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Eco-innovation performance in the European Union economies: Perspective on outcomes

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ABSTRACT

Objective: The objective of this article was to examine the eco-innovation performance of the European Union's economies in terms of eco-innovation outcomes with a particular focus on resource efficiency and socio-economic outcomes.

Research Design & Methods: We used quantitative research methods, such as descriptive statistics, Euclidean distance, and Pearson's correlation index. We based the comparative analysis of the eco-innovation indices related to outputs and outcomes on the Eco-innovation Scoreboard. We conducted it for the years 2013-2022.

Findings: The research results showed that EU countries considered as one group improved their eco-innovation performance as measured by the Eco-innovation Index (EII), as well as in terms of the EII composite indices related to innovation outcomes during the study period. We also observed improvement in the EII and the EII thematic areas observed for both the eco-innovation leaders and catching-up economies. However, the leading countries maintained and even slightly increased the distance to the EU-27 average in terms of the total EII index, while significantly increasing the distance in terms of socio-economic outcomes and eco-innovation outputs. Moreover, the rates of growth of eco-innovation outputs and outcomes were much higher for these countries than the growth rate of their eco-innovation inputs.

Implications & Recommendations: The study highlights the importance of the effective conversion of the eco-innovation inputs into eco-innovation outputs and outcomes, which is a big challenge, especially for the economies with poorer eco-innovation performance. The increase in eco-innovation inputs alone does not translate directly into an increase in eco-innovation outcomes in all conditions. Creating appropriate conditions for the development of eco-innovation requires a coordinated political approach, especially between innovation, research and environmental policy.

Contribution & Value Added: The study contributes to a better understanding of eco-innovation for better policymaking. In particular, it can give a comprehensive picture of eco-innovation outcomes in the European Union as one of the key components of eco-innovation performance. The article also addresses the vital issue of the relationship between eco-innovation inputs and eco-innovation outputs and outcomes.

Article type:	research article
Keywords:	eco-innovation; eco-innovation index; eco-innovation outputs; resource efficiency outcomes; socio-economic outcomes; the European Union; leading economies
JEL codes:	O30, O01, P47

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INTRODUCTION

The article explores the problem of the development of eco-innovation of the EU Member States (EU MSs) with the main focus on the resource efficiency and socio-economic outcomes of their eco-innovation activities. Innovation in general and its specific type of eco-innovation are important factors in achieving sustainable development goals, with their role being particularly crucial in recent years, when the global economy has been shaken by multiple crises. Eco-innovation can contribute to creating smart, sustainable, and inclusive post-crisis growth while addressing Europe's major societal challenges. For the EU companies, it can also be a path to capitalizing on emerging business opportunities and strengthening competitiveness. Although many companies limit investments in innovation in times of crisis or uncertainty (Wang *et al*., 2021), resource efficiency and maximizing eco-innovation outputs and outcomes have been issues of growing importance and interest among scientists and policy-makers in the area of innovation policy and sustainable development (Wei *et al*., 2022; Zulkiffli *et al*., 2022). Innovation can support economic recovery from the COVID-19 pandemic and the crisis caused by Russia's invasion of Ukraine, deepened by the conflict in the Middle East.

Researching this problem implies an accurate measurement of eco-innovation. It is a complex category and measuring its performance requires considering the multiple dimensions included in the methodology of the eco-innovation index (EII).

Considering various aspects of eco-innovation outputs and outcomes in the context of existing global challenges, we formulated the following research questions:

RQ1: What is the latest eco-innovation performance in terms of resource efficiency and socio-economic outcomes in the EU-27 as a group of countries compared to the economies of Eco-innovation leaders in the EU?

RQ2: Is the distance between EU countries regarding the eco-innovation outcomes decreasing or increasing?

RQ3: What is the effectiveness of transforming eco-innovation inputs into outputs and outcomes in the countries that are leaders in eco-innovation in the EU compared to other EU countries?

Following the research questions, we aimed to examine the eco-innovation performance of the European Union's economies in recent years, with a particular emphasis on resource efficiency outcomes (REO) and socio-economic outcomes (SEO). In their efforts to improve their eco-innovation performance, EU countries are trying to effectively convert eco-innovation inputs into outputs and, subsequently, improve their resource efficiency understood as a country's efficiency of resources and GHG emission intensity, and socio-economics outcomes, which refer to the positive societal as well as economic outcomes of eco-innovation. To some extent, we also included eco-innovation outputs (EIO) in the study, which refer to the number of patents and academic publications. We can consider them direct, tangible results of eco-innovation. However, we think that eco-innovation outcomes deserve special attention because in today's turbulent environment, achieving sustainable development goals through innovation requires much more than just delivering innovation outputs, and consequential economic effects and changes that occur in society as a result of eco-innovation are needed (Hajdukiewicz & Pera, 2013).

As in the case of inputs, which were the subject of our previous research, and also in the case of outputs and outcomes, an innovation gap persists between innovation leaders and the other EU MS, including the group of catching-up countries. Considering that eco-innovations are important tools for ensuring economic growth and achieving sustainable development goals, this concept is crucial to businesses and policymakers and the results of the study may provide important guidance in the area of eco-innovation policy.

The article consists of substantive parts. The first section will contain the literature review of previous studies focusing on the nature, impact, and factors driving eco-innovation, and government policy encompassing the efficient conversion of eco-innovation inputs into outputs and outcomes. The second section will present research methods and assumptions of the study. The third part will contain the results of our investigation and discussion. The last part of the study will comprise the main conclusions and research limitations and outline further research directions.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

An eco-innovation is any form of innovation that results in or leads to 'significant and demonstrable progress towards the goal of sustainable development through reducing impacts on the environment, enhancing resilience to environmental pressures, or achieving a more efficient and responsible use of natural resources, including energy' (European Commission, 2011).

In creating a sustainable economy, eco-innovation plays a key role in reducing the negative environmental impacts of economic growth (Dogaru, 2020). We may treat eco-innovation as a category of innovation that resides in both innovation and environmental policy and thus links innovation and sustainability (Doran & Ryan, 2012; Horbach *et al*., 2012). Simultaneously, eco-innovation allows companies to generate revenue by solving environmental problems.

