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How institutions shape the economic returns to investment in European regions?

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ABSTRACT

Most studies of institutional quality and regional growth assume uniform effects across territories. However, this may mask crucial regional heterogeneity, with direct policy implications. We use a latent class framework applied to 230 EU regions over 2009–2017 to identify institution-driven regional parameter groups, and to examine both average effects and catching-up effects associated with changes in the institutional environment. We demonstrate that institutional quality generates highly variable returns to investment in physical capital and innovation. Nordic and Central European regions show highest returns to physical capital and R&D investment, whereas less-developed regions benefit most from education spending. Crucially, we find that improving government quality not only raises average returns but also promotes territorial cohesion. By contrast, regional autonomy shows limited impact on returns. Our findings challenge the one-size-fits-all approach to cohesion policy and indicate that cohesion policy should explicitly promote institutional improvements in addition to capital deployment.

1. Introduction

The disparities in economic growth amongst countries and regions have long preoccupied researchers and policymakers alike. Standard economic growth models attribute production to several inputs, including the accumulation of physical and human capital, innovation, and productivity (Solow, 1957; Romer, 1986; Lucas, 1988). Over time, neoclassical growth models have evolved to incorporate additional factors such as technology and human capital as key drivers of economic growth (Mankiw et al., 1992; Islam, 1995). Yet despite this progress, consensus remains elusive on the fundamental variables that drive growth (Temple, 1999).

This lack of consensus has spurred alternative theories, from endogenous growth theory to new economic geography. Since North's (1990) seminal work, the role of institutions in economic development has stood at the centre of debate. On one hand, institutional quality is believed to enhance the business environment (Acemoglu et al., 2005) and promote economic growth (Rodrik et al., 2004), while also being considered amongst the geographical factors influencing development (Gallup et al., 1999). On the other hand, improvements in institutions may themselves result from economic growth (Barro, 1999). Empirical evidence supports both perspectives.[1] Aghion et al. (2016), for instance, examine the link between corruption and growth in US states, while Bournakis et al. (2023) explore the impact of institutions on economic performance in Sub-Saharan Africa through the lens of natural resource efficiency. Glaeser et al. (2004) highlight the need for careful measurement of institutional quality and the application of robust econometric methods in country-level studies of institutions.

In recent decades, increasing attention has focused on the relationship between government quality and regional economic performance at the subnational level. Traditional growth studies have typically examined average patterns at the country level (Temple, 1999). However, as

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[1] The strength of intellectual property rights protection is often interpreted in the literature as an indicator of institutional quality. See Eicher and García-Peñalosa (2008) for an analysis of its effect on economic growth.

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growth trajectories differ markedly across regions, the relevance of country-wide policy recommendations diminishes: average parameters fail to capture the true drivers of growth in specific locations (Brock and Durlauf, 2001). A growing body of literature examines the effects of institutions at the regional and subnational levels, particularly within Europe (Tabellini, 2010). These studies suggest that government quality not only directly drives economic growth but also indirectly enhances the efficiency of public investments (Rodríguez-Pose and Garcilazo, 2015; Barbero et al., 2023).[2] The influence of institutional quality proves especially pronounced in less-developed or declining regions, where it affects returns to physical and human capital as well as innovation (Rodríguez-Pose and Ketterer, 2020; Rodríguez-Pose and Ganau, 2022). Moreover, many of these regions face challenges related to smart specialisation, a key component of EU cohesion policy reforms (McCann and Ortega-Argiles, 2015).

Such research relies on a variety of methodologies. For example, regression tree analysis (Durlauf and Johnson, 1995), quantile regression (Li and Kumbhakar, 2022) and latent class models (Paap et al., 2005; Battisti and Parmeter, 2013) have been deployed to account for parameter heterogeneity. Research has also identified distinct convergence groups in Europe using methods such as the Phillips and Sul algorithm (Cutrini, 2019; Cutrini and Mendez, 2023; Mazzola and Pizzuto, 2020) and spatial econometrics (Annoni et al., 2019).

A related body of research highlights the crucial role of institutional quality in shaping economic outcomes other than the economic growth of regions and/or countries. At the national level, and focusing mainly on emerging and developing countries, several studies emphasize its influence on the relationship between financial openness and external competitiveness (Aman et al., 2022), as well as on capital accumulation through R&D channels (Nemlioglu and Mallick, 2020). More recently, Beverelli et al. (2024) identify country-specific institutional measures based on exporter and importer fixed effects. At the micro level, noteworthy contributions include the experiment conducted by Carlsson et al. (2024), which concluded that trust in institutions is crucial for economic prosperity among entrepreneurs in Ethiopia, and the study by Agostino et al. (2025), which investigated how institutional quality mitigates the negative effects of weather conditions on firm-level efficiency in the food sector in Italy.

Taking a policy-design perspective focused on regional growth in Europe, the central contribution of this paper lies in demonstrating that institutional effects on regional growth are not uniform—as is typically assumed—but instead are highly heterogeneous across European regions. This heterogeneity has profound implications for policy.[3] While the existing literature establishes that institutions matter, we advance understanding in three ways. First, we estimate region-specific returns to investment in physical capital, R&D, and education, enabling policymakers to identify where each type of investment yields highest returns. Second, we demonstrate that improving institutional quality not only raises average returns but reduces their dispersion across regions, promoting territorial cohesion. Third, we show that these effects vary systematically: developed regions benefit most from improved institutions enhancing capital and innovation returns, whilst less-developed regions perceive the greatest gains in education returns.

We build on this literature by conducting a comprehensive analysis of the impact of institutions on economic development in European regions, estimating region-specific coefficients to account for differences in institutional factors. Using an empirical framework based on the neoclassical growth model and incorporating inequality dimensions (Barro and Sala-i-Martín, 1992), we provide insights into subnational economic growth by identifying regional-level differences in returns to investment in education, physical capital and innovation. Our empirical approach enables us to pinpoint regions with particularly high or low returns on these factors, helping to identify key targets for public and private investment. Given the substantial public funding dedicated to promoting development in Europe, our findings can assist policymakers in better allocating resources to maximise the benefits of cohesion investments.

Our modelling approach is to nest our economic growth model within a latent-class structure. We first calculate class-specific coefficients for the core drivers of economic growth, in line with Paap et al. (2005) and Battisti and Parmeter (2013). We next take a step further than the conventional latent class literature by using the estimated probabilities of class membership of our latent class model (LCM) to derive region-specific coefficients.[4] This permits a better understanding of the regional variability in returns to investment in innovation and human and physical capital. We even go one step further by conducting several counterfactual analyses that allow us to address potential non-linearities in the marginal effects of improvements in institutional quality or changes in regional authority on the returns to education, investment in physical capital, and innovation.[5] Whereas previous research has mainly focused on the average effects of changes in the institutional environment on economic growth, our counterfactual analyses permit us to investigate the convergence (i.e., catching-up) effects associated with such changes. Our analysis thus sheds light on how less-developed regions in the EU can narrow the gap to their more developed counterparts. In essence, we explore both average and catching-up effects on the returns (elasticities) of traditional growth drivers in response to changes in the institutional environment.

It is worth mentioning in this regard that we expect substantial variation in the effects of different types of investment on regional development, owing to the diversity of economic ecosystems and institutional settings across regions (Jackson, 2011). Although previous studies have primarily focused on institutional quality (Charron et al., 2021; Rodríguez-Pose and Ganau, 2022), further research is needed to understand these heterogeneous effects better (Bachtrögler et al., 2020). Research on the absorption capacity of European funds suggests that the institutional framework and fiscal decentralisation explain to a considerable extent the disparities between less developed and more developed regions in Europe (Kersan-Škabić and Tijanić, 2017). Hence, our aim is to demonstrate how regional variations in institutional conditions and absorption capacity influence the economic growth trajectories of European regions. Our findings suggest that policymakers and politicians should focus on reducing public sector corruption, promoting impartiality, and improving the efficiency of public services.

The structure of the paper is as follows. Section 2 provides an overview of institutions in European countries and their role in explaining disparities in economic performance. In Section 3, we introduce the econometric approach, specifically the latent class model, and outline the methodology used to estimate the marginal effects of institutional factors. Section 4 describes the data sources used in our analysis. Section 5 focuses on the role of institutions in regional development, presenting

[2] In a recent paper, Colombo et al. (2024) study the indirect effect of informality through the public expenditure multiplier, concluding that informality is not dependent on the quality of institutions at the national level.

[3] Malikov and Sun (2017) highlight that ignoring potential parameter heterogeneity can lead to biased estimates and misleading policy implications. Similarly, Gude et al. (2018) observe that heterogeneous-coefficient models can provide richer policy insights by allowing policy measures to be tailored more precisely to each unit.

[4] As Greene (2005) notes, the LCM represents a discrete analogue of the random parameters (stochastic frontier) model. Random parameters models assume that individual parameters follow a continuous multivariate distribution. LCM, in contrast, captures only between-group heterogeneity. However, this does not prevent the calculation of observation-specific coefficients, akin to the random coefficients model (Greene, 2005; Orea and Kumbhakar, 2004). In this way, the continuous and discrete approaches are functionally similar.

