Sustainable Development

WILEY

Sustainable Development

RESEARCH ARTICLE

What Drives Sustainable Development in Europe? A Panel and Fuzzy Analysis of Cohesion and Non-Cohesion Countries

Dora Almeida[1,2,3] | Andreia Dionísio[3] | Paulo Ferreira[1,2,3] | Joanna A. Kamińska[4]

[1]VALORIZA—Research Centre for Endogenous Resource Valorization, Portalegre, Portugal | [2]Portalegre Polytechnic University, Portalegre, Portugal | [3]Universidade de Évora, Center for Advanced Studies in Management and Economics (CEFAGE), Évora, Portugal | [4]Department of Mathematics, Wrocław University of Environmental and Life Sciences, Wroclaw, Poland

Correspondence: Joanna A. Kamińska (joanna.kaminska@upwr.edu.pl)

Received: 24 February 2026 | **Revised:** 23 April 2026 | **Accepted:** 14 May 2026

Keywords: cohesion policy | economic and social determinants | European Union | fuzzy-set qualitative comparative analysis | institutional quality | panel data | sustainable development goals

ABSTRACT

The European Union (EU) is highly committed to the 2030 Agenda. However, the EU countries' structural heterogeneity and differing stages of development complicate the efforts to achieve the Sustainable Development Goals (SDGs) and raise questions about whether uniform policies can effectively address diverse needs. To analyze the determinants of the SDG Index score (SDG_IS), the EU-27 countries were considered over the 2012–2023 period, grouped into Cohesion and Non-Cohesion countries, and panel data regression models and fuzzy-set qualitative comparative analysis (fsQCA) were applied as complementary approaches. The panel data regression results revealed a main decoupling: while in Cohesion countries, Gross Domestic Product per capita significantly drove SDG_IS attainment, it lost statistical significance in Non-Cohesion countries, where institutional transparency and inequality reduction emerged as the main drivers. The fsQCA analysis revealed pronounced equifinality, identifying five distinct pathways to high SDG_IS attainment in Cohesion countries and only two in Non-Cohesion countries. Overall, by revealing that as countries develop, the determinants of sustainability may shift from material wealth accumulation to governance quality and distributive justice and that the same level of SDG_attainment can be obtained through qualitatively different causal configurations, our findings challenge the paradigm of "one-size-fits-all" that underlies the current EU cohesion policy and provide an empirical foundation for redesigning EU policies around differentiated, context-sensitive interventions: growth-oriented strategies for Cohesion countries and governance-quality strategies for Non-Cohesion countries, aligned with smart specialization principles.

JEL Classification: C23, I31, Q01, O11, O43, O52, R11

1 | Introduction

The Sustainable Development Goals (SDGs) were established in 2015 with the ambition to be universal and indivisible (Meilland and Lecocq 2024) and represent a global commitment to addressing social, economic, and environmental challenges, requiring coordinated efforts at different levels. Furthermore, the SDGs allow for the evaluation of progress toward achievement through specific indicators and targets, which is essential for identifying areas needing improvement (Georgeson and

Maslin 2018), as they serve as a monitoring tool for international benchmarking and for designing public policies (Firoiu et al. 2023) aligned with the specific and local needs of each country.

The global Sustainable Development Goals Index Score (SDG_IS), developed in 2016, is a composite metric that allows each country to assess its performance on the 17 SDGs on a 0–100 scale, and it is an accepted metric to measure sustainability performance (Massuga et al. 2023). Considering this, the SDG_IS has been used as a dependent variable in several studies that aimed to evaluate different factors, such as governance (Massuga et al. 2023), financial inclusion (Elkhaldi and Mongi 2025), Environmental, Social, and Governance (ESG) practices (Rana et al. 2024), and regional disparities (Kanojia et al. 2025), among others, in sustainable development.

In this regard, and based on the reviewed literature, we consider the SDG_IS as the dependent variable.

Despite this growing body of evidence, there is no unified theoretical convergence in the literature on what drives SDG performance, particularly in contexts characterized by structural heterogeneity. In this regard, this study aims to address this gap by drawing on three complementary theoretical frameworks that jointly motivate the variable selection, the comparative design, and the interpretation of the results. The first is the Environmental Kuznets Curve (EKC) hypothesis, which posits that the relationship between economic growth and environmental quality follows an inverted-U shape: as income rises, environmental degradation initially worsens before improving once a sufficient income threshold is crossed (Grossman and Krueger 1995; Kuznets 1955). Adapted to the SDG context, this hypothesis predicts that the contribution of economic growth to sustainability outcomes diminishes, and may even reverse, as countries reach higher development stages (Groner and Moradi 2024; Wang and Chen 2024). The second is modernization theory, which predicts that as societies develop economically, improvements in governance quality, institutional transparency, and distributional justice progressively displace material wealth as the primary engines of social progress (Inglehart and Welzel 2005). In the SDG context, this theory suggests that institutional variables, such as control of corruption, should be strong predictors of SDG performance in more advanced economies, whereas economic growth should be more decisive in earlier stages of development. Thus, this prediction not only aligns with but also complements the EKC hypothesis, and together they form the core theoretical expectation of the present study: that the determinants of SDG performance are stage-dependent. The third is the smart specialization framework, which is embedded in EU Cohesion Policy, and argues that effective development strategies must be built around each country's or region's specific structural characteristics and existing competitive advantages, rather than applying uniform "one-size-fits-all" solutions across heterogeneous contexts (McCann and Ortega-Argilés 2015). Taken together, these three frameworks are not parallel lenses but mutually reinforcing elements of a single line of argument. While the EKC and modernization theory jointly predict that the determinants of sustainability are stage-dependent, smart specialization provides the normative foundation for translating that prediction into differentiated, context-sensitive policy design. In this regard, our empirical analysis is structured to evaluate the first prediction and inform the second.

Several independent variables have been considered in studies devoted to understanding the drivers of sustainable development, underscoring that sustainable development is inherently multidimensional and cannot be adequately described or evaluated solely by economic indicators. Considering the three theoretical frameworks outlined above, the literature review focuses on the empirical evidence for each key determinant of SDG performance. Gross Domestic Product per capita (GDPpc) is one of the most commonly used indicators to evaluate not only a country's economic prosperity but also its ability to invest in sustainable development (Homer 2025). A higher GDPpc is often correlated with better infrastructure, healthcare, and education systems, which are crucial for achieving the SDGs. Although in some studies the GDPpc reveals a positive association with nearly 70% of SDG indicators (Ament et al. 2020), in others a negative bidirectional relationship has been found between GDPpc growth and SDG scores, indicating that while GDPpc growth can improve certain sustainability indicators, it can also lead to deteriorations in others, such as environmental quality (Groner and Moradi 2024).

To explore the impact of various social and economic factors on sustainable development in the European Union (EU), Tu et al. (2023) considered seven independent variables and concluded that GDPpc inhibits the sustainability transition, while median income per capita has a statistically significant positive impact on SDG_IS. Conversely, corruption was found to have no statistically significant impact. These mixed evidences highlight that the GDPpc has limitations in fully capturing well-being and development, the limitations associated with factors such as income inequality, economic freedom, and the size of the shadow economy, as they can cause discrepancies between GDPpc and other development indicators (Dědeček and Dudzich 2022a, 2022b) which contribute to the identified complex relationship with sustainable development which sometimes inhibits the sustainability transition due to environmental impacts (Tu et al. 2023; Wang and Chen 2024), aligned with the EKC hypothesis.

Another determinant of sustainable development is income inequality, which the literature widely recognizes as a barrier to achieving it (Mai et al. 2025) and as shaping outcomes across multiple SDGs, as several studies reveal. For example, Hou et al. (2024) highlight that reducing inequality can raise carbon emissions, making it difficult to pursue SDG 10 (Reduced Inequalities) and SDG 13 (Climate Action) simultaneously, suggesting a trade-off. Hussain et al. (2023), in a study covering 20 African and Asian countries, found that unequal access to the sharing economy reduces its ability to drive inclusive growth, constraining progress on SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation and Infrastructure), and SDG 10. The Gini coefficient measures income inequality within a country and is widely used to assess the effects of fiscal policies and governance on income redistribution. In relation to sustainable development, Mai et al. (2025) examined G7 countries (1995–2022) and found income inequality to be statistically non-significant but negatively associated with sustainable development, while unemployment showed a strong positive relationship with the SDG_IS, reflecting labor market adjustments during the transition to greener sectors. In contrast, Chen et al. (2021) concluded that high inequality hinders sustainable development by restricting access to resources and opportunities. Therefore, reducing inequality is crucial for promoting inclusive growth and social cohesion, which are key objectives of the SDGs. From a modernization theory perspective, inequality not only reflects the stage of development but also limits states' ability to effectively design and implement policies that support the SDG attainment. In less institutionally developed contexts, weak governance, limited fiscal capacity, and underdeveloped redistributive systems amplify the negative effects of inequality, reducing policy effectiveness and strengthening structural barriers to sustainable development (Farag 2025). Therefore, the relationship between inequality and the achievement of the SDGs depends on institutional quality, with stronger negative effects observed where institutions fail to mitigate unequal access to resources and opportunities (Khan et al. 2026).

To comprehensively address sustainable development challenges, it is also essential to understand the relationship between corruption and the different SDGs. Corruption is broadly defined as the misuse of public power for private gain, thereby undermining institutional trust and reducing the efficiency of public spending (Ortega et al. 2016), and thus plays a relevant role in addressing governance and development challenges (Mombeuil and Diunugala 2021). Similar to the impacts of inequality, the impacts of corruption vary across countries and sectors of society and differ by SDG.

Leung et al. (2025) showed that corruption increases economic inequality and worsens public health outcomes. Similarly, several studies (Budanov et al. 2025; Hope 2020; Hope Sr. 2022; Qazi 2025; Yang et al. 2025) indicate that high corruption levels hinder progress toward SDGs such as SDG 3 (Good Health and Well-being), SDG 2 (Zero Hunger), and SDG 16 (Peace, Justice and Strong Institutions), whereas lower corruption improves performance in SDG 11 (Sustainable Cities and Communities), SDG 2, and SDG 1 (No Poverty). However, evidence is mixed. Fhima et al. (2023) found that corruption consistently harms sustainable development in developed countries but has regime-dependent effects in developing economies, where weak governance may allow highly corrupt countries to achieve higher sustainability levels. In contrast, Tu et al. (2023) reported no significant relationship between the Corruption Perceptions Index (CPI) and sustainability. Thus, this mixed evidence suggests that the relationship between institutional quality and SDG performance is context- and stage-dependent, which aligns with the predictions of modernization theory.

Good health and quality education are central pillars of the SDGs, with education playing a key role in promoting sustainable development by strengthening human capital, economic growth, employability, income, and health outcomes (Erjavec 2020; Hui 2022; Vargas-Merino et al. 2024). Tutar et al. (2026) found that mean years of schooling and life expectancy at birth explain 97.8% of the Human Development Index, highlighting the importance of education and healthcare for human development. Life expectancy, often linked to improved healthcare, nutrition, and living standards, is also positively associated with sustainable development. Similarly, Tu et al. (2023) showed that life expectancy has a statistically significant positive effect on sustainable development performance in the EU. In line with modernization theory, human capital accumulation, captured in this study through average years of schooling (AYS) and life expectancy at birth (LExpBrth), is expected to be a more decisive driver of SDG performance in countries at earlier stages of development, where the marginal returns to investments in education and health are higher. Yet the evidence on the relative importance of education and health for SDG performance remains inconclusive, particularly in advanced economies where these dimensions may already be near saturation levels. This limitation is one that the present study, by applying two complementary approaches, is well positioned to evaluate.

Although innovation is a key driver of economic growth and sustainable development (Dhar et al. 2023; Omri 2020), its effectiveness depends on institutional and structural contexts, as Schultz et al. (2024) demonstrate by analyzing patents as incentives for green technology, concluding that they effectively promote innovation in the Global North due to strong markets and institutions, but are less effective in the Global South, where weak enforcement and limited research and development (R&D) capacity restrict innovation. Innovation has often been positively linked to sustainability, enhancing operational efficiency and long-term competitiveness while minimizing environmental impact (Sempere-Ripoll et al. 2020) by facilitating resource efficiency, reducing waste, and supporting closed-loop systems.

Considering the EU member states, Szántó and Neumanné Virág (2025) found a strong relationship between innovation capacity and achievements regarding the SDGs in economically developed countries, but no similar relationship was found in less developed economies, highlighting a division between Western and Northern member states and Southern and Eastern member states. This pattern aligns with the broader argument that innovation-led development strategies are most effective where the institutional and market conditions needed to support them are already in place (Schultz et al. 2024). The Global Innovation Index (GII) was used in several studies [see, for example, Huarng and Yu 2022, Yu, Huarng, and Huang 2021; Yu, Huarng, and Lai 2021, and Yu and Huarng 2024] to represent national innovation capabilities, making the GII an important reference for governments in designing policy. Notably, Yu and Huarng (2024) applied fuzzy-set qualitative comparative analysis (fsQCA) to analyze SDG achievements across countries and identified multiple relationships between the GII and SDG achievements that vary across economic contexts, highlighting the need for further research, including the configurational and comparative approach adopted in the present study.

The literature review shows that studies use diverse variables and, even when common variables are analyzed, findings remain inconclusive. It also highlights a lack of integrated comparative research on the EU-27, particularly between Cohesion (less developed) and Non-Cohesion (more developed) countries. Despite the EU's strong commitment to the 2030 Agenda, significant disparities persist, driven by historical, socioeconomic, and institutional differences, as well as by the effectiveness of Cohesion Policy and regional governance (Garashchuk et al. 2023; Pîrvu et al. 2019). This highlights the need for a deeper understanding of the variables that drive higher values of the SDG_IS to design better targeted interventions that can reduce regional inequalities and promote convergence toward sustainability across the EU.

Methodologically, most studies rely on linear models, while fuzzy approaches remain underexplored, limiting the analysis of nonlinear sustainability patterns.

Thus, the literature review reveals three interconnected gaps that this study seeks to address. First, thematically, although individual determinants of SDG performance have been extensively studied, the evidence remains inconclusive and fragmented, and no study has jointly examined the full set of economic, institutional, human capital, and innovation determinants within the EU-27 while grounding the analysis in an explicit multi-framework theoretical structure. Second, comparatively, the Cohesion/Non-Cohesion division within the EU has not been used as a lens to understand how countries' stages of development impact the relationship between the different determinants and SDG performance. Third, methodologically, most existing studies rely on linear regression models, while nonlinear approaches remain substantially underexplored.

