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Divergent Pathways to Sustainability: Club Convergence Analysis of EU Progress on the Sustainable Development Goals

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Abstract: The integration of economic growth, social cohesion, and environmental sustainability within European Union (EU) development frameworks has been strategically aligned with the United Nations Sustainable Development Goals (SDGs). These objectives have been positioned to reinforce the EU's welfare state model while fostering harmonization across member states. In this study, the performance trajectories of 27 EU countries from 2000 to 2023 have been assessed to determine whether convergence in SDG outcomes has occurred, and whether progress towards sustainable development has followed a common pathway. The SDG Index and data for 16 individual SDGs were analyzed using the club convergence methodology and the log *t*-regression test, allowing for the identification of heterogeneous dynamic patterns and latent convergence clubs. The results indicate that a singular equilibrium in SDG performance has not yet been achieved, with evidence of structural divergence across several key goals. While convergence has been observed for Goals 1, 9, 12, and 13, significant divergence persists for Goals 2, 5, 6, and 8. These findings underscore the limitations of a uniform policy approach and suggest that differentiated, context-sensitive strategies may be required to close performance gaps. The presence of club convergence further implies that member states are evolving towards distinct equilibria, shaped by domestic policy frameworks, institutional capacities, and socioeconomic contexts. This study addresses a significant gap in the literature by providing a systematic and longitudinal analysis of SDG performance heterogeneity within the EU and contributes to ongoing debates on the effectiveness of supranational sustainability governance. It is argued that recognizing and responding to these differentiated trajectories is critical for the design of targeted policy interventions capable of advancing inclusive and balanced sustainable development across the union.

Keywords: Sustainable Development Goals (SDGs); Club convergence; European Union (EU); SDG performance; Sustainability Transitions; Policy heterogeneity

1. Introduction

Adopted by the United Nations in 2015, the SDGs, as part of the 2030 Agenda for Sustainable Development, present an inclusive and multidimensional framework aimed at addressing global challenges such as poverty, inequality, environmental degradation, and climate change. Comprising 17 goals and 169 specific targets, the SDGs provide a comprehensive approach to development that integrates economic, social, and environmental dimensions (United Nations, 2015). The SDGs build upon the foundation laid by the Millennium Development Goals (MDGs), which primarily focused on poverty alleviation and access to basic services. However, the SDGs

significantly broaden this scope by incorporating critical elements such as sustainable economic growth, environmental sustainability, and climate change mitigation (Sachs, 2012; Griggs et al., 2013).

To effectively realize the SDGs, coordinated efforts and collaboration are essential at both global and national levels (Sachs, 2015). The EU has aligned its development policies with the SDGs, viewing them as a critical framework for enhancing long-term prosperity. The SDGs inform the EU's commitment to reducing inequality, fostering green economic transformation, and ensuring inclusive growth. As extensively discussed on the European External Action Service (EEAS), particularly the Commission's communication titled "A Decent Life for All: Ending Poverty and Leaving a Sustainable Future for the World" emphasizes the EU's commitment to the SDGs and their alignment with EU policies (European Commission, 2024). So, at the core of EU policies, the SDGs guide efforts to reduce carbon emissions, promote environmental sustainability, and encourage a transition to a greener economy (Siddi, 2023). These policies also aim to strengthen the EU's welfare state model, fostering greater social and economic cohesion among member states while ensuring environmental sustainability. Within such contexts, aligning national policies and developing collective strategies for sustainable development is crucial (Griggs et al., 2013). Moreover, achieving the SDGs will require broad-based collaborations that involve not only governments but also the private sector and civil society organisations, which are pivotal in bridging inequalities between countries (United Nations, 2015).

However, despite the EU's overarching commitment to the SDGs, disparities in the rate of progress toward these goals persist across member states. The assumption of this study is that, despite the common policy framework of the EU, countries may converge toward a similar sustainable development path, though economic, social, and environmental factors could create different dynamics across nations. Identifying these differences reveals that sustainable development policies do not function uniformly across countries and that grouping countries by similar development levels could facilitate the creation of more effective policies. If all EU countries are progressing toward SDG at the same pace, uniform policy mechanisms may suffice; however, if distinct clubs emerge, policy frameworks tailored to specific country groups will be necessary. Thus, the primary research problem addressed by the study is to examine the convergence or divergence of SDG performance among the 27 EU member states from 2000 to 2023, focusing on whether a uniform path to sustainable development exists across the union. By utilising Club Convergence Analysis (CCA) and Phillips & Sul (2007)'s log t-regression test, this research aims to identify patterns of convergence or divergence in the EU's SDG performance and provide valuable insights into the dynamics shaping these outcomes. The subsequent sections, respectively, will outline the limited number of field studies in this area, present the data and methodology, and conclude with a discussion of the findings.

2. Western European Regions Review

One of the SDGs, the reduction of economic inequalities, is directly related to addressing income disparities between regions and countries. In this context, studies on income convergence are an essential tool for understanding the causes of economic inequalities and exploring potential solutions. For instance, Ben-David (1993), in their study of six European Economic Community member countries, found that trade liberalisation reduced income inequality, and removing tariffs increased the convergence rate. Similarly, Barro et al. (1991) identified a slow but steady income convergence process in U.S. states and Western European regions. However, Ram (2020) examined the per capita income levels among US states in the period 1997–2018 and revealed that divergence occurred instead of convergence. It was emphasised that this increase in income inequality was related to the fact that capital did not flow to low-income states that provided high returns. De la Fuente (2003) explored income dynamics in 18 OECD countries and found an annual convergence rate of 1.6%, while Chapsa et al. (2015) demonstrated conditional income convergence in the EU-15 countries. Suciu et al. (2021) tested the validity of convergence long-run sustainability in 13 EU members. Batog & Batog (2024) investigated the marginal income convergence of EU members and the downward effect of enlightened crises on growth. Licchetta & Mattozzi (2023) found that the COVID-19 crisis temporarily slowed down the convergence in GDP per capita in the Eurozone and the EU, but this effect was more limited compared to the Global Financial Crisis. While factors such as the timing of the pandemic, the stringency of containment measures and the importance of sectors such as tourism led to different effects, policy support and vaccination reduced the risk of a permanent divergence. An analysis of income convergence across 17 Latin American countries relative to the U.S. revealed stochastic convergence in 11 cases, with Chile, Costa Rica, and Trinidad and Tobago demonstrating both stochastic and β-convergence. Bandyopadhyay (2012) identified two income clubs in India, where lower-income states failed to catch up with higher-income states, while Alexiadis et al. (2021) observed the formation of different income groups (clubs) in U.S. states. Lopez et al. (2021), in their analysis of a sample of 89 countries, examined additional key factors influencing income convergence. Their findings highlight the significant role of economic globalisation and business cycle synchronisation in shaping the convergence process. The results suggest that economies exhibiting a high degree of synchronisation with the global business cycle tend to have growth rates that are more sensitive to global economic fluctuations. Furthermore, the study identifies that the positive impact of economic

globalisation on growth may be more pronounced in economies that are not synchronised with the global cycle. Baumol (1986) showed productivity level convergence between industrialised market economies and planned economies from 1870 to 1979, although this trend was not observed in less-developed countries. Similarly, Luginbuhl & Koopman (2004) examined income dynamics in five European countries from 1970 to 2001 and detected significant convergence in long-term trends. Azomahou et al. (2011) analysed income convergence processes in 157 EU regions from 1990-2005 and 255 regions from 1998-2007, noting that low-income regions tended to diverge, while middle-income regions exhibited convergence. Similarly, Akkay (2022), in his analysis of 81 provinces in Türkiye during the period 1992–2019, found that high-income provinces converged to the average, while low-income provinces moved away from it. In addition, it was found that income differences decreased during periods of economic slowdown and increased during periods of growth. Ceylan & Abiyev (2016) examined per capita income levels in EU-15 countries, revealing that 11 countries converged toward the group average, while Italy, Luxembourg, Portugal, and Sweden diverged during this process. Zhao & Serieux (2020) identified three different income convergence clubs in Latin America and the Caribbean. In a study by Akram et al. (2020) that analysed club convergence (CC) at the per capita output level in 120 countries, the authors found that countries did not converge to a single stable state, with separate clubs forming for different sectors (agriculture, industry, services). Likewise, Akram & Rath (2020) found no absolute or conditional convergence in per capita income in their study of 95 countries' data.

On the other hand, Capella-Ramos et al. (2020) analyzed the effects of fiscal transfers on real growth and income convergence in the EU and the Euro Area and found that structural funds in particular had positive effects in the medium term but limited effects in the long term, and that institutional capacity and technological equipment played a critical role for effective results. Holobiuc (2020), who examined income convergence in the EU at the national and regional levels, found that poorer countries and regions in Central and Eastern Europe exhibited higher growth rates. The study also found that investments, labour productivity, and labour force participation rates positively affected convergence, while excessive debt, high inflation, and unemployment negatively affected growth. Similarly, Alemu et al. (2024) analyzed income convergence between 11 Central and Eastern European countries that became EU members after 2004 and the four largest economies in Europe using data for the period 1994-2019. The findings show that although large economies were initially more advantageous, CEE-11 (11 Central and Eastern European countries) countries showed a significant convergence trend and exhibited relatively higher growth rates despite financial crises. Yang et al. (2024) found an average increase of 11.88% in sustainable development levels in Chinese cities (2016-2022), balanced distribution, and low inequality. It was observed that the differences in sustainable development levels by region decreased in the northeast but not in the west, but in general and in regions in particular, cities with low initial levels developed faster and a similar trend was observed when some factors were controlled. Bigerna & Micheli (2025) examined the convergence of SDGs in 190 countries from 2000 to 2022 and found a general convergence trend in most SDGs, while some targets, such as SDG 2, 5, 8, 9, 10, and 12, diverged from time to time.

The SDGs, particularly Goal 11, Goal 12, and Goal 13, aim to ensure environmental sustainability and reduce ecological disparities among countries. In this context, studies examining the G20 and EU countries have revealed persistent environmental differences between developed and developing economies. In a study by Bilgili & Ulucak (2018) focused on G20 countries, two distinct club convergences regarding ecological footprints were identified between low- and high-income countries. Similarly, Ulucak & Apergis (2018) found three convergence clubs in EU countries. In studies specific to the African continent, Belloc & Molina (2022) analysed the ecological footprint dynamics of 35 African countries, noting that more industrialised countries such as South Africa, Nigeria, and Zambia had higher ecological footprints, while countries like Kenya, Tanzania, and Ethiopia remained at lower levels. Likewise, Ulucak et al. (2020) revealed that 23 Sub-Saharan African countries did not converge to a single steady state in terms of environmental sustainability indicators. However, club convergence was observed in specific environmental components, such as the carbon footprint. Studies on Latin America also show that regional differences persist, and separations in environmental sustainability continue. A spatial analysis by Osman et al. (2022) reveals that the success of African countries in achieving the SDGs and the synergies and trade-offs between the SDGs vary significantly from country to country and over time. Furthermore, the spatial relationships between the SDGs are found to be complex and variable over time. Tillaguango et al. (2021) identified five different convergence clubs in the ecological footprint dynamics of 16 Latin American countries. Işık et al. (2021) examined the ecological footprint dynamics of the United States, Canada, and Mexico, discovering that Canada diverged from the other two countries regarding environmental sustainability, operating under a different regime. Studies conducted in the context of Australia emphasize the importance of sectoral and regional differences in energy consumption and efficiency. Mishra & Smyth (2016) analysed energy consumption in seven sectors of Australia between 1973 and 2014 and found stochastic conditional convergence in all sectors except transportation. Bhattacharya et al. (2019) identified two distinct regional energy efficiency clubs in their study of Australia's energy efficiency dynamics. Similarly, Ivanovski & Churchill (2020) analyzed the convergence processes of greenhouse gas (GHG) emissions across eight Australian states, finding the emergence of different emission groups rather than convergence towards a common point. Haider & Akram (2019) analyzed the ecological and

carbon footprint data of 77 countries, identifying the formation of two distinct clubs. Erdogan & Okumus (2020) studied the per capita ecological footprint dynamics of 89 countries, identifying four clubs in the high-income group, two clubs in the middle-income group, and two clubs in the low-income group.

