eco-innovation on clean energy use. Thus, the significantly influenced components are SDG_07_10, SDG_07_20, SDG_07_30, SDG_07_50 and SDG_07_60. The first variable, SDG_07_10, considers the energy consumed only by the final beneficiaries. The SDG_07_20 quantifies the individual consumption of citizens, excluding transport services. The SDG_07_30 shows the economic result related to the quantity of energy needed to satisfy demand at the national level. The SDG_07_50 includes the share of a country's energy obtained from imports. The SDG_07_60 refers to the part of the population that cannot financially afford to maintain sufficient heat in their houses.

In the SDG7 structure, a diversity of influences can be observed. Thus, there is a positive influence on the first three component variables, and a negative impact was observed on the last two. The most significant positive influence is observed in SDG_07_20, which means that green energy use's most powerful positive effect can be found in this case. It is followed by SDG_07_10 with a unitary regression coefficient and SDG_07_30. The increase in energy productivity due to using renewable sources is a positive effect noted at the EU-27 level during the analysed period.

On the other hand, a negative correlation is observed between clean energy and energy import dependence. It is a particularly significant effect, which shows that at the level of the EU-27 countries, the development of renewable energy sources has led to a decrease in their energy import dependence. Also, the negative and stronger correlation between clean energy and the share of the population that cannot maintain a sufficient heat level at home is noticeable. This negative and strong correlation between these two variables highlights that in the EU-27, the increase in affordable and clean energy amount led to a significant decrease in the share of households unable to ensure adequate heat.

Another significant positive effect of the Eco-Innovation Index is manifested in SDG9 through the variable SDG_09_20, with an above-unit regression coefficient. This variable considers the percentage of highly skilled employees in the high- and medium-high-tech manufacturing and knowledge-intensive service sectors. It is an expected correlation, showing that eco-innovation leads to increased employability in fields, implying highly skilled work. Eco-innovation stimulates areas with high added value, such as knowledge-intensive services or high-tech production, and also leads to improving other sectors, such as education, healthcare services, and public administration. In this regard, a high level of the Eco-Innovation Index stimulates the concentration of the workforce in the high and medium-high-tech industry and less so in the case of the sectors of activity aimed at heavy industry, which is usually less friendly with the natural environment. Thus, as the Eco-Innovation Index has higher values, it will determine a greater need and a higher interest of employees in advanced technologies industries, contributing to the sustainable development of the business environment and society. The educated and highly qualified workforce represents the best economic and social development engine because it induces the need to permanently develop new, innovative goods and services that satisfy their requirements. Thus, eco-innovation is significantly positive for society through the spiral effect on consumption and investments.

The following significant effect of the Eco-Innovation Index is a negative one on the component SDG_11_10 within SDG11. The regression coefficient is negative, slightly above unit. It is a normal correlation, given that this variable is calculated based on the share of people living in overcrowded conditions in the EU-27 countries, based on predefined criteria. This crowd is mainly due to young people living with members of older generations, as they do not have the financial power to support themselves independently. Eco-innovation, through its positive effects on the general increase in the standard of living, has a proven impact of reducing crowding in households at the level of the analysed European countries. This aspect is mainly achieved by young people earning enough to support themselves and leave their parents' homes. It is essential in improving people's quality of life, especially young people.

Another significant effect of the Eco-Innovation Index dimensions is observed on the variables included in SDG12. It has a cumulative positive effect. It materialises through the impact on two components, SDG_12_20 and SDG_12_41. The first variable, SDG_12_20, is calculated as the ratio between the gross domestic product and the domestic consumption of materials used directly in an economy. The second variable, SDG_12_41, shows the proportion of recovered materials reintroduced into the economy out of the total materials used. Thus, at the level of the EU-27 countries, we record an expected positive effect of the Eco-Innovation Index on those two components of SDG12, as both the resources use' productivity and the material recycling rate increase as eco-innovation rises. It is a bi-univocal effect between eco-innovation and these two variables, as they influence and reinforce each other. The significant positive effect of this complex interdependence is reflected in the overall increase in national and worldwide productivity.

The next influence of the Eco-Innovation Index is registered on SDG14 through the variable SDG_14_10. It has a weaker positive impact. This result is most likely because the variable SDG_14_10 is based on the area of marine sites specified under Natura 2000. Natura 2000 is a broader project that includes maritime and terrestrial protected areas designated under the EU animal and bird habitats directives. It is an indicator whose typology is in an ongoing process of being defined and implemented at the level of the European Union. This aspect somewhat justifies the weaker correlation. This interdependence continues with the influence of the Eco-Innovation Index on SDG15 through the variable SDG_15_20. In this case, the correlation is weird and negative, showing that these indicators based on the terrestrial sites included in Natura 2000 are unclear. Moreover, they are not yet properly understood and implemented correctly by all EU-27 countries. A possible explanation for this could be the mitigation of the effects generated by the Eco-Innovation Index only on these sites areas, representing 18% of the total land surface of the European Union. Thus, it is necessary to concentrate efforts on increasing the Eco-Innovation Index and its considerable positive effects on this SDG in the case of the European community.