[5] By 'marginal', we refer to a variation of one standard deviation in our variables that measure the quality of institutions and regional authority.

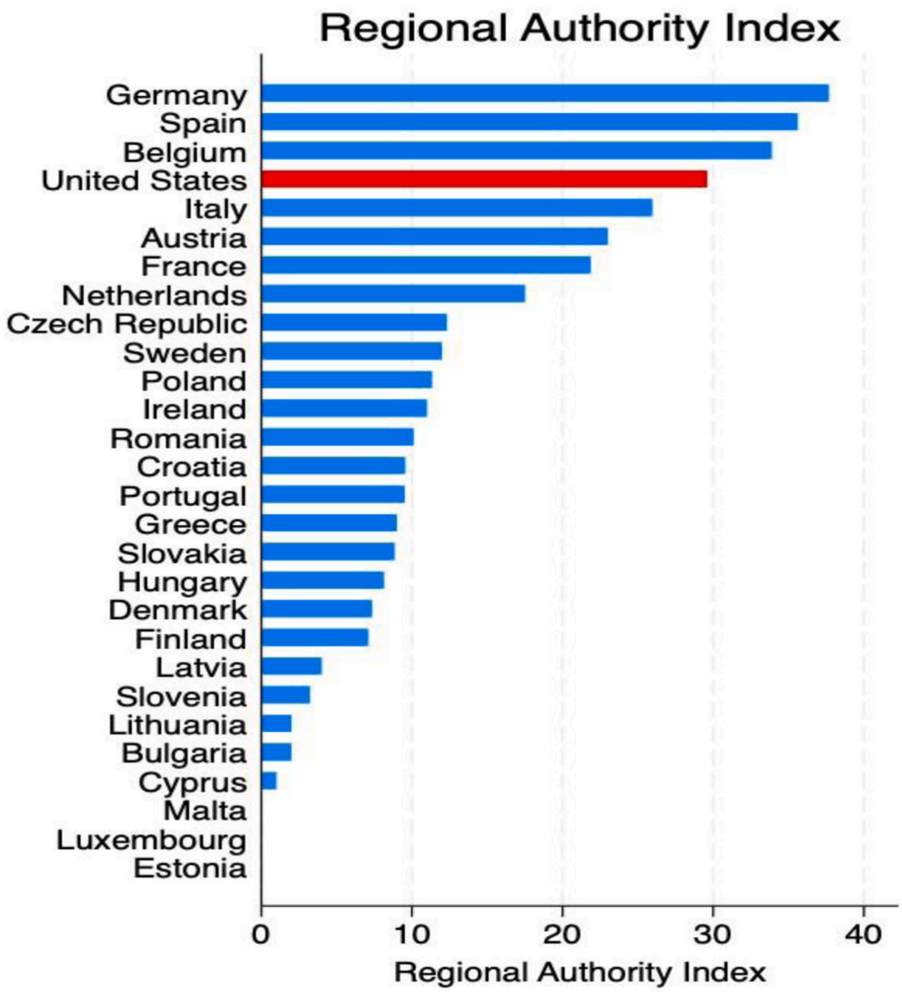

Fig. 1. Regional Authority Index in European countries in 2018.
Source: own elaboration from Hooghe et al. (2016); Shair-Rosenfield et al. (2020).

our empirical application to European regions. Finally, Section 6 presents the main findings and offers policy recommendations based on these results.

2. Institutions and government quality in Europe

Local and regional governments prove crucial for shaping the economic performance of territories (Rodríguez-Pose, 2013). The quality of regional governments directly affects the outcomes of public investments and the ability to deploy European Funds efficiently, thereby influencing economic growth (Rodríguez-Pose and Garcilazo, 2015). The role of government quality commands wide acceptance but the benefits of regional autonomy remain more contested. As Filippetti and Cerulli (2018) note, regional autonomy can enhance the responsiveness of public services to local needs, but it may also reduce opportunities for inter-regional risk-sharing and solidarity. Similarly, variations in government quality can affect the success of decentralisation processes (Charron et al., 2010, 2014), and decentralisation itself can influence government effectiveness (Treisman, 2002). Consequently, both institutional features —government quality and decentralisation— shape the impact of the other on economic growth. Variations in these institutional factors, along with differing governance practices, significantly influence the effective use of European funds and the development potential of regions (Muringani et al., 2019).

These institutional features have evolved significantly in recent years. Between 1950 and 2007, 21 out of 27 EU member states decentralised political power to varying degrees (Shair-Rosenfield et al., 2020). European policy frameworks assume that regions possess sufficient authority to implement policies effectively, and that decentralisation combined with financial capacity facilitates the efficient use of European funds (Van Wolleghem, 2019). The most comprehensive measure of regional authority is the Regional Authority Index (RAI) (Hooghe et al., 2016; Shair-Rosenfield et al., 2020), which covers the period from 1950 to 2018. This synthetic index aggregates ten dimensions of regional authority: five measuring the degree of self-rule (institutional depth, policy scope, fiscal autonomy, borrowing autonomy, and representation) and five assessing shared rule (law-making, executive control, fiscal control, borrowing control, and constitutional reform). Given that investment for regions eligible for Cohesion Policy is defined at the NUTS-2 level, and this is the level used by the European Commission to evaluate cohesion across EU regions, NUTS-2 is the unit of analysis in this study. However, in some countries, such as Belgium

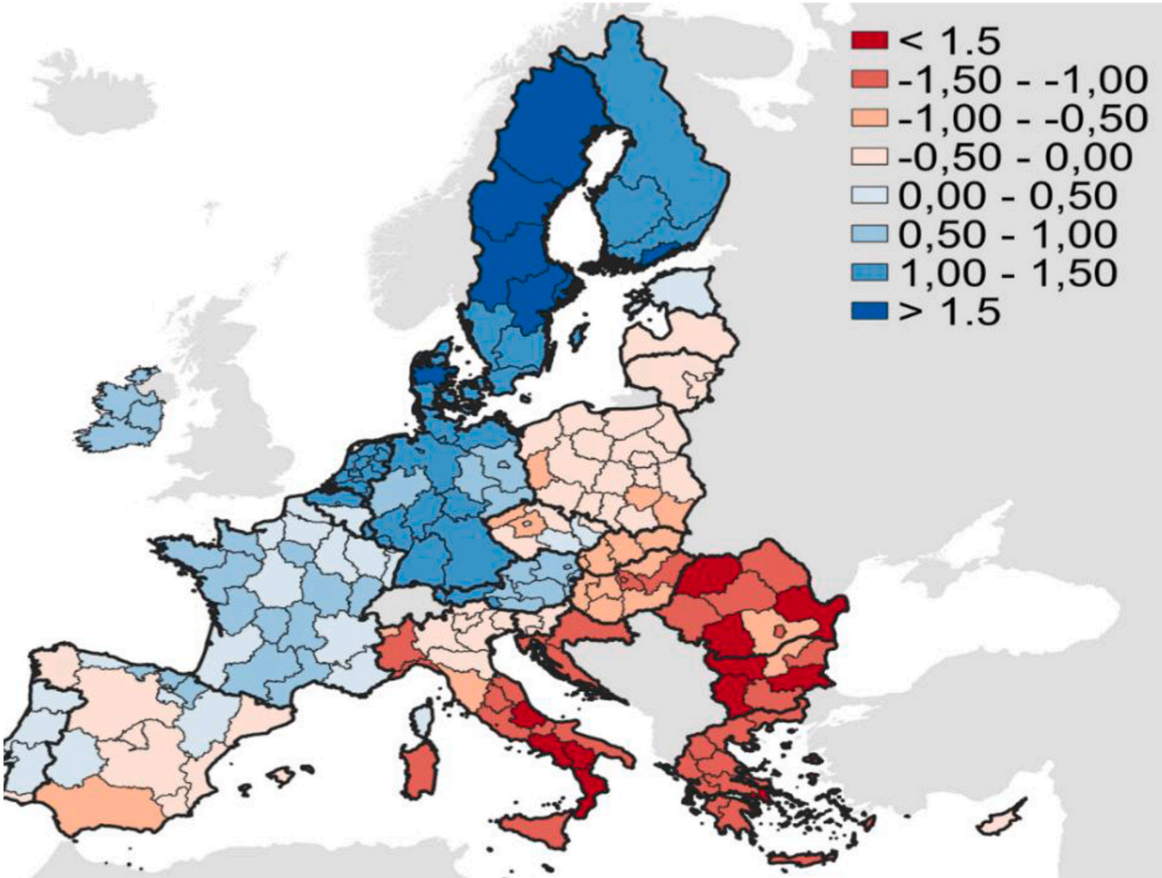

Fig. 2. European quality of government in 2017.
Source: Charron et al. (2021). EuroGeographics for the administrative boundaries.

and Germany, regional authority is assigned at the NUTS-1 level. In these cases, we follow standard practice of assigning the Quality of Government and RAI measures from the NUTS-1 regions to the NUTS-2 subregions.

Decentralisation levels vary considerably across European countries (Fig. 1).[6] Regions in Germany, Spain, and Belgium enjoy the highest levels of autonomy, surpassing even the powers held by states in the United States (used as a point of reference). In contrast, regions in Estonia, Luxembourg, and Malta possess almost no autonomy.