Rochoń (2021) examined the convergence trends of green growth indicators using a larger sample of 130 countries and found that countries fall into different convergence clubs based on their energy transition strategies. This suggests that the global energy transition is not progressing in a homogeneous manner. In their study on China, Feng et al. (2024) investigated the balance between economic growth and environmental sustainability goals using network analysis and the "SDG space" methodology. They found that SDGs 1, 4, 11, and 15 were central within the network structure, with strong interconnections among them. Moreover, the initial level of development was found to be a significant predictor of subsequent performance. Shang et al. (2022) analysed 275 cities in China and demonstrated that the spillover effects of green technology innovation significantly enhanced urban eco-efficiency convergence. Notably, long-term spillover effects were found to be more pronounced, emphasising the contribution of technological innovation to the convergence dynamics of sustainable urban policies. Kuc-Czarnecka et al. (2024), in their examination of the environmental SDG performance of EU Member States, identified an upward convergence pattern. Focusing on the “Planet” dimension of the SDGs, the study observed improvements across most environmental indicators and a narrowing of cross-country disparities. Nonetheless, it highlighted the need for further progress in areas such as energy efficiency and GHG emission reduction. Raman et al. (2025) adopted a broader perspective on the relationship between energy and environmental sustainability. Their comprehensive analysis of the interactions among biofuels, biomass, and bioenergy with the SDGs revealed that SDGs 7, 12, and 13 are particularly central to research in this field. Sustainable bioeconomy and technological optimisation emerged as prominent themes, while weaker yet significant links were identified with socioeconomic dimensions. The findings support the contribution of biofuels to sustainable energy but also emphasise the need for further research on social inequality.

The SDGs require the implementation of policies that support economic growth, social welfare, and environmental sustainability, with public and health expenditures emerging as key tools in this process. Studies such as Mohanty (2011) examining the convergence processes of public and health expenditure have been conducted. The author here analysed the convergence processes of public expenditures and revenues in India, finding that fiscal disparities persist. Similarly, Akram (2023) identified three distinct clubs formed by public expenditures on science, technology, and the environment across Indian states. Apergis (2015) examined public expenditures in 19 developing countries and revealed the existence of three different convergence clubs. In this context, Pradhan et al. (2023) analyzed the impact of public social sector expenditures on the Multidimensional Poverty Index (MPI) in the state of Odisha in India and showed that increasing social sector expenditures plays a decisive role in reducing poverty. The findings related to SDGs 1, 2, 3, 4, 6, 7, 8 and 9 reveal that public expenditures are an effective policy tool towards achieving SDGs.

Regional disparities in healthcare expenditures pose a significant barrier to achieving the SDGs, particularly in developing countries. Panopoulou & Pantelidis (2012) analyzed healthcare expenditures in 19 OECD countries and found convergence across OECD countries, although the United States and Norway diverged from the rest. Similarly, Montanari & Nelson (2013) examined healthcare expenditures and service delivery dynamics in 19 EU member states, highlighting a convergence in the financing aspect but an increase in coverage and service provision inequalities. The trend of convergence in healthcare expenditures is not limited to developed countries. Oyedele & Adebayo (2015), in their study of ECOWAS countries, found divergence in healthcare expenditures but convergence in health outcomes. Similarly, Odhiambo et al. (2015) analyzed public healthcare expenditures in Sub-Saharan African countries and identified both absolute and conditional convergence. Significant differences in health and social expenditures are observed between developed and developing countries. Nghiem & Connelly (2017) analyzed healthcare expenditures in 21 OECD countries and identified three distinct convergence clubs. Clemente et al. (2019) examined healthcare expenditures across U.S. states and identified two main clubs. Das & Ivaldi (2020) analyzed social expenditures among Indian states and found convergence in social spending between the states. Traoré (2021), in his study of public healthcare expenditures in 44 Sub-Saharan African countries, identified eight different convergence clubs and one diverging group. Li et al. (2021) investigated the convergence dynamics of public and private healthcare expenditures in 10 ASEAN countries, revealing that public healthcare expenditures converged in Indonesia, Laos, Cambodia, the Philippines, and Myanmar, but diverged in Brunei, Malaysia, Vietnam, Singapore, and Thailand. Meanwhile, private healthcare expenditures showed a general convergence trend across ASEAN countries.

The SDGs envision achieving inclusive and sustainable economic growth supported by innovative approaches and increased labour productivity. In this context, Barrios et al. (2019) studied innovation activities across 180 European regions, identifying seven distinct innovation clubs. Similarly, Payne et al. (2023) analyzed the dynamics of economic freedom convergence among U.S. states, revealing that partial convergence tendencies exist within specific groups of states instead of complete convergence.

In this context, Ruiz-Rodríguez et al. (2025) analyzed the relationship between information society indicators and socio-economic sustainable development across 231 regions in Europe. Their findings revealed that COVID-

19 disrupted the balance between digitalization and development, exacerbating digital inequalities. The study emphasized that, more than the mere presence of digital infrastructure, usage levels and institutional capacity are the key determinants (Grima et al., 2023). Zyoud & Zyoud (2025) conducted a bibliometric analysis to examine the impacts of Internet of Things (IoT) technologies on SDG 11 during the period 2010–2024. They identified sustainable transportation, smart buildings, and green urbanism as prominent themes, while also highlighting data security and infrastructure deficiencies as major limitations to the effective implementation of such technologies. Similarly, Kaiser & Deb (2025), in their bibliometric review of the "sustainable smart city" literature covering the same period, found that most research in this field is centered on SDG 11. Technologies such as artificial intelligence, big data, and the Internet of Things are prominent in this literature; however, concerns related to data security and inequality are also frequently noted. Additionally, the study pointed out that SDGs 1, 5, and 10 are underrepresented in the existing body of research.

Labour productivity is a critical factor for sustainable development. A study by Temoso et al. (2024) determined that 85 subnational regions in Australia, Canada, the United Kingdom, and the United States formed different clubs in terms of labour productivity, with growth dynamics showing regional disparities. Similarly, Christopoulos & Tsionas (2004) analysed productivity growth across regions in Greece, highlighting the impact of capital deepening on labour productivity. Ha & Lee (2016) found that due to demographic structures, Asian countries show economic convergence with the United States, although low fertility rates might slow down this process.

Although SDG 14 (Life Below Water) was excluded from the analysis in this study due to lack of data, recent literature suggests that marine sustainability remains a critical issue globally. For example, NOAA Fisheries (2022) data show that overfished fish stocks are rebuilding and improvements in sustainable fisheries are beginning. Reuters (2024) shows that aquaculture will reach 51% of world fish production, indicating a fundamental transformation in the blue economy. In addition, Booth et al. (2023) developed a new method based on satellite imaging and machine learning to monitor marine plastic pollution. In addition, a global study conducted by Satterthwaite et al. (2025) revealed that young marine scientists identified data sharing, information systems integration, and interdisciplinary collaboration as priority requirements for ocean sustainability. Together, these studies demonstrate that current progress and ongoing challenges in marine sustainability make it essential to address current gaps in Sustainable Development Goal 14 (SDG 14) with a more systematic approach in the future.

In light of recent developments, it is also essential to incorporate the latest reports on SDGs. The European Commission's 2024 monitoring report indicates that, while considerable progress has been made across the EU in areas such as SDG 1 (No Poverty), SDG 8 (Decent Work and Economic Growth), and SDG 9 (Industry, Innovation and Infrastructure), persistent disparities remain among Member States in their performance on SDG 11 (Sustainable Cities and Communities), SDG 13 (Climate Action), and SDG 14 (Life Below Water) (European Commission, 2024). In parallel, Eurostat's 2024 report documents that between 2007 and 2022/23, the employment rate rose to 75.3%, while long-term unemployment and NEET (Not in Education, Employment or Training) rates declined significantly. The same report notes reductions in income and opportunity inequalities, a decrease in multidimensional poverty, increases in agricultural productivity and organic farming, as well as growth in R&D spending and patent applications. Improvements in energy efficiency and reductions in the use of hazardous chemicals were also reported, alongside expansions in marine protected areas and recovery in fish stocks. Nevertheless, ocean acidification and eutrophication have worsened (Eurostat, 2024). The Europe Sustainable Development Report 2025, jointly published by the SDSN and JRC, highlights that the EU's average SDG Index score remains modest at 72.8, suggesting only limited progress. It further notes stagnation or decline in "Leave No One Behind" indicators, and ongoing difficulties with biodiversity-related goals (SDGs 2, 12–15), which are seen as slowing the overall pace of convergence (Lafortune & Fuller, 2025). According to the European Environment Agency's Trends and Projections in Europe 2023 report, the EU-27 has reduced its net GHG emissions by 31% since 1990 and increased the share of renewable energy to 22.5% by 2022. However, current and planned measures are projected to deliver only a 48% reduction by 2030—falling short by 7 percentage points of what is needed to meet the 2050 climate neutrality target (European Environment Agency, 2023). Additionally, the EEA's 2024 Climate Risk Assessment identifies 21 of the 36 major climate risks in Europe as "critical." It emphasizes the urgent need for adaptation measures, especially concerning degradation of marine ecosystems, agricultural productivity losses, heat stress on healthcare infrastructure, and coastal flooding (European Environment Agency, 2024). The EU's 2023 Voluntary Review further notes that the share of the population at risk of poverty or social exclusion declined from 24% to 21.7% between 2015 and 2021, long-term unemployment continued to decrease, and the employment rate reached a historic high of 74.7% in 2022. Nevertheless, challenges remain, particularly in addressing income inequality and eutrophication in river and coastal ecosystems.

3. Methodology

This study analyses the SDG Index (SDG-I) and the 16 specific sustainability targets of 27 EU member countries for the period 2000–2023, to assess whether convergence has occurred. The study's primary objective is to identify similarities and differences in the SDG performance across countries, thereby highlighting convergence or

divergence patterns. Furthermore, the study aims to evaluate whether trends in the SDG targets have reached a standard equilibrium level, while also examining the dynamics that influence sustainable development performance across nations.

The 2000–2023 period examined in this study encompasses several structural disruptions that have markedly influenced the sustainable development trajectories of EU countries. Notably, exogenous shocks such as the 2008 Global Financial Crisis, the sovereign debt crisis throughout the 2010s, and the onset of the COVID-19 pandemic in 2020 introduced abrupt shifts and transient deviations across key indicators (Baldwin & Weder di Mauro, 2020; Başpınar & Özvarış, 2021; Licchetta & Mattozzi, 2023). These fluctuations necessitate a cautious interpretation of observed convergence or divergence patterns in specific SDGs. In particular, such global disruptions may have amplified inter-country heterogeneity, thereby playing a pivotal role in the emergence of club-based dynamics. Additionally, the issue of endogeneity—a frequent challenge in panel data contexts—must be carefully accounted for in interpreting empirical findings. Pesaran (2020) underscores that units such as countries may exhibit mutual dependence through shared shocks and interconnected dynamics, rendering the consideration of cross-sectional dependence essential in panel-based analysis. In a similar vein, Baltagi (2021) demonstrates how common global shocks can generate cross-sectional dependence, potentially undermining the robustness of econometric inferences if left unaddressed. Moreover, countries' sustainable development outcomes are not only shaped by domestic conditions but also by systemic externalities and international spillovers. The log-t regression methodology developed by Phillips & Sul (2007) offers a flexible framework that accommodates such complexities by incorporating heterogeneity and cross-sectional dependence into its nonlinear, time-varying factor model. While the separation of systematic and idiosyncratic components helps mitigate endogeneity-related biases, it cannot fully eliminate concerns stemming from omitted variables, reverse causality, or measurement errors.

The analytical framework of this study is grounded in the theoretical model proposed by Phillips & Sul (2007), which posits that economies may follow heterogeneous paths over time. Accordingly, it assumes the existence of evolving disparities across countries in terms of sustainable development progress. The model also presumes cross-sectional dependence, recognizing that national trajectories are shaped not in isolation but through shared influences and interactive processes. Importantly, the log-t regression technique does not impose rigid assumptions such as stationarity or homogenous unit roots, making it suitable for modeling both linear and nonlinear dynamics. It further enables testing whether units converge towards a shared long-run equilibrium. Evidence of convergence indicates a collective development trajectory; conversely, divergence implies the formation of distinct "convergence clubs." The model additionally emphasizes the significance of initial conditions and exogenous shocks in shaping long-term growth paths, suggesting that the resulting club structures are inherently sensitive to such structural factors.

The data set utilised in this study consists of the SDG-I and data related to the 16 SDG targets for the mentioned period. The data has been sourced from the Sustainable Development Report 2024 (Sachs et al., 2024). This comprehensive panel dataset provides an in-depth examination of sustainable development performance across countries. Although there are 17 SDGs, an analysis could not be conducted for Goal 14- Life Below Water-due to methodological and empirical constraints. Primarily, the absence of available datasets on key sustainable development indicators associated with Goal 14—such as sea surface temperature, ocean acidification, and sustainable fishery rates—for Austria, Slovakia, Luxembourg, Hungary, and Czechia rendered the inclusion of these countries in the analysis unfeasible. Reports published by major institutional data providers, including Eurostat, Statistik Austria, and the Sustainable Development Solutions Network (SDSN), confirm this data unavailability (Sachs et al., 2024). Also, the integrity of the dataset is of critical importance for the reliable implementation of club convergence analyses concerning the Goal. Preliminary assessments revealed that the exclusion of a single country from any identified club leads to substantial changes in the club composition. This indicates that the club structures are highly sensitive to the sampling of country data. Consequently, conducting analyses with incomplete data would compromise methodological coherence and undermine the validity of the findings. While this decision does not directly affect the analyses related to other SDGs included in the study, it is acknowledged as a limiting factor in the comprehensive evaluation of the environmental sustainability dimension represented by the Goal.

