

Heterogeneous Regional Convergence in the European Union: Club Dynamics, Structural Breaks, and Spatial Spillovers

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Regional convergence remains one of the defining ambitions of European cohesion policy, yet decades of structural funding and institutional integration have failed to produce uniform income catch-up across EU regions. The persistence of economic disparities raises fundamental questions: are European regions converging at all, and if so, toward what equilibrium and at what speed? Classical approaches grounded in neoclassical growth theory (Barro and Sala-i Martin, 1992) impose homogeneous adjustment paths that mask the profound structural, institutional, and geographic heterogeneity characterising the EU's regional landscape. More recent scientists has moved toward club convergence frameworks that allow for multiple steady states, but the literature still lacks a unified empirical treatment that simultaneously captures nonlinear income thresholds, discrete structural breaks, and spatial interdependencies within a single coherent framework.

This study addresses that gap by analysing income convergence across EU NUTS-2 regions from 2000 to 2023, a period encompassing two major waves of EU enlargement, the global financial crisis, the Eurozone sovereign debt crisis, and the COVID-19 shock. By integrating club convergence methodology, β -convergence panel regression, structural break detection, panel threshold regression, and spatial econometric modelling, the paper offers a comprehensive and methodologically layered assessment of how European regions have evolved relative to one another over more than two decades.

Data and Methodology

The empirical analysis draws on Eurostat GDP per capita data for EU NUTS-2 regions, covering 239 regions over 2000–2023. Missing observations are addressed using the constant share backcasting method recommended in the Eurostat Backcasting Manual (2025 edition); five Portuguese regions available only from 2021 are excluded to avoid unreliable imputation. GDP per capita series are log-transformed and filtered using the Hodrick-Prescott (HP) filter with the standard annual smoothing parameter $\lambda = 400$, isolating the persistent structural component of regional income from short-run cyclical fluctuations.

The analytical framework proceeds in five stages. First, the Phillips and Sul (2007, 2009) log-t test is applied to the full panel to assess overall convergence. Where overall convergence is rejected, a data-driven clustering algorithm identifies endogenous convergence clubs, followed by a merge-check procedure to avoid over-fragmentation. Second, β -convergence is estimated

using a two-way fixed-effects panel regression with region fixed effects, year dummies, and country-specific linear time trends. To ensure robustness, models are re-estimated with clustered standard errors, panel-corrected standard errors (Beck and Katz, 1995), and Driscoll-Kraay (1998) standard errors that are robust to general cross-sectional dependence. Third, structural breaks in the convergence relationship are identified using the multiple-break procedure of Bai and Perron (1998, 2003), implemented with HAC-robust inference and cross-sectional averages to absorb common factors. Fourth, panel threshold regression following Hansen (1999) is used to test whether convergence speeds differ across income regimes defined endogenously by lagged GDP per capita. Fifth, spatial dependence is assessed annually via Moran's I and Geary's c statistics, and spatial panel models - both static and dynamic Spatial Durbin Models (SDM) - are estimated to quantify spillover effects. The β -convergence and club analyses are also repeated separately for the subperiods 2000–2012 and 2013–2023 to capture shifts in dynamics before and after the Eurozone crisis.

Key Results

The PS log-t test rejects overall convergence across the full panel of EU NUTS-2 regions, confirming that European regions do not converge toward a common long-run equilibrium. The clustering procedure identifies four stable convergence clubs and one non-convergent unit (EL63: Dytiki Ellada, Greece). Club 1, by far the largest, encompasses 213 regions and exhibits a log-t coefficient of -0.038 with a t-statistic of -1.24, just above the critical threshold, indicating weak but non-rejected convergence within this large and heterogeneous group. Clubs 2 (10 regions), 3 (12 regions), and 4 (3 regions) are smaller and show clearer within-club convergence. Relative transition path plots confirm persistent separation between clubs: Club 1 regions maintained broadly stable growth trajectories, while Clubs 2–4 exhibited slower, more heterogeneous, and in some cases declining relative income paths over the sample period. Descriptive statistics reveal sharp income differences between clubs: mean GDP per capita in 2000 ranged from approximately €18,700 in Club 1 down to €11,100 in Club 4, and by 2023, Club 1 had grown to nearly €36,000 compared to just €11,700 in Club 4 a divergence in absolute terms that underscores the entrenchment of regional inequalities.

