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THE IMPACT OF ECO-INNOVATION AND INVESTMENTS ON SUSTAINABLE ECONOMIC DEVELOPMENT AND TOURISM IN THE EUROPEAN UNION

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Abstract. This paper addresses the sustainable nature of economic growth and tourism development, influenced by eco-innovation and total investments in EU member states. We analyse how eco-innovation group membership (leaders, average performers, and catching-up countries) shapes the contribution of investments and the Eco-Innovation Index (EII) to the dynamics of GDP and gross value added in tourism. The conclusions of the statistical analysis of panel data from the 27 member states of the European Union confirm that, for the 2014–2024 timeframe, all variables differ significantly depending on eco-innovation group membership. Our econometric approach uses fixed-effects (FE) models for three groups of countries defined by their eco-innovation levels in 2024, testing the established hypotheses. The results show that eco-innovation and investments positively and significantly influence both GDP and tourism gross value added. Group membership matters: the lower the eco-innovation level, the greater the influence of both EII and investments on economic growth and tourism development. Eco-innovation proved robust to economic shocks, supporting sustainability policies for both tourism and broader economic growth.

Keywords: eco-innovation, sustainability, investments, GDP, tourism, FE models, panel data models.

JEL Classification: C01, O16, O30, O40, Z32.

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1. Introduction

Eco-innovation has emerged as a key concept within the European Union's policy framework for promoting sustainable economic development, particularly in environmentally sensitive sectors such as tourism.

The indicator developed to assess eco-innovation performance is the Eco-Innovation Index (EII). The EU-27 score for 2014 is taken as the basis for the EII (100%). EU Member States are divided into three equal groups, ranked according to their EII performance scores. The

first group represents the "eco-innovation leaders", the next group is called the "eco-innovation average performers" and the third group consists of the "eco-innovation catch-up countries" (European Commission, 2024).

However, the empirical evidence on how eco-innovation performance captured by the Eco-Innovation Index (EII) interacts with investments' dynamics to influence economic development and tourism activity remains limited and fragmented, therefore, the present paper aims to fill in this gap. Relatively little attention has been paid to whether these relationships differ across countries depending on the grouping based on the Eco-Innovation Index.

This study contributes to the literature by developing econometric models that illustrate the influence profiles of eco-innovation and investments on tourism and economic development, while taking into account cross-country heterogeneity. By integrating these dimensions, the paper provides empirical insights that can support targeted investment policies and frameworks for European eco-innovation funding, and/or regulating their implementation conditions among EU member states.

Considering this context, we assume that eco-innovation and investments have a positive and significant impact on both sustainable economic development and tourism performance. Moreover, we assume that grouping EU member states according to their Eco-Innovation Index at the end of 2024 reveals meaningful differences in economic development and tourism, which can provide a base for differentiated investment policies and implementation frameworks. In addition, tourism itself is expected to contribute directly to sustainable economic development within the analysed period.

The robustness of the Eco Innovation Index during economic shocks highlights eco-innovation as a solution for the sustainability of economic development in the event of such economic shocks and by driving stronger investment effects on GDP dynamics. By correlating these conclusions with the broader research objectives, this paper provides a basis for testing the proposed hypotheses, illustrating how eco-innovation and investment dynamics shape sustainable economic and tourism development in the EU.

The paper makes three distinct contributions to field literature. First, it provides empirical evidence on the impact of eco-innovation and related investments on both GDP and tourism value added. Second, considering the comparisons by groups according to the Eco-Innovation Index (EII), we update classification of eco-innovation groups based on the last year, 2024 – of the analysed period, thus improving the accuracy and contemporaneity of the analysis. Third, we built and interpreted econometric models for economic growth and, respectively, tourism development, depending on investment, eco-innovation, and economic shocks. The econometric modeling framework for GDP and the tourism industry provides robust and policy-relevant empirical results.

The present paper is structured in four main parts. The first part consists of a theoretical background based on literature review related to the main topics such as eco-innovation, investments and sustainable development in the tourism industry. The second part presents the methodology and data used for the research. The third part illustrates the empirical results while the last part presents the conclusions of the research.

2. Theoretical background

2.1. Eco-innovations for the sustainable development of the tourism industry

Eco-innovation started to gain researchers' attention, more intensely, over the last decades. Also referred to in the field literature as sustainable innovation, ecological innovation, green

innovation or environmental innovation (Tumenova & Batov, 2024; Sharma et al. 2020; Rennings, 2000), eco-innovation is defined as innovation which benefits the environment and contributes to environmental sustainability (Rennings, 2000).

In the tourism industry, eco-innovations impact destinations and businesses in various areas being linked with new products, new experiences, alternative travel means, environment preservation, recycling, energy saving, consumers that demand novelty. Considering that each eco-innovation involves the integration of multiple factors and activities, this process is considerably more complex in tourism, since each eco-innovation comprises multiple interrelated innovations. Since reducing environmental impacts, increasing environmental conservation, and fostering local development are essential for the sustainability of tourism activities, it is reasonable to expect that the adoption of eco-innovations is of high interest in the present and will become increasingly important soon (Alonso-Almeida et al., 2016).

Most eco-innovations in tourism come from other industries and have been effectively adapted to this sector, as evidenced by Hjalager's systematic analysis of innovations not originally developed for tourism. These transferred innovations have shaped tourism development by enhancing mobility, productivity, profitability, business growth, and the emergence of new destinations, emphasizing the need for strategic monitoring and knowledge transfer of eco-innovations made in other sectors to the tourism sector (Hjalager, 2015).

Tumenova and Batov (2024), stated that the main drivers for the development of eco-innovations in tourism are the need for environmental regulations of production activities, growing demand for nature tourism, diversification of the offered tourism product, reduction of operating costs, or formation of an appropriate image.

The emergence of digital platforms, artificial intelligence and virtual reality are changing the overall tourist experience, by making innovation the heart of the transformation of the tourism offer (Bourdin et al., 2023). This trend can also positively impact the sustainable development and growth of tourism and also, facilitate the development of environmental-friendly innovations (or eco-innovations).

In their study, overviewing the eco-innovation research in hospitality between 1998 and 2018, Sharma et al. (2020), observed that the most researched themes on eco-innovative practices were: eco-efficient strategy, green-consumerism, CSR and outreach, carbon management, eco-labels (green certifications and standards), management and employee engagement, analysis and evaluation.

Europe is a global leader in the adoption and development of eco-innovations in the tourism industry (Marimon et al., 2012) due to the fact that tourism is a key sector therefore the importance of preserving nature and cultural heritage is a top priority and European strategies converge towards the reach of a circular economy.

2.2. Investments and eco-innovation in European tourism

Investments are an important driver and pillar of tourism economic growth and sustainable development of a country (World Tourism Organization, 2021; UN Tourism, 2024; Portella-Carbó et al., 2025). They affect each pillar of decent work by "increasing jobs, social protection, and bottoms at work, but harm social dialogue" (Castilho & Fuinhas, 2025).

