

REGIONAL CONVERGENCE DYNAMICS IN THE MAIN EUROPEAN ECONOMIES

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Abstract

This paper examines the convergence dynamics of GDP per capita across 98 regions in Spain, Germany, France and Italy over the period 1998-2025. Using the methodology developed by Phillips and Sul (2007, 2009), six convergence clubs are identified. The results reveal substantial structural heterogeneity: the most advanced clubs, composed primarily of German regions, present GDP per capita levels that are persistently above the sample average. Intermediate and lower-income clubs, consisting mainly of French, Italian and Spanish regions, converge towards lower relative income equilibria. To estimate the determinants of regional growth, a heterogeneous dynamic panel model with common effects is used. The findings suggest that regional disparities across Europe reflect not only differences in factor endowments, but also differences in the regions' ability to transform these endowments into economic growth. In particular, human capital and physical capital stock emerge as key factors in explaining these divergences.

Keywords: regional convergence, convergence clubs, NUTS 2 regions, DCCEMG, physical capital, human capital.

JEL classification: O47, R11, C33, O15.

Resumen

En este documento se analizan las dinámicas de convergencia del PIB per cápita entre 98 regiones de España, Alemania, Francia e Italia durante el período 1998-2025. Empleando la metodología de Phillips y Sul (2007, 2009) se identifican seis clubes de convergencia. Los resultados revelan una heterogeneidad estructural: los clubes más avanzados, integrados principalmente por regiones alemanas, presentan niveles de PIB per cápita persistentemente superiores a la media muestral. Los clubes intermedios y bajos, compuestos en su mayoría por regiones francesas, italianas y españolas, convergen hacia equilibrios de menor renta relativa. Para estimar los determinantes del crecimiento de cada región se emplea un modelo de panel dinámico heterogéneo con efectos comunes. Los resultados sugieren que las disparidades regionales europeas no solo responden a diferencias en dotaciones de factores, sino también a la distinta capacidad de las regiones para convertir dichas dotaciones en crecimiento económico. En particular, el papel del capital humano y el *stock* de capital físico destacan como elementos clave en la explicación de estas divergencias.

Palabras clave: convergencia regional, clubes de convergencia, NUTS 2, DCCEMG, capital físico, capital humano.

Códigos JEL: O47, R11, C33, O15.

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1 Introduction

The convergence hypothesis has long been a central pillar of the economic growth literature. Rooted in the neoclassical framework, it posits that poorer economies tend to grow faster than richer ones, thereby reducing income disparities over time (Solow, 1956; Swan, 1956). However, empirical evidence has consistently shown that convergence is neither universal nor uniform. While some countries and regions present clear convergence dynamics, others show divergence. These mixed findings have raised significant questions about the adequacy of traditional empirical approaches based exclusively on β -convergence regressions or aggregate measures of dispersion (σ -convergence). These approaches focus on average behaviours and provide only limited information on the internal structure of the income distribution and changes in regions' relative positions over time.

In response to these limitations, a growing strand of the literature has shifted its focus to the distribution dynamics and club convergence approaches, which explicitly incorporate heterogeneity, non-linear adjustment processes and the possibility of multiple long-run equilibria. These approaches show that convergence can take place within distinct groups of economies that share similar structural characteristics or initial conditions, without necessarily implying overall convergence towards a single steady state. This paper contributes to this avenue of research and adopts said approach to analyse convergence dynamics across the regions of Spain, Germany, France and Italy, with particular emphasis on the identification of convergence clubs. In addition, the paper seeks to identify the factors behind the heterogeneous long-run growth trajectories.

To this end, we first identify groups of regions that follow similar development paths using the methodology developed by Phillips and Sul (2007, 2009). This allows us to observe how the regions perform over time and group them based on certain common patterns, without presupposing that all regions behave equally. By focusing on how each region converges towards or diverges away from the average, the approach captures both the common trends and the specific transition patterns that characterise each group. Once the convergence clubs have been established, a dynamic panel model is estimated to identify the determinants of growth for each cluster of regions.

The results show six convergence clubs for the 98 regions¹ analysed, with clearly differentiated long-run growth paths. The two most advanced clubs, consisting primarily of German regions, converge towards levels of gross domestic product (GDP) per capita above the sample average, driven by high endowments of physical and human capital and a stronger capacity to translate this accumulation into sustained growth. The other four clubs, mainly comprising Spanish, French and Italian regions, converge towards lower relative income equilibria, where the elasticities of physical and human capital progressively decline. Moreover, analysis using the Dynamic Common Correlated Effects Mean Group (DCCMG) estimator (Pesaran and Smith, 2026) reveals that, although human capital and the capital stock are positive determinants of the average long-run GDP per capita across the panel, the magnitude of these effects varies substantially across convergence clubs, suggesting profound structural differences in regional production functions.

The rest of the paper is structured as follows: Section 2 reviews the conceptual framework of convergence, Section 3 describes the data and methodology, Section 4 presents the findings and Section 5 sets out the main conclusions.

¹ The regions correspond to the Eurostat NUTS 2 disaggregation. NUTS 2 is the intermediate level of the European Union's (EU) Nomenclature of Territorial Units for Statistics (NUTS), used to compile regional statistics, conduct socioeconomic analysis and support the design and implementation of EU policies. In Spain, the NUTS 2 regions correspond to the autonomous communities (*comunidades autónomas*). The analysis uses data at this level of disaggregation from the Annual Regional Database of the European Commission (ARDECO).

2 Convergence: the conceptual framework

Convergence literature addresses one of the key topics in fields such as economic growth and development. It seeks to provide empirical support for the central prediction of the Solow-Swan growth model (Solow, 1956; Swan, 1956), namely that regions with lower levels of capital stock will grow faster than those with higher capital stock, leading to long-run convergence across the regions.

The first econometric approach used to test this prediction was developed by Baumol (1986), based on cross-sectional growth regressions. This approach was subsequently popularised by Barro (1991), who derived a growth equation from the standard neoclassical model. Baumol's study demonstrated the importance of sample selection, since convergence was found only among industrialised economies, which limited the scope of the findings.

In the subsequent literature the standard growth regression specification can be expressed as a first-order autoregressive (AR(1)) process in panel data. Within this framework, the dependent variable is the change in the log of gross domestic product (GDP) per capita between the initial period (0) and the final period (T), while the explanatory variable is the initial level of the log of GDP per capita. The specification can be written as:

$$y_{iT} - y_{i0} = \alpha_T - (1 - \rho^T) y_{i0} + \varepsilon_{iT}$$

If $1 - \rho^T > 0$, convergence is observed. The coefficient $\beta = (1 - \rho^T)$ indicates the speed at which the regions in the panel converge towards a common steady state. This type of convergence is known as β -convergence.

This model rests on a series of assumptions concerning both the sample and the underlying dynamics. First, the sample is assumed to be sufficiently homogeneous, such that all regions share similar structural conditions and, in particular, a common intercept (α_T). Second, the model assumes homogeneous dynamics: the persistence coefficient associated with the lagged variable (ρ^T) is identical across all regions. In terms of convergence, this implies that all regions converge at the same speed towards a common steady state. These conditions stem from the general assumption that all regions in the sample share the same long-run equilibrium path.

To relax this restrictive assumption, Barro and Sala-i-Martin (1992) introduced the concept of conditional β -convergence. In the previous specification, the characteristics of the steady state, which are largely unobservable, were captured by the intercept. As a result, convergence may not have been detected in many instances. Conditional convergence addresses this limitation by incorporating additional explanatory variables as proxies for the determinants of the steady state.

$$y_{iT} - y_{i0} = \alpha_T - (1 - \rho^T) y_{i0} + x_i' Z_{iT} + \varepsilon_{iT}$$

Estimation of this specification gave rise to the well-known empirical finding of a convergence rate of around 2% per year, often referred to as the "iron law of convergence" (Sala-i-Martin, 1995).

