



Unpacking regional development in the EU: The interplay of cohesion, institutions, and sustainability

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ABSTRACT

This paper examines regional development in the European Union from a multidimensional and dynamic perspective, addressing the limited understanding of how economic, social, institutional, and environmental dimensions interact over time. While existing research often treats these dimensions separately or relies on static indicators, less attention has been paid to their temporal interdependencies and adjustment dynamics. Using a panel vector autoregressive model with common correlated effects (PVAR-CCE) applied to 233 NUTS-2 regions over the period 2000–2022, the analysis identifies the dynamic interactions linking these dimensions while accounting for cross-sectional dependence and regional heterogeneity. The results provide evidence of a structured system of interdependencies governing regional development. They reveal a dual adjustment structure characterised by a fast-moving economic–social cycle linking employment, income, and youth exclusion, and a slower structural dynamic driven by institutional quality, human capital, and environmental conditions. These dynamics vary across regions and income levels, highlighting persistent structural constraints in lagging regions and more integrated development trajectories in advanced regions. Environmental sustainability emerges as a constitutive component of regional development rather than a peripheral outcome, extending place-based approaches beyond income-based frameworks. Overall, the findings contribute to a more integrated understanding of regional development and provide an empirical basis for assessing the feasibility of EU policy objectives related to cohesion, sustainability, and balanced territorial development.

1. Introduction

Economic performance, social cohesion, and the green transition are critical objectives of the European Union (EU). However, regional disparities remain (European Commission, 2022; European Commission, 2024). More than 28% of people in the EU live in regions with a GDP (gross domestic product) per capita below 75% of the EU average, and several regions exhibit shrinking GDP per capita growth. Moreover, the average income in rural areas is 87.5% of that in urban areas (European Commission, 2024). These facts show that many people in the EU live in less-developed regions and face persistent disparities. However, GDP per capita alone may hide important aspects of regional development, as it does not capture social, institutional, or environmental factors that

shape people's quality of life and regional development trajectories (Borrega et al., 2025; Ferrara et al., 2022; Tomaney, 2017).

For instance, some regions are already experiencing or are at risk of falling into development traps, including old industrial and middle-income regions (Diemer et al., 2022). Development challenges were traditionally associated mainly with less-developed and peripheral regions. However, recent evidence shows that stagnation and related vulnerabilities are increasingly affecting regions beyond the traditional core-periphery divide. In these regions, economic stagnation tends to coincide with social, institutional, and environmental weaknesses, reinforcing development difficulties. This study is motivated both empirically and normatively to examine how economic trends are shaped by, and in turn shape, social, institutional, and environmental

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processes.

Empirically, existing research has rarely examined temporal interactions among developmental dimensions. Normatively, EU cohesion policy explicitly aims to promote balanced regional development across economic, social, environmental, and institutional dimensions. This paper contributes by empirically identifying the dynamic interactions through which economic, social, institutional, and environmental dimensions jointly shape regional development trajectories in the EU. In doing so, it provides an evidence-based framework to assess how the EU's normative objective of balanced and integrated development can be achieved, in line with major strategic agendas such as the Green Deal, the Territorial Agenda 2030, and the European Commission's cohesion objectives. For instance, weaker economic performance is often associated with lower social cohesion and higher inequality (Dijkstra et al., 2020; UNDP (United Nations Development Programme), 2024), while institutional weaknesses can limit the capacity of regions to overcome challenges (Charron et al., 2014; Rodríguez-Pose, 2013). Similarly, environmental vulnerabilities, such as exposure to pollution or climate risks, can reinforce existing economic and social divides (Rodríguez-Pose and Bartalucci, 2024; Safar, 2022). These dimensions form an interdependent system in which changes in one domain may propagate to others over time.

The expected interactions among these dimensions operate through several mechanisms. Economic performance may affect social cohesion through employment and income, while social exclusion may feed back into weaker labour-market participation. Institutional quality can shape regions' capacity to absorb investment, implement policies, and transform economic gains into human capital and social improvements. Environmental pressures, in turn, reflect the carbon intensity of regional development paths and may condition the long-term sustainability of economic and social progress. These mechanisms are consistent with institutional and evolutionary perspectives on regional development, which emphasise that regional trajectories are shaped by institutional capacity, path dependence and adaptation (Boschma and Frenken, 2006; Boschma, 2015; Farole et al., 2011; Gong, 2024).

As highlighted by the IPCC (2023), climate change impacts are intensifying and interact with socioeconomic inequalities. The EU's goal of carbon neutrality by 2050 introduces additional challenges, as the green transition tends to benefit regions with stronger economic and human capital bases, while less developed and rural regions face higher transition risks (European Commission, 2019b; European Commission, 2024; Rodríguez-Pose and Bartalucci, 2024).

A growing body of research highlights the central role of institutional factors in shaping regional development. Charron et al. (2014) document significant regional variation in governance quality through the European Quality of Government (QoG) index. Ferrara and Nisticò (2019) link institutional quality to multidimensional well-being, while Rodríguez-Pose (2013) and Rodríguez-Pose and Ketterer (2020) emphasise the importance of integrated development strategies that combine institutions and human capital. More recently, Muringani et al. (2024) emphasise the role of social and political trust in shaping development trajectories.

Taken together, these challenges underscore the need to better understand regional development and disparities across the EU as outcomes of interdependent economic, social, institutional, and environmental dynamics.

What remains insufficiently explored in the literature is the direction and timing of regional development dynamics, particularly whether improvements in institutional quality precede economic development or whether growth itself creates the conditions for stronger institutions. This limitation is also evident in the literature on regional development traps, which shows that many EU regions struggle to transition to higher levels of development despite relatively high GDP (Diemer et al., 2022; Rodríguez-Pose et al., 2024).

This paper addresses this gap by conceptualising regional development as a multidimensional and dynamic process shaped by interacting

economic, social, institutional, and environmental forces, and by explicitly focusing on the temporal sequencing of these forces. In doing so, it responds to calls for more integrated approaches to development (Borrega et al., 2025; Dasgupta, 2021; Pike et al., 2017; Stiglitz et al., 2009) and extends existing work by moving beyond isolated analyses or static composite indices to examine how development dimensions co-evolve and generate trade-offs over time (Dijkstra et al., 2020; Rodríguez-Pose and Ketterer, 2020; Safar, 2022).

Three research questions guide the paper. First, what are the main short- and medium-term drivers of multidimensional regional development in the EU? Second, how do economic, social, institutional, and environmental dimensions interact dynamically over time? Third, how does institutional quality shape regional development trajectories and condition the interaction between the other dimensions?

We hypothesise that regional development in the EU is governed by interdependent adjustment processes unfolding across different horizons, through which economic, social, institutional, and environmental dimensions interact to shape development trajectories.

The empirical results support this hypothesis. They reveal a dual adjustment structure in which a fast-moving economic–social cycle links employment, income, and youth exclusion. In contrast, a slower structural cycle is driven by institutional quality, human capital, and environmental dynamics. Employment and institutions emerge as key stabilisers, particularly in the post–2008 period, while environmental sustainability constitutes an integral component of regional development rather than a peripheral outcome.