James proposed one of the first definitions of eco-innovation (1997). He views it as 'new products and processes that provide customer and business value but significantly decrease environmental impacts.' Other scholars understand eco-innovation more comprehensively as deliberate entrepreneurial behaviour which involves designing a product and managing it in an integrated manner throughout its life cycle (Kemp & Pearson, 2007). This contributes to the ecological modernisation of contemporary societies by considering environmental concerns in the development of products and related processes. Environmental innovation leads to integrated solutions that aim to reduce resource and energy inputs while improving the quality of a product or service. Meanwhile, Carrillo-Hermosilla *et al.* (2010) view eco-innovation as an innovation dealing with green returns on the market. The importance of eco-innovation is crucial for the economy's growth and in transforming societies towards sustainable development (Jo *et al*., 2015; Arranz *et al*., 2020; Carchano *et al.*, 2023). Eco-innovation should not be limited to environmentally motivated innovations. It needs also to encompass products, processes, and organizational innovations with environmental benefits. The eco-innovation can be oriented, *e.g.*, on resource use, energy efficiency, greenhouse gas reduction, waste minimization, reuse and recycling, and eco-design (Arundel & Kemp, 2009). We can also view eco-innovation through the lens of implementing the novelty in the production, assimilation and exploitation of a product, production process, service or business method that result in reducing environmental pollution (Zubeltzu-Jaka *et al*., 2018), limiting the negative impacts of the intensive use of resources (Yurdakul & Kazan, 2020), and mitigating the environmental risk (Kemp & Pearson, 2007). According to Rennings (2000), eco-innovations differ from normal innovations, because they produce a double externality, consisting of (1) the usual knowledge externalities generated in the research and innovation phases and (2) externalities in the adoption and diffusion phases due to positive impact upon the environment.

In the literature, we can find three main categories of factors driving eco-innovation. These are supply-side factors, demand-side factors and regulatory framework (Triguero *et al.*, 2013; Horbach *et al.*, 2012; Sanni, 2018). The supply side factors include human and technological capabilities such as access to knowledge and research and development, whereas the demand side factors cover all determinants related to the market, *e.g.* market structure and competition. Besides conventional technology-pushed and demand-pulled factors, the regulatory framework and environmental policy are key drivers of eco-innovation. Environmental policies may fall under the 'command-and-control' or 'market-based' types. Market-based instruments such as pollution charges, subsidies, tradable permits, and some types of information programs can encourage firms or individuals to undertake pollution control efforts that are in their own interests and that collectively meet policy goals (Jaffe *et al.*, 2002). By contrast, command and control regulations, by setting uniform standards for firms, tend to force firms to take on similar shares of the pollution burden, regardless of the cost. The type of regulation/policy and the way it is implemented is significantly important (Liao *et al.,* 2020). It should lead firms to effectively address environmental problems rather than restrict firms in a specific technology and leave the environmental problem unsolved.

Supporting eco-innovation with the use of government policy instruments is a big challenge and requires a coordinated political approach (Urbaniec, 2019), especially between innovation research and environmental policy. Implementation of eco-innovation measures, which include both supply-side and demand-side measures, has to be conducted in close inter-organizational collaboration, involving sectoral, local, and national levels. Environmental policy agencies should communicate priorities and cooperate more systematically with innovation policy-makers (Sarkar, 2013).

The EU now acknowledges that sustainable green growth requires eco-innovation (see, *e.g.* European Commission, 2013; European Union, 2022) and that environmental policy and legislation are among the key drivers to promote eco-innovation (European Commission 2011). Environmental policy can also direct research and development efforts and set the pace of technological change. In this regard, the European Commission with the MSs and in cooperation with international standardization bodies set up a dialogue-based process to identify and prioritise those areas where the development of standards and performance targets has the greatest potential in terms of driving eco-innovation. It also uses financial instruments to accelerate eco-innovation absorption and development with particular attention to financial instruments and support services for SMEs (Lai, 2016; Zygmunt, 2022).

Ensuring efficient conversion of eco-innovation inputs (EIIn) into EIO and outcomes should be an issue of particular importance for policy-makers and researchers. Many of the existing studies cover the selected issues of EIO with increased attention to the reduction of negative environmental impacts (Urbaniec *et al*., 2021). However, they do not encompass the analysis of all issues related to the wider effects of eco-innovation, as suggested by Arundel and Kemp (2009) and interactions between inputs and outcomes. They often deal with the evaluation of the eco-innovation situation in the selected economy (Loucanova *et al.*, 2015) or the EU as a group of countries in the previous years (Tarnawska, 2013). Moreover, they enable the comparison of the eco-innovation performance of national economies only to a small extent.

Based on the literature review, we have identified the research gap that indicates the need for further development of comparative analyses revealing the differences and similarities of eco-innovation outcomes between EU MSs' economies, setting directions of change, and providing possible patterns for the countries with low performance. We may view eco-innovation outputs and outcomes from the perspective of different macro- and microenvironment factors affecting them (Rodríguez-Rebés *et al.*, 2021).

The results achieved from the previous analysis for the groups of countries, with the use of EII methodology, showed that the distance between the EU-27 average and leading countries in terms of EIIn and eco-innovation activities (EIA) has slightly narrowed over the period under review (Hajdukiewicz & Pera, 2023). This should translate into reducing the gap also in terms of eco-innovation outputs and outcomes. However, it may vary depending on the country and a given thematic field. It is very important for EU economies to identify those eco-innovation outcomes areas that require substantial improvement. We develop the following research hypothesis in our article:

> **(H.1a,b,c):** During the studied period, the distance in eco-innovation outputs and outcomes occurring between the EU-27 average and the eco-innovation leaders was narrowed in terms of (a) eco-innovation outputs, (b) resource efficiency outcomes, and (c) socio-economic outcomes.

