14th International Conference on Sustainable Development, 09-10 September 2026, Rome, Italy
https://ecsdev.org

GREEN TRANSFORMATION AND SUSTAINABLE DEVELOPMENT DISPARITIES ACROSS EUROPEAN UNION COUNTRIES

Radoslav Mikča
Anita Adamková
Halina Kot

University of Prešov
Faculty of Management and Business,
Prešov, Slovakia

radoslav.mikca@smail.unipo.sk
anita.adamkova@smail.unipo.sk
halina.kot@smail.unipo.sk

INTRODUCTION

The circular economy, central to the European Green Deal and the EU Circular Economy Action Plan, aims to replace the linear „take-make-dispose“ model, yet is often reduced to recycling alone and only weakly linked to sustainable development (Kirchherr et al., 2017). Recycling alone does not reduce environmental pressure if material consumption keeps growing, and efficiency gains in developed countries often shrink once imported resources are accounted for (Korhonen et al., 2018; Wiedmann et al., 2015). Empirical evidence shows that relative decoupling of economic growth from environmental pressure is common, while absolute decoupling remains rare (Haberl et al., 2020). To address this, the paper replaces GDP with a composite Socio-economic Well-being Index (SWI), reframing the research question as whether well-being can rise while the Environmental Pressure Index (EPI) declines, in line with Jackson (2009). As both dimensions are multidimensional, composite indices are used for cross-country comparison, though their construction requires careful, transparent methodological choices (Saisana et al., 2005).

METHODOLOGY

The analysis is based on a balanced panel dataset for all 27 EU member states over 2015 - 2023 (243 observations), using data from Eurostat. Principal Component Analysis (PCA) was used to construct two composite indices as dependent variables: the Socio-economic Well-being Index (SWI), combining healthy life expectancy, GDP per capita, and tertiary education attainment, and the Environmental Pressure Index (EPI), combining air emissions, greenhouse gas emissions, and municipal waste generation. Six explanatory variables were included: circular material use rate, resource productivity, domestic material consumption, renewable energy share, energy productivity, and energy intensity. The empirical strategy comprised three stages: PCA-based index construction (validated via KMO and Bartlett's test), multicollinearity diagnostics (correlation matrix, VIF), and fixed-effects panel regression, selected over random effects based on the Hausman test, with HAC robust standard errors. All analyses were performed in RStudio.

RESULTS

The analyzed indicators show persistent heterogeneity across EU member states in economic performance, energy structure, and circular economy practices, which justifies the use of composite indices and panel data analysis. PCA confirmed adequate data suitability (KMO ≈ 0.60; Bartlett's test $p < 0.001$). PC1 explains 66.79 % of variance in SWI (driven mainly by GDP) and 69.54 % in EPI (driven mainly by industrial and GHG emissions).

Dependent construct (PC1)	Indicator	Factor loading (weights)	Bartlett's Test	KMO	Explained variance (PC1)
SWI	GDP	0.625	$\chi^2 = 189.34$ d.f. = 3 $p < 0.001$	0.63	66.79 %
	HLE	0.565			
	TEA	0.538			
EPI	AE	0.640	$\chi^2 = 298.48$ d.f. = 3 $p < 0.001$	0.59	69.54 %
	GHG	0.618			
	MWG	0.456			

The correlation matrix confirmed no critical multicollinearity; the strongest relationship was between energy productivity and energy intensity (r = -0.867), consistent with VIF diagnostics.

ABSTRACT

This paper investigates sustainable development disparities across 27 European Union countries using Eurostat data over the period 2015–2023. The main objective is to construct composite indicators capturing socio-economic well-being and environmental pressure, and to examine their interrelationships with selected indicators of circular economy performance, resource productivity, and energy efficiency in a cross-country comparative framework. Two composite indices are developed using principal component analysis (PCA): the Socio-economic Well-being Index (SWI) and the Environmental Pressure Index (EPI). The analysis applies correlation assessment and fixed-effects panel regression models with robust standard errors to evaluate the association between the selected explanatory variables and both socio-economic outcomes and environmental pressure. Additionally, a typological analysis identifies groups of countries exhibiting different sustainability trajectories. The results highlight persistent heterogeneity among EU countries and reveal contrasting relationships between socio-economic development and environmental sustainability dimensions. The study provides a multidimensional, data-driven framework for assessing sustainability disparities within the European Union.

Key words

Sustainable development. Green transformation. Composite indicators. Environmental pressure. Socio-economic well-being.