This paper applies a panel vector autoregressive model with common correlated effects (PVAR-CCE) to analyse multidimensional regional development across EU NUTS–2 regions from 2000 to 2022. This framework treats economic, social, institutional, and environmental variables as jointly endogenous, allowing the analysis to capture feedback effects, temporal dynamics, and shock propagation across development dimensions. It also accounts for unobserved common shocks and cross-regional dependence, which are crucial in the EU context due to shared policy frameworks, macroeconomic cycles, and major events such as the financial crisis, the green transition, and the COVID–19 pandemic. This approach extends previous static and single-equation studies towards a dynamic analysis of regional development trajectories.

The remainder of the paper is structured as follows. Section 2 reviews the related literature. Section 3 presents the data and variables. Section 4 outlines the empirical methodology. Section 5 discusses the results, while Section 6 concludes with policy implications.

2. Related literature

The literature on regional development in the EU reveals a growing focus on cohesion policies that aim to reduce disparities, promote social cohesion and economic convergence, and support sustainable development (European Commission, 2022; European Commission, 2024; McCann and Ortega-Argilés, 2015). Recent evidence also shows that EU regional disparities remain shaped by human capital, physical capital, and cohesion funds, reinforcing the importance of analysing regional development beyond income dynamics alone (Giannini and Martini, 2024). Regional development is a concept widely studied across different dimensions: economic (Diemer et al., 2022), social (Dijkstra et al., 2020; UNDP (United Nations Development Programme), 2024), institutional (Ferrara and Nisticò, 2019; Rodríguez-Pose, 2013) and environmental (Safar, 2022). However, much of this literature continues to examine these dimensions separately or treats them as parallel outcomes. As a result, existing research offers limited insight into how these dimensions interact and, crucially, how those interactions evolve over time. We argue that this analysis is necessary to capture interdimensional dynamics of development.

Policy interventions become central to explaining regional development processes. Fidrmuc et al. (2024) show that EU cohesion policy has a positive and significant impact on regional growth, generating

spillover effects beyond recipient regions and reinforcing the multidimensional nature of development. While Ezcurra and Rapún (2006) suggest that regional disparities may be transitory under favourable conditions. Yet, this literature rarely clarifies the timing and persistence of these effects. In particular, it remains unclear whether policy-induced economic improvements translate into sustained social, institutional, or environmental progress, or whether they operate primarily as short-term adjustment mechanisms. This limitation constrains our understanding of the durability of development processes across regions.

Evidence from convergence club analyses further underscores the importance of regional heterogeneity. von Lyncker and Thoennessen (2017) demonstrate that regions converge into distinct groups defined by structural characteristics, such as income levels and human capital, whereas others remain stagnant. Consistently, Ezcurra et al. (2005) show that less-developed regions tend to be geographically concentrated, indicating that convergence is not spatially neutral.

These insights inform the debate on place-based policies. While place-neutral approaches may be inadequate for addressing territorial development problems (Barca et al., 2012), empirical evidence indicates that cohesion policy has a positive effect on regional development beyond GDP, with stronger effects in less-developed regions (Ferrara et al., 2022). Nevertheless, its effectiveness depends on tailoring interventions to regional specificities.

Despite these efforts, underdevelopment and disparities persist. The concept of the regional development trap highlights that EU regions, including middle-income ones, struggle to translate growth into sustained improvements in income, employment and productivity (Diemer et al., 2022). This evidence reinforces the need to approach regional development from a broader, more dynamic perspective that can capture persistent vulnerabilities and heterogeneous trajectories.

Empirical studies on EU regional development have examined regional disparities, cohesion policy, convergence clubs, development traps, and broader territorial development dynamics (see Table 1). While cohesion policy and economic growth contribute to regional development, the evidence reveals persistent heterogeneity and structural constraints that continue to hinder progress in lagging regions. Most studies analyse development outcomes separately, often relying on income-based measures or focusing on specific dimensions of development.

This limitation has prompted a growing critique of development models centred on GDP per capita. Tomaney (2017) and Borrega et al. (2025) argue that development extends beyond income to encompass population well-being, while Pike et al. (2017) and Turok et al. (2017) advocate broader frameworks integrating social and environmental dimensions, including green economy approaches. In particular, Borrega

et al. (2025) provide a systematic review of multidimensional regional development in the EU and show that, despite increasing attention to broader approaches, much of the literature remains centred on economic indicators or treats development dimensions separately.

Empirical evidence further suggests that the relationship between inequality and CO₂ emissions is contingent on territorial contexts. Safar (2022) finds that higher inequality may be associated with lower emissions in France due to constrained consumption among lower-income groups, whereas Uzar and Eyuboglu (2019) show that inequality can increase emissions in Türkiye through elite capture of environmental policy, broadly consistent with the environmental Kuznets curve. These national studies highlight the need for regional-level analyses within the EU.

In response, a growing literature has proposed multidimensional indicators to capture regional development beyond GDP. While such measures improve descriptive accuracy, they often provide static summaries rather than insights into dynamic interactions. Ferrara and Nisticò (2019) show that institutional quality and policy effectiveness shape multidimensional well-being disparities, while Murias et al. (2006) and Hardeman and Dijkstra (2014) develop synthetic indicators such as DEA-based indices and the EU Regional Human Development Index. However, they remain predominantly static and do not examine how development dimensions interact dynamically. As a result, they provide limited insight into whether progress in one dimension precedes, follows, or conditions changes in others.

The green transition further reinforces the need for a multidimensional and territorial perspective. Recent evidence shows that regional progress in the green transition depends not only on environmental performance, but also on structural vulnerabilities, opportunities, institutional capacity, and place-specific conditions (Ritter and Royuela, 2026). This supports the view that environmental sustainability should be treated as an integral dimension of regional development rather than as a separate policy outcome.

Within this broader literature, institutional quality has emerged as a key determinant of regional development. Inclusive and effective institutions are widely recognised as fundamental to economic and social outcomes (Acemoglu et al., 2005; Robinson and Acemoglu, 2012; Rodrik et al., 2004), with strong empirical support at the regional level (Rodríguez-Pose and Ketterer, 2020; Rodríguez-Pose, 2013). The European Quality of Government Index documents substantial territorial variation in governance quality, closely associated with income and social outcomes (Charron et al., 2014). Recent evidence further shows that institutional quality shapes distinct regional development trajectories, with weaker institutional settings limiting the development potential of less advanced regions (Borsekova et al., 2026). Nevertheless,

Table 1
Selected empirical studies on EU regional development and territorial development dynamics.