The quality of subnational governments within the EU also exhibits significant variation. The European Quality of Government Index (QI), developed by Charron et al. (2021), represents the most commonly used indicator to assess government quality at the regional level.[7] This indicator captures citizens' perceptions and experiences of corruption, and the quality and impartiality of public services, particularly in healthcare, education, and policing. These perceptions are collected through a large-scale survey. The national quality of government scores is derived as an unweighted average of four key indicators from the Worldwide Governance Indicators: Control of Corruption, Government Effectiveness, Rule of Law, and Voice and Accountability. The European Quality of Government Index focuses primarily on healthcare, education, and law enforcement and serves as a strong proxy for overall governance quality. High-quality governance in these areas creates a stable business environment, indirectly influencing economic performance by helping create conditions conducive to economic activity.

Fig. 2 shows the distribution of government quality across European regions as of 2017. There exists a strong correlation between government quality, socio-economic development, and social trust within regions (Charron et al., 2014). Nordic countries and certain central European regions display the highest levels of subnational government quality. In contrast, regions in south-eastern Europe tend to exhibit relatively low government quality. However, significant internal disparities are also evident in countries such as Italy, Bulgaria, and Romania, where lower levels of government quality coexist with regions that rank higher, like most of those in Portugal and Spain.

3. Economic growth model

3.1. Latent class specification

This section presents the econometric specification used to examine the relationship between government quality, decentralisation, and economic growth, through a Latent Class Economic Growth (LCEG) model. Our empirical framework is based on the neoclassical growth model introduced by Mankiw et al. (1992). In this model, employment

[6] Filippetti and Cerulli (2018) consider the limited variation in the RAI index at the regional level within European countries as a significant obstacle. Indeed, Figure A1 in the Appendix shows that, with few exceptions, the degree of autonomy is fairly homogeneous across regions within each country. This means that the country-level index can also represent in many cases the average regional level.

[7] The European Quality of Government Index, often labelled as EQI, is based on a survey conducted across all 208 NUTS 1 and NUTS 2 regions of the 27 EU member states, with over 129,000 respondents in the 2021 wave. As the index is only available for 2010, 2013, 2017, 2021, and (now) 2024, we follow Rodríguez-Pose and Ketterer (2020) to address the missing data. Values for the intervening years are estimated using direct interpolation, and for the period before 2010, it is assumed that the regional quality of government difference relative to the national level remains constant.

(L_{it}) grows at rate n_{it}, while physical capital (K_{it}) depreciates at a constant rate δ, and region's total factor productivity (A_{it}) grows exogenously at a constant rate g. Following Islam (1995), we can write the economic growth model in per worker terms as follows:

$$\Delta ln\, y_{it} = \beta_0 - \beta_1\, ln\, y_{it-1} + \beta_2\, ln\, s^K_{it} + \beta_3\, ln\, s^H_{it} - \beta_4 \ln \widetilde{n}_{it} + \beta_5 lns^{RD}_{it} + \eta_i + v_{it} \quad (1)$$

where y_{it} is the per worker production of the ith region in period t; $\widetilde{n}_{it} = n_{it} + g + \delta$ is an adjusted employment growth rate; s^K_{it} and s^H_{it} are, respectively, investment in physical capital and educational levels, the latter as a proxy for human capital; η_i captures time-invariant unobserved region-specific effects; and v_{it} is a traditional disturbance term. We included R&D investment (s^{RD}_{it}) in equation (1) because, following Jones (1995), we assume that the technology parameter A_{it} also depends on the regions' innovation effort.[8]

The slope parameters in equation (1) are common across all regions and are time-invariant. However, this assumption has been questioned by various studies, as it may weaken the effectiveness of policy measures aimed at promoting economic growth in individual regions. To address this limitation, we incorporate the basic economic growth model into a latent class structure.

A conventional Latent Class Model (LCM) assumes a finite number of classes (or groups), where each observation in the sample is probabilistically allocated to a particular class. In our application, a specific economic growth function is estimated for each class. The allocation of regions to a particular class depends on the estimated class membership probabilities, reflecting the uncertainty regarding the true classification of each observation.

To remove the time-invariant unobserved region-specific effects, we apply a within-transformation to equation (1). The economic growth model in class $j = (1, \ldots J)$ can be re-written as follows:

$$Y^*_{it} = \beta_j X^*_{it} + v^*_{it|j} \quad (2)$$

where the superscript (*) indicates a within-transformation of the original variables, and $v^*_{it|j} \sim N(0,\, \sigma_{vj})$.[9] The model is estimated by maximum likelihood (ML) once the j-specific likelihood functions, $LF_{it|j}\left(\beta_j, \sigma_{vj}\right)$, are weighted using the following prior class membership probabilities:

$$\Pi_{ijt}\left(\delta_j' q_{it}\right) = \frac{exp\left(\delta_j' q_{it}\right)}{\sum_{j=1}^{J} exp\left(\delta_j' q_{it}\right)} \quad (3)$$

The estimated coefficients can be then used to compute the posterior class membership probabilities using the following expression:

$$P(j|it) = \frac{\Pi_{ij}\left(\delta_j' q_{it}\right) \cdot LF_{it}\left(\beta_j, \sigma_{vj}\right)}{\sum_{j=1}^{J} \Pi_{ij}\left(\delta_j' q_{it}\right) \cdot LF_{it}\left(\beta_j, \sigma_{vj}\right)} \quad (4)$$

In our study, we use the above conventional LCM to compute coefficients that vary across regions. Following Greene (2005), we estimate the region-specific parameters using the posterior class membership probabilities and the estimated class-specific parameters as follows:

$$\widehat{\beta}_{it}(q_{it}) = \sum_{j=1}^{J} P(j|it)\widehat{\beta}_j = \sum_{j=1}^{J} \frac{\Pi_{ij}\left(\widehat{\delta}_j' q_{it}\right) \cdot LF_{it}\left(\widehat{\beta}_j, \widehat{\sigma}_{vj}\right)}{\sum_{j=1}^{J} \Pi_{ij}\left(\widehat{\delta}_j' q_{it}\right) \cdot LF_{it}\left(\widehat{\beta}_j, \widehat{\sigma}_{vj}\right)} \widehat{\beta}_j \quad (5)$$

Although the set of j-class parameters ($\widehat{\beta}_j$) in equation (2) are common to all observations, each region has its own coefficient ($\widehat{\beta}_{it}$) because they have different posterior class-membership probabilities. The posterior probabilities depend not only on the relative goodness-of-fit of each class when explaining the economic growth of each region, but also on the estimated prior probabilities, which in turn depend, among other class-membership determinants, on QI_{it} and RAI_{it}.[10] These covariates allow us to examine whether the classification of European regions into different classes depends on institutional quality and the degree of regional authority, following the approach of Liu et al. (2020).

The observation-specific coefficients in equation (5) are functions of the group-specific coefficients and the estimated probabilities of class membership, which in turn depend on contextual variables that vary across observations. Thus, our LCM can also be viewed as a heterogeneous and functional-coefficient model. We compute the heterogeneous coefficients using a parametric function. Malikov and Sun (2017) and Sun and Malikov (2018) employ semi- or non-parametric methods to estimate heterogeneous spatial coefficients across both cross-sectional and time dimensions. As Gude et al. (2018) underline, both parametric and non-parametric approaches have their strengths and weaknesses, and each must be carefully considered when constructing models. For instance, non-parametric models, which use kernel smoothing methods to relax parametric assumptions, can better track heterogeneous coefficients (Li and Racine, 2006), but prove practical only when there are few continuous regressors or a large number of observations.[11]

The parametric nature of our approach allows us to handle potential nonlinearities in marginal effects due to changes in the institutional environment through straightforward mathematical expressions. By contrast, the flexible nature of kernel smoothing methods makes it difficult to compute partial derivatives of functional coefficients with respect to changes in their determinants. This limits the analysis of marginal effects of institutional or environmental variables, which forms the focus of our research.

3.2. Auxiliary regressions

One important issue that requires attention is the potential endogeneity of some determinants of regional economic growth. For example, Caselli et al. (1996) and others suggest that variables such as investment in physical capital, educational levels, and R&D investment might be endogenous, as better economic performance could encourage firms and households to increase investment. To address this, equation (1) needs to be estimated using instrumental variables (Wooldridge, 2002) or an equivalent method (see, e.g., Amsler et al., 2016).

In a standard regression setting, simultaneity is typically handled using one of three procedures: two-stage least squares (2SLS), the control function (or residual inclusion) method, or limited information maximum likelihood (LIML). However, extending these methods to a latent class model presents additional challenges. Given that maximum likelihood is the most common method for estimating latent class

[8] This specification can be considered a semi-endogenous economic growth model, as it seeks to replicate the endogenous model introduced by Romer (1990). Rodríguez-Pose and Ganau (2022) propose a similar specification, but they also assume that A_{it} is influenced by the quality of regional institutions.

[9] In our basic economic growth model $Y_{it} = \Delta ln\, y_{it}$, and $X_{it} = \left(1, ln\, y_{it-1}, ln\, s^K_{it}, ln\, s^H_{it}, \ln(n_{it} + g + \delta), lns^{RD}_{it}\right)$.