Since 2016, Europe continues to be a pioneer in the development of eco-innovations in the tourism sector, supported by the European authorities' strategies aimed at implementing a circular economy by 2050 and the imperative need to preserve natural and cultural heritage (Alonso-Almeida et al., 2016).

Eco-innovation finds its purpose through investments. Both investments and eco-innovations foster sustainable and economic development (Brojak-Trzaskowska, 2024).

Nowadays, tourism investments focus more on key areas such as modern technology infrastructure (travel tech), innovation, artificial intelligence, digitalization and smart destinations, sustainable tourism development policies and renewable energy consumption (OECD, 2025, 2026). World Tourism Organization (2021), developed investment guidelines to better understand the opportunities, generate sustainable investments in the tourism ecosystem and provide insights for tourism tech start-ups (UN Trade and Development [UNCTAD], 2025). According to panel econometric results analysis based on 1995 to 2015 period the "renewable energy uses, and tourism investments have a considerable positive impact on both the tourism revenues and the tourist arrivals" in G20 countries (Lu et al., 2019).

The importance of an integrated approach regarding investments in tourism is mentioned in a critical review paper (Corboș et al., 2024): "successful destination requires not only a robust physical infrastructure, but also investment in intangible components such as promotion and professional training". This influences both the tourist experience and local economic development.

A recent empirical result obtained by Sun et al. (2025) from 182 countries (1998 to 2022) indicates that enhancing both institutional quality and tourism infrastructure is crucial for maximizing the economic benefits of tourism and investments' efficiency in tourism to ensure the long-term sustainability of tourist destinations.

The policy makers should work with investors that can fund "essential infrastructure, foster innovation, and elevate service standards", indirectly contributing to economic growth (Jonsson, 2022; Efthimiou, 2025) but also directly by affecting the number of tourists to come (Gövdeli, 2019).

Sokhanvar (2019) listed and analysed 43 important studies' results regarding the effect of foreign direct investments (FDI) on the economy, the interactions between FDI and tourism industry, and the interactions between tourism industry and the economy. The review of literature conducted by the author indicates that there are mixed debates regarding foreign direct investments' (FDI) impact in economic growth, including tourism development.

Economic growth represents a fundamental factor of a country's sustainable development, an economic engine. "According to statistical data and the literature, tourism is one of the most important sectors for economic growth" (Haller et al., 2021). Tourism is very important for economic growth, and the recent contribution of Panagiotidis et al. (2024) brings a synthesis of a comprehensive literature, including even the Tourism-Led Growth Hypothesis (TLGH).

There are numerous studies analysing the relationship between tourism and economic growth and the literature offers a variety of results with contradictions and limitations, most studies focusing on individual countries or groups of countries (Alcalá-Olid et al., 2026; Alcalá-Ordóñez et al., 2024).

Recent empirical study results confirmed a significant relationship between tourism, economic growth, and environment. The study was conducted on a sample of 15 countries that have ranked among the top 10 global tourist destinations in terms of foreign tourist arrivals, during the period 1995–2023, the results being obtained by applying the CS-ARDL method (Alcalá-Olid et al., 2026).

In recent decades, according to European Commission's publications, European tourism investment policies have become a priority, and programs and projects have been initiated to support investments and eco-innovation in tourism (European Commission, n.d.-a, n.d.-b, n.d.-c, n.d.-d, n.d.-e).

3. Data and methodology

Our research methodology is based on the statistical analyses of time series evolution and panel data econometric models in Eviews and SPSS software.

We use the Eco-Innovation Index (EII), whose data from 2014 onwards provides a longer series than the Summary Innovation Index (SII) from the European Innovation Scoreboard, which is based on EU performance in 2018 (European Commission, 2025). Moreover, the perception of eco-innovation is more consistent with the sustainability of tourism development and economic development.

The research conducted in Section 3 is presented together with the interpretation of the results and the conclusions drawn, based on the logic of the following general hypotheses, which are tested through the specific working hypotheses, in Table 1.

Table 1. General and specific working hypotheses of the research

No.	General hypotheses	Specific working hypotheses
1.	The importance of eco-innovation and investments for sustainable economic development and tourism (H1 and H2).	H1: Eco-innovation and total investment have a positive and significant impact on the sustainability of economic growth.
		H2: Eco-innovation and tourism investment have a positive and significant impact on the sustainability of the tourism development.
2.	The significance of the grouping the EU member states by the eco-innovation index at the end of 2024, on economic development and tourism (H3 and H4).	H3: Eco-innovation group membership significantly and differently influences the contribution of investment to economic growth and tourism.
		H4: Eco-innovation group membership significantly and differently influences the contribution of eco-innovation to economic growth and tourism.

Our econometric approach demonstrates the influence of investment and eco-innovation on economic development and in particular on tourism, as shown in Figure 1, which underlies the research methodology.

Figure 1 presents the definition described below of the Eco-Innovation Index (EII), which we have included in a scheme of the national cyber system of economic development.

The Eco-Innovation Index is a composite indicator that provides a comparative assessment of eco-innovations' performance in EU member states that takes into account five themes: Eco-innovation inputs, Eco-innovation activities, Eco-innovation outputs, Resource efficiency outcomes and Socio-economic outcomes (European Commission, 2024).

Eco-innovation inputs are seen as the financial and human capital investments in eco-innovative activities and can be assessed through government allocations and expenditures for environmental and energy research and development, as well as through R&D personnel and researchers (European Commission, 2024).

Eco-innovation activities are considered to be the extent to which companies in a given country are active in eco-innovation, and are assessed by the Number of ISO 14001 certificates (European Commission, 2024).

Eco-innovation outputs are defined as the number of patents and academic literature associated with eco-innovation. They are mainly assessed by Eco-innovation related patents and Eco-innovation related academic publications (European Commission, 2024; European Climate, Infrastructure and Environment Executive Agency, n.d.).

Resource efficiency outcomes are considered the efficiency of resources and GHG emission intensity, and can be measured by using material productivity, water productivity (GDP/total fresh water abstraction), energy productivity and GHG productivity (European Commission, 2024).

Socio-economic outcomes are defined as the positive societal and economic outcomes of eco-innovation. They are measured through exports of environmental goods and service sector, employment in environmental protection and resource management activities, and value added in environmental protection and resource management activities.

The feedback in Figure 1 aligns with the phases of our econometric approaches.

For the 27 EU member states, in the period 2014–2024, we consider the influence of total investment (Gross Fix Capital Formation – GFCF) and EII on GDP. We analyse, especially for tourism, the influence of investments in tourism (GFCF_TOURISM) and EII on Gross Value Added in Tourism (VAG_TOURISM).