Nonetheless, the conditional β -convergence approach has been widely debated in the literature. Following Acemoglu (2009), two main criticisms can be identified. First, the regressors may be endogenous, since variables such as capital, investment and institutional quality are closely linked to income levels, which compromises the

consistency of the estimators. Second, interpretation problems arise with the convergence coefficient: even under the assumption of exogeneity, a negative sign could reflect measurement problems or temporary effects rather than a true process of convergence towards the steady state.

In addition, Barro and Sala-i-Martin (1992) introduced a second type of convergence, namely σ -convergence, defined as the reduction in the dispersion of income levels across economies. A key point is that β -convergence is a necessary, but insufficient, condition for σ -convergence to occur (Sala-i-Martin, 1995).

These limitations prompted the development of the distribution dynamics approach pioneered by Quah (1993, 1996), which analyses the entire evolution of the income distribution rather than focusing exclusively on aggregate moments. By estimating transition matrices, this approach allows persistent patterns to be identified and convergence clubs to be formed within the distribution, thereby offering a richer view of convergence dynamics. However, this methodology also has limitations. In particular, it raises challenges and poses difficulties for identifying the underlying determinants of long-run trajectories, raises interpretation difficulties and is only weakly connected to standard theoretical models, since the steady state does not correspond directly to the fixed point in the estimated dynamic system. Moreover, the results may be sensitive to technical choices, such as the discretisation of the space or the temporal specification of the process (Magrini, 2009).

In light of these considerations, this paper adopts an alternative approach to identifying convergence clubs.² Specifically, we employ the methodology proposed by Phillips and Sul (2007, 2009), which allows convergence dynamics to be analysed in the presence of heterogeneity and potential convergence clubs to be identified endogenously across regions. Section 3.2 provides a detailed explanation of this methodology.

² The distribution dynamics approach proposed by Magrini (2009) was also considered. However, it posed difficulties in accurately identifying the regions belonging to each convergence club. Conversely, the Phillips and Sul (2007, 2009) methodology enables a clearer classification and yields more directly interpretable empirical results.

3 Data and methodology

3.1 Data

The harmonised time series available in the [Annual Regional Database of the European Commission](#) (ARDECO) for European countries for the period 2000-23 allow convergence patterns to be analysed from a broad temporal perspective.³

The variables used in the model estimation are set out in Table 1 and described below. First, we use GDP per capita at constant prices, defined as the ratio of GDP at constant prices to the average population of each region. Second, we use the capital stock per capita. Lastly, we include educational attainment, calculated as the percentage of the population with at least secondary education.

In addition, institutional quality is captured using regional data from the [European Quality of Government Index](#) (EQI). The EQI is a regional-level index that measures the quality of government across European Union countries for different years. In this paper, the 2024 edition is used (Charron, Lapuente and Bauhr, 2021). The index is based on a large citizen survey that captures the public's perceptions and experiences in their region of residence concerning (i) corruption, (ii) the impartiality of public services and (iii) the quality of public services. Regions are scored on these three aspects on a scale from -3 to +3, with higher values indicating better quality of government. For the purposes of this study and to facilitate interpretation, the indicators are rescaled to a range between 0 and 1.

Table 1

Summary statistics of the variables used in the model estimation (a)

Variable	Period	Average	Median	Standard deviation	Min.	Max.
Real GDP per capita (2000 euro)	2000	29,864	29,100	8,154	15,100	60,900
	2023	35,186	33,750	9,828	19,100	72,200
	2000 vs 2023	5,321	4,650	1,674	4,000	11,300
Real capital stock per capita (2000 euro)	2000	92,096	87,026	27,644	47,251	167,588
	2023	117,674	114,275	37,030	43,974	219,569
	2000 vs 2023	25,578	27,248	9,386	-3,277	51,982
Share of total population with secondary education or higher	2000	62%	60%	18%	28%	96%
	2023	77%	80%	10%	54%	94%
	2000 vs 2023 (pp)	15.1	20.0	-8.0	25.9	-2.6

SOURCES: Annual Regional Database of the European Commission and Banco de España.

a A total of 2,353 observations are used for each variable during the period 2000-23. Education data are unavailable for five German regions in the early years of the sample. Accordingly, the average annual change is applied retrospectively to those regions.

³ In some instances, convergence clubs are also determined using the European Commission's GDP per capita projections for 2024 and 2025. The year 2025 serves as the reference period for the initial ordering of regions. Although provisional 2024 data are already available for some regions, data for other regions are projections.

3.2 Identification of convergence clubs

To determine regional convergence clubs, we use the methodology proposed by Phillips and Sul (2007, 2009), which enables convergence dynamics to be detected and potential convergence clubs to be identified endogenously in the presence of heterogeneity across regions. The methodology begins by breaking down the variable of interest, X_{it} (the log of GDP per capita in region i in period t), into a common component and an idiosyncratic component, such that:

$$X_{it} = \mu_t \cdot d_{it}$$

where μ_t captures the aggregate trend common to all regions and d_{it} represents the idiosyncratic factor of each region relative to that path. Under convergence, the idiosyncratic coefficients d_{it} tend to equalise in the long run.

Since the components are not separately observable, the analysis is based on the relative transition parameter, defined as:

$$h_{it} = \frac{X_{it}}{\frac{1}{N} \sum_{j=1}^N X_{jt}} \quad (1)$$

which measures each region's deviation from the cross-sectional average in each period. By construction, the cross-sectional average of h_{it} is equal to 1 in all periods. Values above (below) unity indicate that a region lies above (below) the sample average, while a stable path of h_{it} around a constant value reflects a persistent relative deviation. In particular, stability around 1 is consistent with convergence towards the sample average, whereas stabilisation around other values may be indicative of convergence within clubs. Subscript i identifies a specific region, as does subscript j , which indexes the regions included in the summation, while N denotes the total number of regions considered.

The formal convergence test is based on the log- t test, which evaluates the null hypothesis of convergence ($\alpha \geq 0$) using the dynamics of the cross-sectional variance $H_t = \frac{1}{N} \sum_{j=1}^N (h_{jt} - 1)^2$. This test is implemented through a regression as follows:

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

where $b = 2\alpha$ and $L(t)$ is a slowly varying function, typically $\log t$. Convergence is accepted if the t -statistic associated with b does not allow rejection of the hypothesis $b \geq 0$.

When the overall convergence hypothesis⁴ is rejected, the methodology can be used to endogenously identify convergence clubs, defined as groups of regions that share the same long-run path. To achieve this, regions are typically ordered by their level in the final period available, and a sequential algorithm is applied that combines convergence tests with the progressive inclusion of units.⁵

⁴ Overall convergence means convergence to a single common long-run path. This methodology analyses convergence in the relative transition parameters, rather than β -convergence in the traditional sense of Barro and Sala-i-Martin (1992).

⁵ In the empirical implementation, this test is estimated using the data between the start of the sample and period $t-1$, with the last available year (t) reserved as the reference period for the initial ordering of regions. This approach separates the estimation of convergence dynamics from the unit classification criterion, thereby preventing the final period from simultaneously influencing both steps of the procedure.