The club convergence hypothesis suggests that instead of all economies converging to a single equilibrium, they may converge to different equilibrium levels in subgroups (clubs) that share similar initial conditions and structural characteristics (Baumol, 1986). The club convergence theory assumes that an economy may have multiple long-term equilibrium states. The specific equilibrium that an economy converges to is determined by its initial conditions and its responses to shocks over time. In this context, CCA, developed by Phillips & Sul (2007), tests whether countries or units in panel datasets approach a common equilibrium over time. This method is particularly effective in analyzing convergence or divergence dynamics among countries with heterogeneous data. Additionally, it allows for identifying subgroups (clubs) that converge independently from one another. The fundamental basis of the approach lies in the decomposition of systematic and transient components within the panel dataset. These components are expressed as follows:

$$X_{it} = g_{it} + a_{it} \quad (1)$$

In this equation, g_{it} represents the systematic components and captures the cross-sectional dependence arising from common factors in the panel. On the other hand, a_{it} serves as the transient component, reflecting individual (idiosyncratic) effects. The model does not require rigid assumptions regarding the systematic or transient components, which allows it to accommodate a broad range of data types. Consequently, it can model both linear and nonlinear, stationary and non-stationary processes. Furthermore, it provides the opportunity to simultaneously assess the effects of both common factors and individual characteristics. To better distinguish between common factors and individual components, Phillips & Sul (2007) have reformulated Eq. (1) as

$$X_{it} = \left(\frac{g_{it} + a_{it}}{\mu_t}\right)\mu_t = \delta_{it}\mu_t \quad (2)$$

Here when μ_t represents a common factor that captures the common trends across the panel, δ_{it} is an individual component that measures the contribution of the individual unit over time.

The model assumes that the transient components, such as a_{it} gradually become dominant over time, while the common factors (μ_t) diminish in influence. A scaling method is applied to neutralise the impact of these common factors, which allows for calculating transition parameters to test whether the countries are approaching a common equilibrium. One of the most notable features of this method is the use of the relative transition parameter (h_{it}) which assesses the relative position of individual units relative to the general trend (Phillips & Sul, 2007).

$$h_{it} = \frac{X_{it}}{\frac{1}{N}\sum_{i=1}^{N} X_{it}} = \frac{\delta_{it}}{\frac{1}{N}\sum_{i=1}^{N} \delta_{it}} \quad (3)$$

The parameter h_{it} represents the position and dynamics of a unit within the transition process over time. If the values of δ_{it} or the units converge towards a common constant (δ), then h_{it} will approach unity, indicating that the units have reached a common equilibrium level (Panopoulou & Pantelidis, 2012). A reduction in the cross-sectional variance of the h_{it} statistic is a sign of convergence in the panel and a reduction in heterogeneity among the units. In the models developed by Phillips & Sul (2007) and Phillips & Sul (2009) and Panopoulou & Pantelidis (2012), the approach of h_{it} towards zero signifies that the countries are converging towards a shared growth path.

$$H_{it} = \frac{1}{N}\sum_{i=1}^{N}(h_{it} - 1)^2 \longrightarrow 0 \text{ if } \lim_{t\to\infty} \delta_{it} = \delta, \text{for all } i \quad (4)$$

The log *t* regression developed by Phillips & Sul (2007) is a method used to test whether the members in a panel dataset converge to a common equilibrium over time. The model posits the null hypothesis that all units converge at the same rate ($H_0 : \delta_i = \delta,\ \alpha \geq 0$), and he alternative hypothesis that the units converge at different rates or there is no convergence ($H_A : \delta_i \neq \delta,\ \alpha < 0$). The primary advantage of this model is its ability to examine heterogeneity by identifying both the speed of convergence and the existence of distinct convergence clubs. The log t-test regression used to test the convergence is expressed as

$$\log\left(\frac{H_1}{H_t}\right) - 2\log L(t) = \hat{\alpha} + \hat{b}\log(t) + \hat{u}_t \quad (5)$$

for $t = [rT], [rT] + 1, \ldots, T$ with $r > 0$.

In Eq. (5), $t = [rT], [rT] + 1, \ldots, T$ represents the time elapsed from the beginning of the analysed period. The intercept parameter (*r*), which plays a crucial role in log-t regression analysis, determines the initial observation period to be included in the analysis. Its purpose is to minimize the impact of temporary fluctuations and outliers that may be observed in the early-period data on the analysis results (Phillips & Sul, 2007). This parameter is adapted to the time dimension, with r = 0.20 typically preferred for long-term datasets and r = 0.30 for shorter panel datasets. This choice is critical in obtaining sensitive results that reflect the structure of the period analysed. Lower *r* values encompass more data from the initial period, making them more sensitive to temporary shocks, while higher r values pose a risk of potential information loss (Phillips & Sul, 2007; Sun et al., 2020). Moreover, $L(t)=\log(t+1)$ exhibits the natural logarithm of time. $\hat{b} = 2\hat{\alpha}$ indicates the estimated coefficient of the $\log(t)$ variable. The parameter $\hat{\alpha}$ reflects the speed at which units converge to a common equilibrium. If $t_{\hat{b}} < -1.65$ (at a 5% significance level), it is concluded that the units have not converged to a common equilibrium. In other words, a negative and statistically significant $\hat{b}$ coefficient indicates that the units in the panel exhibit

heterogeneous dynamics by deviating from a common growth path over time. In this context, the sign and significance level of $\hat{b}$ The parameter plays a critical role in empirically determining the convergence or divergence processes (Phillips & Sul, 2007).

The abovementioned method is widely applied in literature as a flexible and robust analytical tool with numerous advantages. Unlike traditional methods, this approach does not rely on assumptions of stationarity or stochastic processes for the variable X_{it} ot the common factor μ_t. This characteristic makes it well-suited to address nonlinear dynamics and cross-sectional heterogeneity. Moreover, the focus on time-varying idiosyncratic components (δ_{it}) enables effective analysis of differences in transition paths between units. Additionally, the emphasis on relative cross-sectional averages rather than absolute values allows this method to overcome the limitations of conventional unit root and cointegration tests (Apergis & Payne, 2017).

Thus, the algorithm is employed to assess whether there is convergence toward a common equilibrium over the long term among a group of units (e.g., countries) and, if so, to analyse how this convergence unfolds. The algorithm classifies units in panel data into subgroups with varying convergence speeds, facilitating a more detailed examination of heterogeneous datasets. A log-t regression test is applied to each potential core group that is formed. The primary aim of this test is to assess whether the selected units exhibit statistically significant convergence tendencies over time. The log-t test statistics obtained for core groups of different sizes are compared, and the group with the highest t-statistic is identified. The highest t-statistic is expected to exceed a certain threshold, such as -1.65, as Phillips & Sul (2007) suggested. If this condition is met, the units that produce the highest t-statistic are considered the "core convergence club," which forms the basis of the analysis. Therefore, the core club formation criterion is based on identifying the largest sub-group exhibiting statistically significant convergence, starting from the highest-performing units in the most recent period, based on the log-t test result (Phillips & Sul, 2007; Phillips & Sul, 2009). The second stage of the CCA aims to expand the boundaries of the core club identified in the first step. During this process, panel members not included in the initial core group are typically ranked according to their performance levels, and they are evaluated for inclusion into the core club, starting from the highest value. After adding each new unit, the convergence tendency of the expanded group towards a common equilibrium is re-examined through the log-t regression test. If the t-statistic obtained from the log-t test for the expanded group exceeds the pre-determined threshold, the new unit is permanently included in the core club. This systematic process of addition and re-evaluation continues until all potential panel members are examined or no new units meet the specified convergence criteria (Apergis & Payne, 2017). This iterative approach expands the initially homogeneous core group by including other units with similar convergence dynamics.

In subsequent stages of the CCA, a similar process is followed for units not included in the initial club, seeking potential new convergence clubs. In this step, units not included in the first club are re-evaluated based on the core club formation and expansion principles. If groups demonstrating meaningful convergence tendencies are formed, these are defined as new independent convergence clubs. However, some units may not be included in any convergence club at this stage. In such cases, these units are classified as "divergent units" because they exhibit differences in long-term equilibrium levels compared to others in the panel (Du, 2017). Finally, the possible merging of different convergence clubs identified by the algorithm is examined. If it is determined that different clubs are moving towards a common equilibrium over time, they are merged under a single large convergence group. However, if significant and statistically meaningful differences persist between the clubs, their independent structures are maintained (Tomal, 2024). This multi-stage approach allows for a detailed analysis of the complex convergence behaviors of units within the panel and enables the identification of different convergence groups and divergent units, considering heterogeneous structures.

Johnson (2019) and Tomal (2024) increased the flexibility and empirical power of the method by introducing time-varying dynamics into the log-t convergence framework developed by Phillips & Sul (2007). Johnson (2019) converted the original fixed slope estimation structure into a kernel-based local linear model using a tricube kernel and 20% of the sample bandwidth, estimated the convergence rate specific to each period ($m'(\log t)$) and presented 99% confidence intervals with a non-overlapping block bootstrap. Tomal (2024) proposed a time-varying club formation algorithm that dynamically updates the number of clubs, size, and memberships over time by using these local linear estimates to endogenously re-determine the “original converging group” at each time point.

4. Results

The common equilibrium convergence test for SDG-I and all SDGs across the 27 EU members for 2000-2023 employing CCA is presented in Table 1. For variables with a t-statistic value greater than -1.65, the null hypothesis (H_0) is accepted, indicating that all countries converge to a common equilibrium level. According to the data in the table, the t-statistic for the SDG Index Score variable is below the critical value of -1.65 at the 5% significance level. This suggests that the null hypothesis (H_0), which posits that all EU member states converge to a common equilibrium level for this variable, is rejected at the 5% significance level.

4.1 Convergence Levels

The t-statistic is examined for each of the targets indicated by the CCA results to determine whether there is a convergence trend. Table 1 demonstrates these trends.

Table 1. Log(*t*) test results

Variables	Coefficient	Standard Error	T-Statistic	Convergence
SDG Index Score	-0.2909	0.0106	-27.3753	X
Goal 1 - No Poverty	1.8408	0.0404	45.5179	√
Goal 2 - No Hunger	-0.4957	0.0142	-34.9919	X
Goal 3 - Good Health and Well-Being	0.0249	0.0419	0.5936	√
Goal 4 - Quality Education	-1.5035	0.0383	-39.2184	X
Goal 5 - Gender Equality	-0.0892	0.03	-2.9714	X
Goal 6 - Clean Water and Sanitation	-0.5097	0.0304	-16.7691	X
Goal 7- Affordable and Clean Energy	-0.8019	0.0149	-53.6898	X
Goal 8- Decent Work and Growth	-0.5957	0.0384	-15.5129	X
Goal 9 - Industry, Innovation & Infrastructure	1.3556	0.1113	12.18	√
Goal 10 - Reduced Inequalities	-0.9874	0.0459	-21.5211	X
Goal 11 - Sustainable Cities and Communities	-0.365	0.0253	-14.4458	X
Goal 12 - Responsible Consumption & Production	0.173	0.0409	4.2265	√
Goal 13 - Climate Action	0.1445	0.0647	2.2317	√
Goal 15 - Life on Land	-0.5718	0.0291	-19.6423	X
Goal 16 - Peace, Justice & Strong Institutions	-0.8705	0.0177	-49.1593	X
Goal 17 - Partnerships for the Goals	-0.4194	0.0402	-10.4339	X

The truncation parameter is set to $r = 0.3$, and the critical value for the t-statistic at the 5% significance level is -1.65. If the t-statistic is less than -1.65, it is concluded that no convergence is occurring. Conversely, if it exceeds -1.65, it is inferred that a convergence trend is present. So, according to the analysis, all EU member countries have converged to a common equilibrium level only with regard to Goals 1, 3, 9, 12 and 13.

4.2 Convergence in SDG-I

The CCA algorithm, in subsequent stages, facilitates the analysis of convergence trends among countries at the group level for variables that do not exhibit convergence characteristics. This approach offers a more nuanced perspective. When convergence is not detected across the entire panel, the method proves particularly effective by identifying whether countries converge to distinct equilibrium levels by forming separate subgroups (clubs). Consequently, it allows for a more comprehensive evaluation of the heterogeneous dynamics among countries and their implications for sustainable development. In the analysis conducted to identify SDG clubs, three CCs were initially identified (Table A1). Results from the club merging test for the SDG variable revealed no convergence between Club 1+2 and Club 2+3 (Table A2). Therefore, each initial club was considered a final club on its own for the SDG variable.

Table 2 presents the final club classification for the SDG variable. Accordingly, Club 1 consists of 22 countries, Club 2 includes 3 countries, and Club 3 comprises 2 countries. The largest group of countries belongs to Club 1.

