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ECO-INNOVATION PERFORMANCE IN THE EU-27: A DESCRIPTIVE AND COMPARATIVE ANALYSIS BASED ON THE ECO-INNOVATION INDEX

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Abstract: *Eco-innovation represents a key driver of the European Union's transition towards a resource-efficient, low-carbon economy. This paper provides a descriptive and comparative assessment of eco-innovation performance across EU Member States over the period 2014–2024, using the Eco-Innovation Index (EII). The analysis draws on official EU-27 time-series data and employs descriptive statistical measures to examine cross-country dynamics, complemented by ranking and change analyses to identify leading, lagging, and catching-up countries. The results indicate a clear upward trend at the EU level, with the EU-27 aggregate index increasing from 100 in 2014 to 127.5 in 2024. Cross-country statistics point to broadly shared progress, as both the mean EII rises from 90.31 in 2014 to 120.88 in 2024 and the median from 84.7 to 116.5. Nevertheless, substantial heterogeneity persists, as evidenced by the wide range of values in 2024 (min 58.8 vs max 180.8). Finland, Denmark, Austria, Luxembourg, and Sweden lead the 2024 ranking, while Bulgaria, Hungary, Poland, Romania, and Greece remain at the lower end of the distribution. Long-run change estimates point to rapid improvements in countries such as Lithuania, Ireland, and Malta, contrasted with modest increases or even decline in some cases (e.g., Romania). Overall, the findings suggest strong aggregate progress alongside persistent structural disparities, bringing into discussion the need for differentiated policy support and further research into the underlying drivers and component dimensions of eco-innovation performance.*

Keywords: *eco-innovation; Eco-Innovation Index; European Union; circular economy.*

JEL Classification: *O31; Q55; Q56*

1. Introduction

Innovation, traditionally viewed as a driver of economic growth, is increasingly complemented by eco-innovation, reflecting a broader shift from conventional growth toward sustainable growth (Peyravi, Peleckis and Jakubavičius, 2023). Within the European context, the discussion is explicitly connected to the EU's eco-innovation agenda, associated policy support measures, and the objectives of the Green Deal and the transition toward a circular economy. Eco-innovation constitutes a key mechanism for addressing the European Union's pressing environmental challenges while simultaneously supporting sustainable economic growth (Henriques, Viseu and Sousa, 2025).

The link between circular economy and eco-innovations is discussed in numerous studies (Pichlak and Szromek, 2022; Peyravi et al., 2024; Afolabi, 2025; Bui et al., 2026). Eco-innovation is seen as a key organisational enabler of the circular economy (CE) because it provides the product, process, and organisational changes needed to replace linear *take–make–dispose* systems with closed-loop material flows (Pichlak and Szromek, 2022). Environmental orientation (internal and external) strengthens both eco-product and eco-process innovation, which in turn increases circular economy practices and improves sustainable performance (Bui et al., 2026). Afolabi (2025) examines the effects of eco-innovation, economic complexity, and digitalization on circular economy performance and demonstrates that all three factors significantly enhance circularity, with digitalization exerting the strongest and most consistent influence across all levels of circular economy development. Eco-innovation plays a particularly important role in countries with lower circular economy performance, while economic complexity delivers greater gains in more advanced economies. These findings suggest that the circular transition is highly context-dependent and requires differentiated policy approaches.

The qualitative study of Hojnik et al. (2023) highlights the pivotal role of digitalization and demographic change in advancing eco-innovation and supporting the transition toward a circular economy. Based on in-depth interviews with companies actively engaged in eco-innovative and circular practices, the findings show that digital technologies enhance transparency, process control, and resource efficiency, thereby reducing energy consumption and environmental impacts. Additionally, demographic shifts influence firms to adapt products and services to evolving consumer needs, reinforcing the strategic alignment between eco-innovation, digital transformation, and circular economy implementation.

Empirical evidence from manufacturing firms shows that product and process innovation improve eco-efficiency primarily through closed-loop production practices, while cleaner production practices play a weaker mediating role. Zhang et al. (2025) demonstrate that closed-loop production significantly mediates the relationship between innovation and eco-efficiency, highlighting that strategic circular practices are more effective than operational cleaner production measures in achieving environmental sustainability.