Reference	Dependent variables	Methods	Main findings
Petrakos et al. (2005)	Regional income disparities	Panel econometric analysis	Economic growth alone does not ensure regional convergence; structural factors play a decisive role in reducing regional disparities.
Ezcurra et al. (2005)	Income inequality, polarization and mobility	Spatial and panel econometric analysis	Regional convergence tends to stall after initial gains, with national and spatial components being fundamental in shaping income distribution
Ezcurra and Rapún (2006)	Regional income disparities	Panel econometric analysis	Regional disparities may be transitory under favourable structural and institutional conditions, although convergence is neither automatic nor uniform.
von Lyncker and Thoennessen (2017)	GDP per capita	Convergence-club analysis	EU regions converge into distinct groups defined by structural characteristics, such as income levels and human capital endowments, whereas other regions remain stagnant.
Fidrmuc et al. (2024)	GDP per capita growth	Instrumental variables and spatial econometric models	EU cohesion funds have a positive and significant impact on regional growth, generating spillover effects that benefit neighbouring regions.
Ferrara et al. (2022)	Regional development index	Panel econometric analysis	Cohesion policy positively affects regional development beyond GDP growth, with stronger effects in less developed regions, supporting a multidimensional view of development.
Diemer et al. (2022)	Income, employment and productivity	Construction of a multidimensional development index and dynamic regional classification	A significant number of EU regions experience persistent development traps,

the effects of institutional quality are not uniform. While strong institutions may enhance resilience and reduce vulnerability (Ezcurra and Rios, 2019), they may also generate trade-offs, particularly when governance reforms prioritise short-term stabilisation over long-term investment (Ferrara and Nisticò, 2019). These findings point to complex and evolving institutional dynamics that are rarely analysed from a temporal perspective.

The interaction among development dimensions can also be understood through institutional and evolutionary perspectives on regional development. Farole et al. (2011) emphasise that cohesion policy outcomes depend on the interaction between growth potential, geography, institutional capacity, and territorial equity. Evolutionary economic geography further suggests that regional trajectories are shaped by path dependence, accumulated capabilities, and adaptation processes (Boschma and Frenken, 2006). Boschma (2015) extends this argument to regional resilience, highlighting that regions differ in their capacity to absorb shocks and develop new growth paths. More recently, Gong (2024) argues for a forward-looking perspective in economic geography, stressing the importance of analysing how present regional structures shape future development possibilities. These perspectives underscore the need for a dynamic framework that examines how economic, social, institutional, and environmental dimensions interact over time.

Overall, despite significant advances, the literature lacks a dynamic regional analysis that jointly examines economic, social, institutional, and environmental dimensions while explicitly focusing on their interactions and sequencing over time. Existing studies remain fragmented and offer limited insight into how short-term adjustments relate to structural transformation. This gap motivates the present study, which adopts a holistic and dynamic framework to analyse interdependencies across EU regions and to assess whether regional development is shaped by distinct but interrelated adjustment mechanisms.

3. Data and variables

The empirical analysis uses a multidimensional dataset on regional development in the EU, integrating economic, social, institutional, and environmental indicators. The panel covers NUTS-2 regions across 27 Member States from 2000 to 2022, encompassing key phases of European integration and adjustment, including the 2004–2007 enlargement, the 2008 financial crisis, the subsequent adjustment period, and the COVID–19 shock and early recovery. This time span places the estimated regional dynamics within a period marked by major common events affecting EU regions, although the model does not explicitly identify the specific causal effects of each episode. Data primarily originate from Eurostat, complemented by the Quality of Government (QoG) dataset and the EDGAR/Eurostat environmental accounts. To address regional gaps, particularly in Portugal, national data from the National Institute of Statistics (INE) were used to ensure consistency. Imputation procedures were applied to maximise regional coverage while preserving temporal and spatial consistency. Missing QoG values were interpolated using national trends from the Worldwide Governance Indicators, following Muringani et al. (2024). A sequential imputation strategy inspired by the European Commission: Directorate-General for Research and Innovation (2025) was then applied: short gaps (up to two years) were filled using linear interpolation, isolated start or end values were extended accordingly, and only when no neighbouring information was available were values replaced by NUTS–1 aggregates.

The selection of variables reflects a multidimensional view of regional development, integrating economic, social, institutional and environmental dimensions. Economic performance is measured through household income per capita and the employment rate, widely used indicators of regional prosperity and labour-market inclusion (Diemer et al., 2022; Hardeman and Dijkstra, 2014; Rodríguez-Pose et al., 2024). Social inclusion is captured by the NEET rate and tertiary education

attainment, reflecting youth exclusion and human capital (Cuestas et al., 2021; Ferrara et al., 2022; Hardeman and Dijkstra, 2014; Rodríguez-Pose et al., 2024). Institutional quality is proxied by the QoG, the most widely used subnational governance indicator in the EU. The environmental aspect is measured by per capita CO₂ emissions, consistent with regional analyses (European Commission, 2024; Rodríguez-Pose and Bartalucci, 2024; Safar, 2022). Table 2 reports variable definitions, transformations, and Table 3 reports descriptive statistics.

To illustrate the regional dynamics underlying the empirical analysis, Fig. 1 maps cumulative changes in the indicators from 2000 to 2022. Beyond highlighting spatial heterogeneity, the maps reveal the coexistence of common EU trends with persistent regional disparities, underscoring the presence of both shared shocks and region-specific dynamics.

4. Methodology

The empirical analysis was based on a PVAR-CCE framework because the objective was to examine regional development as a dynamic system of interdependent dimensions. A single-equation approach would have required imposing a dependent variable and a set of explanatory variables, which would have been inconsistent with the premise that economic performance, social inclusion, institutional quality, human capital, and environmental pressure influence one another over time. The PVAR framework was therefore appropriate because it treated these variables as jointly endogenous and captured how shocks in one dimension propagated to others over time.

The CCE component is particularly important in the EU regional

Table 2
Description and transformation of variables.

Variable	Description	Source	Transformation / Notes
QoG	Composite indicator of government impartiality, corruption control, and quality of public services	University of Gothenburg – Quality of Government Institute, Charron et al. (2014)	Level
CO ₂ emissions per capita	Total CO ₂ equivalent emissions from EDGAR divided by regional population from Eurostat, ensuring consistency in the denominator across indicators	EDGAR / Eurostat – Air Emission Accounts and demo_r_pjangroup	Level with trend
Household income per capita	Income of households (Euro per inhabitant)	Eurostat, nama_10r_2hhinc (for Portugal we consulted INE)	Logarithm, first difference ($\Delta \log$)
Employment rate	Share of employed persons aged 15–64 in the total population of the same age group	Eurostat, lfst_r_lfe2emprr	First difference (Δ)
Tertiary education attainment	Share of population aged 25–64 with completed tertiary education	Eurostat, edat_lfse_04	Level with trend
NEET rate	Young people aged 15–29 not in employment, education, or training	Eurostat, edat_lfse_22	First difference (Δ)

Table 3
Descriptive statistics.