Table 2. Final club classifications for SDG

Variables	Clubs	Countries	Coefficient	T-Statistic
SDG Index Score	Club 1 [22]	Austria, Belgium, Croatia, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Italy, Latvia, Malta, Netherlands, Poland, Portugal, Romania, Slovak Rep., Slovenia, Spain, Sweden	0.0169	0.5573
	Club 2 [3]	Ireland, Lithuania, Luxembourg	1.5067	7.0173
	Club 3 [2]	Bulgaria, Cyprus	0.2987	2.7212

The truncation parameter is set to $r = 0.3$, and the critical value for the t-statistic at the 5% significance level is -1.65. The number of members in each club is indicated in square brackets.

Figure 1 illustrates the relative transition paths of different convergence clubs (Club 1, Club 2, and Club 3) in the context of the SDG-I score. Club 1 exhibited a stable performance level closest to the panel average, demonstrating consistent progress towards achieving SDGs, although no significant improvement was observed. Club 2 initially ranked lower than Club 1, but showed a steady improvement until 2010, aligning more closely with SDGs. However, after 2010, this trend reversed, and a decline in sustainable development performance was

observed, indicating that the countries in Club 2 failed to maintain the momentum from the early years. Club 3 started at the lowest level, experiencing a notable increase until 2010, but this progress slowed thereafter, and the club lagged behind the other two. This indicates that significant disparities in progress towards SDGs persist among the countries, with Club 3 continuing to underperform compared to the other groups.

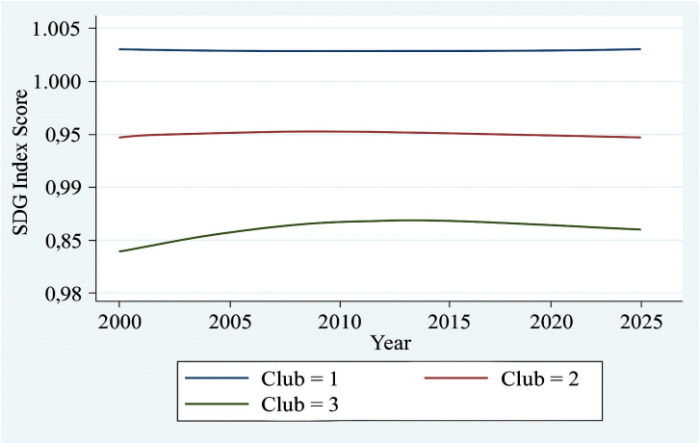

Figure 1. Relative transition path for SDG index score, convergence clubs

As seen in Figure 1, the three clubs do not exhibit a common convergence dynamic in terms of their SDG Index scores. On the contrary, they diverge from the value of 1 while maintaining their respective hierarchical positions. This suggests that divergent development trajectories prevail rather than a movement toward a shared long-term equilibrium in SDG performance.

4.3 Convergence in Goal 2-No Hunger

When no convergence is detected for all countries in the analysis, convergence at the club level is examined. In the analysis conducted to identify clubs for the Goal 2 variable, four convergence clubs and one non-converging club were initially identified (Table A1). The results of the club merging test for the same variable indicated no convergence between clubs 1+2 and 3+4, while convergence was found between clubs 2 and 3 (Table A2). Thus, four clubs for the "No Hunger" variable have been identified and are presented in Table 3.

Table 3. Final club classifications for Goal 2

Variables	Clubs	Countries	Coefficient	T-Statistic
Goal 2	Club 1 [8]	Austria, Belgium, Bulgaria, Croatia, Denmark, Germany, Romania, Spain	0.1679	2.2346
	Club 2 [13]	Estonia, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Poland, Portugal, Slovak Rep., Slovenia, Sweden	0.1517	2.2691
	Club 3 [4]	Cyprus, Czechia, Finland, Greece	0.3136	3.9458
	Club 4 [2]	France, Netherlands	Not Convergent	

For Goal 2, Club 1 consists of 8 countries and exhibits meaningful convergence. Similarly, Club 2-13 countries as well as Club 3- 4 countries also demonstrate convergence. However, Club 4, France and the Netherlands are categorised as a non-converging group. These findings reveal significant disparities not only in the prevention or eradication of hunger among countries but also in substantial performance differences. Furthermore, it is evident that two of the countries in the analysis group have not addressed this issue.

Figure 2 illustrates the relative transition paths of three distinct country groups (Club 1, Club 2, and Club 3) with respect to Sustainable Development Goal 2 (Zero Hunger) over the period from 2000 to 2023. Club 1 consistently remains above the panel average throughout the graph, showing a continuous upward trend. This indicates that the countries in Club 1 have made steady progress toward achieving SDGs and have demonstrated strong performance. Club 2, which encompasses most countries, started at a lower level compared to Club 1, yet showed consistent improvement until 2010. After 2010, however, the performance stagnated, indicating that Club 2 has lost its momentum and needs more support to continue progressing toward the goals. Club 3, on the other hand, started at the lowest level and has shown a continuous decline over time, indicating that the countries in Club 3 have regressed in their progress towards Goal 2 and demonstrate the weakest performance in terms of sustainable development. Furthermore, both Club 2 and Club 3 are below the panel average.

None of the three clubs demonstrates a stable convergence toward the level of "1" over time. The blue path (Club 1) diverges from the reference line, increasing from approximately 1.01 at the beginning of the period to around 1.015 by the end. Similarly, the green path (Club 3) declines from approximately 0.995 to about 0.98, also deviating from the value of 1. The red path (Club 2), meanwhile, remains below the reference value of "1" throughout the entire period, exhibiting only minor fluctuations. Therefore, the clubs have no meaningful convergence trend toward a common equilibrium.

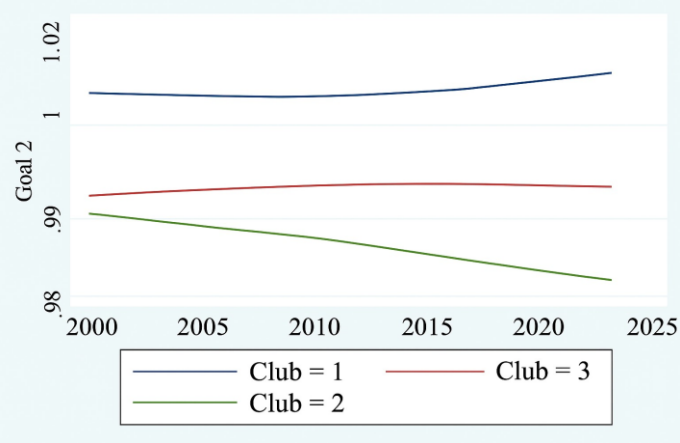

Figure 2. Relative transition path for Goal 2, convergence clubs

4.4 Convergence in Goal 4-Quality Education

In the analysis conducted to identify clubs for Goal 2, an initial classification identified 3 converging clubs and 1 non-converging club (Table A1). The results of the club merging test for the same variable showed that there was no convergence between clubs 1+2 and 2+3 (Table A2). Consequently, for the "Good Health and Well-Being", each initial club was treated as a final club. Table 4 presents the final club classification for this variable.

Table 4. Final club classifications for Goal 2

Variables	Clubs	Countries	Coefficient	T-Statistic
Goal 4	Club 1 [20]	Austria, Belgium, Croatia, Cyprus, Denmark, Estonia, Finland, France, Germany, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Poland, Portugal, Slovenia, Spain, Sweden	0.3228	3.9543
	Club 2 [3]	Greece, Hungary, Malta	3.1586	2.2141
	Club 3 [3]	Bulgaria, Romania, Slovak Rep.	1.9601	6.5599
	Club 4 [1]	Czechia	Not Convergent	

Accordingly, Club 1 consists of 20 countries, Club 2 includes 3 countries, while Club 3 comprises 3 countries. When the largest group of countries belongs to Club 1 and these countries exhibit positive and meaningful convergence toward the specified target, Czechia reflects neither progress nor convergence, but failing to align with other EU members. Greece, Hungary, and Malta are making greater efforts to approach other members in terms of improving education quality, compared to Bulgaria, Romania, and the Slovak Republic.

Figure 3 illustrates the relative transition paths of three distinct country groups (Club 1, Club 2, and Club 3) in terms of Sustainable Development Goal 4 (Quality Education) over the period from 2000 to 2023. Figure 3 illustrates the relative transition paths of three distinct country groups (Club 1, Club 2, and Club 3) in terms of Sustainable Development Goal 4 (Quality Education) over the period from 2000 to 2023. Club 1 started just above the panel average and exhibited a consistent upward trend over the years. This indicates that the countries in Club 1 have maintained a leadership position in educational goals, demonstrating continuous progress. Club 2 began at a level close to the panel average in the early 2000s, but showed a steady decline after 2010. Meanwhile, Club 3 started at the lowest level and consistently followed a downward trend throughout the period under review.

The transition paths of the three analysed clubs do not exhibit a stable convergence toward the level of "1" over time; on the contrary, they show a tendency to diverge from a common equilibrium. These findings indicate that countries are not undergoing a homogeneous convergence process in terms of education quality. Instead, while some countries make progress, others experience setbacks. This pattern of heterogeneous development points to the persistence of structural differences and divergence dynamics among countries in the domain of education quality.

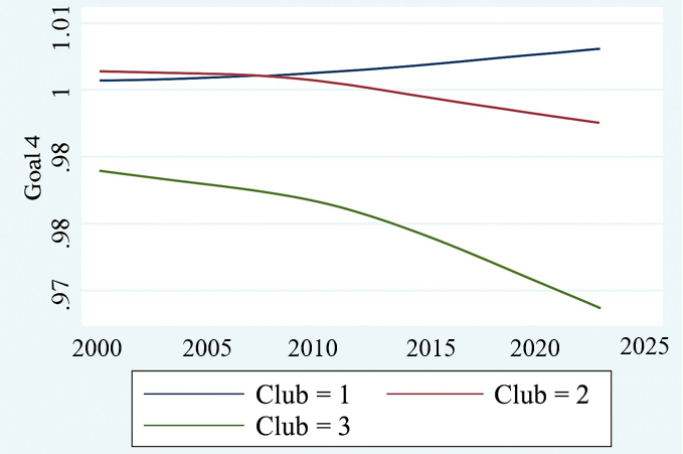

Figure 3. Relative transition path for Goal 4, convergence clubs

4.5 Convergence in Goal 5-Gender Equality

Since the CCA findings indicate no convergence among the 27 EU countries, heterogeneity has begun to be investigated. Countries are grouped into clubs based on their similar performance in achieving gender equality goals. As a result of the CCA, one convergent and one non-convergent club were identified (Table A1). Since the club merging test could not be conducted, each initial club was considered as a final club for the "Gender Equality". Table 5 presents the final club classification for this variable.

Table 5. Final club classifications for Goal 5

Variables	Clubs	Countries	Coefficient	T-Statistic
Goal 5	Club 1 [25]	Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Malta, Luxembourg, Netherlands, Poland, Portugal, Slovak Rep., Slovenia, Spain, Sweden	0.2774	5.9291
	Club 2 [2]	Hungary, Romania	Not Convergent	

Figure 4 presents the relative transition paths of countries in Club 1 with respect to Goal 5 over the period 2000–2023. A consistent and steady upward trend is observed throughout the graph, indicating that these countries have made significant progress toward achieving the "Gender Equality" goal. Although performance began at a relatively low level in the early 2000s and showed a marked improvement by 2023, the noticeable deceleration in the pace of progress is noteworthy.

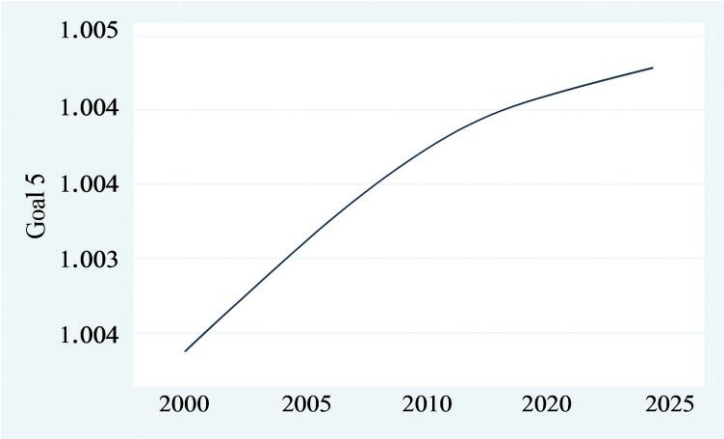

Figure 4. Relative transition path for Goal 5, convergence clubs

Even the members of Club 1 demonstrate a significant convergence, Hungary and Romania are not as willing to take steps towards gender equality as other members, as it can be clearly observed through Figure 4.

The continuous increase observed in Club 1 indicates a growing deviation from the reference line of "1", suggesting that instead of converging toward the panel average in terms of SDG Goal 5 performance, Club 1 is diverging. This implies that the countries in Club 1 are following a development trajectory in gender equality that differs from the overall trend observed in the panel.

4.6 Convergence in Goal 6-Clean Water and Sanitation

This study (Table 1) reveals that the 27 EU members' progress in the domain of Clean Water and Sanitation varies significantly, to the extent that their situations can only be effectively assessed in four distinct groups. For Goal 6, three converging clubs and one non-converging club were identified.