Chaparro-Banegas *et al.* (2023) argued that five factors are key drivers that stimulate eco-innovation performance in European Union countries. They include governance, human capital capacity, research institutions, and public and private R&D investments. They correspond well with the composite indicators adopted by the European Commission (2022) as the components of EII measuring the EIIn and EIA. They pinpoint a country's performance concerning government's environmental and energy R&D appropriations and outlays, R&D personnel and researchers, the value of green early-stage investments, implementation of resource efficiency actions and sustainable products among SMEs, and a number of ISO 14001 certificates, being the components of the eco-innovation index (Hajdukiewicz & Pera, 2023). The improvement of eco-innovation performance at the enterprise level can lead to a sustainable development of the economy and can contribute significantly and profitably to the attainment of the European Green Deal's objectives. Al-Aylani *et al.* (2021) stated that leading countries in eco-innovation often benefit from strong governmental support. The countries that invested the most in the R&D sector showed significant improvements in some inputs of eco-innovation. Government support is an important factor in the field of the ecology and energy sector, as it contributes to the improvement of results, especially with green investments in the initial phase of research, as well as the engagement of expert teams and academic researchers. Focusing on the overall EII, a high overall country's performance does not mean that a country has performed well in all eco-innovation areas (Loucanova & Nosalova, 2020). Drawing conclusions, scholars should analyse specific eco-innovation aspects covering particular fields (Rizos *et al.*, 2015). Eco-innovation is a complex category and it is difficult to identify all the factors affecting its development. Moreover, the drivers and impact of eco-innovation may be different for different countries and different eco-innovation thematic areas (Triguero Cano *et al.*, 2013). Nevertheless, many studies suggest that governments' support for R&D and green investment appear to be a key driver of eco-innovation. As recorded for leading eco-innovators, strong governmental support is crucial for progress and should continuously increase over the years (Al-Aylani *et al.*, 2021). Does this mean, however, that the eco-innovation leaders spend these funds more effectively than others, expressed by a higher growth rate of outputs and outcomes compared to the growth rate of inputs? Moreover, have they improved more than other countries in the crucial area of REO? It is also worth considering whether or how countries with relatively low government support, which cannot expect a significant increase, can improve their relative position in the eco-innovation field. To address these issues, we decided to identify relationships between EIIn compared to achieved eco-innovation outcomes and outputs for the EU economies with developed government support innovation systems versus countries with more limited inputs. Hence, we hypothesised:

> **(H.2):** The EU economies with the best performance in terms of eco-innovation inputs convert them into eco-innovation outputs and outcomes more effectively than other EU countries.

RESEARCH METHODOLOGY

We based the investigation on the EII and its components referring to the eco-innovation performance in terms of EIO, REO, and SEO (Figure 1).

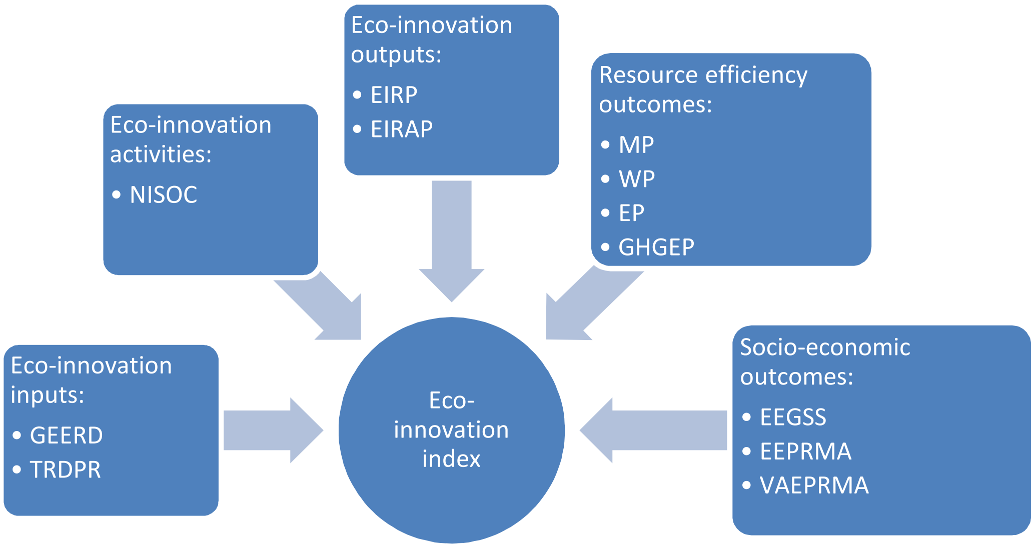

Figure 1. The new EII framework (2021 methodology)

Note: GEERD – Governments environmental and energy R&D TRDPR – Total R&D personnel and researchers; NISOC – Number of IS 14001 certificates; EIRP – Eco-innovation related patents; EIRAP – Eco-innovation related academic publications; MP – Material productivity; WP – Water productivity; EP – Energy productivity; GHGEP – GHG emissions productivity; EEGSS – Exports of environmental goods and service sector; EEPRMA – Employment in environmental protection and resource management activities; VAEPRMA – Value added in environmental protection and resource management activities.
Source: European Eco-innovation Scoreboard, 2022 and own elaboration.

We examined the relationship between the outcomes and the inputs and between the outcomes and the EII for selected EU countries. We analysed the eco-innovation outputs and outcomes in the years 2013-2022. We applied the amended measurement methodology of the EII considering changes introduced in 2021 to the method of the index calculation and its component indicators. The research procedure follows the diagram depicted below (Figure 2).

Firstly, based on the literature review and the thorough analysis of official materials regarding eco-innovation, we identified the specific research problem in the field of eco-innovation performance in the EU. We focused mainly on the eco-innovation outputs and outcomes of the EU countries and also examined their relationships with eco-innovation inputs to assess the effectiveness of converting inputs into outcomes. Following literature (Godin, 2007; Janger *et al*., 2016; OECD/Eurostat, 2018), we understand the eco-innovation outputs and outcomes as different final stages of an innovation process, preceded by two earlier phases, *i.e.*, innovation inputs (resources and capabilities) and innovation activities (supported by resources). While innovation outputs are direct, tangible results of innovation activity, innovation outcomes refer to the broader, longer-term consequences of innovations, including the effects of innovation on organisations, the economy, society, and the environment. However, outputs and outcomes are interconnected, which is why we analysed both of these elements of the innovation process