Another study (Parrilli, Balavac-Orlic and Radicic, 2025) that examines eco-innovation in European SMEs through the lens of *business innovation modes*, shows that firms adopt distinct combinations of science-based (STI) and learning-based (DUI) practices whose effectiveness varies across European macro-regions. The findings reveal that eco-innovation outcomes depend not only on firm-level practices but also on institutional and technological contexts.

The main objective of the paper is to assess the evolution and distribution of eco-innovation performance in the European Union (EU-27) during the period 2014–2024, using the total Eco-Innovation Index (EII), through a descriptive and comparative statistical analysis, in order to identify aggregate trends, differences between Member States, and the dynamics of progress (leaders vs. catching-up).

2. Theoretical background

In the literature, several researchers have focused on identifying and explaining the determinants of eco-innovation. In their analysis, Eryigit and Özcüre (2015) conceptualize eco-innovation as a strategic response that enables firms to achieve

environmental sustainability while enhancing long-term competitiveness, particularly in developing economies. The authors emphasize that eco-innovation is driven by regulatory pressure, market demand, and stakeholder expectations. Empirical evidence for the EU shows that both internationalisation and digitalisation are key drivers of eco-innovation. Vasconcelos-Garcia and Carrilho-Nunes (2024) demonstrate that foreign direct investment initially hampers eco-innovation but exerts a positive effect after two years. In contrast, digitalisation consistently enhances eco-innovation, supporting the *twin transition* hypothesis, whereby digital transformation complements the shift towards low-carbon and resource-efficient practices. Based on using the method of moment quantile regression, Usman et al. (2024) show that digitalization is a strong and consistent driver of eco-innovation across all quantiles. Natural resources display an asymmetric effect, stimulating eco-innovation at lower quantiles but constraining it at higher ones, reflecting inefficient resource use. By contrast, globalization generally exerts a negative impact on eco-innovation, highlighting the need for digital-led and resource-efficient policies to support sustainable innovation.
Considering a large European sample of SMEs and large firms, Rodríguez-Rebés et al. (2024) reveal that organisational innovation—especially new methods of organising work responsibilities and decision-making—is a key driver of eco-innovation in SMEs. Unlike large firms, SMEs' organisational eco-innovation is less influenced by regulation or energy costs and more by leadership, training, reputation concerns, and flexible internal practices, highlighting the importance of organisational capabilities for sustainable innovation. Abdesselam, Kedjar and Renou-Maissant (2024), identify key drivers of eco-innovation related to founders' environmental education and professional experience, as well as voluntary environmental practices such as corporate social responsibility. The authors develop a typology of five eco-innovator profiles, showing that these start-ups differ significantly in their motivations, access to finance, and innovation strategies, with important implications for tailored public policies supporting eco-innovative entrepreneurship. Also, social trust, as an informal institution, is viewed as promoting firms' environmental innovation (Liao and Wei, 2026).
Drawing on a longitudinal case in the European renewable energy sector, Csedő, Zavarkó and Magyari (2023) show that open eco-innovation networks must evolve when market and regulatory uncertainty undermine partners' willingness to participate. Rather than relying on existing complementarities and exploitation of a mature technology, effective network renewal is driven by bridging actors who redirect collaboration toward exploration and future complementarities (e.g., expanding use cases and partner bases) to reduce market-failure risk and sustain sustainable-development impact.
The role of eco-innovation in shaping economic and environmental performance represents another direction that researchers have exploited. According to Ho and Lwesya (2025), eco-innovations aim not only to reduce negative ecological impacts but also to foster long-term economic and societal sustainability. The study of Qureshi, Ahsan and Gull (2022) demonstrates that country-level eco-innovation plays a crucial role in reducing corporate CO_2 emissions in Europe, both from firms' own operations and along their value chains. The findings indicate that a supportive institutional environment for eco-innovation—shaped by public policies, innovation inputs, and financial and regulatory frameworks—encourages firms to adopt eco-innovative strategies. In a recent study, Hamid, Wang and Zang (2026) examine