Once the convergence clubs have been identified, the overall evolution of each group is described using the average transition path:

$$\bar{h}_{kt} = \frac{1}{N_k} \sum_{i \in k} h_{it} \quad (3)$$

where N_k is the number of regions in club k . $\bar{h}_{kt}$ represents the average of the relative transition parameters h_{it} of the regions belonging to club k in each period. A stable trajectory of $\bar{h}_{kt}$, together with a progressive decline in the cross-sectional dispersion of the relative transition parameters across the regions of the club, is consistent with the existence of convergence within the group. Overall, this approach provides a dynamic characterisation of regional heterogeneity and enables an assessment of whether convergence occurs at the aggregate level or within specific clubs, or whether structural disparities persist across regions.

3.3 Long-run dynamics and speed of convergence

Regional convergence speeds are estimated using a panel model with interactive effects. The general specification of the model is:

$$y_{it} = \alpha_i + \gamma_i f_t + \rho_i y_{i,t-1} + u_{it} \quad (4)$$

This model includes an idiosyncratic component, u_{it} , which, in a growth context, may be understood as the set of unobserved characteristics that determine each region starting from different levels. Allowing the model to vary across regions means that the parallel trends assumption is not imposed, an assumption that would imply a common average growth rate across regions. In addition, the model incorporates a time-dependent component, f_t , capturing factors that are common to all of the regions in period t . These factors can be viewed as shocks that can affect the sample regions differently and with varying intensity.

The coefficient of the equation to be estimated is ρ_i , which can be interpreted as the speed at which the region converges to its long-run trend. In this case, convergence speed is expressed in annual terms. Defining this coefficient at the individual level allows for heterogeneous dynamics. This, coupled with the model not imposing a parallel trends assumption, offers important advantages in addressing the heterogeneity inherent in the sample relative to other popular models in the literature, such as the Two-Way Fixed Effects model.

To estimate the ρ_i coefficients, we employ the Dynamic Common Correlated Effects Mean Group (DCCMG) estimator developed by Chudik and Pesaran (2015). This approach allows us to explicitly incorporate and address the presence of latent factors⁶ underlying the model that affect the regions in the sample. Ignoring such factors would imply a failure to adequately control for common effects, which might skew the estimators and compromise the validity of the inferences.

Following Pesaran and Smith (2026), the presence of unobserved common factors can be incorporated explicitly into a panel data model by including an underlying latent factor. For example, if g_t is interpreted as a common productivity factor, the time component can be written as $f_t = g_t - \rho g_{t-1}$. The Common Correlated

⁶ To assess the presence of latent factors in our data, we examine cross-sectional dependence in the panel using the Cross-Sectional Dependence (CD) test proposed by Pesaran (2021), applied to GDP per capita (levels). The results show a very high value for the z-statistic ($z = 139.8$) and a p-value of virtually zero, implying a rejection of the null hypothesis of cross-sectional independence. This provides evidence of unobserved common factors affecting the regions simultaneously, such as macroeconomic shocks or shared dynamics. Accordingly, standard estimators would be inappropriate.

Effects (CCE) approach allows us to proxy the latent factor using cross-sectional averages of GDP per capita. The mechanism underlying this proxy rests on the assumption that the idiosyncratic error components are cross-sectionally independent across units. Under this assumption, the covariances will be zero and the variance of the cross-sectional average of the error term decreases with sample size (N), making the proxy valid in large samples.

In this paper, we estimate a heterogeneous dynamic panel model with common effects for regional GDP per capita. Under this framework, the dynamic specification can be re-expressed as an error correction model that explicitly distinguishes between the long-run relationship and the speed of convergence towards equilibrium. The benchmark specification is:

$$\Delta y_{it} = \alpha_i - \phi_i y_{i,t-1} + \delta_{1i} k_{i,t-1} + \delta_{2i} educ_{i,t-1} + \lambda_{1i} \Delta k_{it} + \lambda_{2i} \Delta educ_{it} + \psi_1 \bar{y}_t + \psi_2 \Delta \bar{y}_t + u_{it}$$

where y_{it} denotes the log of GDP per capita, $k_{i,t-1}$ is the log of capital per capita introduced with a lag, and $educ_{i,t-1}$ is a proxy for human capital, measured as the percentage of the population with secondary or tertiary education. The cross-sectional averages $\bar{y}_t$ and $\Delta \bar{y}_t$ are included following the common correlated effects approach, seeking to capture unobserved common shocks and cross-sectional dependence between regions. Following Pesaran and Smith (2026), the model is estimated separately for each region and all of the coefficients are allowed to vary across regions. The overall panel estimates are obtained as simple averages of the individual coefficients, in line with the mean group approach applied to regional coefficients.

In this specification, ϕ_i represents the speed at which each region transitions towards its own long-run equilibrium path. Specifically, it measures how fast a region corrects deviations of its GDP per capita from that path after accounting for both unobserved common factors and observable determinants of growth. The inclusion of capital and education is motivated precisely by this consideration. Both variables capture differences in the accumulation of physical and human capital that may have persistent effects on output levels and dynamics. Omitting them could therefore lead to developments stemming from changes in regional economic fundamentals being erroneously attributed to convergence. In this context, the inclusion of these covariates⁷ allows ϕ_i to be interpreted as a conditional measure (i.e. the speed at which each region returns to its long-run path after controlling for the effect of observable factors of production), while the cross-sectional averages continue to capture the unobserved common shocks that simultaneously affect the panel as a whole.

This methodology also entails limitations in the interpretation of the results. In particular, the time dimension of the sample is limited, with observations available for only 24 years. This restriction especially affects the precision of the regional estimates, while the panel results are unaffected. Even so, these results provide material information on the heterogeneity of regional dynamics, allowing us to reach a qualitative interpretation. Furthermore, we selected a specification with few explanatory variables since adding further variables would reduce the model's degrees of freedom.

⁷ Alternative specifications were estimated that included net migration and the institutional quality indicator as control variables. However, neither covariate was statistically significant, meaning the signs of their coefficients did not permit a clear economic interpretation. Accordingly, both variables were excluded from the final specification to avoid losing further degrees of freedom.

4 Findings

This section sets out the results of the empirical analysis in two parts. First, it explains the identification of the convergence clubs using the methodology in Phillips and Sul (2007, 2009),⁸ describing their structural characteristics and each group's relative transition path. Second, it presents the results of the error correction model using the Dynamic Common Correlated Effects Mean Group (DCCEMG) estimator, which makes it possible to identify the determinants of long-term growth for the overall panel and for each club identified, as well as their speed of convergence.

4.1 Convergence clubs

A first estimation to identify clubs, based on Equation (2) in Section 3.2, yields a total of eight convergence clubs.⁹ As some clubs comprise a small number of regions, the merging procedure proposed by Phillips and Sul is applied to test for joint convergence among the smaller clubs. This results in six convergence clubs, as the *t*-statistic in Table 2 is greater than -1.65. The coefficient shown in Table 2 should be interpreted as a parameter of the convergence test, not as a direct measure of the economic impact or of the speed of regional growth.

The convergence clubs are identified drawing on the information available for the full sample period. Accordingly, the clubs obtained should be interpreted as characterisations of the regions' long-run trajectories over that period. This approach does not allow us to draw inferences about transition dynamics across clubs over time or about changes in regions' relative deviations, although such changes cannot be ruled out over long horizons.

Chart 1.a and Table A.1 provide details of the 98 regions and the convergence club to which each one belongs. In addition, Chart 1.b shows the average relative transition paths for each of the six clubs.