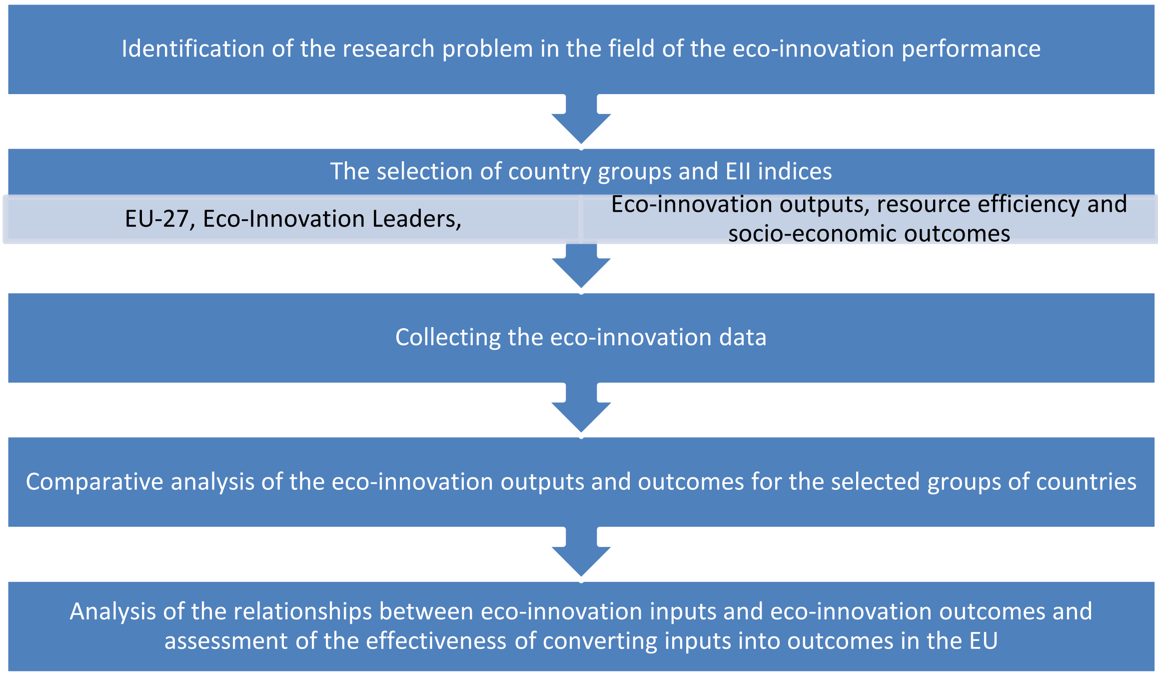

Figure 2. Research conceptualisation
Source: own elaboration.

Secondly, we identified countries that make up the EU eco-innovation leaders, which is the group of countries we analysed in more detail, due to achieving the best results in terms of eco-innovation. According to the recent EU classification, the group consists of Austria, Denmark, Finland, France, Germany, Italy, Luxembourg, the Netherlands, and Sweden. The European Union (27) as one group and eco-innovation catching up were also included in some of our analyses, constituting a reference point in comparative studies. Then, we focused on the three performance components of the EII, which are important from the outcome perspective, *i.e.,* eco-innovation outputs, resource efficiency outcomes and socio-economic outcomes. The data used in our calculations comes from the European Eco-innovation Scoreboard (2022). Due to the changes in the composition of the EII, we decided to narrow our research to the last decade (2013-2022).

Next, we applied the quantitative approach to investigate the research problem and answer research questions. We conducted a comparative analysis of changes in the examined indicators in the selected economies and groups of countries, supported by descriptive statistics and selected taxonomic methods and tools. We used the Euclidean distance to assess the gaps between the EU Eco-innovation leaders and the EU-27 average. We also used Pearson's correlation coefficient (r) to investigate the relations between EIO, REO, and SEO. We explored the differences across the EU countries and the distance of the EU average to leading economies regarding resource efficiency, which encompasses material productivity, water productivity, energy productivity, and GHG (Greenhouse gases) emissions productivity. We also compared the EU countries' eco-innovation performance in terms of EIO, which includes eco-innovation-related patents and publications, and in terms of SEO, which covers, *e.g.*, exports of environmental goods and service sector. We also examined the compound annual change of outputs and outcomes in relation to the compound annual change of inputs in the years

2013-2022, in an attempt to assess the effectiveness of converting inputs into outcomes in the EU. We applied the amended methodology of the EII considering changes in the methodological framework introduced in 2021, which referred to three of five composite indicators of the main EII, namely EIIn and EIO (one of three sub-indicators was removed in both groups compared to the previous EII methodology) and EIA respectively (only one of the three sub-indicators remained) (Figure 1).

RESULTS AND DISCUSSION

The results of the analysis conducted with the use of the EII for the European Union (27) and the group of eco-innovation leaders and catching-up economies (Figure 3) showed an increase in its value and the value of all analysed composite indices between 2013 and 2022.