[10] In our application, q_{it} also includes the dummy variable identifying less developed regions (*less developed$_i$*). This allows examining whether the class classification of the European regions depends on the quality of their institutions and their degree of authority.

[11] A common issue in multivariate nonparametric estimation is the so-called curse of dimensionality, as nonparametric methods rely on local (weighted) averaging. In higher dimensions, observations are more sparsely distributed, causing estimators based on local averaging to perform poorly in such cases.

models, LIML represents the preferred solution. LIML requires modelling the joint distribution of a system that includes both the equation of interest and the reduced form equations for the endogenous variables. However, this approach proves significantly more complex than standard maximum likelihood models, as it is unclear how best to model the joint distribution of a weighted sum of class-specific likelihood functions and the error terms in the reduced form equations for the endogenous explanatory variables. Moreover, in non-linear models like latent class models, the procedures (2SLS, control function, and LIML) are no longer numerically or asymptotically equivalent.

To date, a fully developed endogenous latent class model has not yet been proposed. Therefore, we adopt the two-step procedure outlined by Amsler et al. (2016) to manage the endogeneity of explanatory variables in a somewhat similar setting.[12] Specifically, Amsler et al. (2016) propose using the residuals from the reduced form equations for the endogenous variables as a control function. This requires a two-stage process. In the first stage, the parameters of the reduced form equations are estimated, and in the second stage, the parameters of the equation of interest are estimated using the residuals from the first stage as additional explanatory variables. A key advantage of this two-stage procedure is that it does not require any modification to the likelihood function of the original stochastic frontier model, making it suitable for application in latent class models with endogenous explanatory variables.

Another important feature of the control function approach is that the coefficients of the first-stage residuals can be used to test the null hypothesis that the explanatory variables are exogenous. If the residuals are statistically significant, the explanatory variables are endogenous. The F-tests for the residuals are numerically equivalent to the Durbin-Wu-Hausman (DWH) test, commonly used to assess the endogeneity of a variable. Using the DWH test requires strong instruments (relevance condition) and valid instruments (exclusion restriction).[13] In a standard regression setting, it is possible to test the validity of the instruments if the model is overidentified. However, to our knowledge, the typical Sargan-Hansen test used for this purpose has not yet been adapted for use in a latent class model with endogenous regressors. As a result, it is not possible to test for exclusion or over-identifying restrictions in our application.

Since a fully endogenous latent class model with instrumental variables is not available, we apply the control function approach to address potential endogeneity in physical capital, human capital, and R&D investments. The auxiliary regression models (also known as reduced-form models) can be expressed as:

$$x_{it} = g(Z_{it}, \alpha) + \varepsilon_{it} \tag{6}$$

where x_{it} represents an economic growth driver, and Z_{it} is a set of instrumental variables. Specifically, we focus on investment, innovation, and human capital as endogenous variables. In addition to the exogenous drivers of economic growth (such as lagged GDP and population growth), we include time dummies and European funds (lagged by three periods) as external instruments. Our auxiliary regressions thus help us to understand the role of European Funds in regional development, either through their direct contribution to economic growth drivers or through their indirect effects on growth via investments. Consistent estimates of our economic growth model can be obtained by estimating an augmented version of equation (1) that includes the residuals from the first stage as additional explanatory variables, as shown in:

$$Y_{it}^{*} = \beta_j X_{it}^{*} + \xi \widehat{\varepsilon}_{it} + v_{it|j}^{*} \tag{7}$$

Since it is not possible to conduct Sargan-Hansen tests in a latent class framework, we adopt an economic approach to select external instruments. Specifically, the choice of European funds to instrument each growth driver is based on the objectives pursued by the funds. For each type of investment, we select the funds most relevant to its financing.

Data from the "Cohesion Open Data Platform," which provides information on Cohesion Policy 2014–2020, helps us determine the contribution of different European funds to various economic sectors.[14] The European Regional Development Fund (ERDF) aims to strengthen economic, social, and territorial cohesion by financing investments in network infrastructure (e.g., transport and energy), information and communication technology, human capital, SME competitiveness, and research and innovation. The Cohesion Fund (CF) focuses on transport and energy infrastructure and environmental protection in less developed regions. The European Social Fund (ESF) supports employment creation, investments in education and vocational training, and improvements in employment quality. Therefore, ERDF and CF serve as appropriate instruments for physical capital investment, while ERDF is also suitable for R&D. ESF represents the most appropriate instrument for education or human capital investment.

3.3. Marginal effects and counterfactual analyses

The previous analyses are standard. We extend them to compute *marginal* effects attributable to *marginal* changes in the institutional environment. This novel analysis allows us to undertake several counterfactual analyses where new values for $\widehat{\beta}_{it}$ are simulated once a standard deviation improvement in those variables that measure the quality of institutions and regional authority is generated.[15] We extend here the traditional latent class analyses to compute *marginal* effects attributable to *marginal* changes in the institutional environment. With this in mind, we simulate new values for $\widehat{\beta}_{it}$ once a standard deviation improvement in QI_{it} and RAI_{it} is generated. That is, the institutional factors for each region take on the value of $QI_{it} + \sigma_{QI}$ and $RAI_{it} + \sigma_{RAI}$, where σ_{QI} and σ_{RAI} are respectively the standard deviations of QI_{it} and RAI_{it}. Both σ_{QI} and σ_{RAI} are approximately equal to one as both variables were originally standardized when they were computed.

We next see how these 'shocks' affect the returns of investments in physical capital, education, and innovation, ceteris paribus, with the relative goodness-of-fit of each class explaining the economic growth of each region. That is, the new values for $\widehat{\beta}_{it}$ are simulated as follows:

$$\widehat{\beta}_{it}(q_{it} + \sigma) = \sum_{j=1}^{J} \frac{\Pi_{ij}\left[\widehat{\delta}_j^{\prime}(q_{it} + \sigma)\right] \cdot LF_{it}\left(\widehat{\theta}_j, \widehat{\delta}_j\right)}{\sum_{j=1}^{J} \Pi_{ij}\left[\widehat{\delta}_j^{\prime}(q_{it} + \sigma)\right] \cdot LF_{it}\left(\widehat{\theta}_j, \widehat{\delta}_j\right)} \widehat{\beta}_j \tag{8}$$

where $\sigma = \sigma_{QI}$ if $q_{it} = QI_{it}$, and $\sigma = \sigma_{RAI}$ if $q_{it} = RAI_{it}$. The impact on the returns (elasticities) of each economic growth driver can be evaluated by visually comparing the distributions of both $\widehat{\beta}_{it}(q_{it})$ and $\widehat{\beta}_{it}(q_{it} + \sigma)$, or by testing whether both distributions are equivalent using a

[12] In their stochastic frontier framework, modifying LIML is not straightforward due to the error term in the stochastic frontier model consisting of two random components. Endogeneity arises when the reduced form error correlates with the error in the equation of interest. Amsler et al. (2016) derive their likelihood by factoring the density of the endogenous variables conditional on the instruments and employ a two-stage procedure to obtain the maximum likelihood estimates.

[13] Various tests are available to assess the failure of the relevance condition or the presence of weak instruments, most of which are based on the F statistic for the null hypothesis that the coefficients are equal to zero in the first stage.

[14] See the figure titled "Cohesion Policy Budget by Theme" in the "Overview" tab at the following link: https://cohesiondata.ec.europa.eu/cohesion_overview/14-20.

[15] Our approach is similar to that of Fuller and Sickles (2024), who centre their simulation exercise on the error term, which is assumed to be spatially correlated across geographical units.

Table 1
Descriptive statistics.

Variable	Mean	Std. dev.	Min	Max
Growth of real GDP per capita (%)	0.636	3.521	−16.106	14.565
Real GDP per capita (€)	26,044.213	14,047.786	3755.248	98,748.211
Population growth (%)	0.118	0.881	−11.046	5.635
Investment (Million €)	9894.758	11,779.106	234.260	142,594.797
R&D (€ per capita)	499.307	584.546	3.905	3884.269
Education (%)	25.969	8.829	8.300	57.100
European Funds (% of GDP)	1.087	1.537	0.001	10.545
Quality of Government	0.086	0.998	−2.796	2.818
Regional Authority Index	14.933	9.205	0.000	27.000
Less developed (0/1)	0.202	0.402	0.000	1.000

Note: Descriptive statistics based on a sample of 1.813 observations for 230 regions.

Kolmogorov-Smirnov test.

To examine whether there exists a catching-up effect in the elasticities of each economic growth driver when the institutional environment changes, we propose estimating the following beta-convergence auxiliary regression:

$$\Delta\widehat{\beta}_{it} = a_0 + a_1\widehat{\beta}^{*}_{it} + \varsigma_{it} \quad (9)$$

where $\Delta\widehat{\beta}_{it} = \widehat{\beta}_{it}(q_{it} + \sigma) - \widehat{\beta}_{it}(q_{it})$, and $\widehat{\beta}^{*}_{it} = \widehat{\beta}_{it}(q_{it})$. The estimated a_1 coefficient in equation (9) can be interpreted as a traditional beta-convergence parameter or a *catching-up effect*. If a_1 takes negative values, this means that 'beta-poor' regions (i.e., regions with modest original elasticities) would exhibit a larger improvement in terms of returns of traditional economic growth drivers than 'beta-rich' regions that already have larger returns from education or investments in physical capital and innovation. If a_1 takes positive values, we conclude that an increase in the institutional environment has increased the difference between 'beta-poor' regions and 'beta-rich' regions.