Investment flows, GDP and gross value added in tourism are expressed in 2015 in million euros and we use their logarithms for easy interpretation of the results (LGFCF, LGFCF_TOURISM, LGDP and LVAG_TOURISM). The Eco-Innovation Index (EII) is expressed in percentages with fixed base in the average level of EU 2014.

We build econometric models based on Figure 1: the first phase of the study for modeling GDP as an output using EII and GFCF as inputs, and the second phase of the study for modeling VAG_TOURISM as an output using EII and GFCF_TOURISM as inputs.

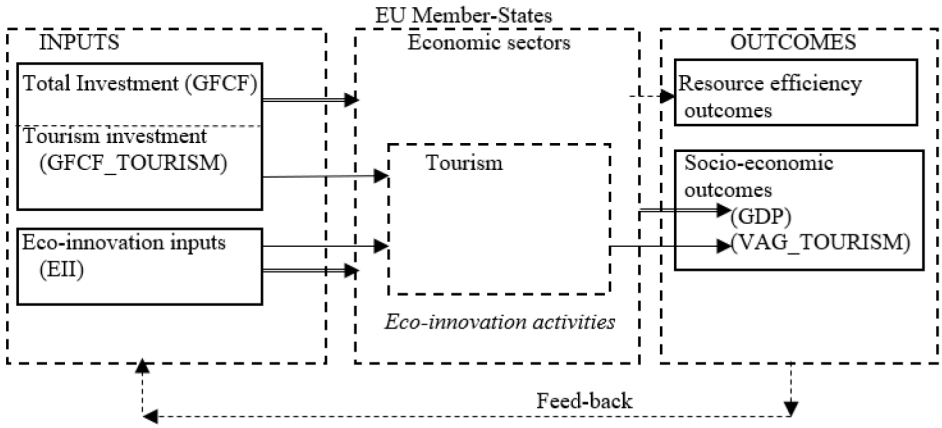

Figure 1. The cyber economic system in the definitional framework of the Eco-Innovation Index

In Section 4.1, we presented the evolution of the EII over the period 2014–2024 for each EU country in each eco-innovation group and then the average evolution of the EII for the three eco-innovation groups.

In Section 4.2, we used SPSS software to test whether eco-innovation groups are significant for the dynamics of the analysed variables, both for the input and output variables in Figure 1. We found that, for the period 2014–2024, all variables are significant according to eco-innovation groups.

Section 4.3 is dedicated to building the best econometric models to explain, as shown in Figure 1, the influences of factors as input variables on the variation of output variables,

for the period 2014–2024. The analysis of correlations between variables during this period and causality tests are followed by the analysis of integration and cointegration of variables.

The eco-innovative grouping of EU countries is taken into account for both the econometric models of sustainable economic development and for the tourism sector. When considering the three groups of eco-innovative countries, the data panels are long, each with 9 countries and 11 years. After testing fixed-effects and random-effects models, we found that fixed-effects (FE) with cross-sections is the best choice. We included a dummy variable in the econometric models to explain the decline in GDP caused by the pandemic in 2020. For the econometric models of gross value added in tourism, we considered two dummy variables for both 2020 and 2021, to explain the persistent effects of the pandemic.

The Conclusions section is based on the comparison of results and validation of hypotheses.

4. Results and discussions

4.1. Eco-Innovation Index in the EU member states over the period 2014–2024

We have analysed the evolution of the EII index for each EU country, as well as at the EU level. We present the evolution of the EII for the three groups of nine EU countries, in descending order of their innovation performance in 2024, compared to the EU average in 2014. In 2024, the EII of Eco-innovation leaders ranges between 133% and 181%, for Average eco-innovation performers, the EII ranges between 109% and 127%, and for Eco-innovation Catching-up countries, the EII ranges between 58% and 99%.

Figure 2 shows the evolution of the EII in each country in the respective group.