Statistic	N	Mean	SD	Minimum	Pctl25	Pctl75	Maximum
QoG	5359	0,98	0,85	−2,67	0,49	1,65	2,63
CO ₂ emissions per capita	5359	10,31	8,05	0,36	6,48	12,34	122,43
log Household income per capita	5359	9,49	0,67	6,80	9,16	9,91	11,40
Employment rate	5336	69,57	7,74	42,10	64,90	75,10	85,60
Tertiary education attainment	5336	25,27	9,84	3,60	17,98	31,40	62,10
NEET rate	5246	16,61	7,65	3,70	11,00	20,80	48,40

Notes: Our dataset is an unbalanced panel of 233 EU27 NUTS–2 regions over the period 2000–2022. We miss information on the six French overseas departments, two autonomous Spanish regions, and one region in Finland. This exclusion was intended to ensure comparability across the mainland EU regions.

context. NUTS–2 regions are exposed to common European and national shocks, shared policy frameworks, macroeconomic cycles, cohesion policy programmes, the financial crisis, the green transition, and the COVID–19 period. Ignoring this cross-sectional dependence could bias the estimated relationships. Following Pesaran (2006) and Chudik and Pesaran (2015), the inclusion of cross-sectional averages proxies unobserved common factors while retaining region-specific dynamic responses. By incorporating these averages, the CCE approach helps account for the common component of such shocks and mitigates potential bias arising from unobserved cross-sectional dependence. Regional fixed effects, subgroup estimations, and temporal splits further help account for heterogeneity across regions and allow the analysis to examine whether the estimated relationships differ across territorial contexts.

Variables were treated in the order of their integration.⁶ Employment, household income (in logarithms), and the NEET rate were identified as integrated of order one (I(1)) and expressed in first differences, whereas QoG, tertiary education, and CO₂ emissions per capita were stationary and kept at levels. This transformation strategy ensures that all variables entering the PVAR-CCE model are stationary. Variables expressed in first differences capture short-term changes, whereas variables kept in levels are interpreted as stationary but persistent processes. Stationarity and cross-sectional dependence were assessed using the Pesaran CD test (Pesaran, 2021), the CIPS unit root test (Pesaran, 2003) and the PANIC approach of Bai and Ng (2004). The PANIC results indicate that household income, tertiary education, and institutional quality share common non-stationary components, reflecting EU-wide shocks, while employment, NEET rate, and emissions are primarily driven by region-specific dynamics. These findings support the use of the PVAR-CCE framework, which explicitly accommodates both common factors and heterogeneous regional responses. The Westerlund test did not detect cointegration among the non-stationary variables, justifying estimation in levels and first differences, without an error-correction term, and focusing on medium-term dynamics.

Formally, the vector of endogenous variables is defined in Eq. (1). The lag length was selected using the Bayesian Information Criterion (BIC), which consistently indicated a VAR (1) specification; therefore, the VAR (1) specification is adopted as the baseline model.

$$\mathbf{y}_{i,t} = (\Delta Emp_{i,t}, \Delta \ln Inc_{i,t}, \Delta NEET_{i,t}, Educ_{i,t}, EQI_{i,t}, Emissions_per_capita_{i,t}) \quad (1)$$

For each region $i = 1, \dots, N$ and year $t = 1, \dots, T$. The model follows the general form:

$$\mathbf{y}_{i,t} = \mathbf{A}_1 \mathbf{y}_{i,t-1} + \mathbf{\Gamma} \bar{\mathbf{y}}_t + \mu_i + \mathbf{u}_{i,t},$$

Where $\bar{\mathbf{y}}_t$ represents the annual cross-sectional means of the variables (levels and differences), μ_i regional fixed effects, and $\mathbf{u}_{i,t}$ is the idiosyncratic error term.

Estimation was carried out using least squares with transformation into first-difference orthogonal deviations (Arellano and Bover, 1995), treating the CCE cross-sectional means as weakly exogenous. Regional fixed effects were removed through within-group transformation. As a robustness check, equation-by-equation fixed-effects regressions were also estimated, including year effects and Driscoll–Kraay standard errors, which allow for heteroscedasticity, serial correlation, and cross-sectional dependence. These results corroborate the main findings obtained from the PVAR-CCE specification.

Dynamic interactions were analysed using impulse response functions (IRFs) following Pesaran and Shin (1998). IRFs were derived from the estimated coefficient matrix and the covariance matrix of the residuals. The forecast horizon was set to 40 periods, allowing the assessment of both short- and medium-term effects. A linear time trend was included in the IRF estimation to account for residual deterministic components.

As a complementary check on the direction of dynamic relationships, time-domain Granger causality tests based on the PVAR-CCE framework were also conducted.

To account for structural heterogeneity, the PVAR-CCE model was estimated across regional and temporal subsamples. Regions were grouped into North, South, West and East Europe, as well as into cohesion and non-cohesion areas using the 75% EU average income threshold. The temporal dimension was split into pre–2008 and post–2008 periods. For the latter, given the short time span, the model was estimated without lags. An interacted PVAR specification allowing coefficients to vary across groups was also estimated, and equality across groups was tested using Wald statistics with robust covariance estimators.

The adopted methodology favours a short- to medium-term view of dynamic adjustment, focusing on the interactions among economic performance, social inclusion, education, institutional quality, and environmental pressure, without imposing or estimating long-run equilibrium relationships. It reflects the complex, multidimensional nature of regional development.

5. Results

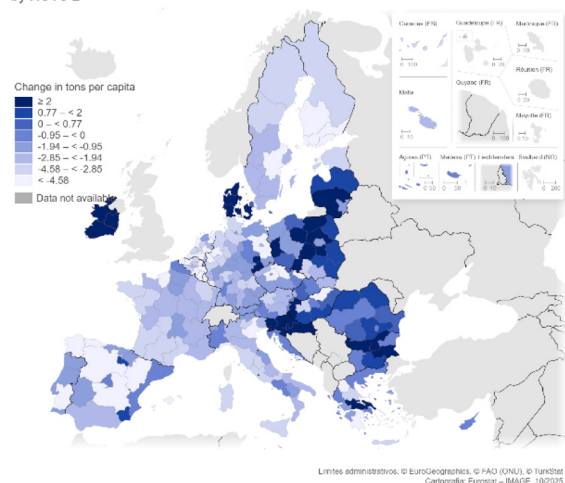
5.1. Overall results of the PVAR-CCE model

Estimation of the PVAR-CCE model confirms the existence of statistically significant dynamic interdependencies among the economic, social, institutional, and environmental dimensions of EU regions, after controlling for cross-sectional dependence and regional heterogeneity. The results provide consistent evidence of a structured system of interdependencies governing regional development dynamics in the EU. They support the existence of differentiated adjustment processes operating across distinct time horizons that link economic, social, institutional, and environmental dimensions. (see Table 4).

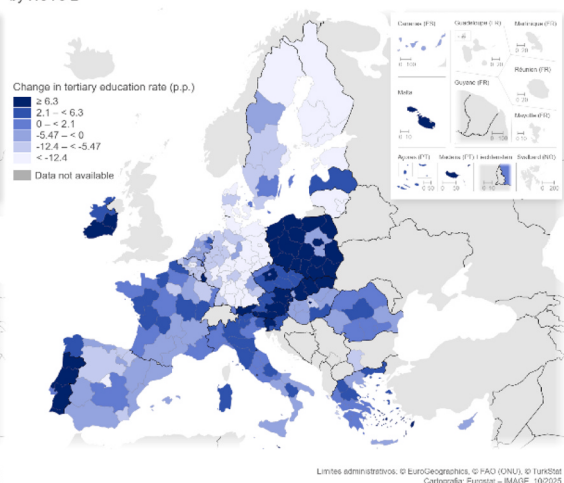
The substantive interpretation of the results combines evidence from three complementary sources. PVAR-CCE coefficients, which identify statistically significant lagged associations. The IRF's capture the direction, timing, and persistence of responses to shocks. The Granger causality tests, which provide additional evidence on the direction of the

⁶ See Appendix A for panel unit root and stationarity tests.