In summary, while the Kolmogorov-Smirnov tests allow us to measure the average effect of a change in the institutional environment, the beta-convergence auxiliary regressions in equation (9) investigate whether there also exists a catching-up effect in the returns (elasticities) of traditional drivers of economic development when the institutional environment changes.

4. Data

The empirical analysis described above is conducted using a dataset of 230 EU NUTS-2 regions over the period 2009–2017. Data on regional gross domestic product (GDP) in constant prices is sourced from the Annual Regional Database of the European Commission's Directorate General for Regional and Urban Policy (ARDECO). Gross fixed capital formation (GFCF), which is used as a proxy for physical capital, population data, human capital (measured as the percentage of the population aged 25 to 64 with tertiary education), and gross domestic expenditure on R&D (GERD), representing innovation, are all extracted from Eurostat.

We also use regionalised data on European funds from the Historic EU Payments dataset, which is available through the Open Data Portal for the European Structural and Investment Funds (ESIF). This dataset

Table 2
Auxiliary panel regression equations.

(1) Investment		(II) R&D		(II) Education	
Intercept	−8.418***	Intercept	−3.071**	Intercept	4.482***
	(1.421)		(1.383)		(0.627)
$ERDF_{it-3}$	−0.124	$ERDF_{it-3}$	8.994***	ESF_{it-3}	6.980***
	(1.538)		(2.012)		(2.171)
CF_{it-3}	−9.333***	$Other_{it-3}$	14.907***	$Other_{it-3}$	1.474**
	(2.786)		(3.119)		(0.687)
$ERDF_{it-3}$ * CF_{it-3}	−8.211	$ERDF_{it-3}$ * $Other_{it-3}$	−623.687***	$ESFF_{it-3}$ * $Other_{it-3}$	−157.314*
	(132.518)		(107.988)		(80.677)
$Other_{it-3}$	2.522				
	(2.264)				
Lagged GDP_{pc}	1.706***	Lagged GDP_{pc}	0.843***	Lagged GDP_{pc}	−0.143**
	(0.142)		(0.137)		(0.063)
Population growth	−0.022	Population growth	−0.022	Population growth	−0.017***
	(0.017)		(0.025)		(0.006)
Year-Effects	Yes	Year-Effects	Yes	Year-Effects	Yes
Observations (N)	1813	Observations (N)	1813	Observations (N)	1713
Model F-statistic	37.94	Model F-statistic	23.48	Model F-statistic	57.83
Model test p-value	0.00	Model test p-value	0.00	Model test p-value	0.00
F-stat. external instruments	21.85	F-stat. external instruments	24.08	F-stat. external instruments	68.11
P-value	0.00	P-value	0.00	P-value	0.00

Notes: The dependent variable in all columns is the log of investment, R&D and Education level, respectively. Investment is defined as the log of the Gross Fixed Capital Formation as the proxy of investment in physical capital (s^{K}_{it}), R&D represents the log of the gross domestic expenditure on R&D (s^{RD}_{it}) and the Education is the log of the percentage of population aged 25 to 64 with tertiary education as the proxy for human capital (s^{H}_{it}). ERDF is the European Regional Development Fund (in logs), CF is the Cohesion Fund (in logs) and ESF is the European Social Fund (in logs). "Other" represents the log of the other European funds not included in the European Funds incorporated in the estimation. Lagged GDP is defined as the regional real Gross Domestic Product (in logs) lagged one period (y_{it-1}) and population growth is defined as the log of the employment growth rate adjusted by the depreciation rate and the total factor productivity growth rate ($n_{it} + g + \delta$). Clustered standard errors by region in parenthesis. ***$p < .01$, **$p < .05$, *$p < .1$.

includes information on payments from various European funds, including the ERDF, the ESF, the CF, the European Agricultural Fund for Rural Development (EAFRD), the European Maritime and Fisheries Fund (EMFF), the Youth Employment Initiative (YEI), and the Fund for European Aid to the Most Deprived (FEAD).

The quality of regional institutions is assessed using the EQI index (Charron et al., 2021), which provides institutional quality data for the years 2010, 2013, 2017, and 2021. Following the methodology of Rodríguez-Pose and Ketterer (2020), we interpolate data for the years in between. For the period prior to 2010, we assume that the difference between regional and national government quality remains constant. To measure regional authority, we use the RAI developed by Hooghe et al. (2016) and Shair-Rosenfield et al. (2020). This index captures the degree of regional autonomy and shared rule across various dimensions, making it an appropriate measure of subnational authority.

Table 1 presents the descriptive statistics for the key variables used in the analysis. Additionally, in the appendix (Table A1), we provide descriptive statistics disaggregated by less developed and more developed regions.[16] Significant disparities are evident in terms of economic growth, investment, and institutional factors. As expected, more developed regions exhibit higher levels of economic growth and greater investment in physical capital, R&D, and education. These regions also tend to score higher in terms of government quality and subnational authority. On the other hand, less developed regions face slower population growth but receive a larger proportion of European funds relative to GDP in an effort to address these disparities. This motivates our research, as we undertake a comprehensive analysis of how variations in institutional factors —specifically government quality and subnational authority— contribute to increasing regional polarisation in terms of the returns on public investments and, ultimately, the effectiveness of European funding.

5. Results

5.1. Auxiliary regressions

This section presents the results of the auxiliary regressions used to obtain the first-stage residuals, which are then added to equation (1) to control for the potential endogeneity of physical capital investment, R&D, and human capital. The parameter estimates from these first-step auxiliary regressions are shown in Table 2. As previously mentioned, in addition to lagged GDP, population growth, and time dummies, we employ several European funds as external instruments. Specifically, we use funds primarily associated with each type of investment to instrument physical capital investment, R&D, and human capital. The remaining funds are aggregated into a single variable and included in the regression to account for any potential relationship they may have with the type of investment being instrumented. All funds are included both individually and in interaction with each other. It is important to note that we have lagged the European funds by three periods, as these funds are typically spent within two or three years of allocation, in line with the N+2 or N+3 rule.

The results from all specifications indicate that the instruments are valid. The F-tests show that the estimated coefficients are statistically significant at any conventional level. Furthermore, the F-statistics for the external instruments are all above 10, confirming their validity and strength as instruments. The first-stage residuals are subsequently used to control for the endogeneity of physical capital investment, R&D, and human capital as drivers of economic growth. In all specifications, we can statistically reject the hypothesis that the estimated coefficients of the first-stage residuals are equal to zero. This means, as expected, we reject the null hypothesis that these three economic growth drivers are exogenous. As previously noted, the standard Sargan-Hansen statistics cannot be computed in a latent class model (LCM) setting. Although applying these tests in a one-class economic growth model is debatable in this context, given the heterogeneity of coefficients for the growth drivers, a Sargan test based on a one-class specification did not lead to the rejection of the European funds' validity as external instruments.

The first set of coefficients in Table 2 shows that, while investment in physical capital increases significantly with the initial level of GDP, it is negatively affected by the cohesion funds.[17] In the second set of coefficients, the ERDF and other European funds are found to play a key role in promoting R&D. Finally, the third set of coefficients reveals that the ESF positively influences human capital investment. Notably, the results also highlight the importance of other European funds in supporting investment in both R&D and human capital. Overall, these findings suggest a positive indirect effect of the ERDF, ESF, and other European funds on economic growth, driven by improvements in R&D and educational levels. However, the negative signs on the interaction terms between ERDF, ESF, and other funds suggest the presence of competition between these instruments.

Note that our analysis in Table 2 assumes that different categories of European funds may exert differential effects on each of the auxiliary regressions. For this reason, we have separately included the funds primarily associated with each type of investment in Table 2. This has forced us to use different definitions of "other funds", as well as different combinations of funds. Obviously, both for symmetry and to facilitate the interpretation of the results, an alternative way of performing the estimates is to use a common categorisation of European funds in all the auxiliary equations. The alternative estimations reveal that the negative effect of cohesion funds on physical capital investment stems from interactions with ERDF and ESF funds.[18] For the R&D and Education auxiliary regressions, the estimated effects of the European funds with significant coefficients are positive, in line with the results in Table 2. Additionally, the other coefficients of the equations prove robust to this specification issue.[19]

[16] Table A2 in the Appendix lists the regions classified as less developed.

[17] This counterintuitive finding merits closer examination. The limited absorption capacity documented in many European regions (see Medve-Bálint, 2018; Marques-Santos et al., 2025) suggests that institutional weaknesses prevent regions from effectively deploying allocated funds. Research has demonstrated that weak governance structures create bottlenecks in project implementation, procurement processes, and monitoring systems. Additionally, the literature identifies crowding-out effects whereby cohesion policy displaces rather than supplements domestic public investment (see Mohl, 2016; Gonzalez-Alegre, 2012). When regions receive EU funds, national governments may reduce their own capital spending, leaving total investment unchanged or even reduced. These mechanisms help explain why cohesion funds show negative coefficients in the physical capital auxiliary regression whilst still supporting R&D and education investments, where absorption capacity constraints and crowding-out effects appear less binding. The finding underscores the importance of institutional quality not merely for maximising returns on investment but for ensuring that allocated funds translate into actual capital formation.