According to Table 6, Finland, when evaluated in terms of both legal and physical measures, has made less progress in this area compared to the other 26 EU members. While Finland is not expected to implement regulations as extensively as other countries, due to its abundant natural water sources and well-preserved nature, which already negate the need for such measures, it is notable that, alongside this country, Malta and Cyprus—both island nations—along with Bulgaria, are also trailing behind other countries in terms of progress in this domain. Subsequently, a club merging test was performed for these clubs, and it was found that convergence was detected for clubs 1+2, while no convergence was observed for clubs 2+3, 3+4, and 4+5 (Table A2). Figure 5 illustrates the transition paths of three different clubs.

Table 6. Final club classifications for Goal 6

Variables	Clubs	Countries	Coefficient	T-Statistic
Goal 6	Club 1 [15]	Austria, Belgium, Croatia, Czechia, Denmark, Estonia, France, Germany, Greece, Hungary, Latvia, Netherlands, Slovenia, Spain, Sweden	0.2891	5.4744
	Club 2 [8]	Ireland, Italy, Lithuania, Luxembourg, Poland, Portugal Romania, Slovak Rep.	0.656	15.2175
	Club 3 [3]	Bulgaria, Cyprus, Malta	0.2081	1.3652
	Club 4 [1]	Finland	Not Convergent	

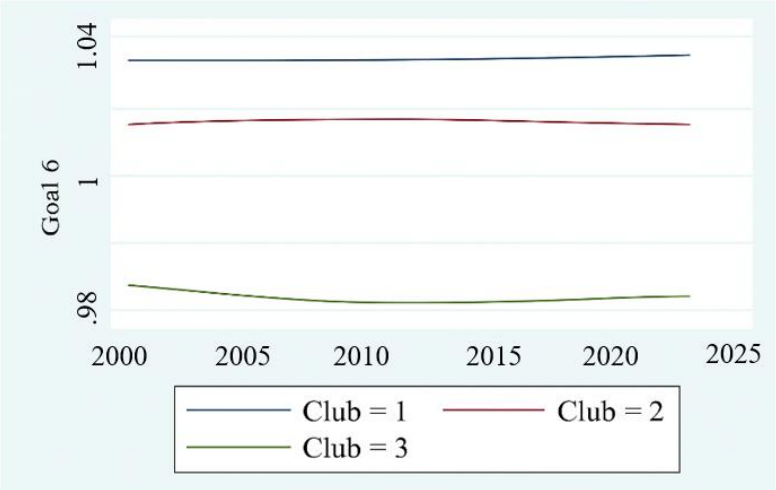

Figure 5. Relative transition path for Goal 6, convergence clubs

Throughout this period, Club 1 has consistently performed above the panel average, maintaining steady alignment with its targets. This indicates that the countries in Club 1 are in a strong position regarding the clean water and sanitation target, showing sustained progress towards achieving this goal. Club 2 began near the panel average, making limited progress until 2010; however, after that, its performance slightly declined. Club 3 exhibited a significant downward trend in the clean water and sanitation target until 2010, but since then, a gradual increase has been observed. This trend suggests that the countries in Club 3 initially lagged behind the clean water and sanitation goal but began showing signs of recovery after 2010.

According to Figure 5, none of the three clubs' paths approach the reference line of "1." Club 1's values have diverged further by rising above 1, while Club 2 has consistently remained below 1 with minor fluctuations. Club 3, on the other hand, has declined from an initial level of approximately 0.945, following a trajectory increasingly detached from the reference value. These findings indicate that none of the clubs exhibit convergence toward a common equilibrium point in the context of Goal 6.

4.7 Convergence in Goal 7-Affordable and Clean Energy

The significant differences observed among the EU countries examined in the area of Affordable and Clean Energy have led to the conclusion that the disparities between these countries should also be analyzed.

The club merger test conducted for the 4 converging clubs revealed that, while no convergence was found for Club 1+2, convergence was present for Club 2+3 and Club 3+4 (Table A2). Table 7 contains the final club classification resulting from the club merger. According to Table 7, countries are divided into four distinct final clubs for Goal 7. While it is observed that all countries considered to be the most developed among the 27 EU countries prioritize this issue, it has been noted that Luxembourg and Lithuania have made minimal progress in this area, to the point where they are unlikely to make a significant impact. Luxembourg's small size and relatively low energy demand are among the most plausible reasons, as even if the country invests in this field, the proportional investments appear relatively low. On the other hand, Lithuania's reliance on more fossil fuels while rebuilding its energy infrastructure after its separation from the Soviet Union can also serve as an explanation. However, regardless of the reasons, it is evident that they lag behind in this regard.

Table 7. Final club classifications for Goal 7

Variables	Clubs	Countries	Coefficient	T-Statistic
Goal 7	Club 1 [5]	Denmark, Estonia, Finland, Latvia, Sweden	-0.0776	-1.6427
	Club 2 [17]	Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Romania, Slovak Rep., Slovenia, Spain	0.0352	0.6401
	Club 3 [3]	Hungary, Malta, Poland	0.486	1.9055
	Club 4 [2]	Lithuania, Luxembourg	Not Convergent	

Figure 6 presents the transition paths of three distinct clubs (Club 1, Club 2, and Club 3) in terms of their performance toward Goal 7 over the period 2000–2023. Club 1 exhibits steady progress. Club 2, starting near the panel average in the early 2000s, displays a limited upward trend across the graph. Club 3, with the lowest starting level, shows a consistent downward trend, indicating a steady decline from the early 2000s to 2023. When the findings of Table 7 are also taken into consideration, it can be stated that, with the exception of Denmark, Estonia, Finland, Latvia, and Sweden, the development of this issue has progressed more slowly than expected since the 2000s. Specifically, in the cases of Hungary, Malta, and Poland, all measures related to clean energy have shown a clear downward trend over the past decade.

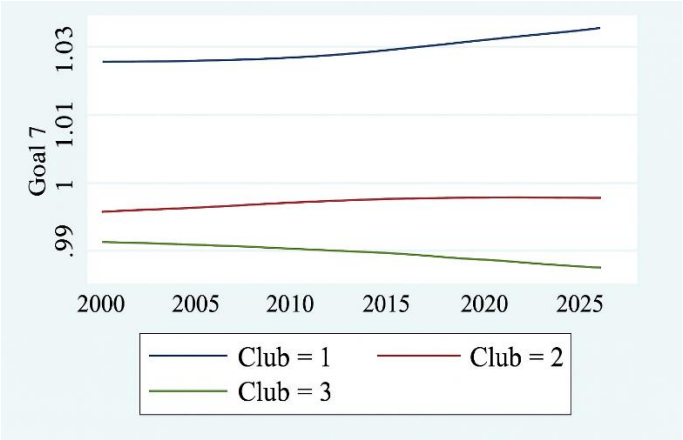

Figure 6. Relative transition path for Goal 7, convergence clubs

4.8 Convergence in Goal 8-Decent Work and Economic Growth

When analyzing the heterogeneous country characteristics in terms of Decent Work and Economic Growth, it has been determined that there are three distinct clubs with clear differences in their rate of progress and regulations. Furthermore, no convergence has been observed between Clubs 1 and 2.

According to Table 8, Club 1 encompasses a total of 24 countries which demonstrates convergence, while Spain does not exhibit any convergence. The fact that Spain's key sectors, such as tourism, construction, and agriculture, are not as sustainable as those of other countries, along with its experience of a fragile and crisis-prone economic

cycle, high inflation, unemployment, and deep structural issues such as income inequality, can be considered as factors contributing to this situation.

Table 8. Final club classifications for Goal 8 (Decent Work and Economic Growth)

Variables	Clubs	Countries	Coefficient	T-Statistic
Goal 8	Club 1 [24]	Austria, Belgium, Bulgaria, Croatia, Czechia, Denmark, Estonia, Finland, France, Germany, Hungary, Ireland, Italy, Latvia, Lithuania, Malta, Luxembourg, Netherlands, Poland, Portugal, Romania, Slovak Rep., Slovenia, Sweden	-0.0592	-1.4152
	Club 2 [2]	Cyprus, Greece	0.3388	1.1617
	Club 3 [1]	Spain	**Not Convergent**	

Figure 7 shows the transition paths of the two clubs between 2000 and 2023 within the scope of Goal 8 (Decent Work and Economic Growth). Club 1 began at a level close to the panel average in 2000 and exhibited steady growth until 2015. This trend indicates that the countries in Club 1 have demonstrated successful performance in creating decent work opportunities and promoting economic growth. However, between 2015 and 2020, the growth rate slowed down, and performance became more stable. In contrast, Club 2 experienced a significant decline during the 2000-2015 period, resulting in worsened performance in relation to Goal 8. Nevertheless, starting from 2015, Club 2 entered a recovery phase, and by 2023, it continued this upward trend, showing a more positive performance towards the objectives of decent work and economic growth. This shift demonstrates that Club 2 has overcome its initial negative dynamics and achieved its set goals.

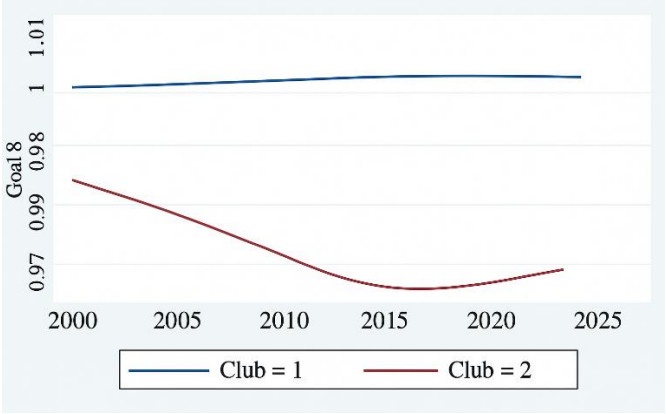

Figure 7. Relative transition path for Goal 8, convergence clubs

According to the figure, the transition path of Club 1 does not show a significant convergence trend towards the reference line "1" over time. Club 2 also does not approach the reference line "1". Although it is seen that Club 2 has exhibited a limited increase from 0.965 to 0.968 in the period after 2015, this change does not reveal a significant convergence towards the reference line value of 1. Since these values are still significantly far from the reference level.

4.9 Convergence in Goal 10-Reduced Inequalities

Via CCA, one converging and one non-converging club have been identified (Table A1). Since the club merging test could not be performed, each initial club has been considered its own final club for the Goal 10 variable. Table 9 presents the final club classification for this variable.

Table 9. Final club classifications for Goal 10

Variables	Clubs	Countries	Coefficient	T-Statistic
Goal 10	Club 1 [25]	Austria, Belgium, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovak Rep., Slovenia, Spain, Sweden	0.0227	0.8968
	Club 2 [2]	Bulgaria, Lithuania	**Not Convergent**	

According to the table, Club 1, comprising 25 member countries, exhibits significant convergence, whereas

Club 2 does not show any kind of convergence. Possible reasons for this situation include that these countries have some of the highest levels of income inequality in Europe, economic growth has not yielded sufficient results in reducing social inequalities, both countries have only slowly rebuilt their economic structures after separating from the Soviet Union, and their traditional cultures are more accustomed to a stratified societal structure.

Figure 8 illustrates the relative transition path of a single club covering 25 EU countries towards Goal 10 (Reducing Inequalities). Club 1 demonstrates convergence, while Club 2 does not, thus highlighting that not all countries follow the same performance trajectory. Club 1 has made consistent progress along its transition path, successfully contributing to reducing inequalities in line with the Goal 10 objectives. From 2000 onwards, Club 1 exhibited a steady upward trend, with gradual improvement until 2010, after which the pace of progress accelerated significantly. This positive trend continued to strengthen towards 2023. These results underscore Club 1's stable and effective progress in reducing inequalities.

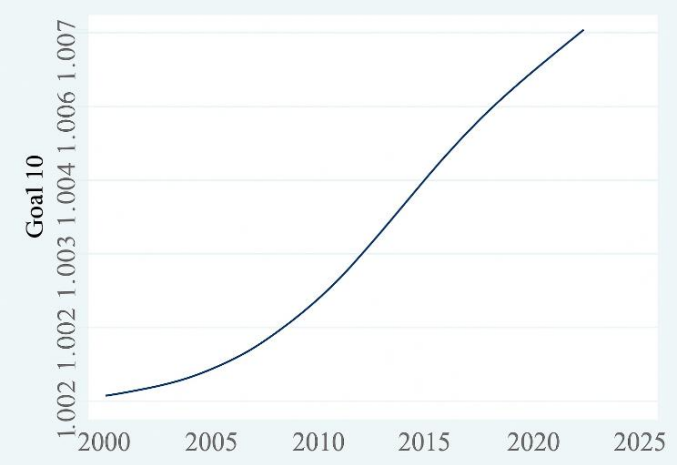

Figure 8. Relative transition path for Goal 10, convergence clubs

The increase in Club 1 does not indicate a convergence towards the value of "1", which is accepted as the reference line, but rather a systematic divergence. Therefore, a convergence dynamic towards the common equilibrium is not observed in the data.