Therefore, this study seeks to fill these gaps and, in doing so, advances a central theoretical claim: that the determinants of sustainable development are not universal but systematically stage-dependent, shifting from material and economic drivers in less developed contexts toward institutional quality and distributive justice in more advanced ones. This claim, grounded in the joint predictions of the EKC hypothesis and modernization theory, has direct implications for how SDG policy should be designed across heterogeneous country contexts and challenges the implicit assumption of universality that underlies much of the existing SDG literature as well as the current architecture of EU Cohesion Policy. To substantiate this claim, the study makes three interrelated contributions. First, it provides an integrated panel data analysis of SDG determinants (income, inequality, institutions, human capital, and innovation) across the EU-27, explicitly comparing Cohesion and Non-Cohesion countries and thereby testing the stage-dependent predictions of the EKC hypothesis and modernization theory. Second, it adopts a methodological approach that combines panel data regression with fsQCA, leveraging the complementary strengths of both methods to capture not only average effects but also causal configurations. Third, it offers evidence-based recommendations to inform the redesign of EU Cohesion Policy, focusing on differentiated, context-sensitive interventions grounded in smart specialization principles.

In light of the above, this study addresses mainly two interrelated research questions: (i) Do the determinants of SDG_IS attainment differ systematically between Cohesion and Non-Cohesion countries in the EU? and (ii) Beyond average and linear relationships, which configurations of causal conditions are associated with high SDG_IS performance within each group?

The remainder of the manuscript is structured as follows: Section 2 presents the data and methodology. Section 3 reports and discusses the empirical findings. Section 4 concludes.

2 | Data and Methods

2.1 | Data

In line with its main objective, which was to analyze the determinants of sustainable development in EU countries, this study compared complex causal configurations (using fsQCA) with the individual effects of each variable (using panel data models) across the EU-27. The selection of the EU-27 member states was mainly motivated by three considerations: (i) the EU represents a uniquely integrated political and economic space with a shared institutional framework and a formal collective commitment to the 2030 Agenda, making cross-country comparisons methodologically coherent; (ii) despite this shared framework, EU member states exhibit relevant structural heterogeneity, for example, in income levels, institutional quality, and development trajectories, generating meaningful variation in the explanatory variables; and (iii) EU Cohesion Policy provides a natural and policy-relevant criterion for grouping countries at different stages of development, allowing the analysis to move beyond simple income-based classifications. Given the EU's commitment to reducing regional disparities and promoting inclusive growth (Casas et al. 2025), examining how different development levels and EU support influence SDG achievement is crucial for designing targeted policies. Accordingly, countries are classified as Cohesion or Non-Cohesion based on the list of member states eligible for support from the Cohesion Fund set out in Annex IV to Commission Implementing Decision (EU) 2021/1130 for the 2021–2027 programming period (European Commission 2021) (see Table 1). Since this eligibility is based on GNI per capita thresholds (EU member states with a GNI per capita below 90% of the EU-27 average are eligible for Cohesion Fund support), the classification reflects structural disparities in economic development across member states and offers a meaningful basis for comparative analysis.

To conduct the analyses, one dependent variable and six explanatory variables were used, as described in Table A1. The dependent variable was SDG_IS, expressed on a 0–100 scale, where 100 represents optimal performance across all 17 SDGs. It is calculated annually as a weighted composite of SDG-specific indicators, following the methodology of Sachs et al. (2025). The SDG_IS was used as the explained variable since it encompasses multiple dimensions of sustainable development (Barberà-Mariné et al. 2024) and is widely recognized as a comprehensive metric for assessing countries' convergence with the United Nations (UN) goals (Diaz-Sarachaga et al. 2018; Jabbari et al. 2020). The

TABLE 1 | Cohesion and non-cohesion countries in the EU (2021–2027).

Cohesion countries	Bulgaria; Croatia; Cyprus; Czechia; Estonia; Greece; Hungary; Latvia; Lithuania; Malta; Poland; Portugal; Romania; Slovakia; Slovenia.
Non-cohesion countries	Austria; Belgium; Denmark; Finland; France; Germany; Ireland; Italy; Luxembourg; Netherlands; Spain; Sweden.

Note: Countries are classified according to eligibility for the Cohesion Fund according to European Commission (2021).

explanatory variables that correlate with the different dimensions of sustainable development are: (i) the natural logarithm of the GDPpc [*log*(*GDPpc*)][1] theory suggests that the effects of GDPpc on various outcomes are multiplicative rather than additive. This variable is expressed in current international dollars converted using purchasing power parities (PPPs) to ensure cross-country comparability. A 1% increase in GDPpc corresponds to an increase of approximately 0.01 in log(GDPpc); (ii) the Gini index (Gini_ce), expressed as a percentage ranging from 0 (perfect equality) to 100 (maximum inequality), is calculated by measuring the area between the Lorenz curve and the line of perfect equality and is widely used to assess the distributional effects of fiscal and economic policies. Higher values indicate greater income dispersion within a country; (iii) the CPI is published annually by Transparency International and is scored on a scale from 0 (highest perceived corruption) to 100 (lowest perceived corruption). The CPI is calculated using 13 different data sources from 12 different institutions that capture perceptions of corruption. Higher values thus reflect greater institutional transparency and lower corruption; (iv) life expectancy at birth (LExpBrth) is measured in years and represents the average number of years a newborn is expected to live under current age-specific mortality conditions. It serves as a proxy for the overall quality of healthcare systems, nutrition, and living standards; (v) the GII, scored on a scale from 0 to 100. The GII was created in 2007 by Prof. Soumitra Dutta (then at INSEAD), but since 2011, it has been developed in partnership with the World Intellectual Property Organization (WIPO). In 2021, WIPO became the sole publisher of the GII, in partnership with the Portulans Institute, headed by Prof. Dutta. It is calculated as the simple average of two equally weighted sub-indices: the Innovation Input Sub-Index, which covers five pillars representing the economic factors that foster and enable innovative activities; and the Innovation Output Sub-Index, which covers two pillars. Higher values reflect a more developed and productive national innovation ecosystem; and (vi) average years of schooling (AYS), measuring the mean number of years of formal education completed by the adult population (aged 25 and over). It reflects the educational attainment of the population, given that education is a cornerstone of sustainable development (Vargas-Merino et al. 2024).

These variables were selected to represent the key dimensions identified in the literature as determinants of sustainable development. Moreover, they allow the operationalization of the key theoretical predictions of the three frameworks outlined in the Introduction: (i) log(GDPpc) for the stage-dependent predictions of the EKC hypothesis; (ii) Gini_ce and CPI for the modernization theory expectation that distributive justice and institutional quality become dominant drivers in more advanced economies; and (iii) AYS, LExpBrth, and GII for capturing the human capital and innovation dimensions that the smart specialization framework identifies as structural foundations of context-sensitive development strategies.

Data for the EU-27 countries were collected from reliable and publicly accessible international sources (see Table A1). The selection of the sources identified on Table A1 was guided by three criteria: international recognition and methodological transparency, cross-country comparability, and temporal coverage spanning the full 2012–2023 period. The dataset had annual frequency and covered the period 2012–2023, based on data availability for CPI and Gini_ce, forming a balanced panel of 324 observations (27 countries × 12 years). Furthermore, 2012 represents an early baseline year prior to the adoption of the 2030 Agenda in 2015, allowing the analysis to capture both pre- and post-Agenda trends in SDG performance. The end year, 2023, corresponds to the most recent year for which complete data were available across all variables and countries. This period included major global and EU events, such as the adoption of the 2030 Agenda in 2015, the COVID-19 pandemic, and key policy changes, including reforms to the Common Agricultural Policy and the launch of the European Green Deal in 2019. These developments significantly influenced socioeconomic and environmental indicators, making this timeframe particularly relevant for analyzing EU progress toward the SDGs. The panel is balanced, meaning that all EU-27 countries have complete observations for all variables across the 12-year period. Country-year observations with missing values would have been excluded during data preparation, although no exclusions were required given the completeness of the selected sources.

2.2 | Methods

To evaluate the determinants of sustainable development (measured by the SDG_IS) in the EU, panel-data regression models and fsQCA were employed, leveraging the complementary strengths of both approaches. Their combination follows an established mixed-methods logic in comparative social science (Meuer et al. 2017), the two methods address analytically distinct yet mutually informative research questions. Panel data regression models answer the question of which variables are statistically associated with SDG performance and the average magnitude of those associations by estimating the net effects and statistical significance of the individual determinants (Section 2.2.1). In contrast, fsQCA answer the question of which combinations of conditions enable countries to achieve high SDG performance by addressing the causal complexity inherent in achieving the SDGs (Section 2.2.2), allowing the identification of multiple, necessary and sufficient configurations (equifinality) that lead to higher SDG_IS values in the distinct realities of Cohesion and Non-Cohesion countries. Neither method alone can capture both dimensions simultaneously: panel models cannot detect conjunctural causation or equifinality, while fsQCA does not estimate the average effects or statistical significance of individual variables.

2.2.1 | Panel Data Regression Models

Panel data analysis combines time-series and cross-sectional dimensions, allowing the analysis of individual heterogeneity and the simultaneous capture of temporal dynamics (Baltagi 2005; Wooldridge 2010). It was therefore a well-suited approach to analyze the determinants of sustainable development across EU countries, as it allows for the control of unobserved individual effects that may be correlated with the regressors. As highlighted by Hsiao (2022), this is a key advantage of panel data models, reducing omitted variable bias and potentially improving estimator efficiency.

Before specifying the models, potential multicollinearity among the regressors was assessed, and stationarity was verified to avoid spurious regressions, as detailed in the subsection on preliminary results.

The base specification for the panel data models was the following:

$$SDG\_IS_{i,t} = \alpha + \beta_1 log\left(GDPpc_{i,t}\right) + \beta_2 Gini\_ce_{i,t} + \beta_3 CPI_{i,t} + \beta_4 LExpBrth_{i,t} + \beta_5 GII_{i,t} + \beta_6 AYS_{i,t} + u_{i,t} \quad (1)$$

where $SDG\_IS_{i,t}$ is the explained variable for country i at time t, $log\left(GDPpc_{i,t}\right)$ is the natural logarithm of GDPpc, $Gini\_ce_{i,t}$ is the Gini index, $CPI_{i,t}$ is the Corruption Perceptions Index, $LExpBrth_{i,t}$ is the life expectancy at birth, $GII_{i,t}$ is Global Innovation Index, $AYS_{i,t}$ is the average years of schooling, α represented the constant term, β_1 to β_6 represented the coefficients of the explanatory variables (to be estimated), and $u_{i,t}$ is the composite error term, corresponding to $u_{i,t} = \mu_i + \varepsilon_{i,t}$, where μ_i captured unobserved time-invariant country-specific heterogeneity, and $\varepsilon_{i,t}$ was the idiosyncratic error term.

Three estimators were considered and reported in a sequential model-selection framework: Ordinary Least Squares (OLS), Fixed Effects (FE), and Random Effects (RE). OLS was estimated first as a baseline, as it assumes independent observations and ignores country-specific characteristics (Wooldridge 2010), which may lead to biased results (Baltagi 2005). Its results are nonetheless reported with robust standard errors for comparative reference. The FE model was then estimated, as it controls for unobserved, time-invariant country-level heterogeneity, providing consistent estimates when these effects are correlated with explanatory variables (Greene 2018; Wooldridge 2010). The RE model, in contrast, assumes country-specific effects are random and uncorrelated with regressors, allowing more efficient estimates by using both within- and between-country variation (Wooldridge 2010). The choice between FE and RE was guided by the Hausman (1978) test, which evaluates whether the individual effects are correlated with the regressors. Under the null hypothesis, both estimators are consistent, but RE is more efficient; under the alternative, only FE is consistent.

As reported in Table A2, the null hypothesis was not rejected for either the Cohesion countries ($\chi^2 = 1.8541$, p value = 0.9326) or the Non-Cohesion countries ($\chi^2 = 4.6784$, *p-value* = 0.5857), providing statistical support for the RE model as the preferred specification in both subsamples. To ensure reliable results, several diagnostic tests were performed prior to and following estimation. The Breusch–Pagan test detected heteroscedasticity in both subsamples. In addition, serial correlation was assessed using the Breusch-Godfrey LM test for panel data (Breusch 1978; Godfrey 1978), and the null hypothesis rejected (the results are reported in Table A2). Because heteroscedasticity and serial correlation were detected, Heteroskedasticity and Autocorrelation Consistent (HAC) robust standard errors (Arellano 1987) were applied to all models to ensure valid inference.

The cross-sectional dependence was formally tested using the Pesaran (2004) CD test applied to the residuals of the FE and RE models for both groups of countries, and the null hypothesis of cross-sectional independence was rejected. To address this, the models were additionally estimated using Driscoll–Kraay standard errors, which are simultaneously robust to heteroscedasticity, serial correlation, and cross-sectional dependence (Hoechle 2007). The results, reported in Table A3, confirm the robustness of the main findings.

Normality of residuals was assessed using the Shapiro–Wilk test, with the null hypothesis rejected for the Cohesion countries, but not for the Non-Cohesion ones. Visual analysis of the residuals (Figure A1) confirmed that the departures from normality were not severe and did not compromise the validity of the results, given the relatively large sample size and the use of robust standard errors.

Finally, the models were estimated for Cohesion and Non-Cohesion countries, as this strategy was justified on both theoretical and empirical grounds: theoretically, because countries at different stages of development may exhibit structurally distinct relationships between the explanatory variables and the SDG performance; empirically, because the descriptive analysis confirmed relevant differences in the mean levels and variability of the key variables across the two groups (Table 2). This approach follows a common practice in comparative regional analysis and allows for direct identification of which determinants are group-specific rather than universal.

2.2.2 | Pooled Fuzzy-Set Qualitative Comparative Analysis (fsQCA)

Following the panel data regression analysis, fsQCA was applied to address the inherent causal complexity of SDG_IS achievement, complementing the first approach by: (i) assessing countries' membership in sets defined by varying degrees of SDG_IS performance rather than treating outcomes as continuous variables; (ii) identifying sufficient and necessary configurations of conditions that consistently lead to higher SDG_IS; and (iii) detecting nonlinear patterns and threshold effects that linear models may not adequately capture, particularly the synergistic interactions among determinants.

fsQCA was employed to identify necessary and/or sufficient conditions for a given outcome. This method enabled the examination of specific causal configurations and aligned with the causes-of-effects approach, aiming to uncover the minimal conditions that produce an outcome in particular cases (Wagemann and Schneider 2010). Unlike traditional quantitative methods that focus on cause-and-effect relationships between variables, fsQCA emphasizes causal complexity.