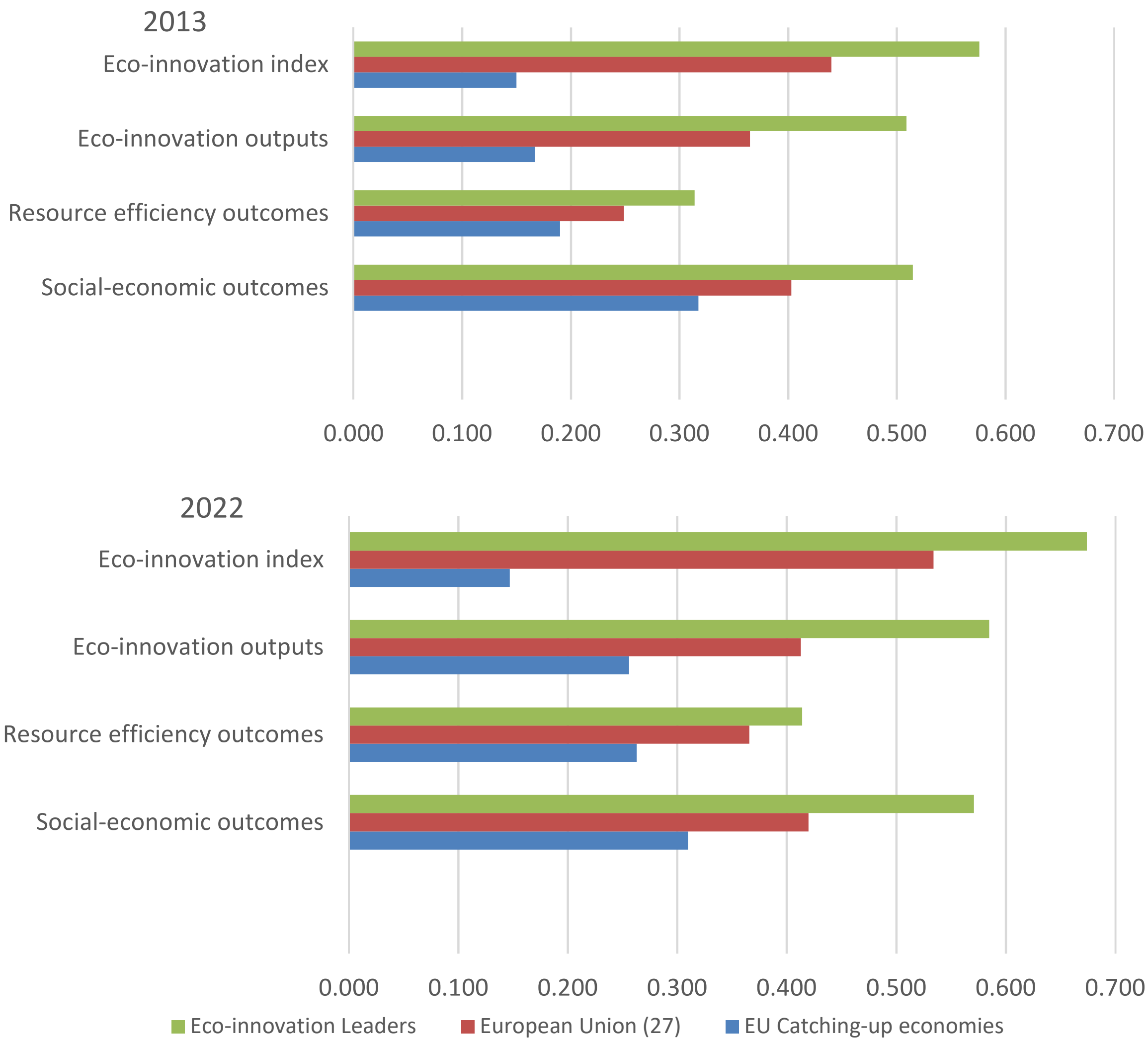

Figure 3. The selected composite indicators of the eco-innovation index* for the European Union-27, eco-innovation leaders and catching-up economies in 2013 and 2022

Note: * The eco-innovation index normalised score (0-1).

Source: European Eco-innovation Scoreboard, 2022 and own elaboration.

The growth was the highest in REO, whilst the lowest in SEO. The distance between the EU-27 average and eco-innovation leaders decreased in REO. In contrast, there was a slight increase in distance for EIO. The distance notably increased in SEO. The eco-innovation leaders maintained the distance to the EU average and significantly increased their distance to catching up economies in terms of the total EII (Figure 3). Thus, the achieved results only partially support the hypothesis 1. In light of our empirical study, we rejected the hypothesis 1a (H1a) and the hypothesis 1c (H1c) and confirmed hypothesis 1b (H1b).

Next, we identified the individual eco-innovation performance and distances between selected EU-leading economies and the EU-27 in terms of EII, EIO, REO, and SEO (Table 1).

Table 1. Eco-innovation index and selected composite indicators for the EU-27 and eco-innovation leaders (2013-2022)

Descriptive statistics	EU-27	FI	LU	SE	DK	AT	DE	IT	FR	NL
EII										
Mean	0.481	0.767	0.748	0.706	0.699	0.671	0.546	0.522	0.519	0.475
Median	0.478	0.765	0.762	0.706	0.697	0.664	0.539	0.523	0.514	0.471
Minimum	0.440	0.742	0.663	0.673	0.668	0.604	0.483	0.451	0.480	0.418
Maximum	0.534	0.799	0.788	0.740	0.737	0.765	0.621	0.569	0.575	0.523
Range	0.094	0.057	0.124	0.065	0.069	0.161	0.138	0.118	0.095	0.104
Standard deviation	0.027	0.021	0.037	0.019	0.019	0.045	0.044	0.036	0.032	0.036
Skewness	0.576	0.265	-1.568	0.178	0.553	0.790	0.325	-0.695	0.362	-0.031
EIO										
–	EU-27	FI	SE	DK	LU	DE	AT	NL	FR	IT
Mean	0.395	0.817	0.795	0.709	0.682	0.580	0.525	0.445	0.358	0.272
Median	0.398	0.830	0.804	0.698	0.691	0.577	0.521	0.457	0.358	0.279
Minimum	0.365	0.735	0.715	0.595	0.469	0.561	0.494	0.410	0.342	0.236
Maximum	0.413	0.877	0.871	0.840	0.798	0.594	0.566	0.473	0.380	0.289
Range	0.048	0.142	0.155	0.245	0.329	0.034	0.073	0.063	0.038	0.053
Standard deviation	0.013	0.046	0.058	0.075	0.092	0.011	0.021	0.022	0.012	0.016
Skewness	-1.179	-0.504	-0.145	0.315	-1.335	-0.183	0.597	-0.491	0.393	-1.375
REO										
–	EU-27	LU	IT	NL	DK	FR	DE	AT	SE	FI
Mean	0.303	0.671	0.617	0.427	0.339	0.337	0.330	0.302	0.266	0.082
Median	0.301	0.680	0.663	0.431	0.338	0.342	0.335	0.311	0.269	0.086
Minimum	0.249	0.652	0.409	0.371	0.075	0.285	0.251	0.242	0.239	0.043
Maximum	0.366	0.681	0.681	0.459	0.307	0.403	0.416	0.347	0.293	0.111
Range	0.117	0.029	0.272	0.088	0.382	0.119	0.165	0.105	0.054	0.067
Standard deviation	0.038	0.013	0.094	0.030	0.026	0.039	0.057	0.032	0.020	0.019
Skewness	0.303	-0.613	-1.570	-0.639	0.365	0.240	0.098	-0.547	-0.060	-0.728
SEO										
–	EU-27	FI	AT	DK	LU	SE	DE	FR	NL	IT
Mean	0.401	0.962	0.799	0.658	0.628	0.528	0.324	0.317	0.301	0.271
Median	0.400	0.962	0.782	0.667	0.608	0.515	0.324	0.311	0.299	0.268
Minimum	0.388	0.958	0.731	0.619	0.544	0.489	0.307	0.295	0.281	0.264
Maximum	0.420	0.962	0.875	0.693	0.733	0.580	0.345	0.351	0.326	0.288
Range	0.032	0.004	0.143	0.074	0.190	0.091	0.038	0.055	0.046	0.024
Standard deviation	0.010	0.001	0.055	0.030	0.059	0.033	0.011	0.018	0.013	0.008
Skewness	0.581	-3.162	0.188	-0336	0.676	0.525	0.272	0.736	0.408	1.616

Note: AT – Austria, DK – Denmark, EU-27 – The European Union, FI – Finland, FR – France, DE – Germany, IT – Italy, LU – Luxembourg, NL – The Netherlands, SE – Sweden.
Source: European Eco-innovation Scoreboard, 2022 and own study.

The results of the calculation of descriptive statistics point to the moderate shifts in EII for the EU-27 and examined countries between 2013 and 2022. It indicates that the performance of the analysed countries was clustered tightly around the mean. There were minor changes in each of the analysed countries. The standard deviation measure confirmed it. We recorded the largest performance differences for Luxembourg in three out of the four presented categories (excluding REO). Austria recorded relatively big changes in EII, REO, and SEO. We noted a remarkable span in EII for Germany and Italy, and in REO for Denmark, Italy and Germany. Moreover, the performance of the Scandinavian countries, *i.e.*, Denmark, Sweden and Finland was outstanding in terms of EIO. Even small differences between the mean and the median indicate a positive or negative skewed distribution of the performance of the analysed economies. In the case of the EII, EIO, and REO for Luxembourg, Italy and the Netherlands, higher performance values were on the left of the average. We recorded similar results in EIO for the EU-27. The mean was quite a bit higher than the median in other cases, and the extreme, more numerous values of the component indicators were on the right side (Table 1).