4.10 Convergence in Goal 11-Sustainable Cities and Communities

Three converging clubs and one non-converging club were identified by evaluating subgroups based on heterogeneity. After applying the club merging test to Club 1, Club 2, and Club 3, it was determined that mergers between Club 1+2 and Club 2+3 exhibited convergence. Table 10 displays the final clubs resulting from the club merging tests for Goal 11.

Table 10. Final club classifications for Goal 11 (Sustainable Cities and Communities)

Variables	Clubs	Countries	Coefficient	T-Statistic
Goal 11	Club 1 [23]	Austria, Belgium, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Slovak Rep., Slovenia, Spain	-0.0586	-1.2665
	Club 2 [3]	Bulgaria, Croatia, Sweden	0.3624	5.6242
	Club 3 [1]	Romania	Not Convergent	

Out of the 27 countries examined, 23, except Sweden, are making significant efforts in creating sustainable cities. Sweden, however, is already in a relatively good position in this regard, so it is normal that its regulations do not appear as intensive as those of the others. However, Bulgaria and Croatia are lagging behind in this area, while Romania is completely diverging from the others on this matter.

Figure 9 shows the transition pathways for Club 1 and Club 2 for the period 2000–2023, under Goal 11 (Sustainable Cities and Communities). Club 1 has maintained a steady performance just above the panel average, positioning itself as a leader in achieving this goal. In contrast, Club 2 started at a significantly lower level in 2000 but exhibited a gradual upward trend over time, particularly showing a marked improvement between 2000 and 2015. However, after 2015, this upward trend stalled, and performance leveled off, remaining stagnant.

The transition path of Club 1, which includes 23 EU countries, approaches the reference value 1, showing a tendency to converge to a common equilibrium. Club 2, starting from 0.992 in 2000, recorded a limited increase

towards 2015, and then remained horizontal in the range of 0.998–0.999, showing no significant convergence dynamics.

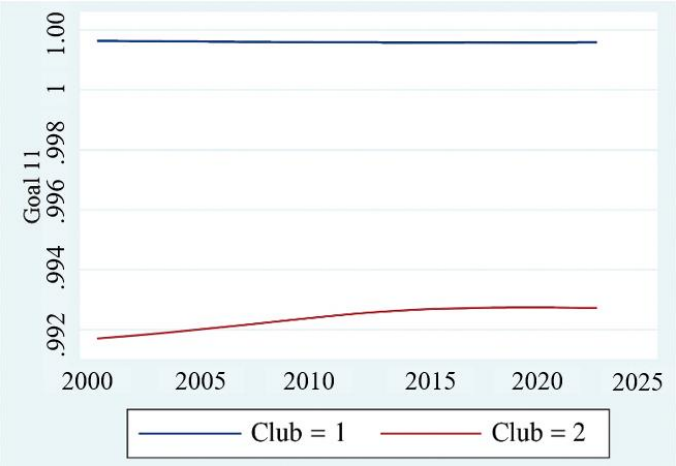

Figure 9. Relative transition Path for Goal 11, convergence clubs

4.11 Convergence in Goal 15-Life on Land

The issue of "Life on Land," which shows no complete convergence among the 27 countries, has been assessed for heterogeneity in Table A1. Through this analysis, two converging clubs are identified, and a club merging test is conducted for Club 1 and Club 2, yielding the conclusion that no convergence exists between Club 1+2 (Table A2). Consequently, the clubs identified in this context have been considered as final clubs. Table 11 presents the final club classifications for Goal 15. According to Table 11, within the scope of Goal 15, Club 1's convergence trend is statistically significant. Similarly for Club 2, convergence is indeed significant as well.

Table 11. Final club classifications for Goal 15 (Sustainable Cities and Communities)

Variables	Clubs	Countries	Coefficient	T-Statistic
Goal 15	Club 1 [18]	Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, France, Germany, Greece, Hungary, Italy, Latvia, Lithuania, Malta, Poland, Romania, Slovak Rep., Slovenia	0.0775	3.8267
	Club 2 [9]	Austria, Belgium, Finland, Ireland, Luxembourg, Netherlands, Portugal, Spain, Sweden	0.2895	3.2192

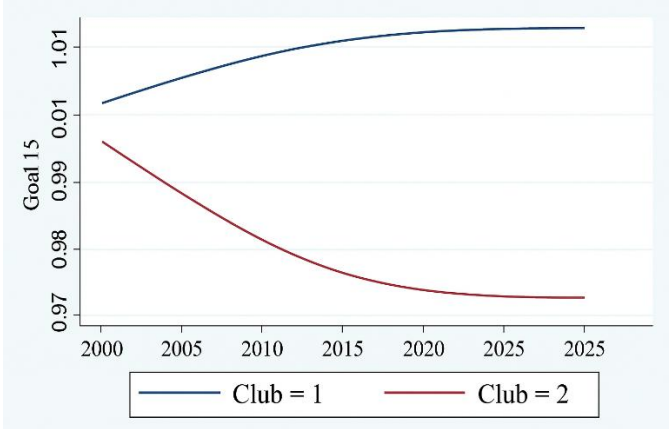

Figure 10. Relative transition path for Goal 15, convergence clubs

Figure 10 shows the transition pathways for the period 2000-2023 for Club 1 and Club 2, in line with Goal 15 (Conservation of Terrestrial Ecosystems). Club 1 maintained its performance steadily and remained at a high level until 2023. In contrast, Club 2 started in 2000 at a lower performance level than Club 1 and exhibited a noticeable downward trend until 2010. However, after 2010, the rate of decline decreased, and performance stabilised at a low level until 2023. This trend indicates that Club 2 made limited progress towards the Goal 15 target and did not

achieve significant performance improvement.

As seen in Figure 10, the transition paths of Club 1 and Club 2 exhibit a systematic departure from the reference value, indicating that both clubs tend to deviate from the equilibrium point rather than converge to a common equilibrium.

4.12 Convergence in Goal 16-Peace, Justice and Strong Institutions

Since no convergence has been determined in terms of peace, justice and/or strong institutions, the extent of heterogeneity and its applicability to the countries have been investigated, and four converging clubs have been identified for Goal 26 (Table A1). Subsequently, a club merging test has been performed for these clubs, and it has been found that convergence occurred for the combination of Club 2+3. However, no convergence is observed for the combinations of Club 1+2 and Club 3+4 (Table A2).

The final clubs, determined by the club merging test, are presented in Table 12. The table shows that the countries are classified into three distinct clubs, and these clubs exhibit converging trends in line with the SDGs.

Table 12. Final club classifications for Goal 16

Variables	Clubs	Countries	Coefficient	T-Statistic
Goal 16	Club 1 [14]	Austria, Belgium, Czechia, Denmark, Estonia, Finland, Germany, Ireland, Latvia, Lithuania, Luxembourg, Netherlands, Portugal, Sweden	0.3335	6.641
	Club 2 [11]	Bulgaria, Croatia, France, Greece, Hungary, Italy, Poland, Romania, Slovak Rep., Slovenia, Spain	0.1872	2.3893
	Club 3 [2]	Cyprus, Malta	0.3897	0.1355

Figure 11 allows us to examine the performance of three different clubs (Club 1, Club 2 and Club 3) between 2000 and 2023 through relative transition paths, in line with Goal 16 (Peace, Justice and Strong Institutions). Club 1 stands out with an initial performance level above the panel average in the year 2000, exhibiting a consistent and steady upward trajectory throughout the period. By 2023, this growth trajectory continues, culminating in the club reaching a significantly high level of performance. In contrast, Club 2 began in 2000 at a level close to the panel average and demonstrated only modest improvement until 2010. However, from 2010 onwards, this trend reversed, with a noticeable decline in performance across the club. This downward trend persisted until 2023, resulting in Club 2's performance falling below its initial level.

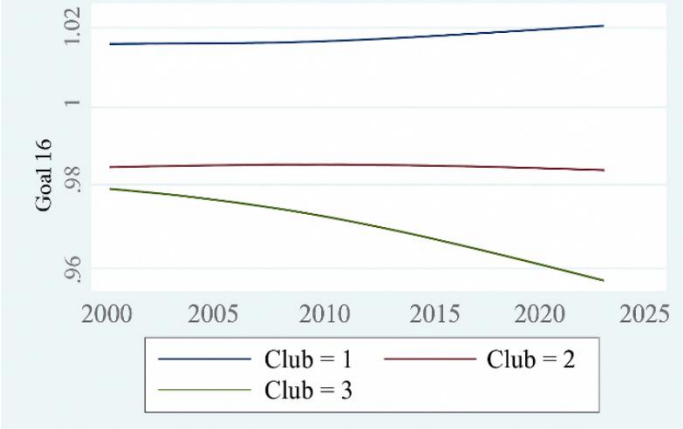

Figure 11. Relative transition path for Goal 16, convergence clubs

Figure 11 shows that no club exhibits a significant convergence dynamic towards the reference line "1"; however, the divergence trend is dominant in all series.

4.13 Convergence in Goal 17-Partnerships for the Goals

Table 1 presents "no convergence" findings of Goal 17, based on the CCA. Thus, heterogeneity has been investigated. Initially, three converging clubs are identified (Table A1). The results of the club merging test for the Goal 17 variable revealed no convergence in the 1+2 and 2+3 club combinations (Table A2). Consequently, each starting club has been accepted as a final club on its own. Table 13 presents the final club classification for Goal 17.

Table 13. Final club classifications for Goal 17

Variables	Clubs	Countries	Coefficient	T-Statistic
Goal 17	Club 1 [3]	Denmark, Germany, Sweden	0.8274	5.006
	Club 2 [7]	Austria, Belgium, Bulgaria, Czechia, Finland, Luxembourg, Netherlands	0.3152	4.1535
	Club 3 [17]	Croatia, Cyprus, Estonia, France, Greece, Hungary, Ireland, Italy, Malta, Latvia, Lithuania, Poland, Spain, Portugal, Romania, Slovenia, Slovak Rep	-0.0329	-0.4523

According to the table, the largest country group is found in Club 3. One of the reasons is that this group faces significant economic challenges such as higher unemployment rates, lower GDP per capita, and slower economic growth, which makes it difficult for them to focus on the SDGs. Additionally, while countries like Denmark, Germany, and Sweden face no significant national or international issues, each country in the third club can be associated with different political and institutional challenges. Furthermore, the successful industrialization steps already taken by the countries in the first group, while the other countries mentioned are still undergoing these processes, can also be considered a contributing factor.

Figure 12 shows the relative transition paths of three clubs (Club 1, Club 2 and Club 3) between 2000 and 2023 in line with the Goal 17 target. Club 1 started well above the panel average in 2000 and stood out with its high performance. However, a limited decline in performance was observed from 2010 onwards. However, from 2010 onwards, a noticeable decline in performance has been observed. By 2023, this downward trend persists, although Club 1 maintains a higher performance level than the other clubs. Club 2, starting near the panel average in 2000, demonstrated a gradual yet limited increase throughout the period. This trend has continued through 2023, reflecting a stable and consistent improvement in performance. Throughout the analysis period, both Club 1 and Club 2 have consistently performed above the panel average. Club 3, in contrast, has shown a more stagnant performance trajectory, exhibiting little notable change throughout the analysis period. A slight decline was observed between 2000 and 2019, though this decrease did not signify a substantial loss in performance, nor did it translate into any substantial progress. Post-2020, a modest upward trend has been noted, though the magnitude of this improvement remains minimal and does not constitute a meaningful enhancement in performance.

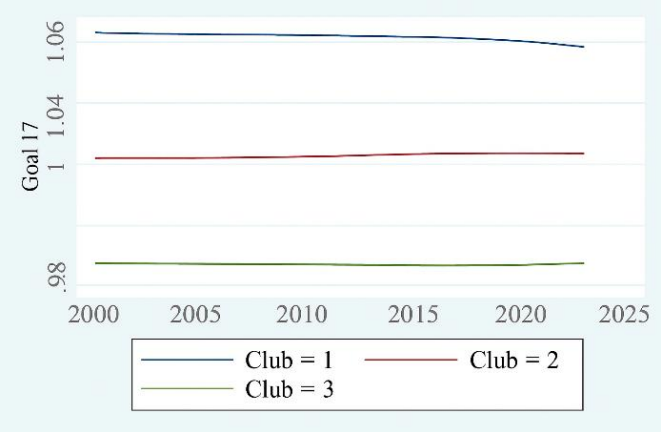

Figure 12. Relative transition path for Goal 17, convergence clubs

Club 1 shows a tendency to slightly approach the reference line, exhibiting a limited regression towards 2023. It is revealed that none of Club 2 and Club 3 show a significant tendency to converge towards the reference line "1"; on the contrary, all series exhibit a divergence dynamic, deviating from the reference value, albeit slightly, over time (Figure 12).