whether AI development, eco-innovation efficiency, the stringency of environmental policy, and green growth improve environmental sustainability in the G7, using the load capacity factor within the load capacity curve framework. It finds that eco-innovation efficiency supports sustainability, while AI, stricter policies, and green growth are associated with lower ecological load capacity, and the LCC hypothesis does not hold for G7 economies. Another recent evidence from EU countries (Wang et al., 2026) shows that financial development tends to increase the ecological footprint, while both energy transition and eco-innovation significantly reduce environmental pressure. Moreover, the interaction between financial development and energy transition, as well as eco-innovation, reveals that financial development has an indirect effect of improving environmental quality when it is aligned with green energy investments and innovation. These findings highlight the importance of integrating financial policies with energy transition and eco-innovation strategies to achieve sustainable development. Other studies (Haseeb et al., 2026) also reinforce the idea that eco-innovation and clean/renewable energy reduce ecological footprint, while financial development increases it. On the other hand, Lasisi et al. (2022) provided evidence from leading eco-innovation economies and showed that environmental-related technologies contribute positively to economic growth but environmental technological innovations exert growth-inhibiting effects.

In their research, Rousselière et al. (2024) have extended the Porter Hypothesis by demonstrating that the economic outcomes of eco-innovation among European SMEs are heterogeneous and highly context-dependent. Using cross-country survey data, the authors show that certain types of eco-innovation—such as energy efficiency, material savings, and the use of renewable energy—are associated with reduced production costs, while others yield no immediate economic returns. Moreover, the impact of eco-innovation is shaped by environmental policy instruments and by the adoption behavior of competing firms, highlighting the importance of differentiated and territorially embedded policy approaches to promote both environmental and economic performance.

Jiang et al. (2024) find that renewable energy (including biofuels), eco-innovation, carbon taxes, and environmental policy stringency are associated with lower CO_2 emissions (and improved air-quality outcomes), supporting progress toward carbon neutrality. In contrast, natural resource dependence and financial development tend to increase emissions, potentially slowing decarbonization unless finance is redirected toward green investment.

Another research topic related to eco-innovations, which has sparked the interest of many authors, focuses on typologies and differences between EU states: clusters, classes, convergence/divergence. In this context, eco-innovation indices provide valuable insights into how eco-innovation evolves across countries over time, helping to identify trends, patterns, and relative performance (Park et al., 2017).

Mačiulytė-Šniukienė and Sekhniashvili (2021) show that eco-innovation is positively associated with economic performance and environmental performance across EU member states. The authors also document cross-country differences in eco-innovation, GDP, and environmental quality, and argue that expanding eco-innovation support could help improve both growth and environmental outcomes, particularly in lagging countries. Domaracká, Seňová and Kowal (2023) consider that weak coordination and synergy among government, institutions, and SMEs helps explain poorer performance in lagging states.

Costantini, Delgado and Presno (2023) investigated whether EU countries are converging toward similar eco-innovation trajectories by applying a club convergence framework to the EU Eco-Innovation Index. The authors found that eco-innovation does not converge uniformly across the EU; instead, countries form three distinct convergence clubs in the aggregate index, while more clusters emerge when the five underlying dimensions are analysed separately. To explain club membership, the ordered logit model results highlight that GDP per capita increases the likelihood of belonging to higher eco-innovation clubs, whereas economic openness is linked to weaker convergence; R&D intensity, environmental taxation, and firm size are not significant country-level drivers.
In their study, Sobczak, Głuszczuk and Raszkowski (2022) developed a typology of EU countries by jointly analyzing eco-innovation and overall innovation performance and identified four country groups, ranging from leaders in both eco-innovation and innovation (e.g., Finland, Sweden, Germany, Luxembourg, Denmark) to a large group of the poorest eco-innovators/innovators largely from newer EU members. In addition, Rađenović, Janjić and Talić (2024) found dynamic shifts of EU countries between clusters over time, reflecting changing eco-innovation strengths/weaknesses and suggesting the need for adaptive, cluster-tailored policies to improve performance and reduce disparities across the EU. This study of Henriques, Viseu and Sousa (2025) evaluates eco-innovation efficiency across the EU-27 using a Window Slack-Based Measure (WSBM) DEA and club convergence analysis across five dimensions (environmental sustainability, finance/support, firm investments, sales impacts, intellectual assets). Efficiency rose during the pandemic windows but weakened afterward, reflecting shocks and volatility. Convergence tests reject full EU convergence and identify two efficiency clubs, implying persistent structural gaps and a need for tailored policy mixes and cross-club collaboration. More recently, Juracka et al. (2026) evaluated EU member states' eco-innovation performance using the EU Eco-Innovation Index, applied maps, cluster analysis, and correspondence analysis to identify patterns and leaders. Apparently, most countries improved over the period (with Romania as the main exception), while Northern and Northwestern Europe consistently contain top performers.