According to Pappas and Woodside (2021), QCA is an innovative technique that combines the strengths of qualitative and quantitative approaches. It integrates the contextual richness of qualitative methods with the capacity of quantitative methods to handle large datasets and generate generalizable findings (C. C. Ragin 2000; C. Ragin 2008). Rather than relying on variance-based analyses and significance testing, QCA focuses on identifying logically simplified configurations of conditions that lead to a specific outcome (C. Ragin 2008). Thus, QCA provides a more holistic and nuanced understanding of complex phenomena and represents a paradigm shift in data analysis.

TABLE 2 | Main descriptive statistics.

	Variable	Min.	Max.	Median	Mean	Std. dev.	Skewness	Kurtosis	CV
EU-27 countries ($n = 3\ 24$)	SDG_IS	71.52	87.10	79.87	79.82	3.20	0.04	2.88	4.01
	$log(GDP_{pc})$	9.70	11.87	10.64	10.65	0.40	0.54	3.65	3.74
	Gini_ce	20.90	40.80	29.35	29.76	3.90	0.27	2.62	13.12
	CPI	36.00	92.00	60.00	63.73	14.35	0.24	1.89	22.52
	LExpBrth	71.20	83.77	81.20	79.86	2.91	−0.76	2.26	3.64
	GII	34.10	64.80	47.88	48.49	7.57	0.22	2.06	15.61
	AYS	8.50	14.30	12.34	12.10	1.11	−0.69	3.41	9.18
15 cohesion countries ($n = 180$)	SDG_IS	71.52	82.96	79.19	78.61	2.56	−0.75	2.95	3.26
	$log(GDP_{pc})$	9.70	11.07	10.40	10.41	0.27	−0.06	2.64	2.59
	Gini_ce	20.90	40.80	30.90	30.63	4.54	−0.16	2.29	14.81
	CPI	36.00	76.00	55.00	54.23	8.02	0.31	2.83	14.79
	LExpBrth	71.20	83.40	77.80	78.16	2.86	0.07	1.80	3.66
	GII	34.10	56.10	42.68	43.39	4.70	0.27	2.39	10.83
	AYS	8.50	13.66	12.37	12.09	1.14	−0.99	3.71	9.43
12 non-cohesion countries ($n = 144$)	SDG_IS	73.76	87.10	80.73	81.32	3.29	−0.05	2.00	4.05
	$log(GDP_{pc})$	10.37	11.87	10.87	10.94	0.33	1.06	3.75	3.01
	Gini_ce	24.10	34.70	28.00	28.67	2.55	0.57	2.40	8.91
	CPI	42.00	92.00	77.00	75.60	11.38	−1.01	3.64	15.05
	LExpBrth	80.20	83.77	81.90	81.98	0.81	0.07	2.16	0.99
	GII	44.50	64.80	56.01	54.88	5.28	−0.19	2.00	9.62
	AYS	9.51	14.30	12.32	12.11	1.08	−0.23	2.87	8.89

Note: "Min.", "Max.", "Std. Dev" and "CV" correspond to the minimum, maximum, standard deviation, and coefficient of variation, respectively.

In fsQCA, variables must be calibrated, as the use of raw data is insufficient. The calibration of all conditions and outcomes followed the guidelines proposed by C. Ragin (2008), who defines membership scores ranging from 0 (fully out) to 1 (fully in), with 0.5 representing the crossover point, where cases are neither fully in nor fully out of the set. As a logistic function was used, thresholds of 0.95 and 0.05 were adopted for full membership and full non-membership, respectively (Wagemann and Schneider 2010). The crossover threshold was 0.5. These thresholds were set based on the empirical distribution of each variable in each subsample (Cohesion and Non-Cohesion countries, respectively), ensuring that the calibration reflected the relative positioning of cases within each country group. This percentile-based approach grounded the calibration in the actual distribution of the data, ensured full replicability, and avoided imposing externally defined thresholds that might not be contextually appropriate. To avoid excluding cases with membership scores of 0.5, following Fiss (2011), a small constant of 0.0000001 was added to all scores below 1. Table A4 presents the specific calibration thresholds for each variable.

For the analysis of necessary conditions, consistency and coverage were used as criteria for selecting solutions. Consistency refers to the proportion of cases displaying the outcome of interest in which a given condition is also present. It ranges from 0 to 1, and C. Ragin (2008) and Schneider and Wagemann (2012) suggested 0.90 as an appropriate cutoff value. Coverage indicates the proportion of cases that follow a particular causal path leading to the outcome (Fiss 2011).

The analysis of sufficient conditions examined the extent to which the outcome occurred when a specific condition or configuration was present, acknowledging that the same outcome may also arise from alternative configurations. According to C. Ragin (2008) the recommended consistency cutoff for sufficiency is 0.80; Schneider and Wagemann (2012) recommended that it should not be less than 0.75, reflecting the degree to which a given combination of conditions constitutes a subset of the outcome set. This approach is grounded in the understanding that causal relationships are best comprehended in set-theoretic terms, rather than mere correlations (Fiss 2011; C. C. Ragin 2000; C. Ragin 2008). It provides a detailed identification of the necessary and sufficient conditions (Fiss 2011). An additional advantage of fuzzy sets is that a specific condition or combination of conditions may be sufficient to produce the desired outcome (Rihoux 2006).

The combination of panel data regression models and fsQCA follows a mixed-method analytical strategy aimed at capturing both net effects and causal complexity in the determinants of sustainable development. Panel data models estimate the average marginal impact of individual explanatory variables on SDG performance across countries and time, identifying the dominant statistical drivers of sustainability outcomes. However, such variance-based approaches assume additive and linear relationships between variables. In contrast, fsQCA allows the identification of conjunctural causation and equifinality, meaning that different combinations of conditions may lead to similar sustainability outcomes. By integrating these two approaches, the study provides a more comprehensive understanding of SDG attainment: panel models identify the main determinants in average terms, while fsQCA reveals the multiple pathways through which countries can achieve high levels of sustainable development.

In the EU context, this complementarity is particularly relevant, as countries may reach similar sustainability outcomes through different combinations of economic capacity, institutional quality, social cohesion, and innovation. In this regard, the main contribution of the study is not only to identify which determinants matter on average but also to show that their relevance depends on the stage of development and on the broader configuration in which they operate.

3 | Results and Discussion

3.1 | Preliminary Results

From 2012 to 2023, both Cohesion and Non-Cohesion countries showed a clear upward trend in the SDG_IS indicator, reflecting overall social and economic progress aligned with the objectives of the SDGs. Throughout the entire period, Non-Cohesion countries consistently presented higher SDG_IS values than Cohesion countries, indicating a persistent development gap between the two groups (Figure 1). Cohesion countries improved the SDG_IS from 77.0 in 2012 to 80.8 in 2023, showing steady progress, especially between 2014 and 2020. However, a slight decline was observed in 2021, likely linked to the social and health impacts of the COVID-19 pandemic, followed by a recovery in subsequent years. Non-Cohesion countries followed a similar pattern, rising from 79.2 to 82.0 and maintaining their advantage despite the temporary stagnation around 2020–2021.

There was a clear asymmetry in the distribution of the SDG_IS across countries in both groups. Within the Cohesion group, some countries presented significantly lower SDG_IS values than the median, namely Cyprus and Bulgaria. In contrast, within the Non-Cohesion group, the pattern was reversed, with countries such as Finland and Sweden displaying significantly higher SDG_IS values than the median.

The main descriptive statistics for the EU-27 countries as a whole and for the Cohesion and Non-Cohesion countries were estimated in a preliminary exploratory analysis, as the distribution of each variable provides relevant information about the main characteristics of the data. The results, presented in Table 2 and Figure 2, revealed that the Non-Cohesion countries exhibited higher mean and median SDG_IS values than the Cohesion countries.

Although both groups of countries exhibited low coefficient of variation (CV), indicating internal homogeneity, the maximum value for the Cohesion countries (82.96) was slightly higher than the mean value for the Non-Cohesion countries (81.32), which may signal a structural gap in achieving the SDGs between the two regions. Concerning the explanatory variables, Non-Cohesion countries presented higher values than the Cohesion countries, confirming their higher level of economic development. However, the most pronounced difference between the two groups concerned the CPI, with Non-Cohesion countries exhibiting substantially higher values (i.e., lower perceived corruption). Additionally, Cohesion countries exhibited greater income distribution inequality.

Regarding innovation, the higher mean GII for Non-Cohesion countries suggested a more robust innovation ecosystem. Regarding human capital, the results were mixed. While LExpBrth was higher and highly homogeneous in Non-Cohesion countries, AYS showed identical means across the two groups, suggesting that convergence in years of schooling does not necessarily translate into immediate economic or innovation impacts.

To further analyze the bivariate relationships between the variables and perform a preliminary check for multicollinearity, Pearson correlation coefficients were estimated (Figure A2). Globally, they aligned with theoretical expectations, identifying a negative association between Gini_ce and the other variables. Furthermore, the correlations among the explanatory variables

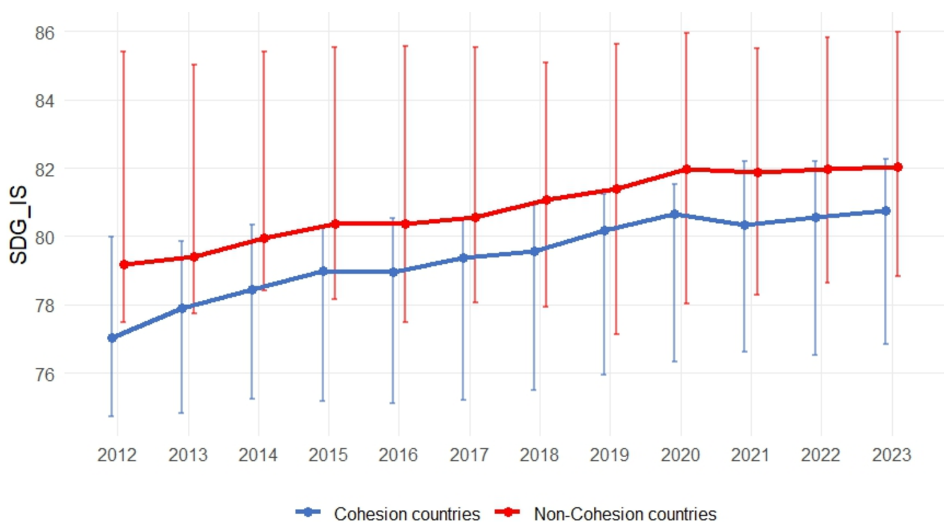


FIGURE 1 | Evolution of the median of SDGs for cohesion and non-cohesion countries with 0.1 and 0.9 percentiles bars.

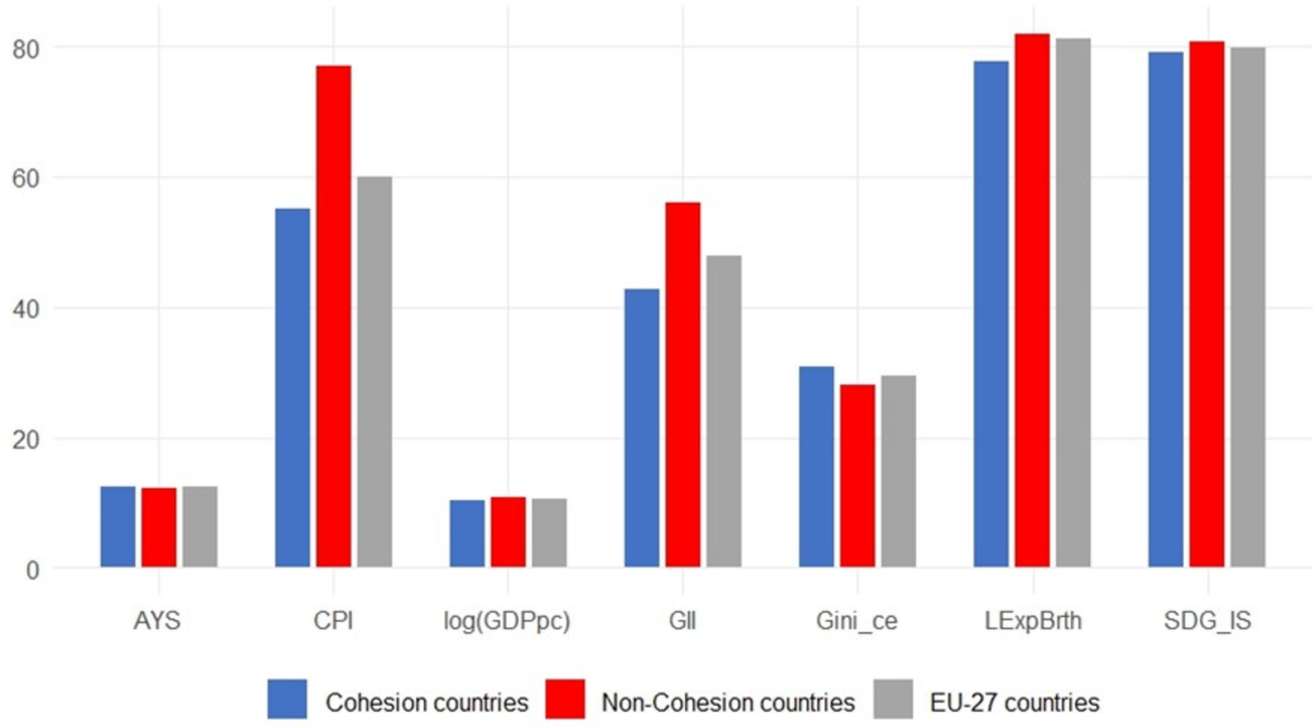


FIGURE 2 | Median values of the variables of the three groups of countries.

underscore the importance of assessing the Variance Inflation Factor (VIF).

Before analyzing the estimators, the econometric assumptions were validated, and the modeling typology was selected. To ensure the reliability of the statistical inferences and avoid spurious regressions, the stationarity of the variables was examined using a dual testing strategy. First, the standard Augmented Dickey–Fuller (ADF) test (Dickey and Fuller 1979) was applied to the full pooled sample, leveraging the large number of observations to maximize statistical power. Second, to account for cross-sectional heterogeneity, the Fisher-type ADF panel unit root test (Maddala and Wu 1999) was conducted for the global panel and for the Cohesion and Non-Cohesion subsamples. The results are reported in Table A5.