5. Discussions

In this study, the convergence of the 27 EU member countries towards a common equilibrium level in the period between 2000 and 2023, based on the Sustainable Development Index and the 16 SDGs are analysed using the club convergence approach. Since, in the existing literature, no studies have been found that analyse the SDG performance of EU countries using CCA and Phillips & Sul (2007)'s log t-regression tests and these methods are considered effective tools for detecting convergence or divergence patterns in countries' sustainable development performance, the inclusion of a broader time span and a more comprehensive set of countries compared to previous

studies represents the contribution of this research to the literature.

The study's findings indicate that full convergence towards a common equilibrium level for all SDG targets was not achieved at the overall panel level. However, countries did converge towards independent equilibrium levels for specific targets, forming distinct subgroups (clubs). Additionally, for the SDG Index Score, no convergence towards a common equilibrium level was observed across all countries within the overall panel. Similarly, convergence was not found for Goals 2, 4, 5, 6, 7, 10, 11, 15, 16, and 17. This indicates that there are persistent heterogeneous dynamics in the performance of the SDGs among EU countries, and that the countries face different challenges and opportunities in their sustainable development processes. Notable differences in performance have been found across countries, with some showing more successful progress while others lag behind. It has been enlightened that it is possible to classify the countries of the AB region according to their alignment with the SDGs as high, medium, and low performers. The countries that demonstrate high performance tend to score well on the SDG Index and show significant progress in areas such as sustainable industry, education, health, and climate action. This group includes Denmark, Germany, Austria, Finland, Sweden, the Netherlands, and France, which stand out for their successful implementations in sustainable development. However, even these countries face challenges, requiring improvements in areas such as ending hunger (Finland, Sweden), sustainable cities and communities (Sweden), life on land (Sweden, the Netherlands, and Austria), peace, justice, and strong institutions (France), and partnerships for the goals (France).

Countries with medium performance, including Ireland, Belgium, Spain, Portugal, Italy, the Czech Republic, Slovenia, Estonia, Poland, Lithuania, and Luxembourg, have made notable progress in health, education, and industry sectors. However, they still need to devote greater efforts to areas such as ending hunger, clean water and sanitation, life on land, peace, justice, strong institutions, and partnerships for the goals. On the other hand, countries exhibiting low performance, such as Bulgaria, Romania, Hungary, Slovakia, Croatia, Greece, Cyprus, Malta, and Latvia, face significant structural challenges in areas like ending hunger, education quality, clean water and sanitation, decent work and economic growth, affordable and clean energy, sustainable cities and communities, peace, justice, and strong institutions, and partnerships for the goals. In these countries, issues such as poverty, unemployment, and sustainable urbanisation emerge as priority policy areas.

The empirical findings for Goal 1 are consistent with the results of Barro et al. (1991), De la Fuente (2003), and Ceylan & Abiyev (2016), supporting the idea of common progress among EU countries in poverty reduction. However, the study by Akram & Rath (2020) diverges from these findings, emphasising that poverty reduction is not a homogeneous global process. Similarly, studies by Panopoulou & Pantelidis (2012) and Odhiambo et al. (2015) show general convergence in healthcare services, supporting the findings of our study for Goal 3. However, Montanari & Nelson (2013) found that while financial convergence in health expenditures existed among EU countries, there were still significant differences in service delivery, which deviates from our findings. For Goal 9, research by Barrios et al. (2019) shows that industrial and innovation investments are becoming more similar among EU countries, which aligns with the results of our study. Yet, Payne et al. (2023) found that there was not complete convergence among U.S. states, but partial convergence trends within certain groups, which does not exactly align with our findings. For Goal 12, the findings from Ivanovski & Churchill (2020) are consistent with the convergence trends identified in this study. For Goal 13, the study by Montanari & Nelson (2013) supports our findings, suggesting general alignment among EU countries in climate action. However, the research by Tillaguango et al. (2021) on Latin American countries identified persistent differences in environmental sustainability, which contrasts with the convergence trends observed in this study.

To bridge the disparities in SDG performance across EU member states, a set of strategic policy recommendations can be considered to foster more coordinated and effective sustainable development efforts. Adopting a holistic and coordinated approach is believed to be the most effective method to address performance disparities in achieving the SDGs. Rather than tackling issues per country, it may prove more efficient for countries facing common challenges to act in regional and thematic groups. For instance, Eastern European countries, which face similar challenges in education, economic growth, and clean water/sanitation, could implement joint financing and capacity-building projects targeted at these issues. Or strengthening social policies and more effective distribution of financial resources are necessary for Reducing Inequalities and Gender Equality. Similarly, Scandinavian countries could lead global sustainable development efforts by improving sustainable cities, life on land, and international partnerships.

6. Conclusions

Given that each country has different needs, it is crucial to establish country-specific priorities and focus on structural reforms. Reforms targeting infrastructure, education, and the labour market are critical for low-performing countries, while medium-performing countries should prioritise environmental sustainability and social justice policies. High-performing countries, in turn, can support others through technology and knowledge sharing. In this process, establishing common funds, investment programs, and incentive mechanisms within the EU is essential. Specifically, low-performing countries should benefit more from EU structural funds and research

and innovation programs such as Horizon Europe. Furthermore, multi-stakeholder collaboration should be encouraged, with local governments, the private sector, civil society organizations, and academic institutions developing joint projects to support sustainable development efforts. Technology and innovation will also play a pivotal role in this process, with digital solutions and big data analysis supporting policymaking. Additionally, as stated by the Ministry of EU in 2004, the EU should increase the number of programs and platforms designed to enhance coordination among member states regarding the SDGs, support collaborations, and mobilise the potential of these initiatives. For example, the Erasmus+ Program can be utilized as a significant tool for developing knowledge, skills, and attitudes related to climate change and supporting sustainable development. The Horizon Europe Program, with a budget of €95.5 billion for 2021-2027, focuses on combating climate change and could prioritise relatively less developed countries within the EU. Doing so would encourage competitive growth across other nations, fostering overall development. Furthermore, as Global Compact Network Türkiye declared unified SDG monitoring and evaluation system should be established across the EU, allowing countries to compare their progress and share best practices. In collaboration with UN agencies, the United Nations prepares an annual SDG Progress Report based on global indicators and data generated by national statistical systems. Considering this report, EU countries could develop target-oriented policies, providing a roadmap for identifying their strengths and weaknesses. This approach will also enhance their capacity to track SDG-related data, improving data-driven decision-making in policy formulation.

This study acknowledges several limitations that provide avenues for future research. A notable constraint is the unavailability of data for Goal 14—Life Below Water—which hindered its inclusion in the analysis. Addressing this gap necessitates developing comprehensive datasets encompassing marine and aquatic indicators, facilitating a more holistic assessment of sustainable development across all goals. Furthermore, the interplay between different SDGs presents a complex landscape of synergies and trade-offs. Further studies investigating interlinkages of the SDGs could reveal how progress in one goal influences others, informing integrated policy approaches.

Author Contributions

Conceptualization, A.Ö.A. and S.E.G.Ö.; methodology, A.Ö.A., S.E.G.Ö and S.G.; software, A.Ö.A., S.E.G.Ö and S.G.; validation, A.Ö.A., S.E.G.Ö., E.Ö and S.G.; formal analysis, A.Ö.A., S.E.G.Ö., E.Ö and S.G.; investigation, A.Ö.A., S.E.G.Ö., E.Ö and S.G.; resources, A.Ö.A., S.E.G.Ö., E.Ö and S.G.; data curation, A.Ö.A. and S.E.G.Ö.; writing—original draft preparation, A.Ö.A. and S.E.G.Ö.; writing—review and editing, S.E.G.Ö, S.G.; visualization, S.E.G.Ö, E.Ö.; supervision, S.G.; project administration, A.Ö.A. and S.G. All authors have read and agreed to the published version of the manuscript. The relevant terms are explained at the CRediT taxonomy.

Data Availability

The data [MS Excel] supporting our research results are included within the article or supplementary material.

Conflicts of Interest

The authors declare no conflict of interest.

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Appendix

Within the scope of Sustainable Development Goal 14 (Life Below Water), no evidence of absolute convergence was identified among the 22 countries included in the analysis. Accordingly, in order to assess the impact of structural heterogeneity on the convergence process, a club convergence analysis was conducted, resulting in the identification of three distinct convergence clubs for this goal (Table A1). Subsequently, a series of club merging tests were performed to explore the potential for convergence among the defined clubs. However, as reported in Table A2, no significant convergence relationship was found among Club 1, Club 2, and Club 3. These findings suggest that the three clubs should be regarded as the final convergence groupings with respect to Goal 14 during the observed period. Table A3 shows the final version of SDGs convergence clubs. The corresponding final club classifications are presented in Table A4.

The truncation parameter is set to r = 0.3, and the critical value for the t-statistic at the 5% significance level is -1.65. The number of members in each club is indicated in square brackets. The findings indicate that the countries examined under Goal 14 are grouped into three distinct convergence clubs, each exhibiting a statistically significant convergence trend within its own group.

Table A1. Initial SDGs convergence clubs

Variables	Clubs	Countries	Coefficient	T-Statistic
SDG İndex Score	Club 1 [22]	Austria, Belgium, Croatia, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Italy, Latvia, Malta, Netherlands, Poland, Portugal, Romania, Slovak Rep., Slovenia, Spain, Sweden	0.0169	0.5573
	Club 2 [3]	Ireland, Lithuania, Luxembourg	1.5067	7.0173
	Club 3 [2]	Bulgaria, Cyprus	0.2987	2.7212
Goal 1	Club 1 [27]	All European Union Member States	1.8408	45.5179
Goal 2	Club 1 [8]	Austria, Belgium, Bulgaria, Croatia, Denmark, Germany, Romania, Spain	0.1679	2.2346
	Club 2 [8]	Italy, Latvia, Lithuania, Luxembourg,Portugal, Slovak Rep., Slovenia,Sweden	0.0760	1.1886
	Club 3 [5]	Estonia, Hungary, Ireland, Malta, Poland	0.3769	4.6959
	Club 4 [4]	Cyprus, Czechia, Finland, Greece	0.3136	3.9458
	Club 5 [2]	France, Netherlands	**Not Convergent**	
Goal 3	Club 1 [27]	All European Union Member States	0.0249	0.5936
Goal 4	Club 1 [20]	Austria, Belgium, Croatia, Cyprus, Denmark, Estonia, Finland, France, Germany, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Poland, Portugal, Slovenia, Spain, Sweden	0.3228	3.9543
	Club 2 [3]	Greece, Hungary, Malta	3.1586	2.2141
	Club 3 [3]	Bulgaria, Romania, Slovak Rep.	1.9601	6.5599
	Club 4 [1]	Czechia	**Not Convergent**	
Goal 5	Club 1 [25]	Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Malta, Luxembourg, Netherlands, Poland, Portugal, Slovak Rep., Slovenia, Spain, Sweden	0.2774	5.9291
	Club 2 [2]	Hungary, Romania	**Not Convergent**	
Goal 6	Club 1[8]	Belgium, Estonia, France, Germany, Latvia, Netherlands, Spain, Sweden	0.2226	4.7402
	Club 2 [5]	Austria, Croatia, Denmark, Greece, Slovenia	0.1942	6.9282
	Club 3 [2]	Czechia, Hungary	0.5638	5.5030
	Club 4 [8]	Ireland, Italy, Lithuania, Luxembourg, Poland, Portugal,Romania,Slovak Rep.	0.6560	15.2175
	Club 5 [3]	Bulgaria, Cyprus, Malta	0.2081	1.3652
	Club 6 [1]	Finland	**Not Convergent**	
Goal 7	Club 1 [5]	Denmark, Estonia, Finland, Latvia, Sweden	-0.0776	-1.6427
	Club 2 [5]	Austria, Bulgaria, Croatia, Greece, Portugal	0.3756	5.3572
	Club 3 [12]	Belgium, Cyprus, Czechia, France, Germany, Ireland, Italy, Netherlands, Romania, Slovak Rep., Slovenia, Spain	0.1584	1.8365