3. Research methodology
The study is quantitative, descriptive and comparative, at the macro (country) level, using a composite indicator of eco-innovation for the Member States of the European Union. The research tracks the evolution over time (2014–2024) and the differences between countries in the performance of eco-innovation. The indicator analyzed is the Eco-Innovation Index (EII), reported annually, with a base of 2014 = 100 for the EU-27 aggregate. The data were sourced from the official European Commission dataset on the Eco-innovation Index (2014–2024).
The Eco-Innovation Index (EII) (European Commission, 2024) is a composite indicator that evaluates eco-innovation performance relative to the EU average, expressed in index scores. It aggregates indicators across five thematic dimensions: eco-innovation inputs, eco-innovation activities, eco-innovation outputs, resource efficiency outcomes, and socio-economic outcomes. In this study, the analysis focuses exclusively on the overall EII.
The indicator is expressed as an index (EU-27 = 100 in 2014), which allows values to be interpreted as relative performance against a common reference baseline. The analysis is conducted at two levels: (i) the EU-wide trend, based on the aggregate

series, and (ii) the cross-country distribution, examined through annual descriptive statistics for the 27 Member States.
For each year included in the analysis (2014–2024), the following indicators were computed for the distribution of EII values across countries: number of observations (N), mean, median, minimum, maximum, standard deviation, and coefficient of variation (CV). For the final year of the period (2024), the top five and bottom five countries in terms of total EII were identified in order to highlight the persistence of structural disparities between leading and catching-up economies.
The data were processed, and statistics were calculated with Excel and Jamovi statistical analysis tool, version 2.6.

4. EU - level analysis of eco-innovation performance: results and discussions

The evolution of the Eco-innovation index at the aggregate level reveals that the EU 27 increases from 100 (2014) to 127.5 (2024), indicating consistent progress in eco-innovation performance over the last decade.

Table 1: Eco-innovation index (EII) over the period 2014-2024 for EU 27 (base 2014=100)

Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
EII	100	101.9	104.2	104	107.4	108	109.6	115	118.9	123.7	127.5

Source: Eco-innovation index, available at: https://green-forum.ec.europa.eu/eco-innovation_en#eco-innovation-scoreboard

Our analysis continued with descriptive statistics of total EII in the EU (27 countries) for the period 2014–2024.

Table 2: Descriptive statistics of total EII in the EU (27 countries), 2014–2024

Year	N	Mean	Median	Min	Max	Standard deviation	Coefficient of variation
2014	27	90.31	84.7	29.8	161.9	35.37	0.392
2015	27	92.23	88.5	30.4	164.4	34.73	0.377
2016	27	95.48	88.3	33.2	170.0	35.12	0.368
2017	27	95.95	89.4	28.1	166.5	34.29	0.357
2018	27	98.41	92.1	36.0	157.2	33.12	0.337
2019	27	100.47	96.0	36.5	164.2	35.04	0.349
2020	27	102.61	96.7	40.1	166.1	34.73	0.338
2021	27	106.34	102.4	43.1	168.2	34.33	0.323
2022	27	111.93	108.1	48.9	178.6	34.81	0.311
2023	27	116.66	115.1	53.9	179.4	34.31	0.294
2024	27	120.88	116.5	58.8	180.8	34.77	0.288

Source: Authors' processing based on data available at: https://green-forum.ec.europa.eu/eco-innovation_en#eco-innovation-scoreboard

The data highlight an upward trend in eco-innovation performance over the period 2014–2024, both through increasing central values (mean and median) and consistent improvement in minimum levels. In parallel, the dispersion dynamics suggest a moderate but incomplete convergence between Member States: differences remain significant, in particular between the leading and catching-up groups.

The evolution of the mean EII (from 90.31 in 2014 to 120.88 in 2024) across countries indicates that, overall, Member States have experienced a gradual increase in eco-innovation performance over the decade under review. At the same time, the increase in the median (from 84.7 to 116.5) is particularly relevant as it shows that progress is not driven by a few high-scoring economies, but reflects an upward movement at the group level.