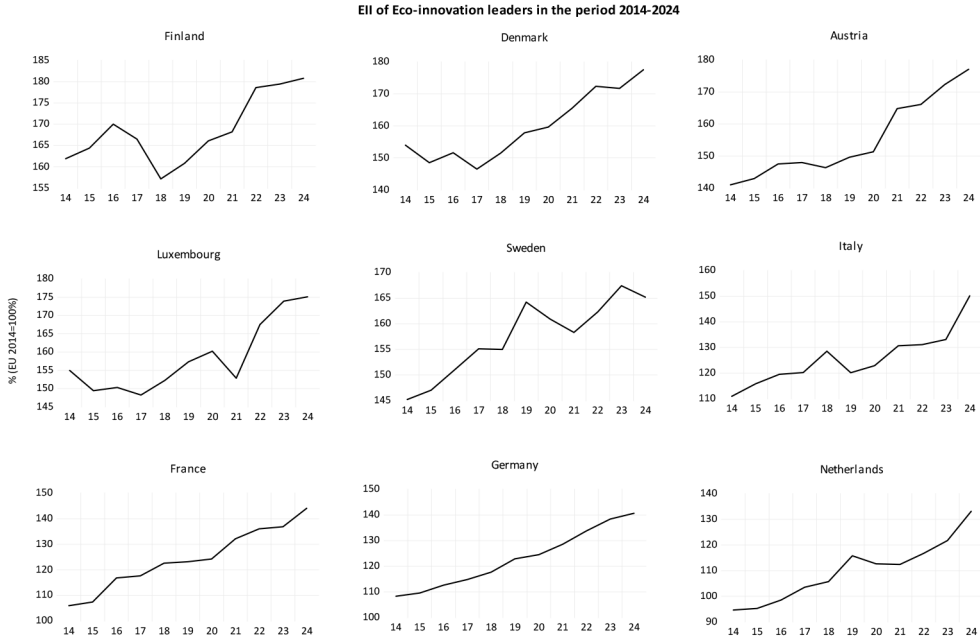

Figure 2. To be continued

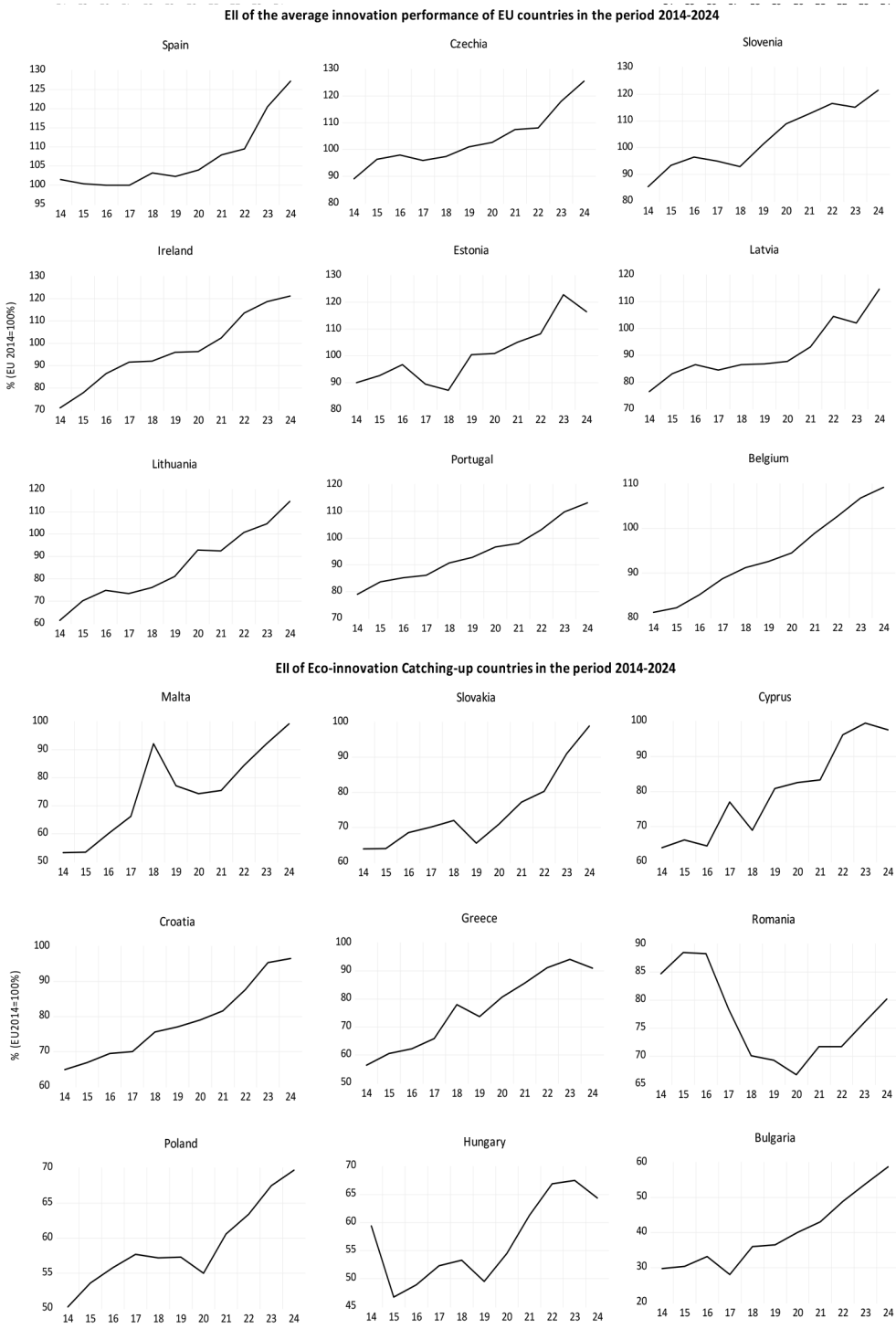

Figure 2. Evolution of Eco-Innovation Index in the groups of performance in the period 2014–2024

Figure 3 shows the average EII in the EU and the average evolution of the EII for each of the three groups of nine countries, in descending order of their eco-innovation performance.

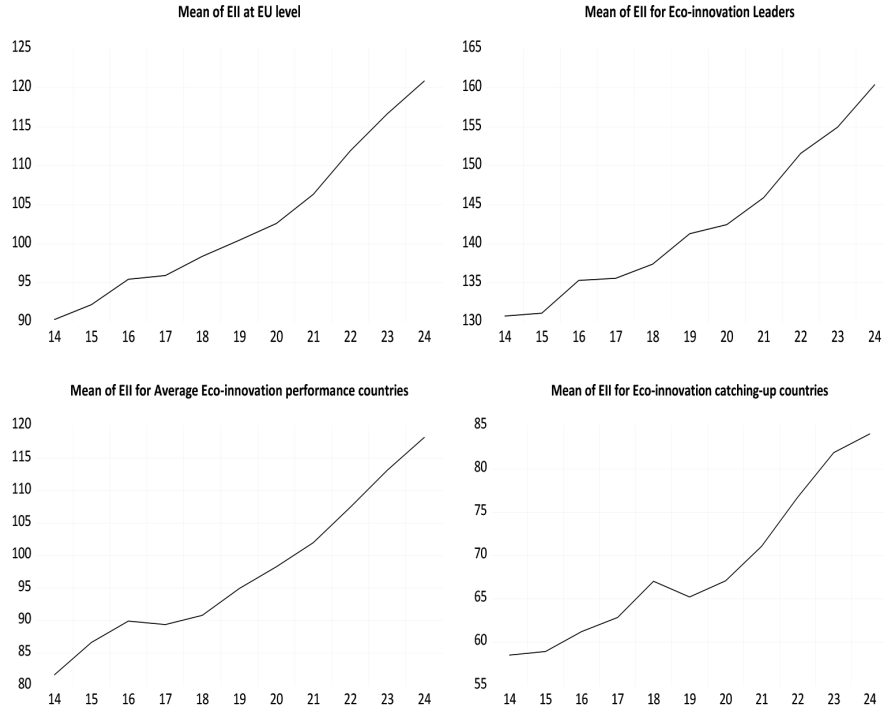

Figure 3. Average evolution of EII at EU level and for the three eco-innovation groups, 2014–2024

The conclusion is that, for most EU countries, the EII had an increasing evolution during the period 2014–2024, not affected by the 2020 pandemic. We can see from the graphs in Figures 2 and 3 that the pandemic marked the beginning of a period of growth in the evolution of the EII, especially for the third group of eco-innovative catching-up countries. The influence of eco-innovation should make tourism and economic development sustainable.

4.2. The importance of eco-innovation groups in the econometric approach to tourism and economic growth over the period 2014-2024

The eco-innovative country groups depend on the EII in 2024 and are presented separately in Figure 3. In Table 2, the variable *eco* defines the three groups of nine countries, in descending order of the eco-innovation index (EII) in 2024.

For each group of eco-innovative countries, we see the mean, standard deviation and number of observations of the variables.

In Table 3, the ANOVA method, in SPSS, shows that the eco-innovation criterion of country grouping is significant for each variable. The *Sig*. value is less than 5%, and the null hypothesis is rejected; the grouping factor is significant for the variation of each variable analysed in the period 2014–2024.