	Club 4 [3]	Hungary, Malta, Poland	0.4860	1.9055
	Club 5 [2]	Lithuania, Luxembourg	**Not Convergent**	
Goal 8	Club 1 [24]	Austria, Belgium, Bulgaria, Croatia, Czechia, Denmark, Estonia, Finland, France, Germany, Hungary, Ireland, Italy, Latvia, Lithuania, Malta, Luxembourg, Netherlands, Poland, Portugal, Romania, Slovak Rep., Slovenia, Sweden	-0.0592	-1.4152
	Club 2 [2]	Cyprus, Greece	0.3388	1.1617
	Club 3 [1]	Spain	**Not Convergent**	
Goal 9	Club 1 [27]	All European Union Member States	1.3556	12.1800
Goal 10	Club 1 [25]	Austria, Belgium, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovak Rep., Slovenia, Spain, Sweden	0.0227	0.8968
	Club 2 [2]	Bulgaria, Lithuania	**Not Convergent**	
Goal 11	Club 1 [13]	Austria, Belgium, Czechia, Denmark, Estonia, Finland, France, Germany, Hungary, Lithuania, Luxembourg, Malta, Spain	0.3946	5.5481
	Club 2 [10]	Cyprus, Greece, Ireland, Italy, Latvia, Netherlands, Poland, Portugal, Slovak Rep., Slovenia	0.3284	4.3008
	Club 3 [3]	Bulgaria, Croatia, Sweden	0.3624	5.6242
	Club 4 [1]	Romania	**Not Convergent**	
Goal 12	Club 1 [27]	All European Union Member States	0.1730	4.2265
Goal 13	Club 1 [27]	All European Union Member States	0.1445	2.2317
Goal 15	Club 1 [18]	Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, France, Germany, Greece, Hungary, Italy, Latvia, Lithuania, Malta, Poland, Romania, Slovak Rep., Slovenia	0.0775	3.8267
	Club 2 [9]	Austria, Belgium, Finland, Ireland, Luxembourg, Netherlands, Portugal, Spain, Sweden	0.2895	3.2192
Goal 16	Club 1 [14]	Austria, Belgium, Czechia, Denmark, Estonia, Finland, Germany, Ireland, Latvia, Lithuania, Luxembourg, Netherlands, Portugal, Sweden,	0.3335	6.6410
	Club 2 [9]	Croatia, France, Greece, Italy, Poland, Romania, Slovak Rep., Slovenia, Spain	0.7140	6.1131
	Club 3 [2]	Bulgaria, Hungary	1.5578	1.5000
	Club 4 [2]	Cyprus, Malta	0.3897	0.1355
Goal 17	Club 1 [3]	Denmark, Germany, Sweden	0.8274	5.0060
	Club 2 [7]	Austria, Belgium, Bulgaria, Czechia, Finland, Luxembourg, Netherlands	0.3152	4.1535
	Club 3 [17]	Croatia, Cyprus, Estonia, France, Greece, Hungary, Ireland, Italy, Malta, Latvia, Lithuania,Poland, Spain, Portugal, Romania,Slovenia,Slovak Rep.	-0.0329	-0.4523

Table A2. Club merging test results for SDGs clubs

Variables	Clubs	Coefficient	T-Statistic
SDG Index Score	Club 1 + 2	-0.0997	-4.0832
	Club 2 + 3	-0.1598	-3.8809
Goal 1		–	
Goal 2	Club 1 + 2	-0.2079	-5.7792
	Club 2 + 3	0.1517	2.2691
	Club 3 + 4	-0.2066	-4.7808
Goal 3		–	
Goal 4	Club 1 + 2	-0.6623	-9.7924
	Club 2 + 3	-0.7083	-19.2086
Goal 5		–	
Goal 6	Club 1 + 2	0.3317	5.8980
	Club 2 + 3	-7.3689	-5.1825
	Club 3 + 4	-0.1676	-7.3689
	Club 4 + 5	-0.4129	-7.2108
Goal 7	Club 1 + 2	-0.1984	-6.4642
	Club 2 + 3	0.0352	0.6401
	Club 3 + 4	-0.0907	-1.2288
Goal 8	Club 1 + 2	-0.5696	-14.2830
Goal 9		–	
Goal 10		–	
Goal 11	Club 1 + 2	-0.0586	-1.2665
	Club 2 + 3	0.0135	0.2787
Goal 12		–	

	Goal 13		–	
	Goal 15	Club 1 + 2	-0.5718	-19.6423
		Club 1 + 2	-0.5413	-33.8139
	Goal 16	Club 2 + 3	0.1872	2.3893
		Club 3 + 4	-3.8311	-12.9081
	Goal 17	Club 1 + 2	-0.1294	-2.3896
		Club 2 + 3	-0.3276	-7.0698

Table A3. Final SDGs convergence clubs

Variables	Clubs	Countries	Coefficient	T-Statistic
SDG Index Score	Club 1 [22]	Austria, Belgium, Croatia, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Italy, Latvia, Malta, Netherlands, Poland, Portugal, Romania, Slovak Rep., Slovenia, Spain, Sweden	0.0169	0.5573
	Club 2 [3]	Ireland, Lithuania, Luxembourg	1.5067	7.0173
	Club 3 [2]	Bulgaria, Cyprus	0.2987	2.7212
Goal 1		-No Poverty		
Goal 2	Club 1 [8]	Austria, Belgium, Bulgaria, Croatia, Denmark, Germany, Romania, Spain	0.1679	2.2346
	Club 2 [13]	Estonia, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Poland, Portugal, Slovak Rep., Slovenia, Sweden	0.1517	2.2691
	Club 3 [4]	Cyprus, Czechia, Finland, Greece	0.3136	3.9458
No Hunger	Club 4 [2]	France, Netherlands	Not Convergent	
Goal 3		− Good Health and Well-Being		
Goal 4 Quality Education	Club 1 [20]	Austria, Belgium, Croatia, Cyprus, Denmark, Estonia, Finland, France, Germany, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Poland, Portugal, Slovenia, Spain, Sweden	0.3228	3.9543
	Club 2 [3]	Greece, Hungary, Malta	3.1586	2.2141
	Club 3 [3]	Bulgaria, Romania, Slovak Rep.	1.9601	6.5599
	Club 4 [1]	Czechia	**Not Convergent**	
Goal 5 Gender Equality	Club 1 [25]	Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Malta, Luxembourg, Netherlands, Poland, Portugal, Slovak Rep., Slovenia, Spain, Sweden	0.2774	5.9291
	Club 2 [2]	Hungary, Romania	**Not Convergent**	
Goal 6 Clean Water and Sanitation	Club 1 [15]	Austria, Belgium, Croatia, Czechia, Denmark, Estonia, France, Germany, Greece, Hungary, Latvia, Netherlands, Slovenia, Spain, Sweden	0.2891	5.4744
	Club 2 [8]	Ireland, Italy, Lithuania, Luxembourg, Poland, Portugal Romania, Slovak Rep.	0.6560	15.2175
	Club 3 [3]	Bulgaria, Cyprus, Malta	0.2081	1.3652
	Club 4 [1]	Finland	Not Convergent	
Goal 7 Accessable and Clean Energy	Club 1 [5]	Denmark, Estonia, Finland, Latvia, Sweden	-0.0776	-1.6427
	Club 2 [17]	Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Romania, Slovak Rep., Slovenia, Spain	0.0352	0.6401
	Club 3 [3]	Hungary, Malta, Poland	0.4860	1.9055
	Club 4 [2]	Lithuania, Luxembourg	Not Convergent	
Goal 8 Decent Work and Economic Growth	Club 1[24]	Austria, Belgium, Bulgaria, Croatia, Czechia, Denmark, Estonia, Finland, France, Germany, Hungary, Ireland, Italy, Latvia, Lithuania, Malta, Luxembourg, Netherlands, Poland, Portugal, Romania, Slovak Rep., Slovenia, Sweden	-0.0592	
	Club 2 [2]	Cyprus, Greece	0.3388	
	Club 3[1]	Spain	**Not Convergent**	
Goal 9		− Industry, Innovation and Infrastructure		
Goal 10 Reduced Inequalities	Club 1[25]	Austria, Belgium, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovak Rep., Slovenia, Spain, Sweden	0.0227	0.8968
	Club 2 [2]	Bulgaria, Lithuania	**Not Convergent**	
Goal 11 Sustainable Cities and Community	Club 1 [23]	Austria, Belgium, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Slovak Rep., Slovenia, Spain	-0.0586	-1.2665
	Club 2 [3]	Bulgaria, Croatia, Sweden	0.3624	5.6242
	Club 3 [1]	Romania	Not Convergent	

Goal 12		− Responsible Consumptiona and Production		
Goal 13		− Climate Action		
Goal 15 Life on Land	Club 1 [18]	Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, France, Germany, Greece, Hungary, Italy, Latvia, Lithuania, Malta, Poland, Romania, Slovak Rep., Slovenia	0.0775	3.8267
	Club 2 [9]	Austria, Belgium, Finland, Ireland, Luxembourg, Netherlands, Portugal, Spain, Sweden	0.2895	3.2192
Goal 16 Peace, Justice and Strong Institutions	Club 1 [14]	Austria, Belgium, Czechia, Denmark, Estonia, Finland, Germany, Ireland, Latvia, Lithuania, Luxembourg, Netherlands, Portugal, Sweden	0.3335	6.6410
	Club 2 [11]	Bulgaria, Croatia, France, Greece, Hungary, Italy, Poland, Romania, Slovak Rep., Slovenia, Spain	0.1872	2.3893
	Club 3 [2]	Cyprus, Malta	0.3897	0.1355
Goal 17 Partnerships for the Goals	Club 1 [3]	Denmark, Germany, Sweden	0.8274	5.0060
	Club 2 [7]	Austria, Belgium, Bulgaria, Czechia, Finland, Luxembourg, Netherlands	0.3152	4.1535
	Club 3 [17]	Croatia, Cyprus, Estonia, France, Greece, Hungary, Ireland, Italy, Malta, Latvia, Lithuania,Poland, Spain, Portugal, Romania,Slovenia,Slovak Rep.	-0.0329	-0.4523

Table A4. Final club classifications for Goal 14 (Life Below Water)

Variables	Clubs	Countries	Coefficient	T-Statistic
Goal 14	Club 1[15]	Croatia, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Latvia, Lithuania, Malta, Poland, Romania, Slovenia, Spain	0.0486	5.0356
	Club 2 [3]	Bulgaria, Italy, Sweden	2.2138	15.2904
	Club 3[4]	Belgium, Cyprus, Netherlands, Portugal	0.7939	5.9838

Note: Austria, Slovakia, Luxembourg, Hungary and the Czech Republic were excluded from the analysis because no datasets were available for indicators related to Target 14 (Life Below Water).

Figure A1 illustrates the divergence of three distinct convergence clubs in terms of Goal 14 performance over the period 2000–2023.

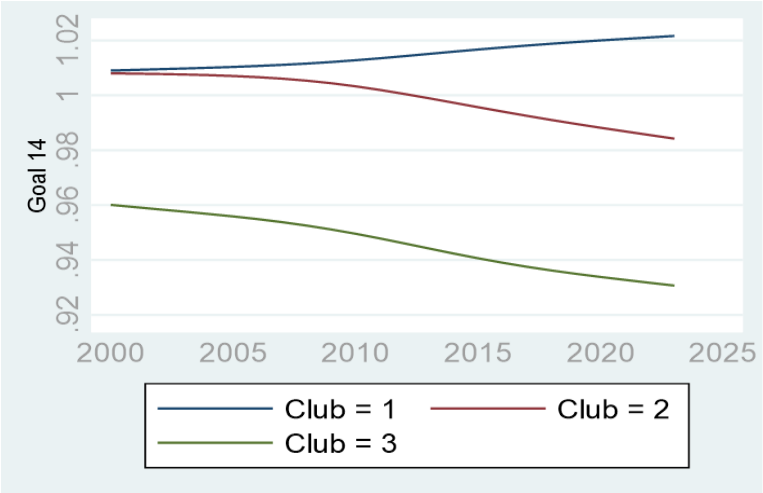

Figure A1. Relative transition path for Goal 14, convergence clubs

While Club 1, initially close to the average, demonstrated a steady upward trajectory, Club 2 experienced a consistent decline, and Club 3, starting from the lowest performance level, deteriorated even further. These divergent trends highlight substantial disparities among the clubs in achieving Goal 14 targets and underscore the necessity of tailored policy interventions for each group. Nevertheless, as elaborated in the main text, the decision to proceed with this analysis despite incomplete data is grounded in sound methodological reasoning. When one country from each group (Cyprus, Denmark, Bulgaria) is excluded from the analysis, the composition of the clubs' changes. This presents a significant methodological concern that must be addressed with appropriate analytical rigor. In club convergence analyses, the completeness of the dataset is critical for accurately determining club structures. The fact that the exclusion of a single country from each group alters the club configuration indicates that these clubs lack stability and that the results are highly sensitive to data coverage. This, in turn, suggests that the findings have limited validity. Therefore, analyses based on incomplete country data were not included in the study. A detailed overview of this issue is presented in both Table A5 and Table A6.

Table A5. Goal 14 club merging test results for SDGs clubs

Variables	Clubs	Coefficient	T-Statistic
Goal 14	Club 1+ 2	-0.1747	-6.5322
	Club 2 +3	-0.3963	-88.9315

Table A6. Final club classifications and club merging test results

Variables	Clubs	Countries	Coefficient	T-Statistic
Goal 14	Club 1 [14]	Croatia, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Latvia, Lithuania, Malta, Poland, Romania, Slovenia, Spain	0.0486	5.0356
	Club 2 [3]	Italy, Portugal, Sweden	2.2138	15.2904
	Club 3 [2]	Belgium, Netherlands	0.7939	5.9838
Goal 14	Club 1+ 2		-0.3660	-17.5404
	Club 2 +3		-0.1119	-45.0188