At the extremes, the table shows a clear evolution of the minimum: the worst annual performances gradually rise over the period (from 29.8 in 2014 to 58.8 in 2024), suggesting that countries lagging behind the EU average are gradually improving their eco-innovation capacity. This increase in the minimum is a relevant indication of bottom-up convergence, i.e., a reduction of gaps by improving the performance of the worst performers.

On the other hand, the maximum remains consistently at very high values, typically associated with leading countries (Nordic and some Western economies). The persistence of a very high maximum suggests the stability of an eco-innovation *frontier group*: some states maintain a structural competitive advantage (research capacity, innovative ecosystem, resource efficiency performance and socio-economic outcomes).

Therefore, although the minimum increases, the difference between the minimum and the maximum remains large, indicating that polarization does not disappear, but turns into a relatively stable structure: the leaders remain leaders, and the catching-up countries advance, but not enough to completely catch the top.

An interesting result is that the standard deviation (SD) remains relatively high throughout the period, with moderate variations between years. This means that, in absolute terms, the differences between countries continue to be important: even if all improve, the gaps between groups may persist.

However, the coefficient of variation (CV), the ratio of the SD to the annual mean, decreases over time from 0.392 in 2014 to 0.288 in 2024. The standard statistical interpretation is that as the mean level of the EII increases, the relative dispersion becomes smaller, suggesting moderate convergence (relatively smaller differences relative to the overall level achieved). In other words, even if the SD does not decrease drastically, the increase in the mean makes the variability proportionally smaller. At the same time, the min–max difference remains large (e.g., in 2024: 58.8 vs 180.8), so a polarization between leaders and catching-up countries persists. From a policy standpoint, this finding is significant: although the EU is making overall progress and the general performance level is improving, disparities remain substantial, continuing to justify differentiated interventions such as targeted support for catching-up countries, incentives for input investment, and measures to accelerate technology transfer.

The EU-27 aggregate data indicate an increase of EII to 127.5 in 2024, with a more pronounced acceleration after 2020. We can observe that both the mean and the median increase more rapidly, while the minimum value also rises at a faster pace. This pattern may be associated with the strengthening of the European policy framework supporting the green transition, alongside intensified pressures for energy efficiency and circularity, which are captured in the index components.

In 2024, the Eco-Innovation Index ranking highlights the existence of a core of leading countries, characterized by very high eco-innovative performances. The top 5 leaders in eco-innovation are Finland (180.8), Denmark (177.5), Austria (177.1), Luxembourg (175.1), and Sweden (165.2). At the opposite end, a group of countries continues to register values significantly below the EU average: Bulgaria (58.8), Hungary (64.4), Poland (69.7), Romania (80.2), and Greece (91.0). This contrast confirms the existence of a persistent polarization between leading states and those in the process of catching up.

The analysis of long-term variation shows that some Member States made remarkable progress between 2014 and 2024 (e.g. Lithuania, Ireland, Malta), while others recorded modest increases or even decreases (e.g. Romania, Hungary). Table 3 shows the absolute variation in the EII for the countries that recorded the largest and smallest increases, respectively.

Table 3: Descriptive statistics of total EII in the EU (27 countries), 2014–2024

The largest increases in EII score		**The smallest increases in EII score**	
Country	**Change 2014 - 2024**	**Country**	**Change 2014 - 2024**
Lithuania	53.3	Romania	-4.5
Ireland	50.1	Hungary	5.0
Malta	46.0	Finland	18.9
Italy	39.2	Poland	19.5
Netherlands	38.5	Sweden	20.0
Latvia	38.3	Luxembourg	20.2
France	38.0	Denmark	23.5
Czechia	36.5	Spain	25.7
Slovenia	36.1	Estonia	26.5
Austria	36.1	Belgium	28.0

Source: Authors' processing based on data available at: https://green-forum.ec.europa.eu/eco-innovation_en#eco-innovation-scoreboard