While panel-data-specific stationarity tests are generally advantageous for capturing individual dynamics, they are known to suffer from low power in panels with a short time dimension (as in our case, where $T = 12$), often failing to distinguish between unit roots and trend-stationary processes (Baltagi 2005; Harris and Tzavalis 1999). As reported in Table A5, the null hypothesis of the pooled ADF test was rejected for all variables at the 5% significance level, confirming that the series were stationary in levels. The Fisher-type ADF test corroborated these results for most variables. However, for and SDG_IS (for the Non-Cohesion countries), the null hypothesis was not rejected. These divergences were mainly due to the short time dimension, which reduces the power of panel unit root tests to detect deterministic trends or slow-moving processes. Given the clear rejection of the unit root in the pooled ADF test and the theoretical support for using level variables in static RE models for short panels (Wooldridge 2010), the variables were treated as stationary. Multicollinearity was then assessed using VIFs, both for the full sample and separately for Cohesion and Non-Cohesion countries, to ensure regressor stability across contexts.

All variables exhibited VIF values below the critical thresholds suggested by Hair Jr. et al. (2019) and as discussed by O'Brien (2007), indicating the absence of multicollinearity (Table A5). To assess whether individual-specific errors were correlated with regressors and to select between FE and RE estimators, the Hausman (1978) test was applied; the results did not reject the null hypothesis, indicating statistical support for the RE model (Table A2).

3.2 | Panel Data Regression Models

Pooled OLS, FE, and RE models were estimated for both country groups. Despite concerns regarding the adequacy of the OLS estimator, as indicated by the Breusch-Pagan Lagrange Multiplier test, its results were reported with robust standard errors for comparative purposes (baseline). To mitigate bias arising from unobserved heterogeneity, two panel-data models (FE and RE) were estimated (Table 3). As the Hausman test did not reject the null hypothesis in either the Cohesion or Non-Cohesion group, the RE model was considered the most appropriate specification and was therefore selected for interpretation.

Considering the results of the diagnostic tests performed and presented in Table A2, the most accurate model is the RE (column (3) in Table 3). The results revealed good explanatory power, particularly in the Cohesion countries, where the adjusted

TABLE 3 | Regression results for the determinants of SDG_IS: cohesion vs. non-cohesion countries.

	Explained variable: SDG_IS					
	Cohesion countries			Non-Cohesion countries		
		Panel data models			Panel data models	
	OLS (Robust SE)	FE	RE	OLS (Robust SE)	FE	RE
	(1)	(2)	(3)	(1)	(2)	(3)
$log(GDP_{pc})$	2.693***	2.852***	2.856***	−7.611***	1.921	1.612
	(0.668)	(0.490)	(0.444)	(0.720)	(1.292)	(1.208)
Gini_ce	−0.395***	−0.084**	−0.090**	−0.198*	0.224**	0.207**
	(0.037)	(0.087)	(0.035)	(0.105)	(0.110)	(0.104)
CPI	0.117***	0.054***	0.052***	0.158***	0.037**	0.043**
	(0.023)	(0.016)	(0.016)	(0.042)	(0.016)	(0.017)
LExpBrth	−0.480***	0.039	0.024	1.875***	−0.020	0.034
	(0.076)	(0.045)	(0.037)	(0.327)	(0.156)	(0.148)
AYS	−0.560***	0.624**	0.573**	1.739***	1.007	1.098
	(0.177)	(0.280)	(0.231)	(0.303)	(0.898)	(0.822)
GII	−0.105***	−0.010	−0.017	−0.109*	−0.069	−0.068
	(0.038)	(0.026)	(0.026)	(0.063)	(0.067)	(0.067)
Constant	105.170***		40.728***	−10.424***		42.198***
	(7.384)		(5.436)	(25.415)		(10.817)
Observations	180	180	180	144	144	144
R^2	0.503	0.780	0.761	0.580	0.560	0.512
Adjusted R^2	0.486	0.753	0.753	0.561	0.501	0.491
Residual std. error	1.838 (df = 173)			2.179 (df = 137)		
F-statistic	29.166*** (df = 6; 173)	94.064*** (df = 6; 159)	550.814***	31.475*** (df = 6; 137)	26.716*** (df = 6; 126)	143.817***

Note: "FE" and "RE" represent the Fixed Effects and Random Effects models, respectively; "***", "**", "*", denote statistical significance at the 1%, 5%, and 10% levels, respectively; Multicollinearity was assessed using the VIF, and all variables displayed values below the critical thresholds, indicating no evidence of multicollinearity; Serial autocorrelation was assessed using the Breusch-Godfrey LM test for panel data (Breusch 1978; Godfrey 1978), applied to the RE model selected for both subsamples. In both groups, the null hypothesis of no serial autocorrelation was rejected; Normality was tested using the Shapiro–Wilk test (Shapiro and Wilk 1965). The null hypothesis was not rejected for Non-Cohesion countries but was rejected for Cohesion countries. This analysis was complemented by a visual evaluation of the residuals, as presented in Figure A1; The Breusch–Pagan test indicated the presence of heteroscedasticity in both groups, leading to the use of robust standard errors. Additionally, the Breusch–Pagan Lagrange Multiplier test (Breusch and Pagan 1980) rejected the pooled OLS specification, indicating the presence of unobserved country-level heterogeneity; cross-sectional dependence was detected for both groups using Pesaran's (2004) CD test. Robustness checks using Driscoll–Kraay standard errors are reported in Table A2.

R^2 reached 0.753. More importantly, the results also show relevant differences between the determinants of sustainable development between Cohesion and Non-Cohesion countries, supporting the rationale for estimating separate models for the two groups.

In terms of the economic dimension, the *log*(*GDPpc*) revealed a positive impact in both Cohesion and Non-Cohesion countries, although the coefficient was higher for Cohesion countries. Specifically, a 1% increase in GDPpc was associated with an average increase of 0.02856 points in SDG_IS for Cohesion countries. This result aligns with the perspective of the EKC hypothesis (Grossman and Krueger 1995) adapted to the SDG context (Groner and Moradi 2024), and suggests that, for Cohesion countries, economic growth was fundamental to SDGs attainment, whereas for Non-Cohesion countries, GDPpc growth was not a dominant factor, pointing to need for policies beyond strictly economic measures.

Regarding inequality (measured by Gini_ce), although statistically significant for both groups, its impact was stronger in Non-Cohesion countries. However, this variable exerted distinct effects across the two groups: negative for Cohesion countries and positive for Non-Cohesion countries. For Cohesion countries, higher inequality was associated with lower SDG_IS values, which is consistent with the theoretical expectation and corroborates the literature identifying inequality as an obstacle to sustainable development (Pickett and Wilkinson 2015; Stiglitz 2012), as it restricts access to resources, weakens social cohesion, and reduces the effectiveness of public policy.

The positive association between income inequality and SDG_IS in Non-Cohesion countries appears counterintuitive and warrants careful interpretation. This result cannot be interpreted as evidence that inequality is beneficial for sustainable development in the Non-Cohesion countries. It is difficult to interpret this finding unambiguously with the available data and estimation strategy, as it likely reflects a combination of structural, compositional, and methodological factors that cannot be fully disentangled in the present analysis. The most theoretically grounded interpretation is that, in advanced economies, the relationship between inequality and sustainability outcomes is mediated by institutional quality. Farag (2025) argues that the link between inequality and progress on the SDGs depends crucially on institutional capacity. Where welfare institutions and redistributive systems are well developed (as is generally the case in Non-Cohesion countries) moderate income inequality can coexist with strong SDG performance, without inequality itself being the direct driver of that performance. In this reading, the positive coefficient does not capture a causal effect of inequality on sustainability but rather reflects the institutional capacity of these countries to sustain high SDG performance despite (not because of) unequal income distributions. This interpretation is consistent with Fhima et al. (2023), who found regime-specific and context-dependent effects of governance variables on sustainable development.

A second, more speculative interpretation relates to the composition of inequality in advanced economies. The Gini coefficient measures income dispersion but does not distinguish between inequality driven by low-end poverty, which is more directly damaging to sustainability outcomes, and inequality driven by high-end concentration in innovation-intensive, high-productivity sectors. In the latter case, income dispersion may partly reflect structural features of knowledge economies that simultaneously generate unequal income distributions and support high levels of institutional and technological capacity. However, this interpretation remains speculative in the absence of decomposed inequality data.

Finally, reverse causality cannot be ruled out, as these countries may have adopted ambitious sustainability policies (e.g., carbon taxes and green transitions) that may lead to a temporary increase in inequality during transitional periods, as the costs and benefits of these transitions are unevenly distributed across income groups, as documented by Hou et al. (2024) for the carbon-inequality nexus. This possibility is consistent with the endogeneity caveat discussed in Section 4 and further underscores the need for caution in interpreting this result. Taken together, these considerations suggest that the positive association between inequality and SDG_IS in Non-Cohesion countries should not be interpreted as a robust causal finding but as a context-specific result reflecting the complex, institution-mediated relationship between distributive outcomes and sustainability performance in advanced European economies.

CPI exerted a positive and statistically significant effect on SDG_IS attainment in both country groups, with a stronger impact in Cohesion countries, highlighting the importance of institutional transparency and quality for implementing the 2030 Agenda (Sachs et al. 2019).

The coefficients of LExpBrth and GII were not statistically significant across the two groups, suggesting that these dimensions did not yet translate into consistent gains in SDG_IS attainment. A possible explanation relates to the relatively high and homogeneous levels of life expectancy across EU member states. This limited cross-country variation reduces the statistical explanatory power of the variable in regression models, even though health outcomes remain an important component of sustainable development. The non-significance of GII contrasted with Szántó and Neumanné Virág (2025), who found a strong relationship between innovation and SDGs achievements in Western and Northern EU countries, but was consistent with Schultz et al. (2024). The lack of statistical significance of GII may reflect the indirect and long-term nature of innovation effects on sustainable development outcomes. Innovation often influences sustainability through technological diffusion, productivity gains, and environmental efficiency improvements, processes that typically unfold over longer time horizons than those captured in the present dataset.

To facilitate a visual comparison between Cohesion and Non-Cohesion countries, Figure 3 presents the estimated coefficients and 95% confidence intervals, highlighting differences in the drivers of sustainable development between the two groups. The findings indicated that they exerted a positive influence on sustainable development in both groups. However, the statistical significance and magnitude of this relationship were more pronounced in Cohesion countries, suggesting that economic growth may no longer have directly translated into progress toward the SDGs in Non-Cohesion countries. This pattern is more consistent with diminishing marginal returns of economic growth for SDG attainment in more advanced economies than with direct evidence that GDP growth compromises sustainability performance.

Overall, the panel regression results highlight the importance of economic, institutional, and social determinants of sustainable development in the EU. However, the results also reveal important structural differences between Cohesion and Non-Cohesion countries. In particular, economic growth appears to remain a key driver of SDG performance in less developed contexts, while its influence becomes weaker in more advanced economies. These findings are broadly consistent with previous empirical studies suggesting that the determinants of sustainable development evolve as countries reach higher levels of economic development, with institutional quality and social factors becoming increasingly relevant (Sachs et al. 2019; Tu et al. 2023).

3.3 | Pooled Fuzzy-Set Qualitative Comparative Analysis (fsQCA)

While the panel data model allows estimation of the mean effect of each explanatory variable on the dependent variable, fsQCA provides a deeper understanding of causal complexity. Specifically, it allowed us to analyze how different combinations of conditions interacted to produce higher levels of SDG_IS attainment. This approach addressed causal complexity by recognizing that multiple pathways (equifinality) may lead to the same outcome, and that conditions may have conjunctural effects rather than operating independently. The data were calibrated according to the procedures described in Section 2.2.2.

The first analysis performed was the assessment of the necessary conditions, as presented in Table A6. The results revealed that no single condition was strictly necessary to achieve high levels

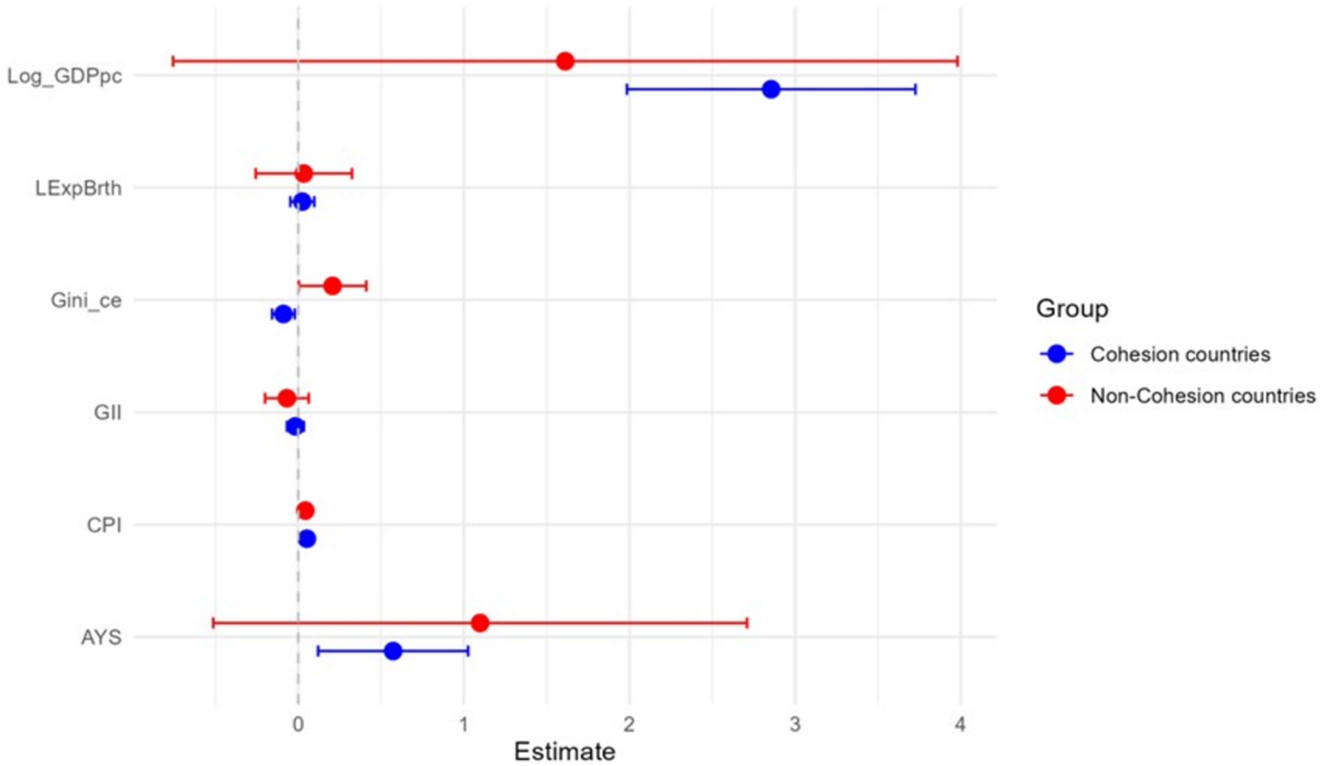


FIGURE 3 | Estimated coefficients for cohesion and non-cohesion countries.

of the outcome (SDG_IS) in both Cohesion and Non-Cohesion countries. As a robustness check, a similar analysis was performed using the absence of SDG_IS as the outcome (Table A7), since a condition may be considered necessary for both the presence and the absence of the outcome. The results of both models were consistent.