The recorded differences enabled us to identify more precisely the distance between EU-leading economies and the EU-27 in three studied composite indicators of the EII.

Table 2. The average distance in terms of EIO, REO and SEO between Eco-innovation leaders and the EU-27 in 2013-2022

Composite indicators	AT	DK	FI	FR	DE	IT	LU	NL	SE
Eco-innovation index	0.436	0.467	0.534	0.196	0.255	0.202	0.517	0.110	0.474
Eco-innovation outputs	0.135	0.326	0.429	0.035	0.190	0.119	0.303	0.059	0.408
Resource effectiveness outcomes	0.033	0.055	0.215	0.049	0.049	0.330	0.379	0.135	0.041
Socio-economic outcomes	0.104	0.066	0.320	0.073	0.088	0.233	0.270	0.037	0.137

Source: European Eco-innovation Scoreboard, 2022 and own study.

The average results of leading economies were significantly above the EU-27 average results in 2013-2022. We recorded the largest advantage for Finland and Luxembourg, which were the best EU performers in this respect, while the results of other member states were relatively close to the EU average. The average distance between the eco-innovation leaders and the EU-27 varied by the examined component indicators. We observed the highest dominance in all analysed components of the EII in the case of Finland and Luxembourg. Denmark's and Sweden's results were significantly above the EU average in the case of EIO but not much higher in REO and SEO. Meanwhile, Italy performed the best in EIO compared to REO and SEO. France's performance was closest to the EU-27 average in all three analysed components. The Netherlands' results were similar to those of the EU-27, particularly in EIO and SEO. Other EU-leading economies achieved a value much closer to the EU-27, at least in one of three component indicators (Table 2).

We conducted a more in-depth analysis of the existing distance for Finland, Luxembourg, Italy, France, and the Netherlands. This group included the best performers (Finland, Luxembourg, and Italy) and countries performing closest to the EU-27 (The Netherlands and France).

The analysis of the results of the EU-27 and five selected leading economies in 2013-2022 showed that Luxembourg improved its performance relative to the EU average in terms of EIO. Finland performed even better in this area, but it maintained its advantage at a similar level in 2022 compared to 2013. It increased between 2013 and 2017 and then slightly narrowed. We observed the smallest advantage for the Netherlands and France. We recorded a slight increase in distance for the latter country. The distance between the EU-27 and Finland and Italy increased in terms of REO. Despite the slight decrease in Luxembourg's resource efficiency results, its distance to the EU average remained high. The difference between the EU-27 and France remained almost at the same level throughout the analysed period. At the same time, we noted a slight decrease in the distance between the EU-27 and the Netherlands. The analysis of SEO showed different patterns of change. The largest increase in the gap occurred between the EU-27 and Italy. In 2022, it reached the level of the distance between the EU-27 and Luxembourg. Similarly, the advantage of the Netherlands over the EU-27 average recorded a slight increase. In contrast, Finland and France recorded a decrease in their relative results in this respect (Figure 4).

Overall, the growth rate of the EII index in the analysed period was lower for the leading countries than for the entire EU. However, a closer look at the achieved results shows that the growth rate of outputs and outcomes was higher for these countries than for the EU-27 (except for REO). Moreover, the growth rates of outputs and outcomes were much higher for these countries than the growth rate of their inputs. We observed a different result in the case of the EU27, for which we recorded a relatively high growth rate in inputs. However, it did not translate into an equally high growth rate in the thematic area of outputs and outcomes, again except for REO. Looking at this latter area in more detail,