Table 2. Summary statistics of eco-innovation groups in the period 2014–2024

eco	Indicator	LGDP	LGFCF	LGFCF_ TOURISM	LVAG_TOURISM	EII
1	Mean	13.2583	11.7012	6.9206	9.1888	142.4414
	Std. Deviation	1.2052	1.2294	1.4399	1.3421	22.6886
	N	99	99	97	99	99
2	Mean	11.7335	10.2495	5.7623	7.7585	97.4929
	Std. Deviation	1.3204	1.3020	1.4888	1.6376	13.3502
	N	99	99	97	99	99
3	Mean	11.2980	9.6661	5.8195	7.5834	68.5949
	Std. Deviation	1.0845	1.0954	0.7901	0.8902	16.7857
	N	99	99	97	99	99
Total	Mean	12.0966	10.5389	6.1675	8.1769	102.8431
	Std. Deviation	1.4684	1.4811	1.3827	1.5051	35.3418
	N	297	297	291	297	297

Table 3. ANOVA for the significance of the eco-innovation criterion in the period 2014–2024

		Sum of Squares	df	Mean Square	F	Sig.
LGDP * eco	Between Groups	209.792	2	104.896	71.978	0.000
	Within Groups	428.454	294	1.457		
	Total	638.247	296			
LGFCF* eco	Between Groups	217.461	2	108.731	74.023	0.000
	Within Groups	431.852	294	1.469		
	Total	649.313	296			
LGFCF tourism * eco	Between Groups	82.692	2	41.346	25.241	0.000
	Within Groups	471.763	288	1.638		
	Total	554.454	290			
LVAG_tourism * eco	Between Groups	153.561	2	76.781	43.663	0.000
	Within Groups	516.991	294	1.758		
	Total	670.552	296			
EII * eco	Between Groups	274189.076	2	137094.538	421.932	0.000
	Within Groups	95526.693	294	324.921		
	Total	69715.768	296			

In Table 4, the nonlinear coefficient *eta* (SPSS) shows the strength of the association, and *eta squared* indicates the proportion of the variable's variation explained by membership in eco-innovative groups defined by the eco variable.

As expected, the EII has a strong association with eco-innovation groups, and most of the explanation of its variation is due to its own values as a grouping criterion. The eco-innovation criterion of the grouping of countries explains approximately one third of both GDP and total investment dynamics, which is an important part.

Table 4. Association measures between variables and eco-innovation groups

Relation	Eta	Association	Eta Squared	Variance explained (%)
LGDP * eco	0.573	moderate	0.329	33.0%
LGFCF* eco	0.579	moderate	0.335	33.5%
LGFCF_TOURISM *eco	0.386	weak	0.149	14.9%
LVAG_TOURISM *eco	0.479	moderate	0.229	22.0%
EII * eco	0.861	strong	0.742	74.2%

The relationship between the eco-innovation criterion and the development of the tourism sector is less strong than at the level of the national economy: even weak in the case of tourism investments and moderate in the case of gross value added in tourism. The variance of gross value added in tourism is influenced by the eco-innovation criterion by 22%. The conclusion is that other factors also influence tourism development.

Concluding that eco-innovation has a significant role in economic development, we can state that eco-innovation and investments in tourism must continue to effectively influence the development of the tourism sector.

4.3. Econometric models of sustainable economic growth and tourism in the EU in the period 2014–2024

Our first direction is to analyse the sustainable nature of economic growth as a result of investment and eco-innovation efforts. We set the logarithm of GDP volume as the dependent variable and, as explanatory variables, the logarithm of GFCF and EII, in Eq. (1). For a better explanation, the dummy variable *D2020* is used in Eq. (2).

$$\widehat{LGDP}_{it} = \hat{a}_0 + \hat{a}_1 LGFCF_{it} + \hat{a}_2 EII_{it}; \quad (1)$$

$$\widehat{LGDP}_{it} = \hat{a}_0 + \hat{a}_1 LGFCF_{it} + \hat{a}_2 EII_{it} + \hat{a}_3 D2020. \quad (2)$$

We also want to emphasize the direct and exclusive influence of EII on GDP dynamics, in Eq. (3); and using the dummy variable for pandemic year, *D2020*, in Eq. (4).

$$\widehat{LGDP}_{it} = \hat{\beta}_0 + \hat{\beta}_1 EII_{it}; \quad (3)$$

$$\widehat{LGDP}_{it} = \hat{\beta}_0 + \hat{\beta}_1 EII_{it} + \hat{\beta}_2 D2020. \quad (4)$$

For the tourism sector, the second research direction, we consider the logarithm of gross value added in tourism, VAG_TOURISM, as the dependent variable and the logarithm of GFCF_TOURISM and EII as explanatory variables, in Eq. (5). In Eq. (6) we use two dummy variables to explain the deep declines in gross value added in tourism, both in the years 2020 and 2021.

To analyse the exclusive influence of EII on the VAG_TOURISM dynamics we use Eq. (7). The effect of the pandemic in 2020 and 2021 is considered in Eq. (8).

$$\widehat{LVAG\_TOURISM}_{it} = \hat{b}_0 + \hat{b}_1 LGFCF\_TOURISM_{it} + \hat{b}_2 EII_{it}; \quad (5)$$

$$\widehat{LVAG\_TOURISM}_{it} = \hat{b}_0 + \hat{b}_1 LGFCF\_TOURISM_{it} + \hat{b}_2 EII_{it} + + \hat{b}_3 D2020 + \hat{b}_4 D2021; \quad (6)$$

$$\widehat{LVAG\_TOURISM}_{it} = \hat{\gamma}_0 + \hat{\gamma}_1 EII_{it}; \quad (7)$$

$$\widehat{LVAG\_TOURISM}_{it} = \hat{\gamma}_0 + \hat{\gamma}_1 EII_{it} + \hat{\gamma}_2 D2020 + \hat{\gamma}_3 D2021. \quad (8)$$

Analysing the correlations of the variables in the period 2014–2024, in Table 5, we observe positive and very strong correlations between the dynamics of GDP (LGDP) and total investment (LGFCF), respectively between the dynamics of gross value added in tourism (LVAG_TOURISM) and investments in tourism (LGFCF_TOURISM), and weak correlations between LGDP, respectively LVAG_TOURISM, with EII.

Table 5. The matrix of correlations, 2014–2024

2014–2024	LGDP	LGFCF	LGFCF_TOURISM	LVAG_TOURISM	EII
LGDP	1				
LGFCF	**0.9918**	1			
LGFCF_TOURISM	0.8903	0.8694	1		
LVAG_TOURISM	0.9310	0.9013	*0.9556*	1	
EII	**0.3783**	0.3964	0.1999	*0.3027*	1

Note: Bold – correlation coefficients between LGDP and its factors. Italic – correlation coefficients between LVAG_TOURISM and its factors.

The Pedroni cointegration tests for the variables in the two econometric models show, for each case, that six out of eleven statistical tests reject the null hypothesis of absence of cointegration. Therefore, the variables LGDP, LGFCF, EII and LVAG_TOURISM, LGFCF_TOURISM, EII respectively are cointegrated over the period 2014–2024.

The Granger causality test shows that LGDP is a Granger cause for LGFCF, and EII is a Granger cause for LGDP; LVAG_TOURISM is a Granger cause for LGFCF_TOURISM and also for EII.