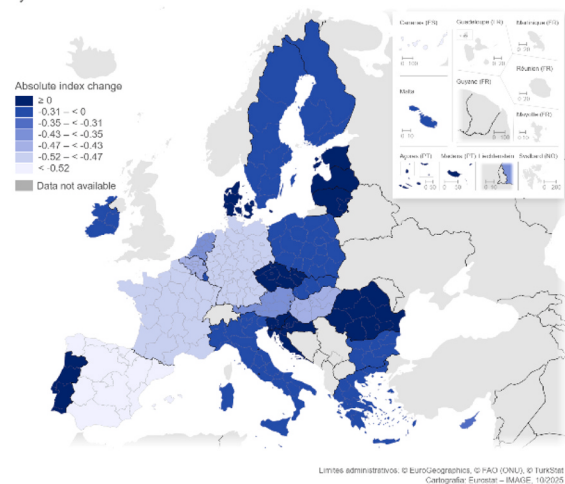
Change in Greenhouse emissions per capita (2000–2022)
by NUTS 2



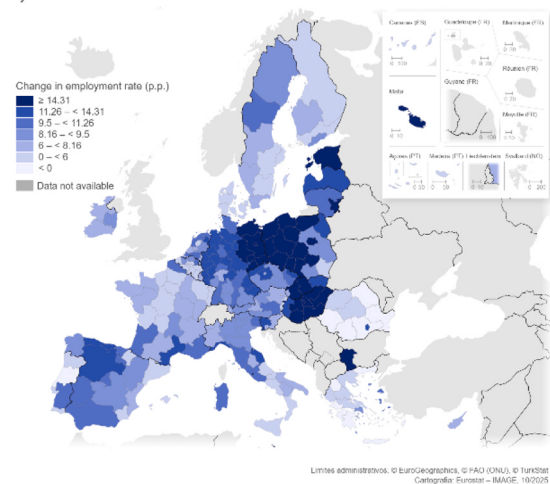
Change in Tertiary Education rate (2000–2022)
by NUTS 2



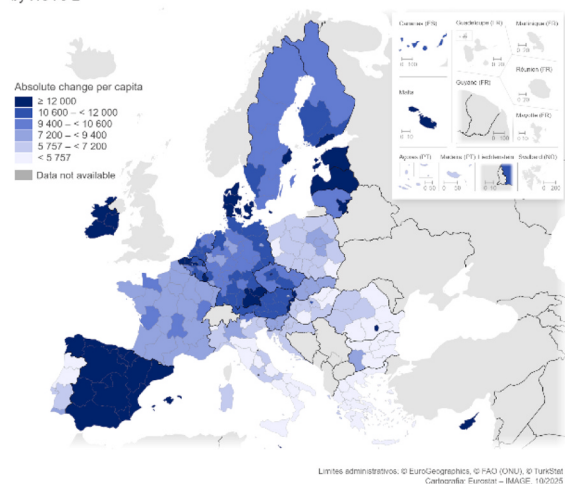
Change in Quality of Government (2000–2022)
by NUTS 2



Change in Employment rate (2000–2022)
by NUTS 2



Change in Income of Households per capita (2000–2022)
by NUTS 2



Change in NEET rate (2000–2022)
by NUTS 2

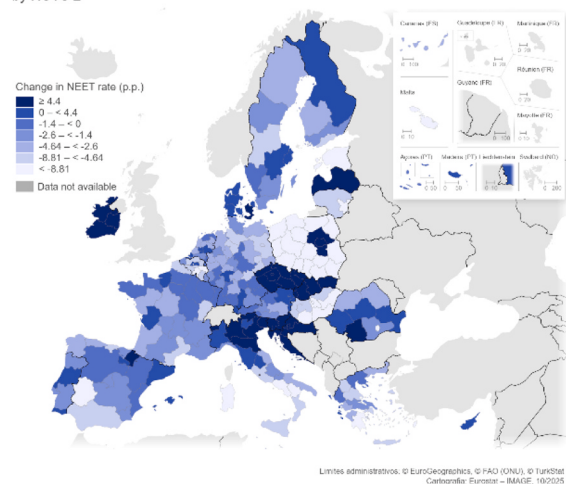


Fig. 1. Changes in emissions, education, institutional quality, employment, income and NEET across EU regions (2000–2022). NUTS–2 cumulative changes showing marked territorial heterogeneity across development dimensions. Sources: EC IMAGE Interactive Map Generator; authors' elaboration.

Table 4

Overall results of the PVAR-CCE model (IRFs global dynamics).

Dimension	Shock	Main response	Direction	Significance	Observed pattern
Economic–Social	Employment → NEET	NEET decreases	Negative	***	Labour-market inclusion immediately reduces youth exclusion
Social–Economic	NEET → Employment	Employment decreases	Negative	***	Youth exclusion feeds back into labour-market fragility
Economic–Economic	Employment → Income	Income increases	Positive	**	Employment growth stimulates household income
Economic–Institutional	Income → QoG	QoG improves	Positive	**	Income gains reinforce institutional quality
Institutional–Social	QoG → Education	Education decreases (short term)	Negative	**	Institutional consolidation temporarily crowds out education
Social–Social	Education → NEET	NEET increases (short/medium term)	Positive	***	Education–labour substitution effect
Social–Institutional	Education → QoG	QoG decreases (temporary)	Negative	**	Institutional adjustment following education shocks
Social (own)	Education → Education	Strong persistence	Positive	***	Cumulative long-term structural change
Environmental	Emissions → Emissions	Very strong persistence	Positive	***	Carbon lock-in and rigid emission pathways
Environmental–Institutional	Emissions → QoG	QoG increases (weak)	Positive	*	Environmental pressure induces institutional response

Notes: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$ Results based on IRFs.

main dynamic relationships. In the discussion below, short-term mechanisms refer to responses observed in the early IRF horizons ($h = 5$ and $h = 10$), whereas persistent or medium-term mechanisms refer to responses that remain visible at later horizons ($h = 20$ and $h = 40$) or reflect strong own-variable persistence.⁷

A central adjustment mechanism emerges around the interaction between employment and youth exclusion. Employment and NEET status exhibit a strong, mutually reinforcing relationship, indicating that labour-market inclusion plays a key role in reducing youth exclusion. In contrast, social exclusion feeds back into labour-market fragility. Employment shocks also translate into higher household income, which, in turn, strengthens the quality of government, thereby revealing a feedback loop linking economic performance and institutional quality.

Structural variables adjust more gradually. Improvements in the QoG are associated with short-term reductions in tertiary education. On the other hand, education shocks temporarily increase youth exclusion and weaken institutional quality, reflecting substitution and adjustment effects during periods of educational expansion. At the same time, education exhibits strong persistence, consistent with a cumulative process of structural change.