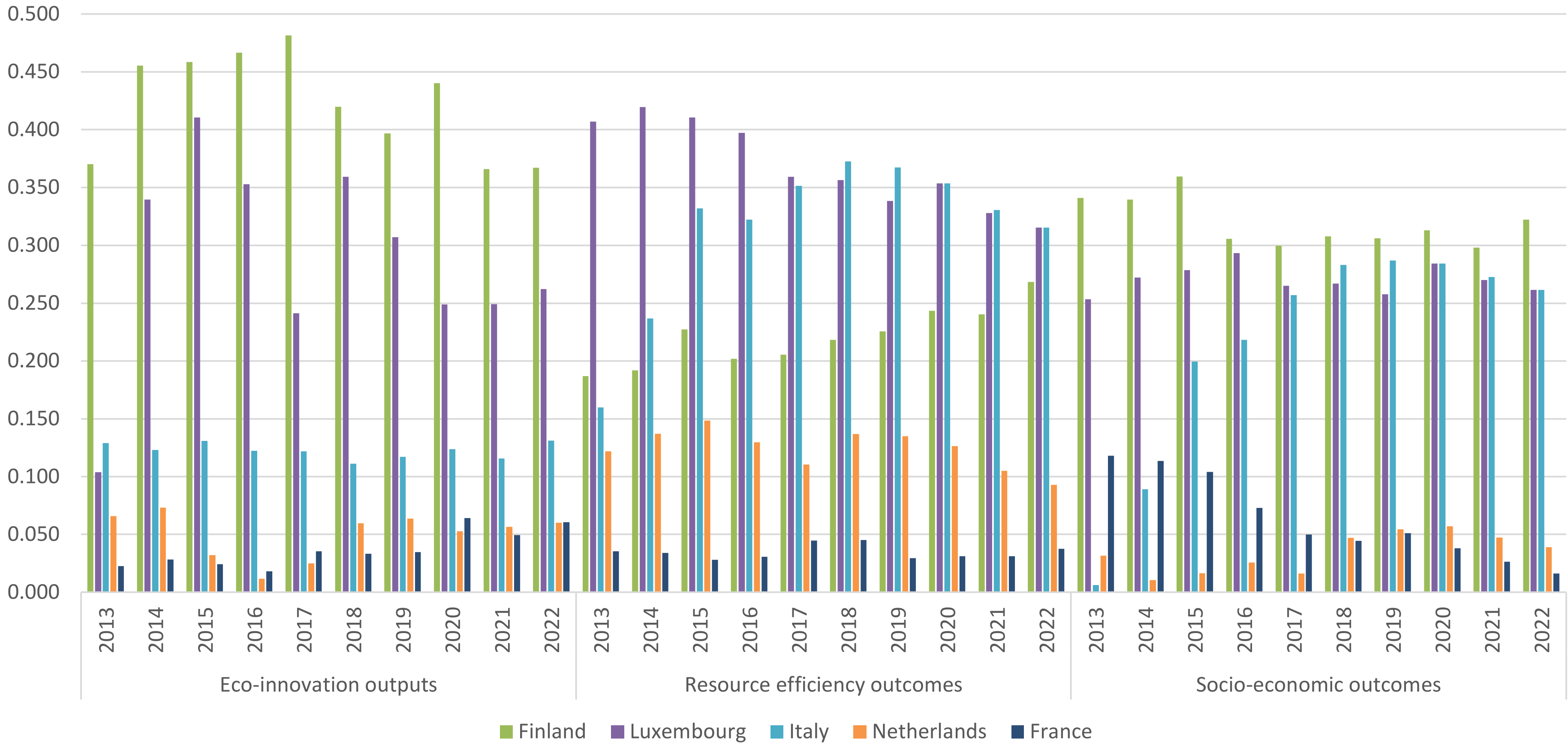

Figure 4. The distance between the selected Eco-Innovation leaders and the EU-27 average according to the eco-innovation outputs and outcomes in 2013-2022
Source: European Eco-innovation Scoreboard, 2022 and own elaboration.

we can notice that although the leading countries recorded lower dynamics of REO than the average in the EU-27. However, the dynamics in relation to the dynamics of inputs were higher for them than for the EU considered as one group. These results support the hypothesis 2. We can explain them by the fact that the effectiveness of converting inputs into outputs and outcomes in countries with weaker results in terms of eco-innovation is limited by many barriers both on the demand and supply side, which have already been at least partially overcome in the countries of innovation leaders. Moreover, EIIn, which provides financial and human resources for eco-innovation activity, can bring results in the longer term, by influencing the supply and demand side of the market, if an appropriate, coordinated government policy in the field of innovation, research, and the environment is applied.

Table 3. Compound annual change of the Eco-innovation index and its composite indicators in 2013-2022 (in%)

Economy	EII			EIIn			EIA			EIO			REO			SEO		
	2013-2017	2018-2022	2013-2022	2013-2017	2018-2022	2013-2022	2013-2017	2018-2022	2013-2022	2013-2017	2018-2022	2013-2022	2013-2017	2018-2022	2013-2022	2013-2017	2018-2022	2013-2022
EU-27	2.6	3.0	2.5	13.3	-4.8	2.3	5.6	-3.6	0.2	2.7	1.1	1.6	5.9	5.4	4.9	-1.0	1.8	0.5
EU leaders	2.7	2.0	2.0	0.0	1.5	0.8	-1.7	0.8	-0.3	4.6	0.1	1.8	6.1	2.6	3.5	-0.5	3.0	1.3
Austria	2.7	4.0	3.0	6.5	7.6	6.2	10.1	1.2	4.3	2.1	1.9	1.7	9.2	0.1	3.4	-1.6	4.5	1.6
Denmark	1.4	1.4	1.2	-3.9	-1.9	-2.4	-0.1	-3.3	-1.7	5.1	4.0	3.9	1.7	4.3	2.8	2.0	0.8	1.1
Finland	2.5	-0.5	0.7	-1.0	-2.8	-1.8	8.6	1.3	3.8	6.0	-2.9	0.7	13.5	1.8	5.8	0.1	0.0	0.1
France	2.4	2.6	2.2	2.4	1.1	1.5	-7.2	-3.0	-4.2	1.7	-0.5	0.4	6.2	4.3	4.5	-1.4	3.9	1.4
Germany	3.5	3.7	3.2	4.5	2.6	3.0	16.3	6.5	9.2	1.8	0.1	0.7	9.5	6.0	6.5	-2.2	2.9	0.6
Italy	5.0	2.2	2.9	-1.8	8.7	3.6	9.0	-7.0	-0.4	5.0	0.8	2.2	16.6	1.3	6.6	-0.3	2.2	1.0
Luxembourg	2.6	2.4	2.2	-5.3	-2.8	-3.4	105,7	-11.2	23.5	10.7	1.5	4.7	0.0	1.0	0.5	-2.9	7.8	2.8
Netherlands	3.1	3.3	2.8	7.0	1.7	3.4	19.4	-1.4	6.1	-0.8	3.0	1.2	3.1	3.1	2.7	0.3	2.3	1.3
Sweden	1.7	0.0	0.6	-3.6	2.8	0.0	-4.6	-9.1	-6.3	6.8	-4.2	0.3	2.7	3.2	2.6	1.1	3.5	2.2

Source: European Eco-innovation Scoreboard, 2022 and own study.

Simultaneously, the changes in particular EII areas and for individual economies occurred with varying intensity over the examined period. We observed the slowdown in changes between 2018 and 2022 for the EU eco-innovation leaders. Most likely, this was due to greater uncertainty and crisis phenomena in the economy during this period, related to the COVID-19 pandemic and Russia's invasion of Ukraine. Finally, we recorded lower rates of change than in the previous years in Finland, Italy, Luxembourg, and Sweden.

Looking closer into composite indicators of the EII, we observed adverse changes that affected the rate of change from 2013 to 2022. We recorded the largest annual changes among all composite indicators in the REO. These are primarily evident in Italy and Finland and secondarily in Austria and Germany from 2013 to 2017. From 2013 to 2022 and 2018 to 2022, the development of the REO in the EU-27 has been faster than in the leading economies. Only Finland, Germany, and Italy performed better than the EU-27 as a whole. Changes in the other analysed economies were slower. The slightest changes in REO occurred in Luxembourg. The average annual rate of change in the EU-27 was higher in 2018-2022 compared to the eco-innovation leaders. Denmark and Luxemburg were the main drivers of change in the latter group of countries. We recorded the lowest compound annual rate of change in SEO. Both in the EU-27 and the leading economies, the performance decreased between 2013-2017. Luxembourg, Germany, Austria, France, and Italy mainly influenced the result of the leading group in these years in this thematic area. For the whole analysed period, we recorded the highest change in the overall EII for Germany, Austria, Italy, and the Netherlands (Table 3).

Moreover, we tried to find out if the composite indicators on the inputs' side are strongly linked with the indicators on the 'effects' side for the leading countries, and which of the composite indicators strongly relate to the total EII.