Sufficient conditions were subsequently assessed, and the intermediate solutions for both groups are presented in Table 4. In fsQCA, directional expectations guided the intermediate solution by specifying theoretically whether a condition's presence or absence should contribute to the outcome (Fiss 2011; C. Ragin 2008). In our case, the intermediate and parsimonious solutions were identical, indicating that all identified conditions were core conditions with strong empirical consistency and that no peripheral conditions emerged. This suggests that the results reflected robust empirical patterns that were not dependent on theoretical assumptions (Schneider and Wagemann 2012).

For Cohesion countries (Panel A), economic growth, measured by, was, as revealed by conditions C2, C4, and C5, the main determinant of SDG_IS attainment. Notably, under conditions C4 (counterintuitive) and C5, even in the absence of lower perceived corruption or high life expectancy at birth, higher economic growth appeared to compensate for these factors, leading to SDG_IS attainment and suggesting a compensatory effect of material wealth in these countries. Condition C2 represented the classic combination of wealth and human capital, confirming modernization theory, which posits that as societies develop economically, corresponding improvements in social and political structures, including education, occur.

Alternatively, SDGs can be achieved through social cohesion (C1), driven by low inequality, or through investment in education (C2 and C3), which offset weaker health outcomes in C3. This suggests that low inequality alone can be sufficient to achieve high SDG_IS performance and highlights its strong link with the outcome variable. This finding aligns with Pickett and Wilkinson (2015), who reported empirical evidence that reducing inequality enhances social cohesion and enables more inclusive development. Globally, the model accounted for approximately 93% of cases and achieved an overall solution consistency of 0.6758, indicating substantial explanatory power (C. Ragin 2008) and equifinality.

For Non-Cohesion countries (Panel B), GDPpc growth lost prominence. In these countries, SDG_IS attainment is supported by two configurations. The first combines lower inequality with high institutional transparency, reflecting a typical model of sustainable development associated with the most advanced EU economies and aligned with Sachs et al. (2019), who argue that, in more developed contexts, institutional quality and distributive justice become paramount for sustainable development.

The second configuration combines higher levels of innovation alongside lower GDPpc, suggesting that SDG_IS attainment is driven by high innovation capacity. This finding highlights the importance of innovation in post-industrial economies (Omri 2020). Notably, the presence of a lower GDPpc in this pathway suggests that innovation may act as a substitute for, rather than a complement to, aggregate wealth, potentially reflecting economies in which knowledge-intensive specialization translates technological gains into broad sustainability outcomes across multiple SDG dimensions.

TABLE 4 | fsQCA results for the intermediate solution.

Outcome: SDG_IS					
Panel A: cohesion countries					
Conditions	**C1**	**C2**	**C3**	**C4**	**C5**
$log(GDP_{pc})\_fz$		●		●	●
AYS_fz		●	●		
CPI_fz				⊗	
Gini_ce_fz	⊗				
LExpBrth_fz			⊗		⊗
GII_fz					
Consistency	0.7619	0.7948	0.7855	0.8188	0.7334
Raw coverage	0.8069	0.4505	0.4443	0.5914	0.5062
Unique coverage	0.1115	0.0042	0.0016	0.0106	0.0474
Overall solution consistency			0.6758		
Overall solution coverage			0.9298		
Panel B: non-cohesion countries					
Conditions	**C1**	**C2**			
$log(GDP_{pc})\_fz$		⊗			
AYS_fz					
CPI_fz	●				
Gini_ce_fz	⊗				
LExpBrth_fz					
GII_fz		●			
Consistency	0.7426	0.7585			
Raw coverage	0.4798	0.5989			
Unique coverage	0.1521	0.2712			
Overall solution consistency			0.7203		
Overall solution coverage			0.7510		

Note: Cutoff sufficiency = 0.80; Solid circles (●) indicate the presence of a condition, and crossed circles (⊗) indicate its absence. All circles are of equal size, meaning that all identified conditions are core conditions (the intermediate solution coincides with the parsimonious solution). Blank cells indicate "don't care".

Globally, the model accounted for approximately 75% of cases, with lower overall coverage in Non-Cohesion countries, suggesting greater causal heterogeneity in this group, which may reflect greater institutional and policy diversity among wealthier EU member states. The simpler solution structure in Non-Cohesion countries, compared with Cohesion countries (two pathways vs. five pathways), suggests that as countries develop, pathways to sustainable development become more constrained.

Taken together, the results obtained from the panel data models and the fsQCA analysis provide complementary and mutually reinforcing insights into the determinants of sustainable development in the EU. While the panel regression models identify the average net effects of individual variables, the fsQCA results add a configurational layer to these findings and reveal that sustainable development outcomes emerge from different combinations of economic, institutional, and social conditions. In other words, the same level of SDG_IS can be achieved through qualitatively different combinations of conditions, none of which would be detectable by examining variable effects in isolation. Furthermore, the fsQCA results align with the panel data model findings by showing that the variables that yield high SDG_IS do so only when combined with specific supporting conditions. This evidence underscores not only the stage-dependent but also the configurational nature of sustainable development pathways across the EU. Moreover, these findings are consistent with previous studies emphasizing the multidimensional and context-dependent nature of sustainable development. For example, Tu et al. (2023) highlight the role of governance and social factors in shaping sustainability outcomes in the EU, while Szántó and Neumanné Virág (2025) show that innovation contributes differently to SDG performance depending on countries' development levels. Overall, the results reinforce the idea that sustainable development pathways are heterogeneous and that different configurations of determinants may lead to similar sustainability outcomes across European countries.

4 | Conclusion

This study examined the determinants of sustainable development across the 27 EU countries by combining two complementary analytical approaches: panel data regression models and fsQCA. By distinguishing between Cohesion and Non-Cohesion countries, the study provides new insights into how structural differences and development stages shape the drivers of progress toward the SDGs.

The empirical results reveal that sustainable development trajectories within the EU are heterogeneous and cannot be explained by a single set of determinants. Panel data models show that economic growth remains a statistically significant driver of SDG performance, but its influence becomes weaker in Non-Cohesion countries. At the same time, institutional transparency and inequality dynamics emerge as relevant determinants in both contexts. The fsQCA analysis complements these findings by identifying multiple causal pathways leading to high SDG performance. In particular, five different configurations were identified for Cohesion countries and two for Non-Cohesion countries, confirming the presence of equifinality in sustainable development processes. These results highlight that similar levels of sustainability performance can be achieved through distinct combinations of economic, institutional, and social conditions.

4.1 | Theoretical and Policy Implications

Taken together, the results suggest that the determinants of sustainable development evolve as countries advance economically. In earlier stages of development, material factors such as economic growth and investments in human capital appear to play a stronger role in enabling progress toward the SDGs. In more advanced economies, however, institutional quality, social cohesion, and innovation capacity appear to become increasingly relevant drivers of sustainable development performance. In this regard, the results have implications that extend beyond the EU context, because they suggest that the pursuit of sustainable development cannot be governed by a single set of determinants and that policies designed around universal drivers risk being ineffective or even counterproductive in contexts where those drivers no longer operate as expected. Thus, our findings provide empirical grounding for a broader theoretical argument: as countries develop, the mechanisms through which progress toward the SDGs is achieved undergo a qualitative shift, consistent with the joint predictions of the EKC hypothesis and modernization theory. This shift is not merely a statistical finding but a structural feature of the EU's development landscape that should inform how both scholars and policymakers conceptualize the relationship between development and sustainability.

Our findings have concrete and differentiated implications for EU policy design, highlighting that EU cohesion policy may benefit from moving beyond a "one-size-fits-all" approach toward more differentiated strategies aligned with countries' development stages. In Cohesion countries, where economic growth and human capital emerge as the dominant drivers of SDG performance, cohesion policy investments should prioritize growth-enabling policies alongside education and skills development. However, it is important to note that the fsQCA results reveal equifinality within this group, with some countries achieving high SDG performance through social cohesion pathways, while others achieve it through growth-led pathways. This suggests that redistributive instruments, particularly those targeting inequality reduction, should remain an integral part of the policy mix rather than being treated as secondary to growth objectives. For Non-Cohesion countries, the two fsQCA configurations highlight distinct policy priorities. Countries for which combined institutional transparency and low inequality (C1) was identified as the relevant pathway should focus on maintaining the redistributive and governance frameworks that underpin this pathway, such as progressive fiscal systems, strong public institutions, and anti-corruption enforcement. Countries for which the higher SDG performance is driven by innovation should ensure that EU research and innovation instruments (e.g., Horizon Europe) are explicitly connected to the SDGs and evaluated against sustainability outcomes rather than solely economic competitiveness metrics.

Finally, our findings underscore the need to condition the Structural and Cohesion Fund allocations not only on income thresholds but also on the empirically identified determinants of SDG performance relevant to each country group. For organizations and sustainability managers, the core implication is that no single sustainability strategy is universally sufficient across the EU, meaning that approaches must be tailored to each country's institutional and developmental context, with growth-aligned strategies being more relevant in Cohesion contexts and governance- and innovation-driven strategies being more relevant in Non-Cohesion contexts.

4.2 | Limitations and Future Research

Despite its contributions, this study presents several limitations that should be acknowledged. First, the analysis relies on the SDG_IS as an aggregate indicator of sustainable development. Although widely used, this index may mask important trade-offs and synergies between specific SDGs. Second, while each explanatory variable was selected for its theoretical grounding in the EKC hypothesis, modernization theory, or the smart specialization framework, measurement limitations should be acknowledged: (i) CPI measures perceptions of corruption rather than objective institutional quality, which may introduce sensitivity to survey methodology and potential measurement error; (ii) the Gini coefficient captures income dispersion but does not distinguish between inequality driven by low-end poverty and inequality driven by high-end concentration in productive sectors. Furthermore, it does not capture wealth inequality or multidimensional deprivation, limitations that may partly explain the counterintuitive result observed in Non-Cohesion countries; (iii) GII is also, like SDG_IS, a composite index. In this regard, its components may not be equally relevant across development stages, and the scores may reflect structural features (e.g., country size and economic specialization) beyond pure innovation capacity; and (iv) LExpBrth exhibits relatively limited cross-country variation within the EU sample, which may reduce its statistical explanatory power in regression models despite its theoretical relevance as a proxy for healthcare quality and living standards. Third, while the combination of panel data models and fsQCA enhances analytical depth, neither approach can fully address the issue of causal direction. Fourth, grouping countries by Cohesion and Non-Cohesion, although policy-relevant, may still mask important within-group heterogeneity, particularly in the Cohesion group, which includes both Southern European countries (Greece, Portugal) and Eastern European countries (Poland, Czechia) with distinct development trajectories. Fifth, the potential endogeneity arising from reverse causality between SDG_IS and some explanatory variables, particularly GDPpc and CPI, cannot be excluded. While the composite nature of SDG_IS may help attenuate the risk of short-run reverse causality, future research could employ instrumental-variables or system-GMM approaches (noting that the latter performs best when N substantially exceeds T) to provide a more direct test of causal direction. Finally, the 12-year panel is sufficient for cross-sectional variation analysis but constrains long-run dynamic analysis.

Future research could extend this analysis in several directions. For example, examining sustainable development drivers at the regional level (e.g., NUTS 2 regions) could provide additional insights into intra-country disparities in SDG performance. Moreover, further research could investigate the role of additional institutional and environmental variables in shaping sustainability outcomes. Finally, disaggregating the SDG index into specific goals could help identify potential trade-offs and synergies between economic growth, environmental sustainability, and social development across different European contexts.

Author Contributions

Dora Almeida: conceptualization, writing – original draft, methodology, visualization, data curation, investigation, funding acquisition. **Andreia Dionísio:** investigation, writing – original draft, writing – review and editing, validation, methodology, supervision, funding acquisition. **Paulo Ferreira:** supervision, formal analysis, writing – review and editing. **Joanna A. Kamińska:** investigation, writing – review and editing, visualization, supervision.

Acknowledgments

Andreia Dionísio acknowledges financial support from FCT—Fundação para a Ciência e a Tecnologia, I.P., under the framework of UIDB/04007—CEFAGE. Dora Almeida and Paulo Ferreira acknowledge financial support from Fundação para a Ciência e a Tecnologia (grant UID/05064/2025). Dora Almeida also acknowledges support from European Social Fund Plus (grant ALT2030-FSE+-01459600, Alentejo 2030).

Funding

This work was supported by European Social Fund Plus, Alentejo 2030, ALT2030-FSE+-01459600. Fundação para a Ciência e a Tecnologia, UID/05064/2025 and UIDB/04007—CEFAGE.

Endnotes

[1]By considering, the relationships were linearized, heteroscedasticity was reduced, the capacity to handle skewness was improved, and the robustness and interpretability of the panel data regression models were enhanced (Chen et al. 2025; Karaçuha et al. 2020; Orekhov et al. 2020).

References

Ament, J. M., R. Freeman, C. Carbone, A. Vassall, and C. Watts. 2020. "An Empirical Analysis of Synergies and Tradeoffs Between Sustainable Development Goals." *Sustainability* 12, no. 20: 8424. https://doi.org/10.3390/su12208424.

Arellano, M. 1987. "Practioners' Corner: Computing Robust Standard Errors for Within-Groups Estimators." *Oxford Bulletin of Economics and Statistics* 49, no. 4: 431–434. https://doi.org/10.1111/j.1468-0084.1987.mp49004006.x.

Baltagi, B. H. 2005. *Econometric Analysis of Panel Data*. 3rd ed. John Wiley & Sons.