4.3.1. Econometric models of sustainable economic growth of the EU

We found that the fixed-effects cross-sectional model, with the SUR option, is the best fit for explaining the variation in GDP dynamics for Eqs. (1)–(4). The results in Table 6 show that the FE models are valid for each of the three groups of eco-innovative countries. When considering the eco-innovative country groups, the panel data is long, each with 9 cross-sections and 11 years, and the FE model is a good choice.

We included the dummy variable to explain the decline in GDP caused by the 2020 pandemic. FE models in equation (1a) with LGFCF, EII, and D2020 as explanatory variables are the best models, as shown in Table 6 and also in the graphs in Figure 4. The pandemic caused a larger decrease in average GDP, of 3.3% for group 1, closely of 3.2% for group 2, and smaller for group 3, of 2.3%.

When we consider Eq. (3), the EII coefficients are the same as in model (4). Table 6 contains only the results of the FE model from Eq. (4). For the third group the dummy coefficient is not significant.

As we see in Table 6, the EII coefficients of the three groups in the FE models with LGFCF, EII, and D2020 (Eq. (2)) are almost the same as those of the corresponding groups in the FE models without the dummy variable (Eq. (1)). This observation leads to the conclusion that *the contribution of eco-innovation activities* (*EII*) *to GDP is not affected by the pandemic shock*. *The pandemic has even amplified the contribution of total investments to GDP growth*, *especially for the group of less eco-innovative countries*.

Analysing the coefficients of the dummy variable in the group models in Eq. (4), we observe that the decline caused by the pandemic is greater in more innovative countries than in the less innovative ones, and for the third group it is even insignificant.

Table 6. Cross-sectional FE models of GDP dynamics in the EU in the period 2014–2024

Leaders gr. 1 Average gr. 2 Catch-up gr. 3	FE Cross-section, SUR (Eq. (1))			FE Cross-section, SUR (Eq. (2))			FE Cross-section, SUR (Eq. (4))		
	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3
LGFCF	0.271***	0.135***	0.396***	0.276***	0.154***	0.401***	–	–	–
EII	0.002***	0.006***	0.003***	0.002***	0.006***	0.003***	0.003***	0.007***	0.008***
D2020	–	–	–	–0.033***	–0.032***	–0.023***	–0.034***	–0.021***	–0.006
C	9.806***	9.794***	7.252***	9.719***	9.588***	7.203***	12.761***	11.014***	10.764***
H_0 normality	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
H_0 independence	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: *** Significance at p-value < 1%.

The EII coefficients of these models (Eq. (4)) support GDP growth more in less eco-innovative countries, especially in the case of the third group.

We found that total investments have greater influences on GDP in models (Eq. (1)) and (Eq. (2)) of the group 3 of Eco-Innovation Catching-up countries: for every 1% increase in GFCF, GDP increases on average by 0.4%, when other factors have a constant influence. Countries in this group have an average GDP growth of 0.3% for every 1 percentage point increase in the EII, in both models.

The next group with high influence of GFCF is group 1 of Eco-Innovation Leaders, for which a 1% increase in GFCF brings a 0.27% increase in GDP, according to both models (Eq. (1)) and (Eq. (2)) and having the same influence of each 1 percentage point increase in EII of approximately 0.2% in GDP growth.

Group 2 of Average Eco-Innovative countries shows similar influences in both models, for a 1% increase in GFCF of approximately 0.13%–0.15% on GDP and 0.6% for each 1% increase in EII.

We conclude that countries in group 3, make development efforts and have greater effects of investment dynamics (LGFCF) on GDP growth. Group 2 has reached an average level of eco-innovation and has the greatest benefits from it on GDP growth. Group 1 of Eco-Innovation Leaders maintains total investments efficiency and a moderate influence of eco-innovation on GDP dynamics even lower than that of group 3.

We conclude that the different contributions of GFCF to GDP depend on the eco-innovation grouping of EU countries. *The contribution of GFCF dynamics to GDP is higher for countries with a lower level of eco-innovation, recorded in 2024*. This conclusion supports the working hypothesis H3.

In the models of Eqs. (3) and (4) we consider only the influence of EII, and the impact of total investments is captured in the effects of eco-innovation. *The lower the existing level of innovation, the greater the influence of EII on GDP dynamics*: for group 3, a 1 percentage point

increase in eco-innovation index brings an increase of approximately 0.8% in GDP, 0.7% for group 2 and 0.3% for group 1, respectively. This conclusion supports the working hypothesis H4. The conclusions demonstrate hypothesis H1, according to which eco-innovation and total investments significantly and positively influence GDP dynamics.

If we consider only the influence of eco-innovation on GDP dynamics, *the positive effects of eco-innovation on GDP are felt more in less developed countries*, also supporting working hypothesis H4.

Figure 4 shows the actual and theoretical average values of LGDP determined with FE models (Eq. (2)) for each group of eco-innovative countries. The graph of GDP dynamics at the EU level presents the theoretical average LGDP values, based on the theoretical LGDP (Eq. (2), Table 6) of the three groups of eco-innovative countries.

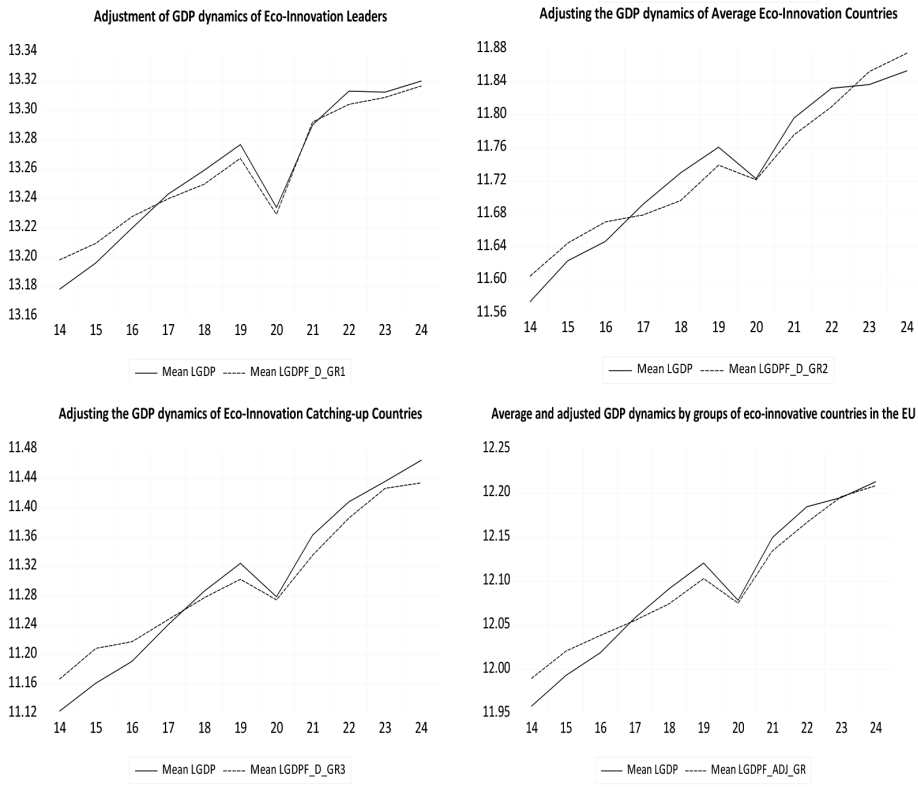

Figure 4. Adjusting GDP dynamics at the level of each group of eco-innovative countries and at the EU level

4.3.2. Econometric models of tourism development sustainability in the EU

The econometric models for tourism gross value added are similar to those for GDP, but we use the dynamics of tourism investment, LGFCF_TOURISM, in Eqs. (5)–(8). We follow the same methodology for building econometric models, first for the three groups of countries by the level of eco-innovation achieved in 2024.