Table 2
Classification of convergence clubs (a)

Club	Number of regions	Coefficient	Standard error	<i>t</i> -statistic
Club 1	6	-0.04	0.06	-0.643
Club 2	20	0.02	0.05	0.377
Club 3	32	0.12	0.06	1.901
Club 4	24	-0.02	0.05	-0.439
Club 5	9	0.18	0.16	1.115
Club 6	7	-0.23	0.22	-1.041

SOURCE: Authors' calculations drawing on the Annual Regional Database of the European Commission.

a The Phillips and Sul (2007, 2009) methodology is used for the natural log of GDP per capita over the 1998-2025 period. Summary results are presented for the clubs based on the estimation of Equation (2) in Section 3.2. In all cases, the *t*-statistic is greater than -1.65, indicating the existence of convergence within each club. The β coefficient obtained from the log-*t* regression does not correspond to the concept of β -convergence in the traditional growth literature.

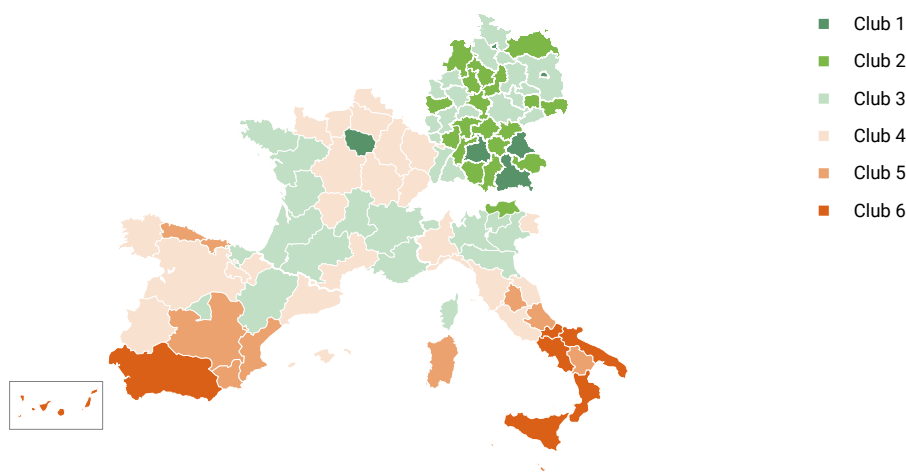
⁸ The convergence clubs are identified using data from 1998 to 2025, with 2025 being used for ordering individuals in the clustering procedure.

⁹ The log-*t* test applied to the regions as a whole rejects the overall convergence hypothesis, pointing to the existence of heterogeneity in the paths of gross domestic product (GDP) per capita and warranting analysis by convergence club.

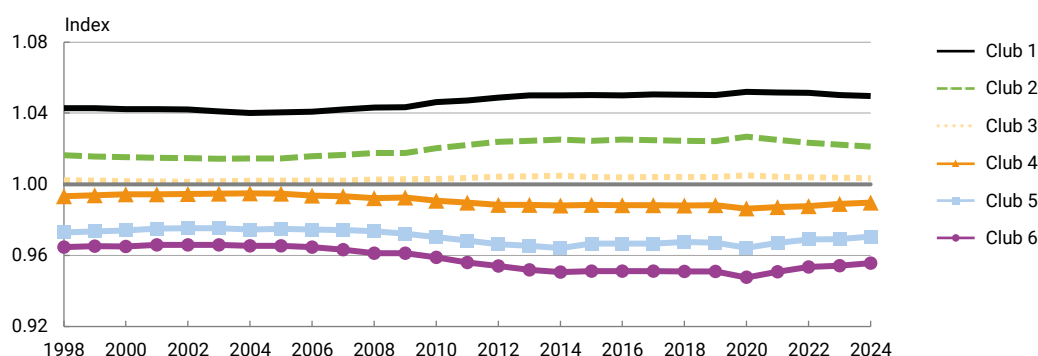
Chart 1

Regional convergence clubs

1.a NUTS 2 regions used and their convergence clubs (a)



1.b Average relative transition paths, by convergence club (b)



SOURCE: Authors' calculations drawing on the Annual Regional Database of the European Commission.

a The Phillips and Sul (2007, 2009) methodology is used for the natural log of GDP per capita over the 1998-2025 period.

b The Phillips and Sul (2007, 2009) methodology is used for the natural log of GDP per capita over the 1998-2025 period. The average paths (Equation (3) in Section 3.2) are calculated as the average of the relative transition paths of the regions belonging to each club (Equation (1) in Section 3.2).

4.2 Dynamics and characteristics of the clubs

Estimation of the dynamic panel model with heterogeneous coefficients for the set of 98 regions of Spain, Germany, France and Italy provides evidence of conditional convergence in the analysed regions between 2000 and 2023. Estimation is at individual level, thereby enabling long-run adjustment dynamics for each region. The average for all the regions corresponds to the mean speed of convergence parameter (coefficient of error correction). As Table 3 shows, this parameter stands at around 0.49,¹⁰ consistent with a process of adjustment towards long-run equilibrium paths. This speed implies that approximately half of the deviations are corrected within one year. Although this

¹⁰ This speed of convergence is faster than that found in the literature. This is because a large part of the literature uses panel models with two-way fixed effects that, by assuming dynamic homogeneity and parallel trends, tend to skew the estimated convergence downwards when there are unobserved common factors and heterogeneity across units. In this respect, using the heterogeneous dynamic panel with common effects yields more consistent estimates and, therefore, potentially higher speeds (Pesaran and Smith, 2026).

Table 3

Long-run determinants (a) (b)

Estimator	Estimator	Standard deviation	<i>t</i> -statistic	<i>p</i> -value
Speed of convergence	0.49	0.03	18.47	0.00
Long-run elasticity of capital stock	0.29	0.12	2.50	0.01
Long-run semi-elasticity of human capital	0.45	0.17	2.67	0.01
Total units	98			
Number of periods	23			

SOURCES: Annual Regional Database of the European Commission and Banco de España.

- a** Long-run elasticities and semi-elasticities are calculated excluding regions whose estimated individual speed of convergence is greater than 1, as this implies an unstable (explosive) dynamic and precludes an economic interpretation of the long-run coefficients.
- b** Human capital is proxied by the percentage of the total population with at least secondary education.

speed exceeds the annual convergence rates of around 2% commonly documented in the β -convergence literature, the two figures are not strictly comparable as they capture different mechanisms of economic adjustment.¹¹

As regards the structural determinants, the long-run estimates indicate that both the capital stock and the population's educational attainment level have a positive impact on regional GDP per capita. However, the value estimated for the secondary education ratio (0.45) is higher than that for the capital stock (0.29),¹² suggesting that differences in human capital play a particularly significant role in explaining the regional disparities observed. This is in line with the literature on economic growth, which highlights the role of human capital both as a direct production factor (Barro, 1991; Mankiw, Romer and Weil, 1992) and through its influence on productivity and technological diffusion (Nelson and Phelps, 1966; Benhabib and Spiegel, 1994).

As described above, all European regions exhibit convergence processes, but they do not all converge towards the same long-run levels, as Chart 1.b shows. Analysis at club level enables us to characterise the structural heterogeneity of the regional convergence process in greater detail. The results show the coexistence of various levels of development associated with differences in income per capita, endowments of physical and human capital and the way in which factors of production translate into long-term growth.

The regions in Clubs 1 and 2 are located mostly in Germany. Charts 2.a and 2.b show the relative path of GDP per capita (the relative transition parameter defined in Equation (1)) for these regions relative to the overall sample average in the period 1998-2025 (which takes the value 1 in Chart 1). As can be seen, the GDP per capita levels of these regions are persistently higher than the overall sample average. At the same time, there is evidence of an intra-club convergence process, as the relative transition paths within each club tend to move progressively closer together and dispersion across regions declines. Nevertheless, the long-run relative level of GDP per capita of Club 1 remains above that of Club 2.