Table 4. The value of Pearson's correlation coefficient (r) between components of the eco-innovation index and the EII for Eco-Innovation Leaders, 2022

Variables	EII	EIIn	EIA	EIO	REO	SEO
EII	1.000	0.204	0.178	0.783**	-0.350	0.933***
EIIn	0.204	1.000	0.005	0.284	-0.722**	0.224
EIA	0.178	0.005	1.000	0.151	-0.221	0.210
EIO	0.783**	0.284	0.151	1.000	-0.528	0.716**
REO	-0.350	-0.722**	-0.221	-0.528	1.000	-0.531
SEO	0.933***	0.224	0.210	0.716**	-0.531	1.000

Note: EII – Eco-innovation index, EIIn – eco-innovation inputs, EIA –co-innovation activities, EIO – eco-innovation outputs, REO – Resource effectiveness outcomes, SEO – socio-economic outcomes; *** p < 0.01; ** p < 0.05.
Source: European Eco-innovation Scoreboard, 2022 and own study.

The study revealed strong correlations between EII, EIO and SEO. We found no significant relationship between the other components of the EII and the total EII. Moreover, the results achieved by the eco-innovation leaders show that there was a negative relationship between inputs (EIIn) and REO (Table 4). This last finding is a bit surprising, but we can probably explain it by the fact that the results in terms of efficiency of resources and GHG emission intensity in these economies are the current effect of financial and human capital investment made much earlier.

Table 5. The value of Pearson's correlation coefficient (r) between components of the eco-innovation index for the EU-27, 2022

Variables	EII	EIIn	(EIA	EIO	REO	SEO
EII	1.000	0.737***	-0.093	0.859***	0.328*	0.633**
EIIn	0.737***	1.000	-0.203	0.605**	0.160	0.236
EIA	-0.093	-0.203	1.000	-0.194	-0.327*	0.204
EIO	0.859***	0.605**	-0.194	1.000	0.141	0.570**
REO	0.328*	0.160	-0.327*	0.141	1.000	-0.284
SEO	0.633**	0.236	0.204	0.570**	-0.284	1.000

Note: EII (main) – eco-innovation index, EII – eco-innovation inputs, EIA – co-innovation activities, EIO – eco-innovation outputs, REO – resource effectiveness outcomes, SEO – socio-economic outcomes; *** p < 0.01; ** p < 0.05; * p<0.1
Source: European Eco-innovation Scoreboard, 2022 and own study.

We also examined the correlation strength between individual component indices and the total EII in EU-27 as one group of countries. We found that the strongest correlation occurred between EIIn, EIO, SEO, and EII and the weakest – between EIA, REO and EII (Table 5). Unlike in the group of eco-innovation leaders, for the EU-27, we recorded a strong relationship between EIIn and the EII. Catching up countries may want to improve their overall eco-innovation to pay particular attention to improvements in the thematic area of EIO and SEO, following the example of leading countries, but at the same time, they cannot neglect other areas of eco-innovation performance.

CONCLUSIONS

The article aimed to examine the eco-innovation performance of the European Union's economies in terms of its outcomes with a particular focus on REO and SEO. Eco-innovation contributes significantly to the economy's growth and transforming societies towards sustainable development. One of the main challenges in European eco-innovation is to ensure the effective conversion of inputs into outputs and improve the REO and SEO in the EU economies.

The research results showed that EU countries considered as one group improved their eco-innovation performance as measured by the overall EII, as well as in terms of the index components related to innovation outcomes during the study period. We also observed improvement in the EII and in the EII thematic areas for both the eco-innovation leaders and catching-up economies. However, the leading countries maintained and even slightly increased the distance between the EU-27 average in terms of the total EII, while significantly increasing the distance in terms of SEO and EIO. The only one of the studied eco-innovation thematic areas in which the leading countries reduced the distance to the EU-27 average (yet extending it to the group of Catching-up) was REO. Thus, the achieved results only partially support the hypothesis 1. In light of our empirical study, we rejected the hypothesis 1a (H1a) and the hypothesis 1c (H1c) and confirmed the hypothesis 1b (H1b). This may indicate serious difficulties and barriers in catching up with leading countries by countries with weaker eco-innovation results in terms of eco-innovation outputs and outcomes.

The countries with the best results in terms of eco-innovation outcomes were Finland and Luxembourg, whilst we recorded the highest growth rates of the REO in the leading group for Germany and Italy, and in the SEO for Luxembourg and Austria.

Even though the growth rate of inputs in the economies of eco-innovation leaders was lower than the EU average, they recorded a significantly higher growth rate of EIO and SEO than the EU average growth rate, and lower but still at a high level growth rate of REO, which contributes to the persistent gap between them and other EU economies.

Moreover, the rates of growth of outputs and outcomes were much higher for these countries than the growth rate of their inputs. We observed a different result in the case of the EU-27, for which we recorded a relatively high growth rate in inputs. However, it did not translate into an equally high growth rate in the thematic area of outputs and outcomes. This proves the higher efficiency of the use of inputs by the leading countries. Thus, the obtained results support the hypothesis 2. At the same time, the results indicate problems with ensuring the effectiveness of operations by the catching-up countries. This may relate to long-term lagging behind in these countries, which have recorded significant improvements, especially in terms of resource efficiency, but insufficient to improve overall eco-innovation results and to reduce the distance to the leading economies. This also shows the importance of conducting an appropriate innovation policy integrated with the general economic development policy, and coordinated with the research and environmental policy, because improvement in inputs or company innovation activities does not translate directly into improved eco-innovation outcomes in all conditions. The strong correlation between EIO, SEO, and the total EII in the leading countries indicates that this are the thematic areas that are particularly important for achieving significant improvement in the field of eco-innovation and that the attention of business and policy-makers should not focus excessively on the size of inputs, especially financial ones, but more on the effectiveness of their use.

There are some limitations to our study that need to be considered. Based on the European Commission indicators, the research did not cover all aspects that need to be addressed to improve a country's eco-innovation performance in terms of outcomes. Moreover, changes in the EII methodology introduced by the European Commission resulted in difficulties in data comparability and access to some data.

Despite the limitations, this study will contribute to a better understanding of eco-innovation for better policymaking. In particular, it can give a comprehensive picture of eco-innovation outcomes in the European Union as one of the components of the eco-innovation performance. It also highlights the importance of creating appropriate conditions for the development of eco-innovation, including creating sound policy frameworks at the national, regional, and international levels.

The study is certainly worth continuing. Future research directions may include a more thorough comparison of eco-innovation leaders and catching-up countries, considering more detailed, disaggregated measures of eco-innovation (*e.g.* EIIn and SEO sub-indicators). Scholars may also consider the further identification of various factors affecting eco-innovation beyond those included in the EII. Research can also go beyond EU countries and cover other regions of the world. It would also be worth extending research on eco-innovation by analysing the micro level, focusing on various aspects of eco-innovation management in enterprises.

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