In the models of tourism gross value added (LVAG_TOURISM) which are considering the variable LGFCF_TOURISM, the panel is unbalanced for some missing data in the year 2024.

For this reason, the SUR option may be replaced by cross-sectional weights for FE models. To obtain a balanced panel, we can consider the period 2014–2023, using the SUR option. The results of the cross-section FE models based on Eqs. (5) and (6) are presented in Table 7. Table 8 contains the cross-sectional FE models of LVAG_TOURISM based on Eqs. (7) and (8).

If we consider the dynamics of tourism investments and EII as explanatory variables for the dynamics of gross value added in tourism in Eq. (5), we observe in Table 7 that the FE models are not valid. Even the LGFCF_TOURISM has significant coefficients for all groups, the EII coefficient is significant only for group 3 of Eco-Innovative Catching up countries, while for the other two groups it is not significant, and the hypotheses of residuals are not met for any of them.

When considering the dummy variables for the pandemic effects to explain the decline in both 2020 and 2021 in Eq. (6), for the balanced panel from 2014–2023, the FE models of all three groups are valid, with all coefficients being significant at p-value less than 1%, in Table 7.

A 1% increase in tourism investments leads to a 0.20% increase in tourism gross value added of countries in the third group, being higher than in the other two more eco-innovative groups. For the third group, the influence of EII is greater than for the other two groups of more developed countries in terms of eco-innovation. LGFCF_TOURISM and EII have positive and significant coefficients showing different influences on the VAG_TOURISM dynamics of each of the three groups, consistent with hypotheses H2 and H4.

We identify the same trend present in GDP dynamics, namely *the lower the eco-innovation, the greater the positive effects of both tourism investment dynamics and EII on tourism gross value added*. These conclusions support hypotheses H3 and H4.

The plot of theoretical values of LVAG_TOURISM for each group in Figure 5 is based on the corresponding FE model in Eq. (6) shown in Table 7. The average theoretical values at EU level, in Figure 5, consist of a panel obtained with the theoretical LVAG_TOURISM values for each group.

Table 7. Cross-sectional FE models of VAG_TOURISM dynamics in the EU in the period 2014–2024 based on LGFCF_TOURISM and EII (Eq. (5) and (6))

Leaders (Gr. 1) Average (Gr. 2) Cachting-up(Gr.3)	FE Cross-section, weights 2014–2024, unbalanced (Eq. (5))			FE Cross-section, SUR 2014–2023, balanced (Eq. (6))		
	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3
LGFCF_TOURISM	0.401***	0.173***	0.307***	0.060***	0.182***	0.208***
EII	0.000	0.000	0.007***	0.002***	0.001***	0.005***
D2020	–	–	–	–0.490***	–0.468***	–0.483***
D2021	–	–	–	–0.402***	–0.353***	–0.173***
C	6.355***	6.737***	5.317***	8.537***	6.652***	6.051***
H_0 normality	No	No	No	Yes	Yes	Yes
H_0 independence	No	No	No	Yes	Yes	Yes

Note: *** Significance at p-value < 1%.

The cross-sectional FE models based on Eq. (7) in Table 8 are valid for the three groups, but the EII coefficient for group 2 of average eco-innovation countries is not significant.

Only the groups' models in Eq. (8) are all valid. The FE models with dummy variables in Eq. (8) show significant coefficients. We observe the positive influence of EII on the dynamics of VAG_TOURISM, in accordance with hypothesis H2.

We observe the same trend of *higher EII influence on the tourism performance indicator for the group with a lower level of eco-innovation*, being in accordance with hypotheses H2 and H4.

Table 8. Cross-sectional FE models of VAG_TOURISM dynamics in the EU in the period 2014–2024, considering only the Eco-Innovation Index (Eqs. (7) and (8))

Leaders (Gr. 1) Average (Gr. 2) Cachting-up (Gr.3)	FE Cross-section, SUR 2014–2024, balanced (Eq. (7))			FE Cross-section, SUR 2014–2024, balanced (Eq. (8))		
	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3
EII	0.002***	0.000	0.009***	0.003***	0.002**	0.008***
D2020	–	–	–	–0.500***	–0.474***	–0.524***
D2021	–	–	–	–0.410***	–0.356***	–0.193***
C	8.950***	7.740***	6.987***	8.879***	7.624***	7.060***
H_0 normality	Yes	Yes	Yes	Yes	Yes	Yes
H_0 independence	Yes	Yes	Yes	Yes	Yes	Yes

Note: *** Significance at p-value < 1%.