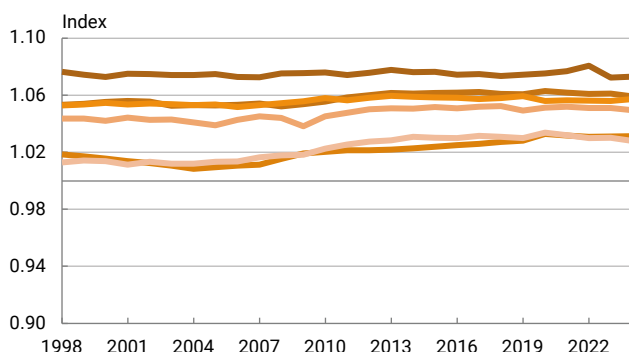
¹¹ The coefficient of error correction captures how fast the regions return to their long-run equilibrium after a shock, while β -convergence reflects the gradual narrowing of income gaps between economies.

¹² The values correspond to the long-run estimates derived from the dynamic model. In the case of physical capital, as the variables are in logs, the coefficient is interpreted as an elasticity. Meanwhile, the coefficient associated with education is interpreted as a semi-elasticity, which reflects the percentage change in GDP per capita due to changes in the share of the population with at least secondary education.

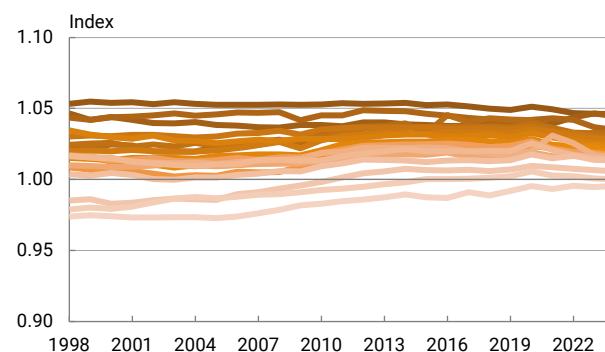
Chart 2

Relative transition paths, by convergence club (a)

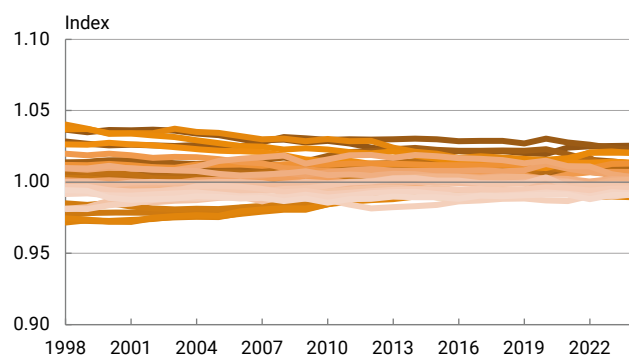
2.a Club 1



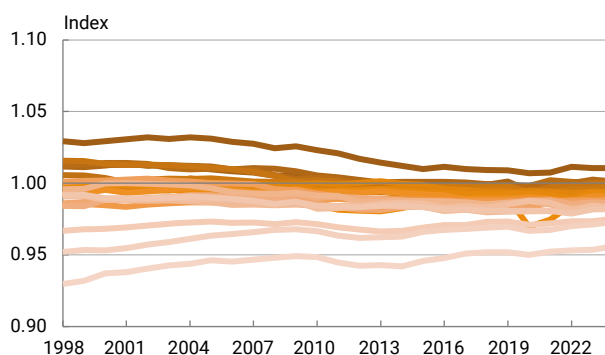
2.b Club 2



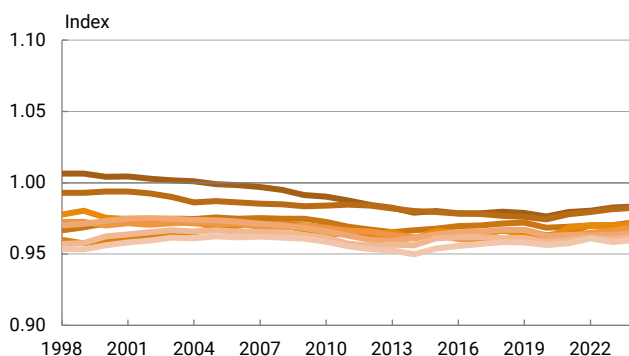
2.c Club 3



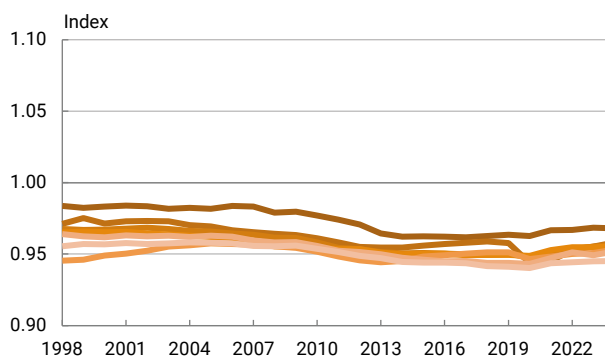
2.d Club 4



2.e Club 5



2.f Club 6



SOURCE: Authors' calculations drawing on the Annual Regional Database of the European Commission.

a The charts show the relative transition paths of the regions belonging to each club (Equation (1) in Section 3.2).

Broadly speaking, the Club 1 and 2 regions have higher relative human capital endowments than those in the other clubs (Table 4), as proxied by the share of the population with a secondary or tertiary education, and a higher ratio of capital stock per capita. However, there are significant differences between the two groups in how these factors translate into long-run income levels. Clubs 1 and 2 show relatively high elasticities of physical and human capital. However, physical capital plays a more decisive role in income generation among the Club 1 regions,

Table 4

Key statistics, by club (2000-23)

Club	1	2	3	4	5	6
Number of regions	6	20	32	24	9	7
GDP per capita (median, log)	10.8	10.5	10.4	10.3	10.0	9.9
Capital stock per capita (median, log)	11.8	11.6	11.5	11.6	11.4	11.3
Capital stock: 25th percentile	11.7	11.5	11.4	11.4	11.2	11.1
Capital stock: 75th percentile	11.9	11.8	11.6	11.6	11.6	11.4
Human capital (median, %) (b)	84.9	83.7	79.2	61.6	53.7	47.8
Human capital: 25th percentile	83.0	82.9	66.8	55.9	46.7	46.2
Human capital: 75th percentile	84.9	85.1	83.9	68.7	59.0	50.3
Speed of convergence (median) (a)	0.29	0.41	0.52	0.46	0.34	0.39
Speed: 25th percentile	0.24	0.24	0.37	0.31	0.24	0.37
Speed: 75th percentile	0.29	0.64	0.67	0.56	0.43	0.43

SOURCES: Annual Regional Database of the European Commission and Banco de España.

a Speeds are calculated excluding regions whose estimated individual speed of convergence is greater than 1, as this implies an unstable dynamic.

b The percentage of the total population with at least secondary education is used as a proxy for human capital.

whereas in Club 2 the elasticity of human capital suggests that secondary education accumulation translates more strongly into improvements in income per capita in the long run (Chart 3.a).