Environmental dynamics are characterised by pronounced inertia. Per capita emissions display very high persistence, confirming the rigidity of carbon pathways. At the global level, environmental shocks do not generate significant short-term trade-offs with economic or social outcomes. However, weak institutional responses suggest that environmental pressures may indirectly influence institutional quality.

Generally, the global PVAR-CCE points to a dual adjustment structure. A fast-moving economic–social cycle driven by employment, income and youth exclusion, and a slower structural dynamic involving institutions, education and the environment. This interpretation is further supported by time-domain Granger causality tests, which confirm the direction of the main dynamic linkages identified by the PVAR-CCE model.

5.2. Temporal dynamics: pre–2008 and post–2008

The comparison between the pre- and post–2008 periods reveals marked changes in the structure of interdependencies linking the economic, social, institutional and environmental dimensions of EU regional development (Table 5).

Prior to 2008, regional dynamics were largely driven by direct economic mechanisms. Income growth served as the main transmission

channel, with income increases systematically followed by higher per-capita emissions. However, income shocks had weak effects on employment and youth exclusion, indicating a limited connection between growth and social cohesion. Employment and tertiary education behaved mainly as reactive variables. Educational expansion was associated with short-term declines in employment and increases in NEET rates, reflecting a temporary substitution between education and labour market participation. Institutional quality played a secondary but supportive role, improving employment outcomes and reducing youth exclusion. Overall, the pre-crisis configuration reflects a pattern of development in which economic growth played a dominant role, while social and institutional transmission mechanisms remained weak.

After 2008, the dynamics changed substantially. Social and institutional mechanisms gained prominence, and employment emerged as a central stabilising force. The employment–NEET relationship strengthened significantly, with employment shocks leading to a stronger, more immediate decline in youth exclusion than in the pre–2008 period. At the same time, institutional dynamics gained prominence. After 2008, the quality of government responded more systematically to economic and environmental developments, and these institutional adjustments were associated with improvements in income levels and reductions in emissions. These institutional gains were accompanied by short-term trade-offs in education, consistent with a reallocation of public resources towards macroeconomic and social stabilisation during the post–2008 adjustment. Environmental dynamics also evolved after 2008. Although per-capita emissions remained highly persistent, environmental shocks became more influential within the system. Growth continued to be associated with temporary increases in emissions, indicating incomplete decoupling. Nevertheless, the interaction between institutional improvements and education indicates early signs of a transition toward less pollution-intensive growth trajectories.

Taken together, the post–2008 period is characterised by a shift away from growth-led adjustment towards a configuration in which employment and institutional quality play a central role in economic and social stabilisation, with emerging links to environmental performance.

5.3. Disparities between high- and low-income regions

The comparison between regions above and below 75% of the EU average household income reveals two distinct structural patterns of regional development (Table 6).

In low-income regions, employment emerges as the primary adjustment mechanism. Positive employment shocks lead to stronger reductions in youth exclusion than in more developed regions, underscoring the central role of labour markets for short-term social

⁷ Detailed PVAR-CCE estimates, impulse response functions, and Granger causality test results are reported in Appendices B, C, and D, respectively.

Table 5

Temporal dynamics of regional development: pre–2008 and post–2008 (IRFs).

Dimension	Shock	Main response	Direction	Significance	Observed pattern
Pre–2008	Income → Emissions	Emissions increase	Positive	**	Income growth translated into higher pollution
	Education → Employment	Employment decreases	Negative	**	Short-term education–labour substitution
	Education → NEET	NEET increases	Positive	**	Temporary rise in youth exclusion during educational expansion
	QoG → Employment	Employment increases	Positive	*	Institutions foster labour-market inclusion
	QoG → NEET	NEET decreases	Negative	**	Institutional quality reduces social exclusion
Post–2008	Emissions → Employment	Employment decreases	Negative	**	Resource-intensive growth undermines labour markets
	Employment → NEET	NEET strongly decreases	Negative	***	Employment becomes a key stabilisation mechanism
	QoG → Education	Education decreases (short-term)	Negative	**	Reallocation towards macroeconomic stabilisation
	QoG → Income	Income increases	Positive	**	Improved institutional effectiveness
	QoG → Emissions	Emissions decrease	Negative	**	Institutions mitigate environmental pressure
	Emissions → Income	Income increases (temporary)	Positive	*	Incomplete growth–environment decoupling
	Emissions → Education	Education decreases	Negative	**	Environmental shocks constrain human capital
	Employment–NEET	Faster adjustment	Negative	***	Stronger social sensitivity after the crisis

Notes: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$ Results based on IRFs. Wald tests confirm significant differences between periods.

Table 6

Disparities between high- and low-income regions (IRFs).

Dimension	Shock	Main response	Direction	Significance	Interpretation
Low-income regions	Employment → NEET	NEET strongly decreases	Negative	**	Employment acts as a key tool of social inclusion
	QoG → Income	Income increases	Positive	***	Institutions act as development accelerators
	QoG → NEET	NEET decreases	Negative	*	Institutions stabilise social vulnerability
	QoG → Education	Education decreases (short term)	Negative	***	Trade-off between institutional consolidation and education
High-income regions	Income → Education	Education increases	Positive	**	Growth strengthens human capital formation
	Education → QoG	QoG improves	Positive	**	Human capital reinforces institutional quality
	Education → Emissions	Emissions decrease	Negative	**	Human capital supports a more sustainable growth model

Notes: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$ Results based on IRFs. Wald tests confirm statistically significant differences between income groups.

stabilisation. By contrast, income shocks play a limited structural role. The absence of a significant income–education response indicates that economic gains do not translate into human capital accumulation, consistent with persistent development traps.

Institutional dynamics are particularly important in lagging regions. Improvements in the QoG significantly increase household income and reduce youth exclusion, confirming the role of institutions as stabilising and enabling factors. However, these gains are accompanied by short-term declines in tertiary education, indicating a trade-off between institutional consolidation and longer-term investment in human capital.

High-income regions exhibit a more stable, self-reinforcing development structure. Income growth is positively associated with education, indicating that economic gains are effectively transformed into human capital accumulation. Education, in turn, strengthens institutional quality and contributes to emissions reductions, reflecting a mature development model in which human capital, institutions and environmental sustainability interact positively. Shocks in these regions are smaller and more persistent, consistent with higher resilience.

Overall, the IRF analysis confirms the existence of a dual regional

development structure within the EU. While high-income regions operate through virtuous cycles linking growth, education and institutions, low-income regions remain more dependent on short-term employment adjustments and institutional support, with limited capacity to transform cyclical gains into sustained structural development.

5.4. Geographical asymmetries across European regions

The analysis by geographical blocks reveals pronounced asymmetries in how economic, social, institutional and environmental shocks propagate across EU regions (Table 7).

In Southern regions, employment dominates regional dynamics and acts as the main adjustment mechanism. Positive employment shocks reduce youth exclusion and support income growth, but these effects are short-lived, indicating strong cyclical dependence and structural fragility. Environmental constraints remain binding, as higher emissions are associated with weaker labour-market outcomes.