For the full sample of 239 regions, the baseline fixed-effects estimate yields $\beta = -0.0256$ ($p < 0.01$), confirming conditional convergence on average. Within-club estimates reveal substantial heterogeneity: Club 1 converges at a moderate pace ($\beta = -0.0225$, $p < 0.05$), while Clubs 2 and 3 exhibit notably faster within-club convergence ($\beta = -0.0471$ and -0.0474 , respectively). Club 4, consisting of only three regions, shows no statistically significant convergence, with a positive and insignificant coefficient ($\beta = +0.0246$), suggesting stagnation or mild divergence. Subperiod analysis indicates that convergence was somewhat faster before 2012 ($\beta = -0.0243$) than after ($\beta = -0.0218$), with the slowdown consistent with the post-crisis fiscal consolidation and structural adjustment that constrained regional catch-up across much of Europe.

The Bai-Perron multiple-break procedure applied to the full sample detects two statistically significant structural breaks in 2005 and 2012 (95% confidence intervals: [2004, 2006] and [2011, 2013], respectively). The 2005 break coincides with the aftermath of the 2004 EU enlargement, which introduced ten new member states with substantially lower income levels and altered the composition and dynamics of the regional convergence process. The 2012 break

corresponds to the peak of the Eurozone sovereign debt crisis, which disrupted fiscal transfers, suppressed investment, and weakened institutional capacity in many peripheral regions. These two break dates provide empirical justification for the subperiod decomposition employed in the β -convergence analysis. Panel threshold regression identifies a single significant income threshold at $\ln y_{t-1} = 9.68$ (approximately €16,000 in GDP per capita terms), dividing regions into low- and high-income regimes. Convergence coefficients are nearly identical on both sides of the threshold ($\beta = -0.0243$ below and -0.0246 above), suggesting that while the threshold captures genuine nonlinearity in the level of income dynamics, it does not alter the direction or fundamental nature of convergence; rather, it reflects regime-level differences in the adjustment process. Models with two or three thresholds are rejected, confirming a parsimonious single-threshold structure.

Moran's I and Geary's c statistics are positive and statistically significant in every year from 2001 to 2023 for both the level and growth rate of regional GDP per capita, confirming persistent and strong global spatial clustering across EU NUTS-2 regions. Regions with similar income levels and growth rates tend to be geographically proximate, indicating that economic spillovers, labour mobility, trade linkages, and policy interactions generate spatial dependence that standard panel estimators would fail to capture. The static Spatial Durbin Model yields a spatial autoregressive coefficient of $\rho = 0.301$ ($p < 0.001$), confirming substantive spatial interaction in regional growth. The coefficient on initial income remains negative ($\beta = -0.0193$, $p < 0.001$), consistent with conditional convergence after controlling for spatial dependence. Long-run impact decomposition reveals a negative and significant direct convergence effect (-0.0165 , $p < 0.001$) and a positive and significant indirect spillover effect ($+0.0140$, $p < 0.05$), implying that proximity to wealthier regions stimulates growth in neighbouring areas and partially offsets the income-equalising tendency of local convergence. The dynamic SDM confirms these patterns qualitatively, with $\rho = 0.238$ ($p < 0.001$) and evidence of strong persistence in regional growth trajectories.

Conclusions and Policy Implications

The results collectively demonstrate that regional convergence in the EU is a heterogeneous, nonlinear, and spatially interdependent process. Four stable convergence clubs have emerged over 2000–2023, with no evidence of overall European convergence. Convergence was faster in the pre-crisis period, slowed after 2012, and is shaped by two discrete structural breaks corresponding to EU enlargement and the Eurozone crisis. A single income threshold divides regions into two regimes, while spatial analysis confirms that regional growth is deeply embedded in geographic networks of economic interaction.

These findings carry important implications for cohesion policy. The existence of distinct convergence clubs with markedly different income trajectories and the persistence of Club 4 regions near stagnation indicates that uniform policy instruments are unlikely to deliver balanced regional development. Effective cohesion strategies must recognise club membership and spatial embeddedness, targeting investment, innovation support, and institutional capacity-building to the specific structural conditions of lagging regions. The positive spatial spillover effects identified here also suggest that place-based policies that strengthen inter-regional linkages through infrastructure investment, cross-border labour markets, and regional innovation

ecosystems may be more effective than purely redistributive transfers in promoting long-run income convergence across Europe.