Both clubs show moderate speeds of convergence (ϕ_i in Equation (5)), although these are somewhat slower in Club 1 than in Club 2, pointing to a more gradual transition towards equilibrium in Club 1. This pattern suggests that differences between clubs are explained not only by the speed of adjustment, but also by the nature of the equilibrium towards which they are converging. In the case of Club 1, convergence towards GDP per capita paths is supported by high returns on physical capital and, to a lesser extent, on human capital, amid significant accumulation of both factors. Club 2, despite having similar endowments, appears to rely relatively more on human capital as a driver of long-term growth, although the effects are more dispersed across the regions.

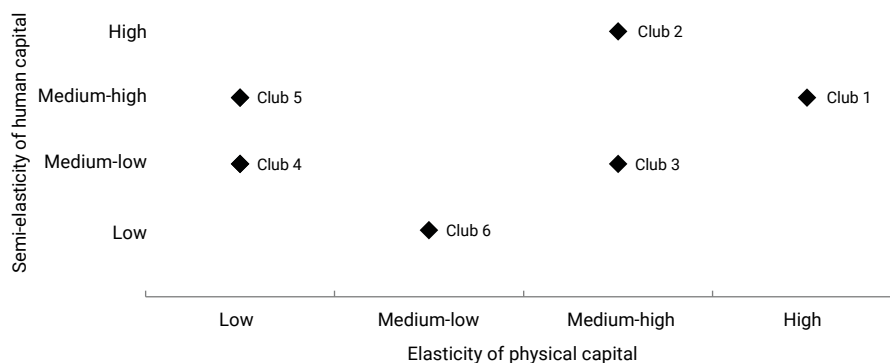
Clubs 3 to 6 include virtually all the French, Italian and Spanish regions, as well as some German ones. As with the higher-income clubs, a convergence process can be observed within each club over the last 25 years (Charts 2.c to 2.f), although the long-run level of GDP per capita differs. The regions in Clubs 3 to 6 have lower GDP per capita levels than Clubs 1 and 2 and show a progressive decrease in human capital endowments, which is particularly marked in Clubs 5 and 6, where educational attainment levels are significantly lower than those in the more advanced groups. By contrast, the capital stock differences are somewhat smaller. This pattern is reinforced by the long-run estimates. Broadly speaking, the elasticities associated with the capital stock are low and the effect of secondary education diminishes, meaning that the regions in these clubs may face constraints in transforming physical and human capital accumulation into long-term improvements.

This evidence is consistent with the recent region-specific literature, which underscores the role of absorptive capacities and spatial externalities in growth processes. Studies have shown that the effectiveness of physical capital investment largely depends on the existing level of human capital and on the regional environment, which shape regions' capacity to adopt and diffuse technological advances (Jung and López-Bazo, 2017; Sanso Navarro,

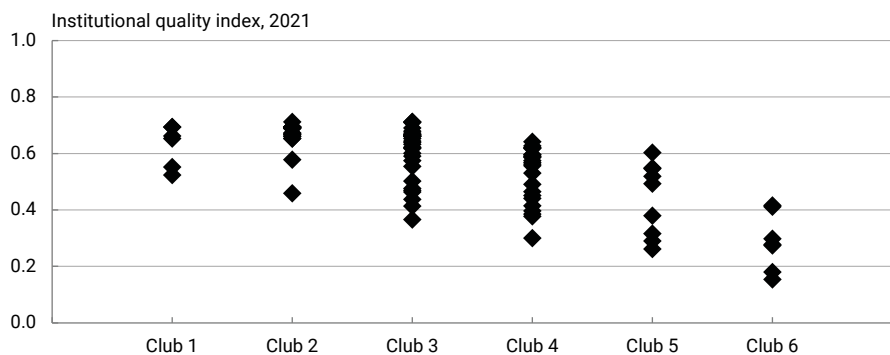
Chart 3

Club characteristics

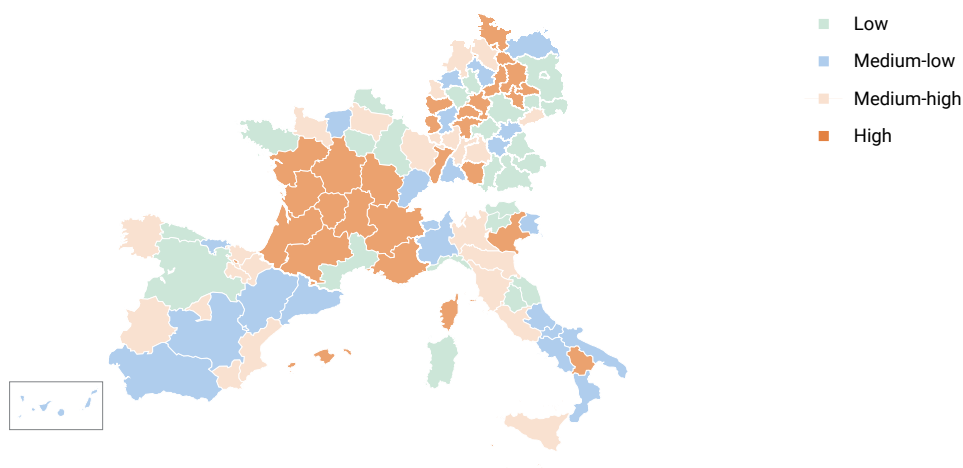
3.a Elasticities, by club (a) (b)



3.b Institutional quality in each convergence club (c)



3.c Speed of convergence (b)



SOURCE: Authors' calculations drawing on the Annual Regional Database of the European Commission and Charron et al. (2021).

- a** Long-run elasticities and semi-elasticities are calculated excluding regions whose estimated individual speed of convergence is greater than 1, as this implies an unstable (explosive) dynamic and precludes an economic interpretation of the long-run coefficients.
- b** The qualitative categories (low, medium-low, medium-high and high) are constructed based on the distribution quartiles of the variable analysed.
- c** Convergence clubs are identified using the methodology proposed by Phillips and Sul (2007, 2009) and the log of GDP per capita for the period 1998-2025. Institutional quality is measured based on the European Quality of Government Index developed by Charron et al. (2021); the index is rescaled to a 0-1 range, with values closer to 1 indicating better quality of government and values closer to 0 reflecting lower institutional quality.

Vera-Cabell and Ximénez-de-Embún, 2017). Along the same lines, the literature on regional development emphasises that regional disparities are explained not only by factor accumulation, but also by differences in institutional quality, human capital and other local conditions that influence the efficiency with which economies transform investment into economic development (Rodríguez-Pose, 2013; McCann, 2015).

As regards the speed of convergence, Clubs 3 to 6 exhibit transition processes towards long-run equilibria. In particular, Clubs 3 and 4 stand out for their faster convergence, which is consistent with stronger transition dynamics, while convergence in Clubs 5 and 6 is slower and less disperse. Overall, these results suggest that the constraints faced by these clubs do not lie in their capacity to converge, but rather in the nature of the equilibria towards which they are converging. In other words, these regions are transitioning towards their steady state, but their long-run levels are constrained by a more limited capacity to transform productive inputs into income per capita, especially in the absence of high levels of human capital.

In addition to human and physical capital, the literature provides evidence of other relevant determinants of growth, such as institutional quality. Several studies, including Filip and Setzer (2025), identify institutional quality as one of the main determinants of economic growth and resilience at regional level. For descriptive purposes, Chart 3.b presents the institutional quality of the identified regional clubs in 2021. Although including this variable in our estimates does not yield statistically significant results, the clubs with higher GDP per capita levels (that is, the higher-ranked clubs) generally exhibit greater institutional quality. However, while this pattern is consistent with existing evidence, it should not be interpreted as a causal relationship derived from our results.