[18] The results are available in Table S1 in the Supplementary Materials. The alternative estimations reveal that the negative effect of cohesion funds on physical capital investment stems from interactions with ERDF and ESF funds. This suggests that when multiple fund types are deployed simultaneously, coordination challenges and overlapping objectives may further constrain physical capital formation. The interaction terms capture these substitution effects amongst different fund categories, reinforcing the absorption capacity interpretation.

[19] We have also estimated the auxiliary regressions in Table 2 using an aggregated variable that combines all European funds. These results are available in Table S2 in the Supplementary Materials. We confirm that aggregate European funds have the same sign and statistical significance as the specific categories of funds used in each auxiliary regression —negative for physical capital investment, and positive for R&D and Education— thus reinforcing the robustness of our findings. Complete results from all alternative fund categorisations are available, ensuring full transparency whilst avoiding cluttering the main text with multiple specification checks.

To conclude this subsection, it should be highlighted that we have also estimated an auxiliary regression for Government Quality.[20] In addition to lagged GDP, population growth, and time dummies, we use the precipitation variability during the growing season —spring and summer— in the pre-industrialisation period (1500–1750) to instrument regional government quality.[21] The logic behind the instrument, as stated by Rodríguez-Pose and Ganau (2022), is that higher levels of precipitation variability —a proxy for weather risk— led to the development of efficient local institutions when subsistence was based on agriculture. In line with this argument, we find a significant coefficient for spring precipitation variability in this auxiliary regression, as shown in Table A3 in the Appendix.

5.2. Basic economic growth models

In this subsection, we examine the role of institutions on economic development following the standard specification in previous studies on institutions and regional development (e.g., Crescenzi et al., 2016; Rodríguez-Pose and Ganau, 2022). Table 3 shows the estimated coefficients. Column (I) presents the basic economic growth model based on equation (1). At this stage, institutional variables —QI_{it} and RAI_{it}— are not included. Columns (II) and (III) show the augmented models, which include QI_{it} and RAI_{it}, respectively, and their interactions with the growth drivers. Finally, in column (IV), we include both institutional factors (QI and RAI) simultaneously, alongside their interactions with the other economic growth drivers.[22] These interactions allow us to evaluate how institutions influence the returns on these drivers. All models are estimated using a fixed-effects estimator to control for unobserved region-specific effects, which may be correlated with traditional growth drivers. We also account for potential endogeneity of $ln\, s_{it}^{K}$, lns_{it}^{RD} and $ln\, s_{it}^{H}$ by including residuals from auxiliary regressions (not shown), whose coefficients are statistically significant. This confirms that the null hypothesis of exogeneity can be rejected.

The estimated coefficients in Table 3 indicate that the traditional growth drivers —education, investment in physical capital, and R&D— are statistically significant and positively contribute to regional development across all models. The negative coefficients for lagged GDP per capita and population growth suggest a process of convergence, with less developed regions catching up in terms of income per capita. Columns (II) and (IV) suggest that regional government quality (QI) represents an indirect factor shaping economic growth. Higher government quality enhances the returns on local innovation efforts (as seen in the positive elasticity of lns_{it}^{RD}) and regional convergence, as shown by the negative and significant coefficient of the interaction $ln\, y_{it-1}QI_{it}$. The coefficient of the interaction $lns_{it}^{H}QI_{it}$ is negative and statistically significant. Although unexpected, this negative coefficient suggests that

Table 3
Parameter estimates. Basic economic growth models.

	(I)	(II)	(III)	(IV)
Intercept	0.006***	0.017***	0.015**	0.022***
	(0.000)	(0.005)	(0.006)	(0.007)
Lagged GDP	−0.642***	−0.617***	−0.656***	−0.671***
	(0.053)	(0.052)	(0.048)	(0.048)
Population growth	−0.015*	−0.098***	−0.086***	−0.081***
	(0.008)	(0.011)	(0.009)	(0.011)
Investment	0.224***	0.217***	0.226***	0.220***
	(0.027)	(0.026)	(0.025)	(0.025)
R&D	0.096***	0.087***	0.074***	0.078***
	(0.021)	(0.017)	(0.017)	(0.016)
Education	0.093***	0.115***	0.138***	0.142***
	(0.023)	(0.020)	(0.021)	(0.020)
Government Quality interactions				
Intercept		−0.005		−0.003
		(0.006)		(0.006)
Lagged GDP		−0.054***		−0.054***
		(0.014)		(0.015)
Population growth		−0.045***		0.001
		(0.006)		(0.016)
Investment		0.001		0.003
		(0.004)		(0.005)
R&D		0.020***		0.021***
		(0.005)		(0.005)
Education		−0.023**		−0.020**
		(0.009)		(0.010)
Regional Authority Index interactions				
Intercept			−0.043***	−0.051***
			(0.009)	(0.008)
Lagged GDP			−0.048*	−0.029
			(0.026)	(0.023)
Population growth			−0.046***	−0.043***
			(0.006)	(0.015)
Investment			0.010*	0.007
			(0.006)	(0.005)
R&D			0.007	−0.001
			(0.006)	(0.005)
Education			−0.027***	−0.019**
			(0.008)	(0.008)
Number of observations	1813	1813	1813	1813
Number of regions	230	230	230	230
Model F-statistics	71.72	56.16	67.76	52.66
Model test p-value	0.00	0.00	0.00	0.00
F-statistics residuals	77.47	88.74	118.02	111.73
P-value	0.00	0.00	0.00	0.00
Adjusted R-squared	0.45	0.49	0.50	0.52

Notes: The dependent variable is the log of real Gross Domestic Product (GDP) growth in all models ($\Delta ln\, y_{it}$). Lagged GDP is defined as the regional real Gross Domestic Product (in logs) lagged one period (y_{it-1}) representing the convergence process. Population growth is defined as the log of the employment growth rate adjusted by the depreciation rate and the total factor productivity growth rate ($n_{it} + g + \delta$). Investment is defined as the log of the Gross Fixed Capital Formation as the proxy of investment in physical capital (s_{it}^{K}), R&D represents the log of the gross domestic expenditure on R&D (s_{it}^{RD}) and the Education is the log of the percentage of population aged 25 to 64 with tertiary education as the proxy for human capital (s_{it}^{H}). All estimations include the residuals of the auxiliary equations for Investment, R&D and Education. Estimations based on a sample of 1813 observations for 230 regions. Intercept in Government Quality (QI) and Regional Authority Index (RAI) interactions represents the direct effect (not interacted with any other variable) of both institutional factors. Clustered standard errors by region in parenthesis. ***$p < .01$, **$p < .05$, *$p < .1$.

[20] These results appear in Table A3 in the Appendix rather than in Table 2 in the main text because the residuals from this equation are not used to estimate our LCEG model. Government Quality affects economic growth only through the prior probabilities of class-membership in our model, not through a direct channel requiring instrumentation in the growth equation itself. Nevertheless, we present this auxiliary regression to demonstrate that we have carefully considered potential endogeneity of the institutional quality measure and to provide readers with a fuller picture of our empirical strategy.

[21] More concretely, using precipitation data from Pauling et al. (2006), we construct a time-varying instrument using 25-year intervals of precipitation from 1500 to 1700 to instrument regional quality of government between 2009 and 2017. The instrument exploits the insight that pre-industrial weather variability shaped institutional development when agricultural subsistence made weather risk management crucial. Regions facing greater precipitation variability during growing seasons developed more sophisticated collective action mechanisms and governance structures to coordinate risk-sharing and resource management. These deeply embedded institutional patterns persist across centuries, making historical precipitation variability a valid instrument for contemporary government quality. The exclusion restriction holds because pre-industrial weather patterns affect modern economic growth only through their historical impact on institutional development, not through any direct channel.

[22] All the explanatory variables have been mean-centred, allowing the first-order coefficients to be interpreted as elasticities evaluated at the sample mean.

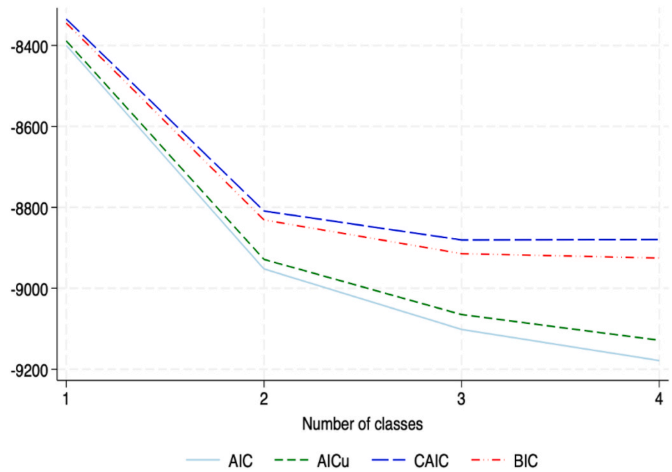

Fig. 3. Specification tests for determining the number of regimes. Note: AIC: Akaike Information Criterion. AICu: X. CAIC: Consistent Akaike Information Criterion. BIC: Bayesian Information Criterion. Source: own elaboration.

increases in government quality diminish the positive impact of human capital. Equivalently, lower educational levels imply larger effects of government quality on economic growth. This suggests that in regions with lower educational attainment, the positive effects of improved government quality on growth are stronger. In other words, high-quality institutions prove crucial for growth in regions with lower human capital levels.