Finally, a significant negative impact of the Eco-Innovation Index is revealed on SDG17 through the variable SDG_17_50. This variable is based on the share of environmental taxes in total governmental taxes and fees. It generally refers to taxes on pollution, emissions, energy production from fossil fuels, and so on. Taxes on polluting energy represent approximately 75% of the total environmental taxes applied at the European level. Thus, this correlation shows us that as the eco-innovation index increases, the pollution generated by energy production decreases. As a result, the share of environmental taxes in the total volume of governmental taxes will be lower, this aspect having a considerable positive effect on the preservation of the natural environment and the conservation of heritage and protected areas, implying an increase in the living conditions of humanity and a sustainable social, cultural and economic development. The more energy production is based on renewable, sustainable resources, the more pollution taxation will be reduced, and eventually, it will no longer be needed. It is a very long-term effect, bringing significant benefits to the environment.

As can be seen from the highlighted results based on the EU-27 countries analysis for 2013-2019, Eco-innovation Index dimensions have both significant positive and negative effects on many variables that compose the SDGs.

Based on the reliable data for SDG variables, relevant results were revealed for 11 of the 17 SDGs defined by the United Nations.

6. Implications

The empirical research reveals new insights into the relationship between eco-innovation, by its five dimensions, and sustainable development, outlined by the sustainable development goals.

Based on the empirical research results, policymakers may fit their decisions to strengthen the five eco-innovation dimensions' actions to achieve the sustainable development of the EU-27 member states until 2030, in accordance with the United Nations' general development objectives.

Thus, the study highlights that socio-economic and resource-efficiency outcomes are the eco-innovation dimensions with the most significant potential for future improvement. To increase European countries' eco-innovative performance, policymakers must focus primarily on these two dimensions.

Also, it emphasises the most sensitive SDGs to the impact of eco-innovation dimensions, such as employment in high-technology manufacturing and knowledge-intensive services, the quality of education, access to affordable and sustainable energy, and reducing poverty, thus being of interest to policymakers' options.

7. Conclusions

Eco-innovation is essential in supporting the shift toward a circular economy and achieving sustainable development goals by decreasing the harmful environmental impact of the production and consumption model and improving natural resource use efficiency.

This study is part of the current trend among practitioners and researchers to reveal more analytically how eco-innovation can support sustainable development. Although there is a broad literature on this subject, too little is known about the influence of eco-innovation dimensions on countries' sustainable development achievement. Moreover, an emphasis on this research topic regarding European countries has recently been observed.

Thus, the present study analyses the possible influence of eco-innovation on countries' sustainable development, using a database of the current EU-27 Member States (including Croatia and excluding the UK) for seven years.

The relevance of this paper relies on its essential contribution to revealing the eco-innovation influence on EU-27 Member States' sustainable development achievement, considering five different eco-innovation dimensions, components of the Eco-Innovation Index, a less addressed approach until now. Thus, the study's results cover two complementary perspectives, providing valuable findings. Firstly, it reveals the interaction of these five dimensions within the Eco-Innovation Index structure. Further, it highlights the cumulative effects of the five Eco-Innovation Index dimensions on the sustainable development goals, supporting EU-27 Member States' sustainable development achievement and covering its economic, environmental, and social dimensions.

As the paper's findings evidence, currently, in the EU-27 countries, only three out of five dimensions, i.e., outputs, inputs and eco-innovation activities, perform significantly within the Eco-Innovation Index. In our opinion, the most critical dimensions, related to the efficiency of natural resource use and the increase in the economic-social level, have a reduced positive or even negative effect. So, there is potential for future improvement in eco-innovation dimensions performance within the Eco-Innovation Index structure.

Further, the arguments brought by this study's results entitle appreciating that up to now, due to the influence of eco-innovation dimensions, only part of the United Nations' sustainable development goals is on the way to being achieved.

The research results argue and support the influence of eco-innovation in achieving EU-27 Member States' sustainable development, outlined by the sustainable development goals. Thus, they reveal favourable relevant effects of the five eco-innovation dimensions on reducing poverty and hunger, ensuring healthy life and well-being, and improving the quality of education. Forwards, the eco-innovation dimensions significantly positively influence access to affordable and sustainable energy, supporting sustainable infrastructure and industrialisation, developing robust, secure, sustainable cities, and promoting sustainable consumption and production while protecting the natural environment. It is only the beginning of an endeavour that must be continued faster to avoid reaching a critical point with irreversible damage to the natural environment.

Therefore, eco-innovation is an excellent tool for environmental protection, with favourable effects on the economy and society.

This research's conclusions align with and strengthen the arguments brought by recent studies, highlighting that circular economy practices support the achievement of most of the 17 SDGs.

The limitations of this study are that the research results highlight the cumulative effects of the five dimensions of the Eco-innovation Index on SDGs, considering a sample of countries limited to the EU-27 Member States, a specific period and based only on the SEM model.

Considering that the main contribution of this research is represented by the expansion and development of the existing studies on this topic, future research could dynamically assess the influence of the five eco-innovation dimensions on achieving sustainable development goals for the EU-27 countries. The results of a dynamic analysis would allow for properly establishing appropriate strategies based on eco-innovation to increase the pace of achieving the SDGs for European countries by the 2030 target. It might also value the advantages induced by using other research models or expanding the sample of the analysed countries. Thus, depending on data availability and timeliness, the study may be extended by considering a higher number of countries from other continents and by analysing the possible different influences that eco-innovation may have on sustainable development in the case of varied economies, countries, or regions.

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Author contributions

GLS and AI built up the study and were responsible for the data analysis design and development. GLS was responsible for establishing the relevance and timeliness of the proposed research topic and the theoretical background. GLS and AI were responsible for data collection and analysis. AI and GLS were responsible for data interpretation, implications, conclusions, and the article's first draft. Both authors agreed on the final version of the article.

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