Eastern regions exhibit a similar level of vulnerability, alongside a greater role for environmental and educational channels. Economic expansion is closely linked to rising emissions, whereas educational

Table 7

Geographical asymmetries across European regions (IRFs).

Dimension	Shock	Main response	Direction	Significance	Observed pattern
South	Employment → NEET	NEET decreases	Negative	**	Employment is the main channel of social cohesion
	Employment → Income	Income increases	Positive	**	Labour market drives short-term economic gains
	Emissions → Employment	Employment decreases	Negative	*	Dependence on polluting sectors limits green transition
	Income → Emissions	Emissions increase	Positive	*	Carbon-intensive growth pattern
East	Education → NEET	NEET increases	Positive	**	Short-term social costs of educational expansion
	Education → QoG	QoG improves	Positive	**	Human capital fosters institutional modernisation
	Education → Emissions	Emissions decrease	Negative	**	Gradual environmental improvement via education
	QoG → Income	Income increases	Positive	**	Institutions stabilise and regulate growth
West	QoG → Emissions	Emissions decrease	Negative	**	Regulatory capacity mitigates environmental pressure
	QoG → Emissions (short term)	Emissions increase	Positive	*	Productive growth coexists with high carbon intensity
	Education → QoG	QoG improves	Positive	**	Human capital reinforces institutional quality
	Education → QoG	QoG improves	Positive	**	Strong feedback between human capital and institutions
North	Education → Emissions	Emissions decrease	Negative	***	Mature green transition

Notes: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$. Results based on IRFs. Wald tests confirm statistically significant differences across geographical blocks.

expansion generates short-term increases in youth exclusion alongside medium-term improvements in institutional quality and reductions in emissions. This points to gradual structural adjustment driven by human capital, albeit with short-term social costs.

Western regions exhibit a more stable and institutionally mature development model. Improvements in the quality of government support income growth and mitigate environmental pressures, while education reinforces institutional capacity over time. Some short-term coexistence of growth and carbon intensity persists, but longer-term dynamics favour more sustainable trajectories.

Northern regions represent the most integrated and resilient configuration. Strong feedback between education and institutional quality enables rapid absorption of economic and social shocks, while increases in tertiary education are consistently associated with emissions reductions, reflecting an advanced stage of the green transition.

Globally, the results confirm the persistence of geographical heterogeneity in the EU. Southern and Eastern regions remain more exposed to economic and environmental volatility, whereas Western regions benefit from stronger institutional stabilisation. Northern regions exhibit the most balanced and sustainable development model, based on mutually reinforcing interactions among human capital, institutions, and environmental performance.

6. Discussion

The results provide empirical support for the hypothesis that regional development in the EU is governed by interdependent adjustment processes unfolding over different time horizons. Specifically, they indicate that development is shaped by two structurally distinct yet interdependent adjustment mechanisms. On the one hand, a short-term economic–social cycle links employment, income and youth exclusion, which respond rapidly to shocks. On the other hand, a structural cycle is dominated by institutional quality, education and environmental dynamics. This distinction is consistent with the literature emphasising the coexistence of rapid adjustment processes and slower structural transformations in regional development (Giannakis and Bruggeman, 2017; Nijkamp et al., 2024; Petrakos et al., 2005). In line with Ferrara and Nisticò (2019), Rodríguez-Pose (2013) and Rodríguez-Pose and Ketterer (2020), our findings confirm that institutions and human capital frame and constrain the effects of short-term economic dynamics.

Employment emerges as the main mechanism of social and economic transmission. The strong bidirectional relationship between employment and the NEET rate highlights the central role of labour markets in shaping social cohesion, consistent with evidence that young people are particularly vulnerable to labour-market instability (Bell and Blanchflower, 2011; Rambla and Scandurra, 2021). The strengthening of this relationship after 2008 confirms that the financial crisis amplified social fragility and reinforced employment as a stabilising mechanism (European Commission, 2019a). This suggests that post-crisis regional development dynamics have become more dependent on inclusion mechanisms than on economic growth alone.

The post–2008 results should be interpreted in light of the broader macroeconomic environment that followed the financial crisis and the subsequent sequence of systemic shocks affecting EU regions. The temporal split reveals differences in the relationships among the variables before and after 2008, indicating that regional dynamics evolved during a period marked by the financial crisis, public debt pressures, fiscal consolidation, constraints on public investment, and, later, the COVID–19 pandemic and early recovery. Although the PVAR-CCE framework does not identify the specific effects of particular policies or events, the inclusion of CCE and the temporal split help account for shared shocks and changing macroeconomic conditions. The results show that employment and institutional quality became more prominent in the post–2008 period, suggesting a stronger role for these dimensions in regional adjustment and resilience.

Institutions display a dual and complex role. In the medium term,

improvements in institutional quality enhance performance and reduce social exclusion, corroborating the literature on the importance of governance for regional development (Charron et al., 2014; Muringani et al., 2024; Rodríguez-Pose and Ketterer, 2020). In the short term, however, institutional shocks are associated with negative responses in education, reflecting adjustment costs linked to governance reforms that prioritise administrative efficiency and enforcement over long-term investment in human capital, whose returns materialise more slowly (Robinson and Acemoglu, 2012; Rodríguez-Pose, 2013). This mechanism is particularly relevant in less-developed regions, where strong institutions compensate for the absence of self-regulating economic mechanisms (Crescenzi et al., 2016), acting as stabilisers that guide structural investment while limiting inefficient interventions.

The environmental dimension exhibits high persistence, consistent with theories of carbon lock-in (Unruh, 2000). Emissions respond weakly to short-term social and economic shocks, confirming that environmental trajectories depend on deep structural transformations (N. Stern, 2008). Nevertheless, post–2008 dynamics reveal emerging signs of change. Income gains associated with environmental shocks and education-driven emission reductions in advanced regions point to a gradual decoupling of growth from pollution, in line with the environmental Kuznets curve literature (D. Stern, 2004).

Having established these system-wide adjustment mechanisms, the discussion turns to how they differ across levels of development. The contrast between high- and low-income regions reveals two distinct development systems. Less-developed regions rely predominantly on short-term mechanisms centred on employment, display weak links between income and education, and are more vulnerable to institutional and environmental shocks. These dynamics are consistent with the literature on regional development traps (Diemer et al., 2022; Rodríguez-Pose and Bartalucci, 2024). Persistent underperformance should be understood as the result of interacting constraints rather than a single cause. The findings suggest that economic, social, institutional, and territorial factors reinforce one another over time, consistent with the literature on regional development traps and place-based development (Barca et al., 2012; Diemer et al., 2022; Rodríguez-Pose et al., 2024). Weak productive structures, limited human capital accumulation, weaker institutions, and lower absorptive capacity reduce the ability of lagging regions to translate policy support and short-term improvements into sustained development (Becker et al., 2013; Rodríguez-Pose and Ketterer, 2020). As a result, policies that work in more advanced regions may not yield the same outcomes where the necessary economic, institutional, or human capital conditions are absent. Persistent underperformance is therefore best understood as a systemic development trap.