Barberà-Mariné, M.-G., L. Fabregat-Aibar, V. Ferreira, and A. Terceño. 2024. "One Step Away From 2030: An Assessment of the Progress of Sustainable Development Goals (SDGs) in the European Union." *European Journal of Development Research* 36, no. 6: 1372–1397. https://doi.org/10.1057/s41287-024-00641-0.

Breusch, T. S. 1978. "Testing for Autocorrelation in Dynamic Linear Models." *Australian Economic Papers* 17, no. 31: 334–355. https://doi.org/10.1111/j.1467-8454.1978.tb00635.x.

Breusch, T. S., and A. R. Pagan. 1980. "The Lagrange Multiplier Test and Its Applications to Model Specification in Econometrics." *Review of Economic Studies* 47, no. 1: 239. https://doi.org/10.2307/2297111.

Budanov, K., V. Vereshchak, V. Kudriavtsev, S. Mokliak, and K. Rubel. 2025. "Peace and Development: A Strategy for Global Engagement." *Revista de Cercetare Si Interventie Sociala* 89: 48–60. https://doi.org/10.33788/rcis.89.3.

Casas, P., T. Christou, A. García-Rodríguez, N. J. Lazarou, S. Salotti, and I. Stamos. 2025. "European Cohesion Policy and Sustainable Development Goals 1, 8 and 10." *Annals of Regional Science* 74, no. 4: 99. https://doi.org/10.1007/s00168-025-01421-2.

Chen, X.-S., M. G. Kim, C.-H. Lin, and H. J. Na. 2025. "Development of Per Capita GDP Forecasting Model Using Deep Learning: Including Consumer Goods Index and Unemployment Rate." *Sustainability* 17, no. 3: 843. https://doi.org/10.3390/su17030843.

Chen, Z., Y. Ma, J. Hua, Y. Wang, and H. Guo. 2021. "Impacts From Economic Development and Environmental Factors on Life Expectancy: A Comparative Study Based on Data From Both Developed and Developing Countries From 2004 to 2016." *International Journal of Environmental Research and Public Health* 18, no. 16: 8559. https://doi.org/10.3390/ijerph18168559.

Dědeček, R., and V. Dudzich. 2022a. "Causes of Limitations of GDP Per Capita as an Indicator of Economic Development." In *Regulation of Finance and Accounting. ACFA ACFA 2021 2020. Springer Proceedings in Business and Economics*, edited by D. Procházka. Springer. https://doi.org/10.1007/978-3-030-99873-8_4.

Dědeček, R., and V. Dudzich. 2022b. "Exploring the Limitations of GDP Per Capita as an Indicator of Economic Development: A Cross-Country Perspective." *Review of Economic Perspectives* 22, no. 3: 193–217. https://doi.org/10.2478/revecp-2022-0009.

Dhar, B. K., J. Shaturaev, K. Kurbonov, and R. Nazirjon. 2023. "The Causal Nexus Between Innovation and Economic Growth: An OECD Study." *Social Science Quarterly* 104, no. 4: 395–405. https://doi.org/10.1111/ssqu.13261.

Diaz-Sarachaga, J. M., D. Jato-Espino, and D. Castro-Fresno. 2018. "Is the Sustainable Development Goals (SDG) Index an Adequate Framework to Measure the Progress of the 2030 Agenda?" *Sustainable Development* 26, no. 6: 663–671. https://doi.org/10.1002/sd.1735.

Dickey, D. A., and W. A. Fuller. 1979. "Distribution of the Estimators for Autoregressive Time Series With a Unit Root." *Journal of the American Statistical Association* 74, no. 366: 427. https://doi.org/10.2307/2286348.

Elkhaldi, A. H., and A. Mongi. 2025. "Financial Inclusion Towards Sustainability in MENA Countries: The Moderating Role of Financial Institution Efficiency Using Panel Quantile Regression." *Review of Accounting and Finance* 74, no. 366: 427–431. https://doi.org/10.1108/RAF-11-2024-0489.

Erjavec, E. 2020. "Reinforcement of Social Sustainability through Education and Public Intangible Capital." In *In Challenges on the Path Toward Sustainability in Europe: Social Responsibility and Circular Economy Perspectives*, edited by V. Žabkar and T. Redek. Emerald Publishing Limited. https://doi.org/10.1108/978-1-80043-972-620201014.

European Commission. 2021. "Commission Implementing Decision (EU) 2021/1130 of 5 July 2021 Setting Out the List of Regions Eligible for Funding From the European Regional Development Fund and the European Social Fund Plus and of Member States Eligible for Funding From the Cohesion Fund for the Period 2021–2027 (Notified Under Document C(2021) 4894)." *Official Journal of the European Union L* 244: 10–20. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32021D1130.

Farag, M. I. H. 2025. "Bridging Inequality: Contemporary Challenges to Achieve Sustainable Development Goals Across and Within Nations." *International Journal of Sustainable Development Goals* 1: 333–352. https://doi.org/10.59543/ijsdg.v1i.16131.

Fhima, F., R. Nouira, and K. Sekkat. 2023. "How Does Corruption Affect Sustainable Development? A Threshold Non-Linear Analysis." *Economic Analysis and Policy* 78: 505–523. https://doi.org/10.1016/j.eap.2023.03.020.

Firoiu, D., G. H. Ionescu, L. M. Cismaș, L. Vochița, T. M. Cojocaru, and R.-Ú. Bratu. 2023. "Can Europe Reach Its Environmental Sustainability Targets by 2030? A Critical Mid-Term Assessment of the Implementation of the 2030 Agenda." *Sustainability* 15, no. 24: 16650. https://doi.org/10.3390/su152416650.

Fiss, P. C. 2011. "Building Better Causal Theories: A Fuzzy Set Approach to Typologies in Organization Research." *Academy of Management Journal* 54, no. 2: 393–420. https://doi.org/10.5465/amj.2011.60263120.

Garashchuk, A., F. I. Castillo, and P. P. Rivera. 2023. "Economic Cohesion and Development of the European Union's Regions and Member States - A Methodological Proposal to Measure and Identify the Degree of Regional Economic Cohesion." *Socio-Economic Planning Sciences* 88: 101621. https://doi.org/10.1016/j.seps.2023.101621.

Georgeson, L., and M. Maslin. 2018. "Putting the United Nations Sustainable Development Goals Into Practice: A Review of Implementation, Monitoring, and Finance." *Geo: Geography and Environment* 5, no. 1: e00049. https://doi.org/10.1002/geo2.49.

Godfrey, L. G. 1978. "Testing Against General Autoregressive and Moving Average Error Models When the Regressors Include Lagged Dependent Variables." *Econometrica* 46, no. 6: 1293. https://doi.org/10.2307/1913829.

Greene, W. H. 2018. *Econometric Analysis*. 8th ed. Pearson.

Groner, T., and A. Moradi. 2024. "Sacrificing Sustainability for a Higher GDP Growth Rate." *Development and Sustainability in Economics and Finance* 2–4: 100015. https://doi.org/10.1016/j.dsef.2024.100015.

Grossman, G., and A. Krueger. 1995. "Economic Growth and the Environment." *Quarterly Journal of Economics* 110, no. 2: 353–377. https://doi.org/10.2307/2118443.

Hair, J. F., Jr., W. C. Black, B. J. Babin, and R. E. Anderson. 2019. *Multivariate Data Analysis*. 8th ed. Cengage Learning EMEA.

Harris, R. D. F., and E. Tzavalis. 1999. "Inference for Unit Roots in Dynamic Panels Where the Time Dimension Is Fixed." *Journal of Econometrics* 91, no. 2: 201–226. https://doi.org/10.1016/S0304-4076(98)00076-1.

Hausman, J. A. 1978. "Specification Tests in Econometrics." *Econometrica* 46, no. 6: 1251–1271. https://doi.org/10.2307/1913827.

Hoechle, D. 2007. "Robust Standard Errors for Panel Regressions With Cross-Sectional Dependence." *Stata Journal* 7, no. 3: 281–312. https://doi.org/10.1177/1536867X0700700301.

Homer, J. 2025. "Beyond the Preston Curve: Analyzing Variations in Life Expectancy Around the World Using Multivariate Regression Circa 2000 and 2015." *System* 13, no. 7: 577. https://doi.org/10.3390/systems13070577.

Hope, K. R. 2020. "Corruption Reduction as a Target of the Sustainable Development Goals: Applying Indicators and Policy Frameworks." In *The Emerald Handbook of Crime, Justice and Sustainable Development*, edited by J. Blaustein, K. Fitz-Gibbon, and N. W. Pino. R. White. Emerald Publishing Limited. https://doi.org/10.1108/978-1-78769-355-520201009.

Hope, K. R., Sr. 2022. "Reducing Corruption and Bribery in Africa as a Target of the Sustainable Development Goals: Applying Indicators for Assessing Performance." *Journal of Money Laundering Control* 25, no. 2: 313–329. https://doi.org/10.1108/JMLC-03-2021-0018.

Hou, A., A. Liu, and L. Chai. 2024. "Does Reducing Income Inequality Promote the Decoupling of Economic Growth From Carbon Footprint?" *World Development* 173: 106423. https://doi.org/10.1016/j.worlddev.2023.106423.

Hsiao, C. 2022. *Analysis of Panel Data Fourth*. 4th ed. Cambridge University Press.

Huarng, K.-H., and T. H.-K. Yu. 2022. "Analysis of Global Innovation Index by Structural Qualitative Association." *Technological Forecasting and Social Change* 182: 121850. https://doi.org/10.1016/j.techfore.2022.121850.

Hui, H. 2022. "The Influence Mechanism of Education on Health From the Sustainable Development Perspective." *Journal of Environmental and Public Health* 2022: 7134981. https://doi.org/10.1155/2022/7134981.

Hussain, H. I., F. Kamarudin, N. A. M. Anwar, M. Ali, J. J. Turner, and S. A. Somasundram. 2023. "Does Income Inequality Influence the Role of a Sharing Economy in Promoting Sustainable Economic Growth? Fresh Evidence From Emerging Markets." *Journal of Innovation & Knowledge* 8, no. 2: 100348. https://doi.org/10.1016/j.jik.2023.100348.

Inglehart, R., and C. Welzel. 2005. "Modernization, Cultural Change, and Democracy: The Human Development Sequence." *Cambridge University Press*. https://doi.org/10.1017/CBO9780511790881.

Jabbari, M., M. Shafiepour Motlagh, K. Ashrafi, and G. Abdoli. 2020. "Differentiating Countries Based on the Sustainable Development Proximities Using the SDG Indicators." *Environment, Development and Sustainability* 22, no. 7: 6405–6423. https://doi.org/10.1007/s10668-019-00489-z.

Kanojia, S., N. Kapoor, M. Chhabra, and P. Sethi. 2025. "Regional Disparities and International Spillover in Achieving the Sustainable Development Goals (SDGs) Across the Globe." *Discover Sustainability* 6, no. 1: 993. https://doi.org/10.1007/s43621-025-01898-z.

Karaçuha, E., V. Tabatadze, K. Karaçuha, N. O. Önal, and E. Ergün. 2020. "Deep Assessment Methodology Using Fractional Calculus on Mathematical Modeling and Prediction of Gross Domestic Product Per Capita of Countries." *Mathematics* 8, no. 4: 633. https://doi.org/10.3390/math8040633.

Khan, M. U., B. A. Shah, and U. Ullah. 2026. "The Heterogeneous Role of Globalization on SDG 10: The Moderating Effect of Institutional Quality and Mediating Role of Green Growth in Developing Countries." *Sustainable Development* 1–24. https://doi.org/10.1002/sd.70916.

Kuznets, S. 1955. "Economic Growth and Income Inequality." *American Economic Review* 45, no. 1: 1–28.

Leung, C. K., J. Ko, F. Liang, and W. K. Ming. 2025. "Economic Inequality and Corruption as Social Determinants of Health: An Empirical Analysis Across 136 Countries (2001–2020)." *Social Sciences and Humanities Open* 12: 101686. https://doi.org/10.1016/j.ssaho.2025.101686.

Maddala, G. S., and S. Wu. 1999. "A Comparative Study of Unit Root Tests With Panel Data and a New Simple Test." *Oxford Bulletin of Economics and Statistics* 61, no. S1: 631–652. https://doi.org/10.1111/1468-0084.0610s1631.

Mai, S., L. Qing, U. Mehmood, A. A. Almulhim, and A. A. Aljughaiman. 2025. "From Digital Advancement to SDGs Disruption: How Artificial Intelligence Without Inclusion Threatens Sustainable Development in G7 Economies." *Journal of Environmental Management* 394: 127411. https://doi.org/10.1016/j.jenvman.2025.127411.

Massuga, F., M. A. Larson, M. R. Kuhl, and S. L. D. Doliveira. 2023. "The Influence of Global Governance on the Sustainable Performance of Countries." *Environment, Development and Sustainability* 26, no. 11: 28567–28589. https://doi.org/10.1007/s10668-023-03827-4.

McCann, P., and R. Ortega-Argilés. 2015. "Smart Specialization, Regional Growth and Applications to European Union Cohesion Policy." *Regional Studies* 49, no. 8: 1291–1302. https://doi.org/10.1080/00343404.2013.799769.

Meilland, A., and F. Lecocq. 2024. "Mapping National Development Priorities Under the Sustainable Development Goals Framework: A Systematic Analysis." *Sustainability Science* 19, no. 1: 75–88. https://doi.org/10.1007/s11625-023-01377-2.

Meuer, J., and C. Rupietta. 2017. "A Review of Integrated QCA and Statistical Analyses." *Quality & Quantity* 51, no. 5: 2063–2083. https://doi.org/10.1007/s11135-016-0397-z.

Mombeuil, C., and H. P. Diunugala. 2021. "UN Sustainable Development Goals, Good Governance, and Corruption: The Paradox of the World's Poorest Economies." *Business and Society Review* 126, no. 3: 311–338. https://doi.org/10.1111/basr.12241.

O'Brien, R. M. 2007. "A Caution Regarding Rules of Thumb for Variance Inflation Factors." *Quality & Quantity* 41, no. 5: 673–690. https://doi.org/10.1007/s11135-006-9018-6.

Omri, A. 2020. "Technological Innovation and Sustainable Development: Does the Stage of Development Matter?" *Environmental Impact Assessment Review* 83: 106398. https://doi.org/10.1016/j.eiar.2020.106398.