Regarding regional authority (RAI), columns (III) and (IV) show that greater regional autonomy is not necessarily associated with higher growth rates. However, regions with higher autonomy tend to converge more quickly. Additionally, regional authority enhances the impact of physical capital investment but its interaction with human capital is negative, implying that education proves less significant for growth in more decentralised regions.[23]

These findings are consistent with earlier studies, which also highlight the indirect effects of government quality and regional authority on regional development. These institutional factors shape the returns on investment in physical capital, human capital, and innovation, influencing the convergence process.[24] However, a limitation of linear models is the assumption that the returns on traditional growth drivers are the same across all European regions. Significant regional differences in institutional quality and autonomy suggest that these returns may vary. To address this issue, we embed the basic economic growth model into a latent class framework, allowing for heterogeneity in parameters based on variations in institutional quality and regional authority. In the following sections, we present the results of the Latent Class Economic Growth (LCEG) model.

5.3. Latent Class Economic Growth model

5.3.1. Number of regimes and class-membership

The first step in an LCM is determining the optimal number of classes or regimes. We assess the number of growth regimes using statistical criteria such as the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC), which penalise overfitting. The preferred model is the one with the lowest AIC or BIC values or the most parsimonious model if no substantial changes in these values occur. Based on these model selection statistics (see Fig. 3), we find that a three-regime specification for the economic growth equation proves optimal.

Accordingly, we estimate our Latent Class Economic Growth (LCEG) model with three classes. Table 4 presents the estimated parameters for both a simple one-class economic growth model and the coefficients of the three regimes from our LCEG model. In addition to estimating the economic growth coefficients, our LCEG model also estimates the prior class-membership probabilities. These probabilities depend on factors such as government quality (QI_{it}), the regional authority index (RAI_{it}), a dummy variable identifying less developed regions ($less\ developed_i$), and the interaction term $QI_{it} \cdot less\ developed_i$.[25] The estimated coefficients of the prior class-membership probabilities are also presented in Table 4, as these parameters are estimated simultaneously with the economic growth model coefficients. To complement this, we include two additional tables in the Appendix. Table A5 shows the most probable class predictions for more and less developed regions, while Table A6 outlines the main characteristics of the regions allocated to each class.

[23] We have also estimated our baseline economic growth models in Table 3 but adding the residuals from the auxiliary regression for Government Quality. The results of this robustness analysis are shown in Table A4 of the Appendix. We obtain roughly the same results as in Table 3, except for the larger (positive) direct effect of quality of institutions on regions' economic growth when we instrument for potential endogeneity. This confirms the robustness of our core findings whilst suggesting that failure to address institutional endogeneity may understate the direct growth effects of government quality. Nevertheless, our primary interest lies in how institutions shape returns to investment rather than their direct growth effects, and these interaction effects prove stable across specifications.

[24] In Table 3, the variables have been centred to the global mean to interpret the first-order direct coefficient (often referred to as the direct effect) as a marginal effect evaluated at the sample mean. Unlike previous studies, the direct effect of institutional quality is not significant in our estimations. However, when using the standard approach based on fixed effects panel data estimation without this transformation, the direct effect of institutional quality becomes positive and significant, consistent with most of the scholarly literature. This discrepancy reflects our focus on heterogeneous effects rather than average direct effects.

[25] The interaction $RAI_{it} \cdot less\ developed_i$ is not included in the model specification. During maximum likelihood estimation, we encountered persistent convergence problems when attempting to include this interaction term. The optimisation algorithm failed to converge to a stable solution, likely due to collinearity between the RAI and the Less Developed dummy combined with the relatively small number of less developed regions possessing high RAI values. This created an identification problem wherein the algorithm could not reliably separate the effects of the interaction from the main effects. Rather than forcing a problematic specification that might yield unreliable estimates, we follow standard econometric practice and exclude the interaction term. This exclusion does not materially affect our core findings regarding how institutional quality shapes region-specific returns to investment.

Table 4
Latent Class estimation results.

Variable	All	Class 1	Class 2	Class 3
Growth equation:				
Intercept	0.000	0.000	−0.005**	0.002***
	(0.000)	(0.003)	(0.002)	(0.001)
Lagged GDP	−0.642***	−0.397***	−1.154***	−0.847***
	(0.053)	(0.055)	(0.218)	(0.122)
Population growth	−0.015*	−0.013***	−0.033	−0.083***
	(0.008)	(0.003)	(0.046)	(0.016)
Investment	0.224***	0.235***	0.370***	0.281***
	(0.027)	(0.032)	(0.032)	(0.017)
R&D	0.096***	0.017	0.102**	0.036
	(0.021)	(0.022)	(0.050)	(0.023)
Education	0.093***	0.172***	0.150	0.101***
	(0.023)	(0.030)	(0.106)	(0.034)
Class equation:				
Intercept		–	−0.549	0.648
			(0.820)	(0.753)
Government Quality		–	1.662 *	1.518 **
			(0.863)	(0.690)
Less Developed		–	−0.403	−2.408
			(0.704)	(4.816)
Government Quality·Less Developed		–	−1.449	−1.512
			(1.401)	(6.305)
Regional Authority Index		–	0.099	0.763
			(0.505)	(0.466)
Observations	1813	645	173	995

Note: *Growth equation* is the estimation of equation (1), in which the dependent variable is the log of real Gross Domestic Product (GDP) growth in all models ($\Delta ln\, y_{it}$), for all regions and for each class. Lagged GDP is defined as the regional real Gross Domestic Product (in logs) lagged one period (y_{it-1}) representing the convergence process. Population growth is defined as the log of the employment growth rate adjusted by the depreciation rate and the total factor productivity growth rate ($n_{it} + g + \delta$). Investment is defined as the log of the Gross Fixed Capital Formation as the proxy of investment in physical capital (s_{it}^{K}), R&D represents the log of the gross domestic expenditure on R&D (s_{it}^{RD}) and the Education is the log of the percentage of population aged 25 to 64 with tertiary education as the proxy for human capital (s_{it}^{H}). *Class equation* is the estimation of the coefficients of the prior class-membership probabilities determinants. The determinants are the Government Quality (QI_{it}), a dummy variable that takes value one for less developed regions named Less Developed, the interaction between them and the Regional Authority Index (RAI_{it}). All estimations include the residuals of the auxiliary equations for Investment, R&D and Education. The F-statistic for the residuals in our LCM is 244.41 with a p-value close to zero. Estimations based on a sample of 1813 observations for 230 regions. Clustered standard errors by region in parenthesis. ***$p < .01$, **$p < .05$, *$p < .1$.

Four important points should be noted here.

1. *Class Membership Probabilities:* The prior probabilities represent only one component of the posterior class-membership probabilities, which are ultimately used to cluster observations. Therefore, the coefficients in Table 4 indicate the likelihood of regions tending to belong to each class, but the final classification is primarily determined by how well the class-specific parameters predict the dependent variable for each observation. Thus, the final classification may not perfectly align with the prior class-membership coefficients.
2. *Interpretation of Classes:* Although the estimated class-membership probabilities could technically be used to classify regions, the primary purpose of the latent classes in this context is as an econometric tool to derive region-specific coefficients. Much like how an artist mixes basic colours to create a painting, the latent classes help in understanding the variation in economic drivers across regions, but the focus rests on the resulting picture (i.e., region-specific growth estimates), not the basic classes themselves.
3. *Heterogeneous Responses to Economic Growth Drivers:* Allocating regions to specific classes reveals that they experience different economic developments and respond differently to growth drivers. Latent class models aim to capture the effect of unobserved characteristics that modulate the impact of observed economic growth drivers on regional development. These unobserved factors help explain the heterogeneity in growth across regions.[26]
4. *Endogeneity Issues:* We again account for potential endogeneity of $\ln s_{it}^{K}$, $\ln s_{it}^{RD}$ and $\ln s_{it}^{H}$ by including their first-stage residuals as control variables. We do not instrument Government Quality as this variable influences economic growth through its effect on the prior class-membership probabilities of our LCEG model, and there is currently no established methodology to handle endogenous class-membership determinants.[27]

Let us now summarise the results from Table 4 and the supplementary tables that relate to class-membership. In Table 4, the reference category for the class equation is the first class. Thus, a positive coefficient indicates a higher likelihood of belonging to the second or third class compared with the first. The significant positive coefficients for government quality suggest that regions with higher institutional quality are more likely to be in the second and third classes, whilst regions with lower institutional quality are more likely to fall into the first class. However, some exceptions do exist. The lack of significance for the RAI index in the second and third columns suggests that regions with a high degree of autonomy are more likely to be found in the first class, indicating that regional autonomy may not be strongly correlated with higher economic growth.