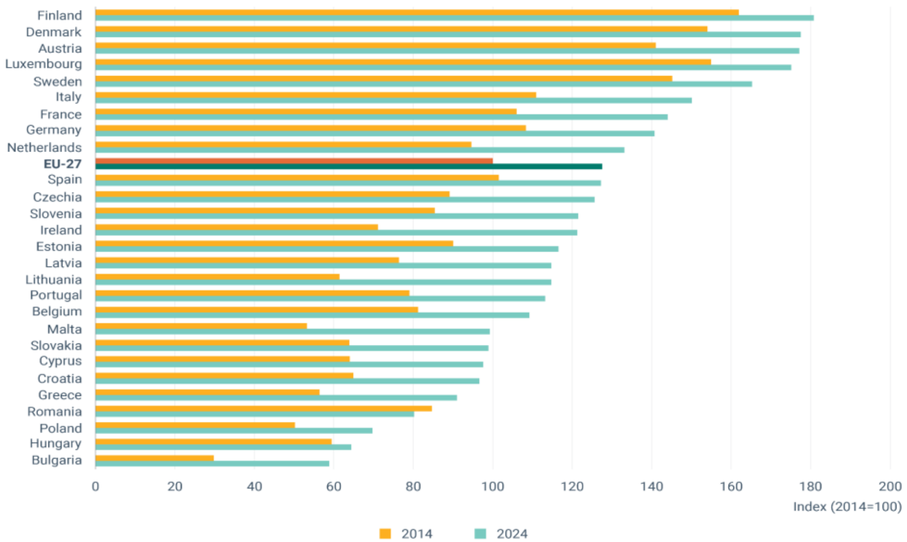

Figure 1: Evolution of the eco-innovation index across EU Member States over the period 2014–2024 (benchmark: EU-27 = 100 in 2014)

Source: Eco-innovation index, available at https://green-forum.ec.europa.eu/eco-innovation_en#eco-innovation-scoreboard

These results suggest that national policies, absorption capacity of European funds and structural reforms can significantly accelerate the development of eco-innovation, even in economies that start from lower initial levels.
Overall, the data point to a substantial improvement in eco-innovation performance across the EU-27 between 2014 and 2024, as evidenced by the upward shift in central tendency measures and the steady rise in minimum values. At the same time, dispersion remains elevated, and the gap between the best-and worst-performing countries persists, indicating the presence of heterogeneous eco-innovation development trajectories.

5. Conclusions

The descriptive analysis of the Eco-Innovation Index (EII) for the EU-27 over the period 2014–2024 highlights a clear upward trend in eco-innovation performance across the European Union. A noticeable acceleration is observed after 2020, a period associated with the intensification of European policies related to the Green Deal and the transition towards a circular and climate-neutral economy. Therefore, the aggregate EU-27 series (2014 = 100) rises to 127.5 in 2024, indicating a sustained improvement in eco-innovation performance at the European level over the past decade. In parallel, the cross-country distribution confirms that this increase is not exclusively the result of a small number of high-performing economies: both the mean and median country scores increase significantly between 2014 and 2024, suggesting a relatively widespread improvement across the EU-27. However, differences between countries remain significant. In 2024, the min–max range remains very wide (from 58.8 to 180.8), indicating the persistence of a structural polarization between eco-innovation leaders and catching-up countries.
The results confirm the existence of a stable core of leaders in 2024 (Finland, Denmark, Austria, Luxembourg and Sweden) and a group of countries performing significantly below the EU average (Bulgaria, Hungary, Poland, Romania and Greece). This pattern suggests that eco-innovation performance in the EU is not following full convergence, but rather partial convergence, in which aggregate progress coexists with persistent differences between groups.
Regarding the long-term dynamics (2014–2024), it is noteworthy that some states have registered substantial leaps (e.g. Lithuania, Ireland, Malta), indicating the real potential for catching-up through public policies and implementation capacity, while other states have evolved slowly or even registered declines (e.g. Romania). Overall, the decrease in the coefficient of variation (CV) over the period suggests moderate convergence, but the amplitude of the min–max differences shows that the gaps remain large enough to require targeted interventions and differentiated support mechanisms.
The analysis has several important implications. For EU policy, the aggregate progress indicates the effectiveness of the general direction of green transition policies, but the persistence of gaps suggests the need for instruments adapted to groups of countries (leaders vs. catching-up), including the transfer of good practices and support for institutional and investment capacities. For catching-up states, the results justify prioritizing measures that accelerate the adoption of eco-innovation and reduce structural differences, as the *bottom-up* progress is visible, but insufficient to decisively reduce polarization.

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