These results suggest that production factors do not have a homogeneous impact on regions and that the capacity to transform physical and human capital accumulation into economic growth varies. Consequently, the process of regional growth in Europe does not follow a single, uniform dynamic, but rather reflects the coexistence of multiple equilibria. Convergence mainly occurs within each club, where regions share similar structural characteristics, while differences in human capital, productive systems and institutional quality, inter alia, may determine divergent long-run trajectories across groups. This persistent structural heterogeneity suggests that disparities between regions reflect profound differences in their capacity to generate and sustain growth.

4.3 Regional convergence in Spain

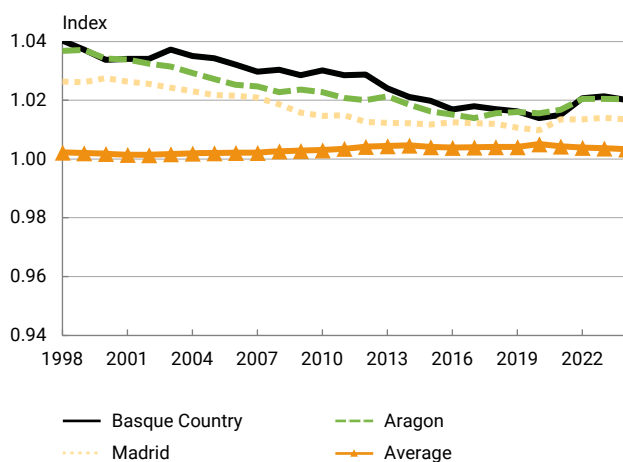
The Spanish regions are in Clubs 3 to 6, i.e. the clubs whose long-run equilibrium is at medium or low levels of GDP per capita within the four countries in the sample. This is consistent with previous evidence on the existence of heterogeneous convergence dynamics and the formation of regional clubs in Europe, where structural differences shape growth trajectories (Phillips and Sul, 2007, 2009; Monfort, Cuestas and Ordóñez, 2013).

Detailed analysis by region reveals that the Club 3 regions (Madrid, Basque Country and Aragon) presented higher relative GDP per capita levels than the overall sample average in 1998. However, this gap has gradually narrowed over time, suggesting some loss of relative advantage (Chart 4.a). At the same time, some convergence can be observed in the trajectories of the Club 3 regions, which may be interpreted as a partial reduction in disparity among these Spanish regions. The dynamics of this process, however, vary across regions. Madrid and the Basque Country show relatively higher speeds of transition, while Aragon is converging more gradually towards its long-term level (Chart 3.c).

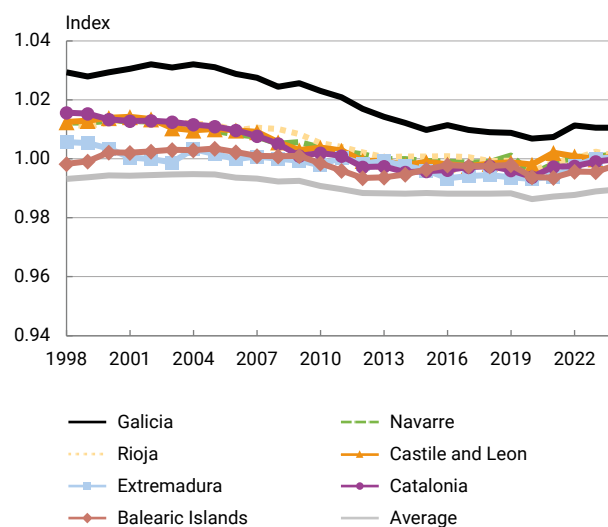
Chart 4

Relative transition paths of Spanish regions (a)

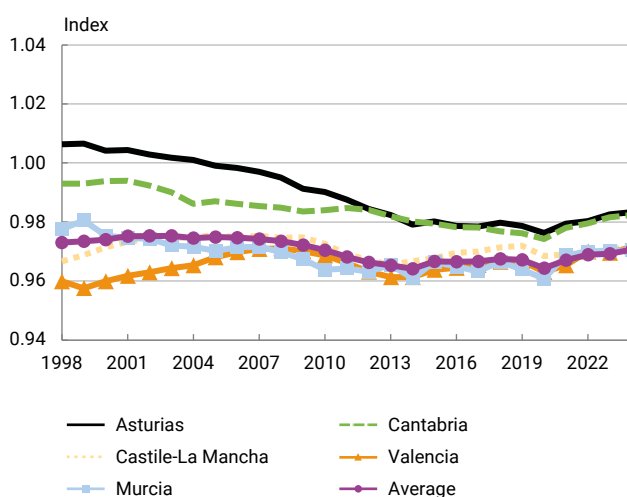
4.a Club 3



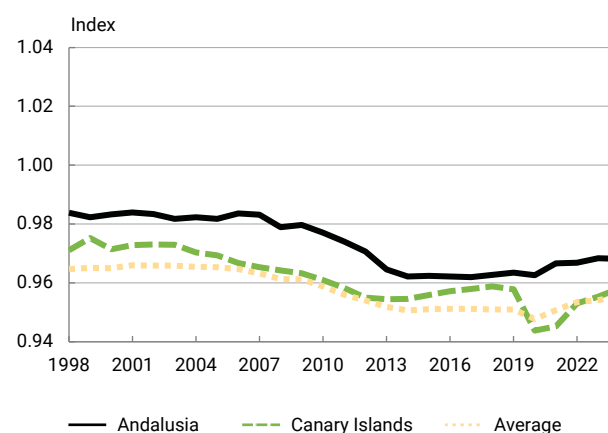
4.b Club 4



4.c Club 5



4.d Club 6



SOURCE: Authors' calculations drawing on the Annual Regional Database of the European Commission.

a The charts show the relative transition paths of the Spanish regions in each club (Equation (1) in Section 3.2), together with the average paths for all regions analysed in each club.

Club 4 includes Galicia, Navarre, Rioja, Castile and Leon, Extremadura, Catalonia and the Balearic Islands (Chart 4.b), which have followed somewhat different trajectories. Specifically, Extremadura and the Balearic Islands have performed in line with the overall sample average throughout the period. The remaining regions (especially Galicia) started from a more favourable relative position and have gradually converged towards levels slightly above the average for the analysed regions as a whole. The speed of convergence presents marked heterogeneity, with the estimates suggesting a comparatively faster transition towards long-term relative levels in the Balearic Islands and a more gradual process of convergence in Castile and Leon (Chart 3.c).

Club 5 includes Asturias, Cantabria, Castile-La Mancha, Valencia and Murcia (Chart 4.c). The initial situations of these regions in 1998 were notably heterogeneous and exhibited significant dispersion in their relative positions, which has gradually declined over the period analysed. Despite initially being among the better-positioned regions, Asturias and Cantabria have seen a gradual loss of their relative advantage and progressively moved away from the average for the regions as a whole. By contrast, Castile-La Mancha and Valencia have undergone a catch-up process and moved steadily towards higher levels of relative income. Speeds of convergence generally stand around intermediate values, suggesting a gradual transition process. The main exception is Asturias, where the speed of convergence has been slower, indicating a more gradual transition towards its long-run equilibrium path (Chart 3.c).

Lastly, Club 6 includes Andalusia and the Canary Islands (Chart 4.d), where the initial relative GDP per capita levels were below the overall sample average, a gap that has since widened.

As regards factor endowment, the results suggest a significant share of Spanish regions are below the median of their respective clubs in terms of GDP per capita, physical capital and human capital (Table 5). However, this pattern is not homogeneous and coexists with some intra-club heterogeneity, with certain regions exhibiting levels equal to or higher than those of their peers. Overall, these results point to a less favourable relative position in terms of factor endowment and income levels for several Spanish regions, albeit with appreciable differences depending on the club concerned.