In contrast, more-developed regions exhibit self-reinforcing interactions between human capital and institutional quality, generating cumulative development processes (Di Cataldo and Rodríguez-Pose, 2017; European Commission, 2019b).

A key contribution of this paper is to show that these development systems also differ systematically in how institutions and education shape environmental sustainability. While place-based approaches traditionally conceptualise regional development primarily in terms of economic performance, human capital and institutional quality (Becker et al., 2013; Fischer and LeSage, 2015; Rodríguez-Pose and Ketterer, 2020), the results demonstrate that environmental sustainability is a constitutive component of regional development systems. Limited institutional capacity in less-developed regions hampers the translation of education into economic and environmental gains, reinforcing development traps. In advanced regions, education operates as a transformative force, simultaneously strengthening institutions and improving environmental performance.

These dual development systems also manifest spatially across the EU. Southern regions show greater difficulty in decoupling economic growth from environmental sustainability, reflecting carbon-intensive productive specialisations and high exposure to macroeconomic

shocks. Persistent labour-market and social fragilities further limit the effectiveness of short-term adjustment mechanisms. These findings align with the literature linking Southern Europe's development challenges to weak governance, exposure to austerity policies and reduced effectiveness of public investment following the financial crisis (Fidrmuc et al., 2024; Fratesi and Rodríguez-Pose, 2016; Rodríguez-Pose and Ketterer, 2020).

In Eastern Europe, the results point to a structural catch-up trajectory in which traditional growth drivers dominate in the short term, while institutional improvements and environmental gains materialise more gradually. Labour markets adjust relatively quickly but at the cost of short-term social outcomes, consistent with evidence on institutional flexibility and sectoral adjustment (Marelli et al., 2012). Convergence in specific environmental domains, such as circular economy practices, contrasts with lagging institutional and policy improvements (Silvestri et al., 2020), in line with the medium-term dynamics identified in this study.

Western and Northern EU regions display a more mature development model characterised by stable interactions among innovation, human capital and institutional quality. Employment growth is largely driven by education and innovation, while strong institutions buffer economic shocks and promote inclusive growth (Di Cataldo and Rodríguez-Pose, 2017). At the same time, the literature highlights diminishing returns from prolonged exposure to cohesion policy and potential risks of environmental complacency, even in high-performing regions (Fidrmuc et al., 2024; Silvestri et al., 2020). These insights help interpret the distinction observed between predominantly regulatory development patterns and more integrated configurations, particularly in Northern Europe.

Despite extensive territorial evidence on labour markets and institutions, the environmental dimension remains underdeveloped in empirical analyses of European regional development models. Only a limited number of studies explicitly include environmental variables, and none systematically analyse their joint interaction with labour structures and institutional quality (e.g. (Silvestri et al., 2020)). The central contribution of this article is to address this gap by explicitly integrating environmental sustainability into the analysis of regional development systems and to demonstrate how interactions among labour markets, institutions, and environmental dynamics condition development trajectories and the scope for decoupling growth from environmental impacts.

Overall, the results point to a gradual transformation of the EU development model, from a paradigm centred on growth to one in which social resilience, institutional quality and environmental sustainability play central roles. This transformation remains uneven across space, and convergence increasingly depends on the capacity of less-advanced regions to translate short-term stabilisation into structural dynamic and environmental progress.

7. Conclusion

This paper demonstrates that regional development in the EU is structured by adopting a multidimensional, dynamic perspective that integrates economic, social, institutional, and environmental dimensions. Using a PVAR-CCE framework applied to EU NUTS-2 regions, the analysis captures both common EU-wide shocks and region-specific adjustment mechanisms, enabling a systematic assessment of how development processes unfold over time.

Three main conclusions emerge from the analysis. First, EU regional development is characterised by a dual adjustment structure. A fast-moving economic-social cycle links employment, income, and youth exclusion and plays a central role in short-term stabilisation, particularly after 2008. In parallel, a slower structural dynamic involving institutional quality, human capital, and environmental conditions shapes medium- to long-term development trajectories. This distinction implies that episodes of economic recovery do not automatically translate into

sustained regional progress in the absence of deeper institutional and human-capital transformation.

Second, labour-market inclusion and institutional quality function as key transmission and stabilisation mechanisms within this system. Employment acts as a central social buffer, closely connected to reductions in youth exclusion, while institutional quality conditions the persistence and effectiveness of development gains. These mechanisms vary systematically across levels of development and over time, helping to explain why similar economic shocks generate divergent regional outcomes across the EU.

Third, environmental sustainability is not peripheral to regional development dynamics but structurally embedded within them. While per-capita emissions exhibit strong persistence, the interaction between institutions, education, and environmental outcomes indicates that the capacity to transition towards less carbon-intensive development paths depends on governance quality and human capital. This interaction is markedly stronger in more developed regions, whereas in less developed regions, institutional constraints limit the translation of environmental and educational improvements into inclusive growth.

Taken together, these conclusions are directly relevant to EU Cohesion Policy, the European Green Deal, and the Territorial Agenda 2030. The results suggest that balanced regional development cannot be achieved through uniform policy instruments, as regions differ not only in their levels of development but also in the mechanisms through which economic, social, institutional, and environmental shocks are transmitted over time.

For policy, this implies that employment-oriented measures remain essential for short-term stabilisation, particularly in less-developed and crisis-exposed regions. The strong relationship between employment and youth exclusion indicates that labour-market inclusion is a key channel for reducing social vulnerability. However, employment gains alone are unlikely to generate lasting development unless they are accompanied by improvements in income, skills, and institutional capacity.

Cohesion policy should therefore focus not only on economic outcomes but also on the conditions that allow development gains to persist. More advanced regions appear better able to convert economic gains into improvements in education, institutional quality, and environmental sustainability, highlighting the importance of investments in governance, education, and human capital.

The green transition reinforces this need for territorially differentiated policy packages. The persistence of CO₂ emissions suggests that emission-intensive development paths are difficult to reverse. Decarbonisation strategies should therefore be accompanied by institutional and productive capacity-building, particularly in lagging regions where adjustment costs may be higher.

Overall, the findings support integrated and place-based policy approaches. Employment, social inclusion, governance, education, and environmental objectives should be addressed jointly, with policy priorities adapted to the specific constraints and development trajectories of different regions.

From a research perspective, the analysis is subject to limitations. The linear PVAR-CCE framework captures average dynamic responses across regions and may therefore understate threshold effects, asymmetric responses, and non-linear adjustment paths. Although the CCE structure accounts for unobserved common shocks, the model does not identify the causal effects of specific policy interventions or crisis episodes, such as the COVID-19 pandemic.

Future research could extend this approach by exploring non-linear dynamics, explicitly modelling specific policy interventions, and examining the institutional mechanisms through which governance capacity affects regional development outcomes. In particular, future work could distinguish between overall governance quality and more specific dimensions of administrative capacity, policy implementation, public investment management, and the absorption of EU funds.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.pirs.2026.100157](https://doi.org/10.1016/j.pirs.2026.100157).

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