Orekhov, V. D., O. S. Prichina, A. S. Gizyatova, A. V. Blinnikova, and O. G. Kukharenko. 2020. "Development of the Indicative System for Assessing GDP Per Capita Using Cumulative Indices, Including Human Capital." *Journal of Advanced Research in Dynamical and Control Systems* 12: 1139–1152. https://doi.org/10.5373/JARDCS/V12SP5/20201867.

Ortega, B., A. Casquero, and J. Sanjuán. 2016. "Corruption and Convergence in Human Development: Evidence From 69 Countries During 1990–2012." *Social Indicators Research* 127, no. 2: 691–719. https://doi.org/10.1007/s11205-015-0968-8.

Pappas, I. O., and A. G. Woodside. 2021. "Fuzzy-Set Qualitative Comparative Analysis (fsQCA): Guidelines for Research Practice in Information Systems and Marketing." *International Journal of Information Management* 58: 102310. https://doi.org/10.1016/j.ijinfomgt.2021.102310.

Pesaran, M. H. 2004. "General Diagnostic Tests for Cross Section Dependences in Panels." *CESIFO* 1229: 40. https://www.CESifo.de.

Pickett, K. E., and R. G. Wilkinson. 2015. "Income Inequality and Health: A Causal Review." *Social Science & Medicine* 128: 316–326. https://doi.org/10.1016/j.socscimed.2014.12.031.

Pîrvu, R., C. Drăgan, G. Axinte, S. Dinulescu, M. Lupăncescu, and A. Găină. 2019. "The Impact of the Implementation of Cohesion Policy on the Sustainable Development of EU Countries." *Sustainability* 11, no. 15: 4173. https://doi.org/10.3390/su11154173.

Qazi, A. 2025. "Risk Forecasting for Shortfalls in Achieving Sustainable Development Goals: A Corruption Perspective." *Journal of Safety Science and Resilience* 6, no. 2: 237–249. https://doi.org/10.1016/j.jnlssr.2024.10.003.

Ragin, C. 2008. *Redesigning Social Inquiry Fuzzy Sets and Beyond*. University of Chicago Press.

Ragin, C. C. 2000. *Fuzzy-Set Social Science*. University of Chicago Press.

Rana, M., M. A. Al Mamun, H. Islam, and M. K. Hossain. 2024. "Exploring the Impact of ESG Practices on Sustainable Development Goals Achievement in South Asia." *Review of Economics* 75, no. 3: 249–274. https://doi.org/10.1515/roe-2024-0053.

Rihoux, B. 2006. "Qualitative Comparative Analysis (QCA) and Related Systematic Comparative Methods." *International Sociology* 21, no. 5: 679–706. https://doi.org/10.1177/0268580906067836.

Sachs, J. D., G. Lafortune, G. Fuller, and G. Iablonovski. 2025. "Financing Sustainable Development to 2030 and Mid-Century." In *Sustainable Development Report 2025*. Dublin University Press.

Sachs, J. D., G. Schmidt-Traub, M. Mazzucato, D. Messner, N. Nakicenovic, and J. Rockström. 2019. "Six Transformations to Achieve the Sustainable Development Goals." *Nature Sustainability* 2, no. 9: 805–814. https://doi.org/10.1038/s41893-019-0352-9.

Schneider, C. Q., and C. Wagemann. 2012. *Set-Theoretic Methods for the Social Sciences: A Guide to Qualitative Comparative Analysis*. Cambridge University Press.

Schultz, F. C., V. Czyrnik, and I. Pies. 2024. "Is There a Case for or Against Patents to Incentivize Green Technologies?: A Critical Evaluation of Innovation Incentives for the Global North and Global South." *Sustainability Nexus Forum* 32, no. 1: 20. https://doi.org/10.1007/s00550-024-00558-6.

Sempere-Ripoll, F., S. Estelles-Miguel, R. Rojas-Alvarado, and J.-L. Hervas-Oliver. 2020. "Does Technological Innovation Drive Corporate Sustainability? Empirical Evidence for the European Financial Industry in Catching-Up and Central and Eastern Europe Countries." *Sustainability* 12, no. 6: 2261. https://doi.org/10.3390/su12062261.

Shapiro, S. S., and M. B. Wilk. 1965. "An Analysis of Variance Test for Normality (Complete Samples)." *Biometrika* 52, no. 3/4: 591–611. https://doi.org/10.2307/2333709.

Stiglitz, J. E. 2012. *The Price of Inequality. How Today's Divided Society Endangers Our Future*. W. W. Norton & Company.

Szántó, B., and I. Neumanné Virág. 2025. "A Fenntartható Fejlődés és az Innováció Kapcsolatának Területi Különbségei az Európai Unióban." *Területi Statisztika* 65, no. 6: 794–824. https://doi.org/10.15196/TS650603.

Tu, Y.-X., O. Kubatko, V. Piven, B. Kovalov, and M. Kharchenko. 2023. "Promotion of Sustainable Development in the EU: Social and Economic Drivers." *Sustainability* 15, no. 9: 7503. https://doi.org/10.3390/su15097503.

Tutar, H., H. T. Mutlu, and D. Streimikiene. 2026. "Rethinking Sustainable Development: Multidimensional Comparisons Across Countries and Regions." *Sustainable Development* 34, no. S1: 183–196. https://doi.org/10.1002/sd.70157.

Vargas-Merino, J. A., C. A. Rios-Lama, and M. H. Panez-Bendezú. 2024. "Critical Implications of Education for Sustainable Development in HEIs - A Systematic Review Through the Lens of the Business Science Literature." *International Journal of Management Education* 22, no. 1: 100904. https://doi.org/10.1016/j.ijme.2023.100904.

Wagemann, C., and C. Q. Schneider. 2010. "Qualitative Comparative Analysis (QCA) and Fuzzy-Sets: Agenda for a Research Approach and a Data Analysis Technique." *Comparative Sociology* 9, no. 3: 376–396. https://doi.org/10.1163/156913210X12493538729838.

Wang, B., and T. Chen. 2024. "What Do the Sustainable Development Goals Reveal, and Are They Sufficient for Sustainable Development?" *PLoS One* 19, no. 11: e0310089. https://doi.org/10.1371/journal.pone.0310089.

Wooldridge, J. M. 2010. *Econometric Analysis of Cross Section and Panel Data*. 2nd ed. MIT Press.

Yang, Y., S.-H. Chih, and C.-R. Chiu. 2025. "Association Between the Environmental Efficiency and Corruption Perception Index: A Dynamic Alternative Metafrontier SBM Approach." *Journal of Environmental Management* 374: 124046. https://doi.org/10.1016/j.jenvman.2025.124046.

Yu, T. H.-K., and K.-H. Huarng. 2024. "Causal Analysis of SDG Achievements." *Technological Forecasting and Social Change* 198: 122977. https://doi.org/10.1016/j.techfore.2023.122977.

Yu, T. H.-K., K.-H. Huarng, and D.-H. Huang. 2021. "Causal Complexity Analysis of the Global Innovation Index." *Journal of Business Research* 137: 39–45. https://doi.org/10.1016/j.jbusres.2021.08.013.

Yu, T. H.-K., K.-H. Huarng, and Y. T. Lai. 2021. "Configural Analysis of Innovation for Exploring Economic Growth." *Technological Forecasting and Social Change* 172: 121019. https://doi.org/10.1016/j.techfore.2021.121019.

Appendix A

TABLE A1 | Data description.

Variable	Code	Description	Source
Sustainable Development Goal Index score	SDG_IS	The SDG Index provides an annual assessment of SDG progress covering all 193 UN member states. Although every UN member state has a country profile, only those with less than 20% missing data receive an SDG Index score (SDG_IS) and ranking. The SDG_IS is presented on a 0–100 scale and can be interpreted as a percentage of optimal performance on the SDGs. Therefore, the difference between 100 and a country's SDG_IS represents the percentage-point gap that must be closed to achieve optimal SDG performance. Higher SDG_IS values correspond to better SDG performance.	Sustainable Development Report—https://dashboards.sdgindex.org/explorer/ See Sachs et al. (2025)
GDP per capita	GDPpc	Gross domestic product (GDP) represents the value of goods and services produced within an economic territory during a given accounting period. The indicator is divided by the total population to obtain a per capita estimate. This indicator is expressed in current international dollars, converted using purchasing power parities (PPPs), meaning that no adjustment is made to account for price changes over time. The PPP conversion factor serves as a currency conversion factor and as a spatial price deflator. PPPs convert different currencies into a common currency and, in the process, equalize their purchasing power by eliminating differences in price levels across countries, thereby enabling volume or output comparisons of GDP and its expenditure components.	World Bank—https://data.worldbank.org/indicator/NY.GDP.PCAP.CD
Gini index	Gini_ce	The Gini index (Gini_ce), created by Corrado Gini in 1912, measures income inequality within a population. The Gini_ce and the Gini coefficient represent the same concept, differing only in that the Gini_ce is expressed as a percentage. Thus, the Gini_ce is equal to the Gini coefficient multiplied by 100 and expressed in percentage. A value of 100% represents maximum inequality, in which case only one inhabitant receives the total wage income. Whereas a value of 0% denotes total equality in wage income distribution across all inhabitants.	Countryeconomy—https://countryeconomy.com/demography/gini-index
Corruption Perceptions Index	CPI	The Corruption Perceptions Index (CPI) is a composite index that scores and ranks countries/territories based on perceived levels of public sector corruption, as assessed by experts and business executives. It is the most widely used indicator of corruption worldwide. Scores range from 0 (highest level of perceived corruption) to 100 (lowest level of perceived corruption).	Transparency International—https://www.transparency.org/en/cpi/2024
Life expectancy at birth	LExpBrth	Life expectancy at birth is the number of years a newborn is expected to live, based on the age-specific mortality rates prevailing in the country or region at that time. It is an important indicator of quality of life in a region. A higher value indicates a longer life expectancy.	Countryeconomy—https://countryeconomy.com/demography/life-expectancy
Global Innovation Index	GII	The Global Innovation Index (GII) is structured around two sub-indices of equal importance that capture comprehensive innovation ecosystems: the Innovation Inputs Sub-Index (five core pillars representing the economic factors that foster and enable innovative activities) and the Innovation Outputs Sub-Index (two pillars). The Outputs Sub-Index maintains equal influence with the Inputs Sub-Index in determining the overall GII score, meaning that innovation output elements and indicators are weighted equally relative to innovation inputs at the sub-index level. The overall GII score is calculated as the average of the Inputs and Outputs Sub-Indices, from which the GII country rankings are produced. The GII ranges from 0 to 100, with higher values indicating greater innovation capacity.	Kaggle—https://www.kaggle.com/datasets/karlakovacs/global-innovation-index-wipo-2011-2024-data/data
Average years of schooling	AYS	AYS represents the average number of years that adults in a country have spent in formal education (it does not account for education quality or informal learning). It reflects the overall educational attainment of the population based on completed levels of schooling. It captures the extent of schooling adults have accumulated over their lifetimes, reflecting the outcomes of past investments in education systems. Thus, higher values indicate a population with stronger educational foundations.	Our World in Data—https://ourworldindata.org/grapher/average-years-of-schooling

TABLE A2 | Diagnostic tests for panel data models.

Countries	Test	Null hypothesis (H0)	Test statistic	*p*
Cohesion	Shapiro–Wilk	The data follows a normal distribution	0.9504	0.0000
	Breusch-Pagan	Homoscedasticity (constant error variance)	18.6466	0.0048
	Breusch-Pagan Lagrange Multiplier	No panel effects (pooled OLS is appropriate)	607.5952	0.0000
	Breusch-Godfrey	No serial correlation on the residuals	54.5284	0.0000
	Pesaran CD	Cross-sectional independence	4.6337	0.0000
	Hausman	Both estimators (FE and RE) are consistent, but RE is more efficient	1.8541	0.9326
Non_Cohesion	Shapiro–Wilk	The data follows a normal distribution	0.9841	0.0951
	Breusch-Pagan	Homoscedasticity (constant error variance)	22.2760	0.0011
	Breusch-Pagan Lagrange Multiplier	No panel effects (pooled OLS is appropriate)	320.7245	0.0000
	Breusch-Godfrey	No serial correlation on the residuals	64.7995	0000
	Pesaran CD	Cross-sectional independence	4.1666	0.000
	Hausman	Both estimators (FE and RE) are consistent, but RE is more efficient	4.6784	0.5857

TABLE A3 | Robustness check: regression results with Driscoll–Kraay standard errors for cohesion and non-cohesion countries.

	Explained variable: SDG_IS					
	Cohesion countries			Non-Cohesion countries		
		Panel data models			Panel data models	
	OLS (Robust SE)	FE	RE	OLS (Robust SE)	FE	RE
	(1)	(2)	(3)	(1)	(2)	(3)
log(GDPpc)	2.693***	2.852***	2.856***	−7.611***	1.921***	1.612***
	(0.668)	(0.250)	(0.248)	(0.720)	(0.325)	(0.566)
Gini_ce	−0.395***	−0.084**	−0.090***	−0.198*	0.224***	0.207***
	(0.037)	(0.042)	(0.034)	(0.105)	(0.057)	(0.048)
CPI	0.117***	0.054***	0.052***	0.158***	0.037***	0.043**
	(0.023)	(0.006)	(0.010)	(0.042)	(0.013)	(0.017)
LExpBrth	−0.480***	0.039	0.024	1.875***	−0.020	0.034
	(0.076)	(0.059)	(0.056)	(0.327)	(0.176)	(0.147)
AYS	−0.560***	0.624***	0.573***	1.739***	1.007***	1.098**
	(0.177)	(0.162)	(0.169)	(0.303)	(0.354)	(0.500)
GII	−0.105***	−0.010	−0.017	−0.109*	−0.069**	−0.068*
	(0.038)	(0.021)	(0.017)	(0.063)	(0.033)	(0.037)
Constant	105.170***		40.728***	−10.424***		42.198***
	(7.384)		(6.771)	(25.415)		(14.093)
Observations	180	180	180	144	144	144
R^2	0.503	0.780	0.761	0.580	0.560	0.512
Adjusted R^2	0.486	0.753	0.753	0.561	0.501	0.491
Residual Std. error	1.838 (df = 173)			2.179 (df = 137)		
F-statistic	29.166*** (df = 6; 173)	94.064*** (df = 6; 159)	550.814***	31.475*** (df = 6; 137)	26.716*** (df = 6; 126)	143.817***

Note: "FE" and "RE" represent the Fixed Effects and Random Effects models, respectively; "***", "**", and "*", denote statistical significance at the 1%, 5%, and 10% levels, respectively; This table replicates the structure of Table 3, reporting OLS, FE, and RE estimates with Driscoll–Kraay standard errors applied to the FE and RE models. Driscoll–Kraay standard errors are simultaneously robust to heteroscedasticity, serial correlation, and cross-sectional dependence (Hoechle 2007) and were applied following the detection of cross-sectional dependence in both subsamples using the Pesaran (2004) CD test. The OLS model retains the same standard errors as in Table 3, as Driscoll–Kraay standard errors are not applicable to pooled OLS in a panel context. Point estimates are identical to those in Table 3; differences across tables reflect changes in standard errors only.