Table 5
Key statistics for Spanish regions (2000-23)

	Deviation from the club median				
	Club	GDP per capita (%)	Capital stock per capita (%)	Education ratio (pp)	Speed of convergence (pp)
Basque Country	3	-4.9	-0.9	-13.7	0.10
Aragon	3	-17.3	12.6	-21.4	-0.20
Madrid	3	2.4	-5.9	-12.4	0.04
Galicia	4	-25.2	-32.2	-11.1	0.09
Navarre	4	6.5	23.4	0.0	0.00
Rioja	4	-6.9	-6.8	-6.1	0.12
Castile and Leon	4	-20.0	0.0	-7.8	-0.16
Extremadura	4	-37.9	-26.0	-21.7	0.01
Catalonia	4	1.9	-16.4	-6.2	-0.12
Balearic Islands	4	-4.6	-1.2	-10.3	0.32
Asturias	5	-1.0	19.4	2.6	-0.21
Cantabria	5	4.8	6.7	5.0	0.02
Castile-La Mancha	5	-8.7	-6.3	-9.4	0.08
Valencia	5	0.7	-16.6	-2.6	0.13
Murcia	5	-5.0	-25.3	-6.9	0.15
Andalusia	6	-4.7	-18.8	-2.5	0.04
Canary Islands	6	5.3	-9.8	1.7	-0.02

SOURCES: Annual Regional Database of the European Commission and Banco de España.

5 Conclusions

This paper analyses the dynamics of GDP per capita convergence in 98 NUTS 2 (Nomenclature of Territorial Units for Statistics) regions in Germany, France, Italy and Spain between 1998 and 2025, to identify the underlying structure of regional convergence in the main euro area economies.

The results show that the 98 regions analysed are not converging towards a single common steady state. Using the methodology in Phillips and Sul (2007, 2009), we identify six convergence clubs, each one grouping regions that share similar long-run growth trajectories. This finding is consistent with the literature on club convergence and reinforces the idea that the convergence process in Europe is fundamentally heterogeneous, with multiple long-run equilibria.

A heterogeneous dynamic panel model with common effects is used, applying the Dynamic Common Correlated Effects Mean Group (DCCCEMG) estimator for the regions analysed. The results provide evidence of conditional convergence, with an average speed of transition of around 0.49. The structural determinants of long-term growth confirm the positive role of physical and human capital, although human capital has a larger effect than physical capital for the panel average. This is consistent with the literature on endogenous growth, which emphasises the role of human capital not only as a direct production factor but also as a facilitator of technological diffusion and innovation. Analysis at club level adds important nuance to this result: the more advanced regions show high returns on both factors, while returns are smaller in the less developed clubs, pointing to structural differences in the regions' effective production functions.

Detailed analysis shows that no Spanish regions are in the top two clubs in terms of GDP per capita. The strongest regions (Madrid, Basque Country and Aragon) are in Club 3, while Andalusia and the Canary Islands are classified in Club 6 (the lowest-ranked club). This pattern suggests that regional disparities within Spain are persistent and, in some cases, have intensified.

Overall, this paper's findings suggest that policies aimed at reducing regional disparities in Europe should go beyond the mere accumulation of production factors. The evidence indicates that a region's capacity to transform physical and human capital into sustained growth depends on structural characteristics such as institutional quality and the productive system. Cohesion policies at both national and supranational level should therefore be designed with sufficiently long horizons to enable structural change. Along these lines, the evidence shows that European funds have had positive medium-term growth effects at regional level (Canova and Pappa, 2025). Moreover, the existence of multiple stable equilibria also reinforces the need for specific policies by region type, rather than homogeneous strategies applied uniformly across Europe.

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Annex

Table A.1
NUTS 2 regions used and their convergence clubs (a)

Code	Region	Club	Code	Region	Club	Code	Region	Club
Spain								
ES11	Galicia	4	ES24	Aragón	3	ES52	Comunitat Valenciana	5
ES12	Principado de Asturias	5	ES30	Comunidad de Madrid	3	ES53	Illes Balears	4
ES13	Cantabria	5	ES41	Castilla y León	4	ES61	Andalucía	6
ES21	País Vasco	3	ES42	Castilla-La Mancha	5	ES62	Región de Murcia	5
ES22	Comunidad Foral de Navarra	4	ES43	Extremadura	4	ES70	Canarias	6
ES23	La Rioja	4	ES51	Cataluña	4			
Germany								
DE11	Stuttgart	1	DE50	Bremen	2	DEA4	Detmold	2
DE12	Karlsruhe	2	DE60	Hamburg	1	DEA5	Arnsberg	3
DE13	Freiburg	3	DE71	Darmstadt	2	DEB1	Koblenz	3
DE14	Tübingen	2	DE72	Gießen	3	DEB2	Trier	3
DE21	Oberbayern	1	DE73	Kassel	2	DEB3	Rheinhessen-Pfalz	2
DE22	Niederbayern	2	DE80	Mecklenburg-Vorpommern	2	DEC0	Saarland	3
DE23	Oberpfalz	1	DE91	Braunschweig	2	DED2	Dresden	2
DE24	Oberfranken	2	DE92	Hannover	2	DED4	Chemnitz	3
DE25	Mittelfranken	2	DE93	Lüneburg	3	DED5	Leipzig	2
DE26	Unterfranken	2	DE94	Weser-Ems	2	DEE0	Sachsen-Anhalt	3
DE27	Schwaben	2	DEA1	Düsseldorf	3	DEF0	Schleswig-Holstein	3
DE30	Berlin	1	DEA2	Köln	2	DEG0	Thüringen	3
DE40	Brandenburg	3	DEA3	Münster	3			
France								
FR10	Ile de France	1	FRF1	Alsace	3	FRJ1	Languedoc-Roussillon	4
FRB0	Centre — Val de Loire	4	FRF2	Champagne-Ardenne	4	FRJ2	Midi-Pyrénées	3
FRC1	Bourgogne	4	FRF3	Lorraine	4	FRK1	Auvergne	3
FRC2	Franche-Comté	4	FRG0	Pays de la Loire	3	FRK2	Rhône-Alpes	3
FRD1	Basse-Normandie	4	FRH0	Bretagne	3	FRL0	Provence-Alpes-Côte d'Azur	3
FRD2	Haute-Normandie	4	FRI1	Aquitaine	3	FRM0	Corse	3
FRE1	Nord-Pas de Calais	4	FRI2	Limousin	4			
FRE2	Picardie	4	FRI3	Poitou-Charentes	3			
Italy								
ITC1	Piemonte	4	ITF4	Puglia	6	ITH3	Veneto	3
ITC2	Valle d'Aosta/Vallée d'Aoste	3	ITF5	Basilicata	5	ITH4	Friuli-Venezia Giulia	4
ITC3	Liguria	4	ITF6	Calabria	6	ITH5	Emilia-Romagna	3
ITC4	Lombardia	3	ITG1	Sicilia	6	ITI1	Toscana	4
ITF1	Abruzzo	5	ITG2	Sardegna	5	ITI2	Umbria	5
ITF2	Molise	6	ITH1	Provincia Autonoma di Bolzano	2	ITI3	Marche	4
ITF3	Campania	6	ITH2	Provincia Autonoma di Trento	3	ITI4	Lazio	4

SOURCE: Authors' calculations drawing on the Annual Regional Database of the European Commission.

a The Phillips and Sul (2007, 2009) methodology is used for the natural log of GDP per capita over the 1998-2025 period.

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