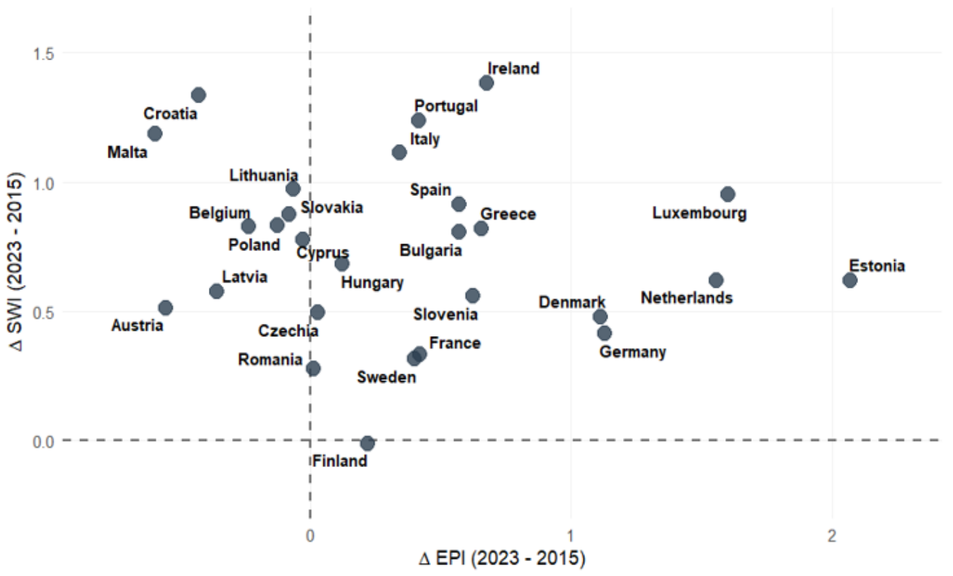
ACKNOWLEDGEMENTS

This paper was supported by the Grant Agency of Prešov University under projects GaPU 30/2026 and GaPU 31/2026. Furthermore, this research was supported under the projects KEGA 032PU-4/2026 and KEGA 031PU-4/2025.

Fixed-effects panel regression (Hausman test) shows energy productivity (EP) as the only variable significant in both models: it increases socio-economic well-being (β = 0.059, $p < 0.001$) but also environmental pressure (β = 0.110, $p < 0.05$), consistent with a rebound effect. Domestic material consumption (DMC) shows no effect on well-being but significantly reduces environmental pressure (β = -0.165, $p < 0.001$), likely reflecting a shift toward lower-emission materials such as biomass and construction inputs. Resource productivity (RPR) shows a weak positive effect on well-being only ($p < 0.10$). CMU, RES, and EI show no significant effects. The models explain 61.73 % (SWI) and 48.47 % (EPI) of the variation.

Independent variables	Model 1 (SWI)	Model 2 (EPI)
CMU	0.00701	-0.01005
	(0.00873)	(0.02414)
RPR	0.20481^	-0.63786
	(0.10907)	(0.46168)
DMC	0.02159	-0.16461***
	(0.01934)	(0.04535)
RES	0.00794	0.01799
	(0.00922)	(0.01967)
EP	0.05920***	0.11039*
	(0.01741)	(0.05258)
EI	-0.00208	-0.00946
	(0.00141)	(0.00720)
Diagnostics		
R^2	61.73 %	48.47 %
N	243	243

The quadrant analysis of ΔSWI and ΔEPI (2015 - 2023) reveals heterogeneous development trajectories across EU member states, going beyond the average effects captured by the regression models.



CONCLUSION

The results show that resource and energy efficiency improvements do not automatically translate into better environmental outcomes. Energy productivity (EP) plays a dual role, boosting socio-economic well-being while simultaneously increasing environmental pressure, pointing to a rebound effect within the EU. Domestic material consumption (DMC), by contrast, emerges as a key determinant of environmental pressure, suggesting that sustainability requires regulatory caps on material throughput, not just efficiency gains. The quadrant typology reveals considerable heterogeneity: absolute decoupling was achieved only by a small group of countries (e.g., Malta, Croatia, Lithuania, Slovakia, Poland), while others, notably Estonia, Netherlands, Luxembourg, and Germany, show an unfavorable trajectory toward higher environmental pressure. This heterogeneity calls for differentiated, country-specific policy design alongside common EU objectives. Addressing this requires demand-side instruments such as material footprint targets, carbon border adjustments, or caps on total material consumption, rather than efficiency-driven policy alone.