TABLE A4 | Calibration thresholds for fuzzy-set qualitative comparative analysis.

Variable	Cohesion countries Full membership [0.95]	Cohesion countries Crossover point [0.50]	Cohesion countries Full non membership [0.05]	Non-cohesion countries Full membership [0.95]	Non-cohesion countries Crossover point [0.50]	Non-cohesion countries Full non membership [0.05]
SDG_IS	81.91	79.19	73.24	86.12	80.73	76.40
log(GDPpc)	10.84	10.40	9.98	11.67	10.87	10.53
Gini_ce	37.41	30.90	23.39	33.19	28.00	25.40
CPI	69.05	55.00	42.00	90.00	77.00	53.00
GII	50.93	42.68	36.30	63.10	56.01	45.93
LExpBrth	82.31	77.80	74.20	83.37	81.90	80.70
AYS	13.55	12.37	9.70	14.08	12.32	10.12

TABLE A5 | Unit root test and variance inflation factor (VIF) analysis.

	EU-27 (pooled sample)					Cohesion countries			Non-cohesion countries		
Variable	ADF test statistic	*p*	Fisher-type ADF test statistic	*p*	VIF	Fisher-type ADF test statistic	*p*	VIF	Fisher-type ADF test statistic	*p*	VIF
SDG_IS	−3.971	0.011	126.248	0.000	N/A	103.209	0.000		23.039	0.518	N/A
log(GDPpc)	−5.083	0.010	2.474	1.000	2.392	1.417	1.000	1.722	1.057	1.000	1.697
Gini_ce	−4.411	0.010	100.192	0.000	1.434	56.190	0.003	1.493	44.002	0.008	2.178
CPI	−3.920	0.013	258.093	0.000	5.171	103.735	0.000	1.852	154.359	0.000	6.850
LExpBrth	−4.004	0.010	199.817	0.000	3.086	136.835	0.000	2.492	62.982	0.000	2.115
AYS	−4.723	0.010	346.106	0.000	2.096	101.525	0.000	2.145	244.581	0.000	3.192
GII	−3.767	0.021	150.794	0.000	4.524	48.135	0.019	1.666	102.659	0.000	3.316

Note: N/A indicates that the value is not applicable, as SDG_IS is the dependent variable.

TABLE A6 | Analysis of necessary conditions for SDG_IS attainment.

Outcome: SDG_IS			
Panel A: cohesion Countries			
Variable	**Inclusion necessity**	**Relevance of necessity**	**Coverage necessity**
AYS_fz	0.7386	0.8052	0.7353
log(GDPpc)_fz	0.7334	0.7843	0.7128
CPI_fz	0.7290	0.7076	0.6446
GII_fz	0.6533	0.7409	0.6349
LExpBrth_fz	0.6342	0.7269	0.6125
GINI_ce_fz	0.5068	0.6633	0.4853
Panel B: Non-cohesion Countries			
Variable	**Inclusion necessity**	**Relevance of necessity**	**Coverage necessity**
AYS_fz	0.7628	0.7339	0.6788
GII_fz	0.7539	0.7454	0.6844
CPI_fz	0.7138	0.8173	0.7354
log(GDPpc_fz)	0.6509	0.6856	0.5851
LExpBrth_fz	0.5482	0.6854	0.5258
GINI_ce_fz	0.5439	0.6668	0.5089

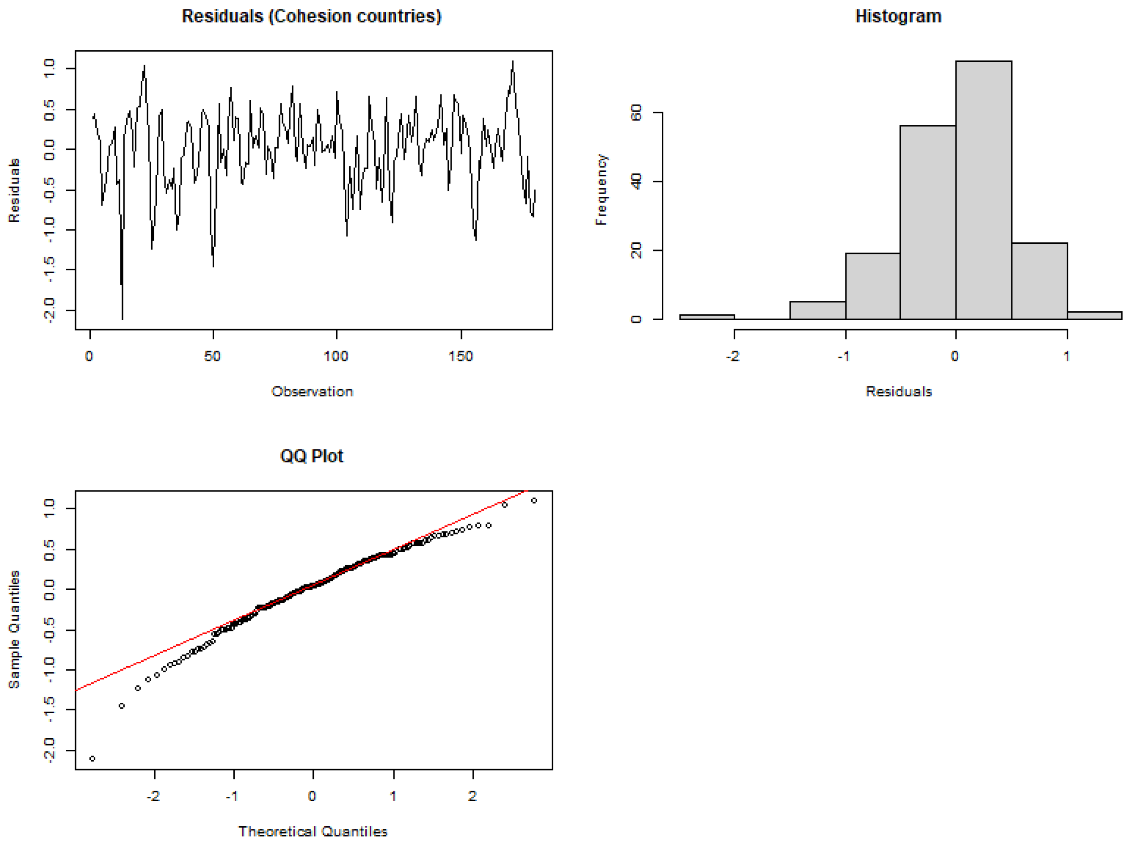
Note: Following Wagemann and Schneider (2010), a consistency threshold of 0.90 was adopted as the cutoff value for identifying a necessary condition.

TABLE A7 | Analysis of necessary conditions for the absence of SDG_IS attainment (˜SDG_IS).

Outcome: ~SDG_IS			
Panel A: cohesion countries			
Variable	**Inclusion necessity**	**Relevance of necessity**	**Coverage necessity**
GINI_ce_fz	0.7715	0.8458	0.8151
CPI_fz	0.6545	0.7041	0.6386
GII_fz	0.6151	0.7541	0.6595
LExpBrth_fz	0.6068	0.7448	0.6466
log(GDPpc)_fz	0.5636	0.7252	0.6043
AYS_fz	0.5280	0.7226	0.5800
Panel B: non-cohesion countries			
Variable	**Inclusion necessity**	**Relevance of necessity**	**Coverage necessity**
GINI_ce_fz	0.6906	0.7803	0.7233
log(GDPpc)_fz	0.6840	0.7436	0.6881
LExpBrth_fz	0.6765	0.7906	0.7264
AYS_fz	0.5597	0.6669	0.5575
GII_fz	0.5498	0.6768	0.5587
CPI_fz	0.4984	0.7357	0.5748

Note: Following Wagemann and Schneider (2010), a consistency threshold of 0.90 was adopted as the cutoff value for identifying a necessary condition; "˜" denotes the absence (negation) of the outcome.

Panel A: Cohesion countries



Panel B: Non-Cohesion countries

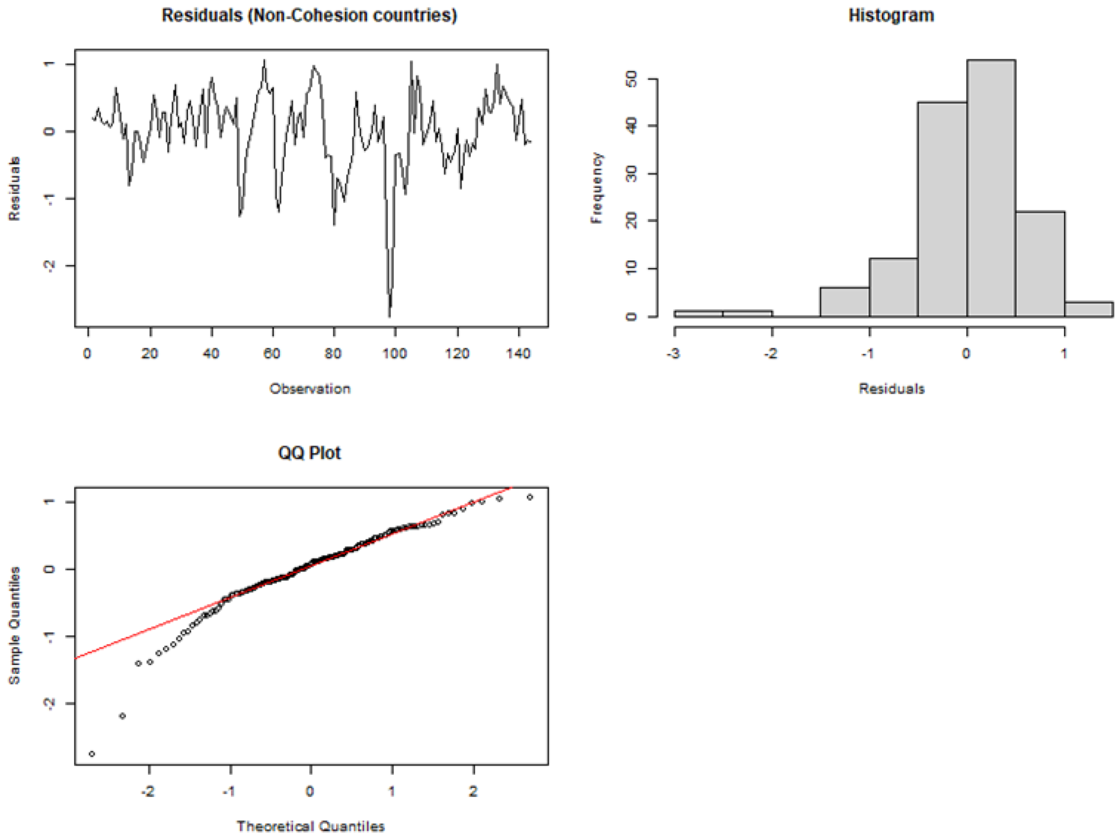


FIGURE A1 | Residual diagnostic plots.

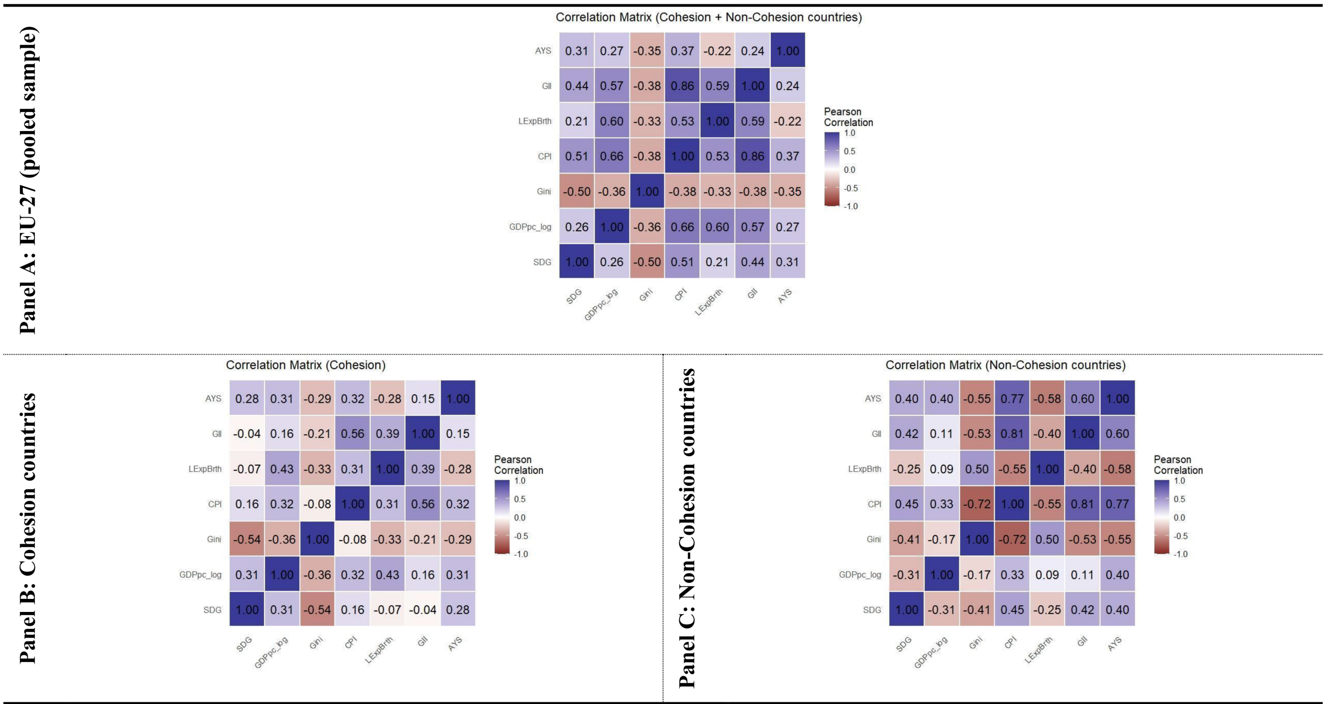


FIGURE A2 | Correlation matrices.