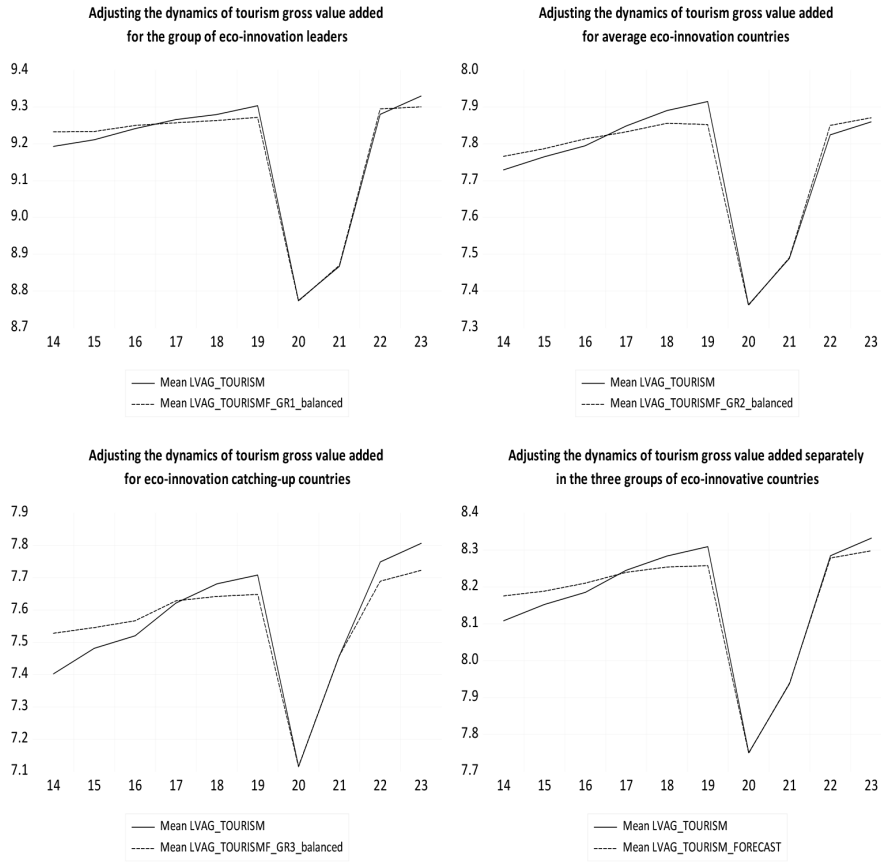

Figure 5. Adjustment of tourism gross value added of EU eco-innovative groups, 2014–2024

The effect of a 1-point increase in the EII of 0.8% on the dynamics of VAG_TOURISM (Eq. (8)) is the same as the influence of the EII on the dynamics of the GDP of eco-group 3, in the model of Eqs. (3) and (4) in Table 6. We observe deep decreases in tourism gross value added in the pandemic year 2020, but also in 2021, as identified in the models in Eq. (6) in Table 7, and presented in Figure 5.

We observe almost the same coefficients of EII in the FE models (Eq. (7)) and (Eq. (8)), both without and with dummy variables. We conclude that the influence of EII on LVAG_TOURISM is not affected by the pandemic shocks in the two years.

Eco-innovation gives a sustainable character to the economic development of tourism.

5. Conclusions

The research results verify the general and working hypotheses, and the conclusions describe how influencing factors act on economic growth and tourism development according to the classification based on the eco-innovation criterion.

The groups that depend on the Eco-Innovation Index (EII) are dynamic. The status of the three groups, each with nine member states, at the end of 2024, determines the category in which each country falls in. Countries in the eco-innovation catch-up phase have an EII below 100%, the countries with average eco-innovation performances have an EII above 100% and below 130%, and the eco-innovation leaders have an EII above 130%.

Our research contains econometric models that reveal certain characteristics of the influence profiles of investments and EII on both tourism and economic growth, depending on the groups of eco-innovative countries.

Knowing this grouping criterion is important for establishing different policies and investment frameworks for European eco-innovation funding programs or for regulating the conditions for their implementation.

Hypothesis H1 is supported by the positive and significant coefficients of the variables eco-innovation index (EII) and total investments (LGFCF), in all panel data models of GDP dynamics, i.e. economic growth.

Comparing the FE models of GDP growth based on eco-groups in Table 6, we found that *the contribution of the eco-innovation index* (*EII*) *on GDP dynamics is not affected by the pandemic shock*.

The decline in GDP caused by the pandemic is greater in the most innovative countries than in the least innovative ones (hypothesis H4). *The lower the existing level of innovation in less developed countries, the greater the influence of EII on economic growth* (*GDP dynamics*) (hypothesis H4).

The 2020 pandemic amplified the contribution of total investments to GDP's growth, especially for the group of less eco-innovative countries. The contribution of total investments (*GFCF dynamics*) *to economic growth* (*GDP dynamics*) *is higher for the lower level of eco-innovation, existing in 2024* (hypothesis H3).

Hypothesis H2 is supported by the positive and significant coefficients of the eco-innovation index (EII) and tourism investments (LGFCF_TOURISM) variables in all panel data models of the dynamics of gross value added in tourism (LVAG_TOURISM), significantly contributing to tourism development.

The analysis of tourism development by eco-groups shows that, especially for the third group of catching-up eco-innovation countries, we identify that the tourism development strategy is based on eco-innovation well supported by tourism investments. We observe that

the influence of eco-innovation is greater for the third group of eco-innovative catching-up countries. *The lower the development of eco-innovation, the greater the influence of both eco-innovation and the dynamics of tourism investments on the tourism development indicator* - gross value added, confirming hypotheses H3 and H4.

The conclusion regarding the Eco-Innovation Index was that the EII had an increasing evolution during the period 2014–2024 for most EU countries, not being affected by the pandemic shock. On the contrary, the EII had a period of expansion after 2020 (Section 3.1). This means that *eco-innovation can be a solution for the sustainability of economic development in the event of economic shocks*.

The relationship between investments and eco-innovation is described based on econometric analyses of the economic growth of EU countries belonging to the three eco-innovation groups, in the year 2024.

Based on the conclusions of econometric models, we can state that the positive effects of eco-innovation and investments on GDP of eco-groups are greater in less developed countries. *Eco-innovation can provide the solution to sustainable economic development through its robustness to shocks and by driving stronger investments' effects on GDP dynamics*.

A similar conclusion is valid for tourism development. *The lower the development of the eco-innovation group, the greater the influence of both eco-innovation and the dynamics of tourism investments on the tourism performance indicator – gross value added*.

Our work is important for establishing the various frameworks of European eco-innovation funding programs, European tourism investment policies, as well as for regulating their implementation in EU countries. We use various research methods that can be examples for studying the economic problems of sustainable development.

The limitations of our study may become future research directions. First future direction may be extending the analysis for all European countries, regardless of their EU membership status. A further research direction could consider establishing an eco-innovation indicator that is not linked to the EU level, but which ensures comparability. A limitation is that our study only considers the impact of total investments, tourism investments and eco-innovation on the economic growth, and tourism development, respectively, ignoring the role and contribution that green investments can have in the sustainable economic development of a country and in achieving the sustainable development goals.

Another limitation is that our study only considers tourism investments in general, without focusing on how certain types of tourism investments impact economic growth and sustainable development in different eco-innovation groups. Correlations between European funds, public policy measures and eco-innovation country groups can also be considered as limitation of our study. Therefore, these research directions can also be prospected in future studies.

Also, future research could replicate the econometric modeling framework using updated data for extended time series, with the aim of assessing the robustness of the relationship between eco-innovation and investments on GDP and gross value added in tourism, over time. Further studies could apply the same econometric models to other areas outside the European Union.

Furthermore, econometric models could be extended by using alternative sustainability indicators. Therefore, this paper is a valuable resource both in its conclusions and in the fact that it represents a solid basis for further research.

Author contributions

LD and CD are responsible for statistical analysis, econometric modelling, interpretation of results and conclusions. DR, AS and AN are responsible for the theoretical background, data collection, interpretation of results and conclusions. All authors have contributed to the idea of the study and established together the steps to be taken. All authors agreed on the present version of the article.

Disclosure statement

The authors declare no conflicts of interest and they have no competing financial, professional, or personal interests from other parties that are related to the subject of this paper.

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