Table A5 in the Appendix shows how regions are distributed across the three classes. We find that the third class predominantly includes more developed regions, but a notable number of more developed

[26] A necessary condition for identifying the parameters of the latent class probabilities is that the sample must be generated from different groups of observations, so there must exist some economic growth heterogeneity. Whilst we could attempt to link part of this parameter heterogeneity to certain explanatory variables by modelling the prior probabilities of the LCM, as mentioned earlier, much of this heterogeneity is driven by unobserved regional characteristics that make one class predict an observation more accurately than another.

[27] Choi and Okui (2024) note that applying IV-type estimators in such models proves nontrivial due to the unobserved nature of class membership. As in our application, they propose a two-stage least squares approach to handle endogeneity in models with group-specific coefficients. Sarrias (2021), on the other hand, adapts Heckman-style models for use in latent class probit models, estimating them via maximum likelihood estimation. However, neither approach addresses endogeneity in the equation modelling prior class membership probabilities. Sarrias (2021), for instance, assumes that a latent continuous variable (F*) determines class assignment as a linear function of determinants (z) plus an error term (e), which is assumed to be i.i.d. extreme Value Type I and uncorrelated with (z). Whilst this issue does not directly affect class-specific coefficients, it can bias estimates if it distorts sample separation. Unlike traditional selection models, we lack information on true class assignments. As Greene (2010) notes with regard to stochastic frontier models, the standard two-step correction method relies on linearity, a condition not met by our highly nonlinear latent class model. The likelihood function in a latent class framework represents a weighted sum of class-specific likelihoods, where the weights themselves (the prior probabilities) are functions of potentially endogenous determinants. Instrumenting these determinants would require modelling the joint distribution of the instrumented variables and the error terms across all classes simultaneously. This is a problem for which no established solution exists. Since no method currently exists for addressing endogenous class-membership determinants in this framework and given that government quality affects growth primarily through shaping the returns to investment rather than through direct channels, we leave this methodological extension for future research. Our approach of instrumenting the growth drivers themselves (physical capital, R&D, education) whilst treating the class-membership determinants as given represents the current frontier of feasible estimation in this setting.

Table 5
Latent Class estimation results in the spatial SLX model.

Variable	All	Class 1	Class 2	Class 3
Growth equation:				
Intercept	0.000	−0.002**	0.002***	0.000
	(0.000)	(0.001)	(0.000)	(0.001)
Lagged GDP	−0.606***	−1.191***	−0.625***	−0.427***
	(0.052)	(0.067)	(0.078)	(0.041)
Population growth	−0.007	−0.114***	−0.051***	−0.004**
	(0.005)	(0.021)	(0.014)	(0.002)
Investment	0.202***	0.355***	0.254***	0.228***
	(0.027)	(0.029)	(0.021)	(0.021)
R&D	0.086***	0.019	0.011	0.003
	(0.022)	(0.020)	(0.015)	(0.017)
Education	0.076***	0.065*	0.132***	0.185***
	(0.026)	(0.034)	(0.023)	(0.027)
Spatial lags				
Lagged GDP	−0.042***	−0.151**	−0.040***	−0.081***
	(0.010)	(0.063)	(0.008)	(0.016)
Population growth	−0.040***	0.144***	−0.094***	−0.047***
	(0.012)	(0.025)	(0.016)	(0.008)
Investment	0.035***	0.039*	0.005	0.074***
	(0.009)	(0.021)	(0.007)	(0.015)
R&D	0.002	0.119***	−0.004	−0.005
	(0.005)	(0.022)	(0.007)	(0.005)
Education	0.028	−0.016	−0.030*	0.066***
	(0.017)	(0.043)	(0.015)	(0.023)
Class equation:				
Intercept		–	1.231***	0.182
			(0.411)	(0.737)
Government Quality		–	−0.978***	−2.870***
			(0.320)	(0.539)
Less Developed		–	−2.926*	1.968**
			(1.743)	(0.893)
Government Quality·Less Developed	–		−0.676	4.570***
			(1.097)	(0.939)
Regional Authority Index	–		0.741**	−1.179**
			(0.332)	(0.501)
Observations	1813	268	987	558

Note: *Growth equation* is the estimation of equation (1), in which the dependent variable is the log of real Gross Domestic Product (GDP) growth in all models ($\Delta ln\, y_{it}$), for all regions and for each class. Lagged GDP is defined as the regional real Gross Domestic Product (in logs) lagged one period (y_{it-1}) representing the convergence process. Population growth is defined as the log of the employment growth rate adjusted by the depreciation rate and the total factor productivity growth rate ($n_{it} + g + \delta$). Investment is defined as the log of the Gross Fixed Capital Formation as the proxy of investment in physical capital (s^{K}_{it}), R&D represents the log of the gross domestic expenditure on R&D (s^{RD}_{it}) and the Education is the log of the percentage of population aged 25 to 64 with tertiary education as the proxy for human capital (s^{H}_{it}). Finally, the interactions with the W weight matrix indicate the spatially lagged economic growth drivers, or the effect of economic growth driver in neighbor regions. *Class equation* is the estimation of the coefficients of the prior class-membership probabilities determinants. The determinants are the Government Quality (QI_{it}), a dummy variable that takes value one for less developed regions named Less Developed, the interaction between them and the Regional Authority Index (RAI_{it}). All estimations include the residuals of the auxiliar equations for Investment, R&D and Education. Estimations based on a sample of 1813 observations for 230 regions. Clustered standard errors by region in parenthesis. ***p < .01, **p < .05, *p < .1.

Table 6
Latent Class estimation results including European Funds.

Variable	All	Class 1	Class 2	Class 3
Growth equation:				
Intercept	−0.001***	−0.005***	0.002**	−0.001
	(0.000)	(0.002)	(0.001)	(0.002)
Lagged GDP	−0.657***	−1.162***	−0.759***	−0.326***
	(0.054)	(0.069)	(0.112)	(0.063)
Population growth	−0.015*	−0.044***	−0.092***	−0.015***
	(0.008)	(0.009)	(0.014)	(0.002)
Investment	0.235***	0.423***	0.270***	0.209***
	(0.027)	(0.025)	(0.019)	(0.026)
R&D	0.093***	0.087***	0.046***	0.011
	(0.020)	(0.021)	(0.016)	(0.020)
Education	0.091***	0.185***	0.122***	0.164***
	(0.023)	(0.025)	(0.019)	(0.062)
Interactions with Funds				
Investment	0.001	−0.011	0.011	−0.002
	(0.006)	(0.025)	(0.007)	(0.014)
R&D	−0.002	−0.032**	0.007	0.005
	(0.003)	(0.013)	(0.005)	(0.006)
Education	0.034***	0.222***	0.044***	0.000
	(0.008)	(0.021)	(0.014)	(0.025)
Class equation:				
Intercept		–	1.037***	−1.197
			(0.270)	(1.320)
Government Quality		–	−0.205	−1.574***
			(0.472)	(0.515)
Less Developed		–	1.159	1.526
			(1.221)	(1.055)
Government Quality·Less Developed		–	2.600	0.890
			(2.003)	(0.662)
Regional Authority Index		–	0.572***	−0.078
			(0.210)	(0.494)
Observations	1813	238	1269	306

Note: *Growth equation* is the estimation of equation (1), in which the dependent variable is the log of real Gross Domestic Product (GDP) growth in all models ($\Delta ln\, y_{it}$), for all regions and for each class. Lagged GDP is defined as the regional real Gross Domestic Product (in logs) lagged one period (y_{it-1}) representing the convergence process. Population growth is defined as the log of the employment growth rate adjusted by the depreciation rate and the total factor productivity growth rate ($n_{it} + g + \delta$). Investment is defined as the log of the Gross Fixed Capital Formation as the proxy of investment in physical capital (s^{K}_{it}), R&D represents the log of the gross domestic expenditure on R&D (s^{RD}_{it}) and the Education is the log of the percentage of population aged 25 to 64 with tertiary education as the proxy for human capital (s^{H}_{it}). All economic growth drivers are interacted with European Funds. *Class equation* is the estimation of the coefficients of the prior class-membership probabilities determinants. The determinants are the Government Quality (QI_{it}), a dummy variable that takes value one for less developed regions named Less Developed, the interaction between them and the Regional Authority Index (RAI_{it}). All estimations include the residuals of the auxiliar equations for Investment, R&D and Education. Estimations based on a sample of 1813 observations for 230 regions. Clustered standard errors by region in parenthesis. ***p < .01, **p < .05, *p < .1.

regions are also allocated to the first class. Similarly, lagging-behind regions are mostly found in the first class, though some more developed regions also belong to this class. This distribution is driven by two forces: the goodness-of-fit of the class-specific parameters in predicting regional economic growth and the prior class-membership probabilities shown in Table 4.

These results highlight an important insight: the growth drivers and institutional characteristics that influence regional development are not uniform across Europe. Regions with lower government quality tend to belong to the first class, where institutional weaknesses may limit the returns on traditional growth drivers such as physical capital and education. Conversely, regions with higher government quality, more frequently allocated to the second and third classes, experience better returns on innovation and physical capital investment, which suggests that strong institutions play a key role in enhancing regional economic performance.

In summary, the LCEG model reveals that institutional quality significantly shapes regional economic outcomes by influencing how

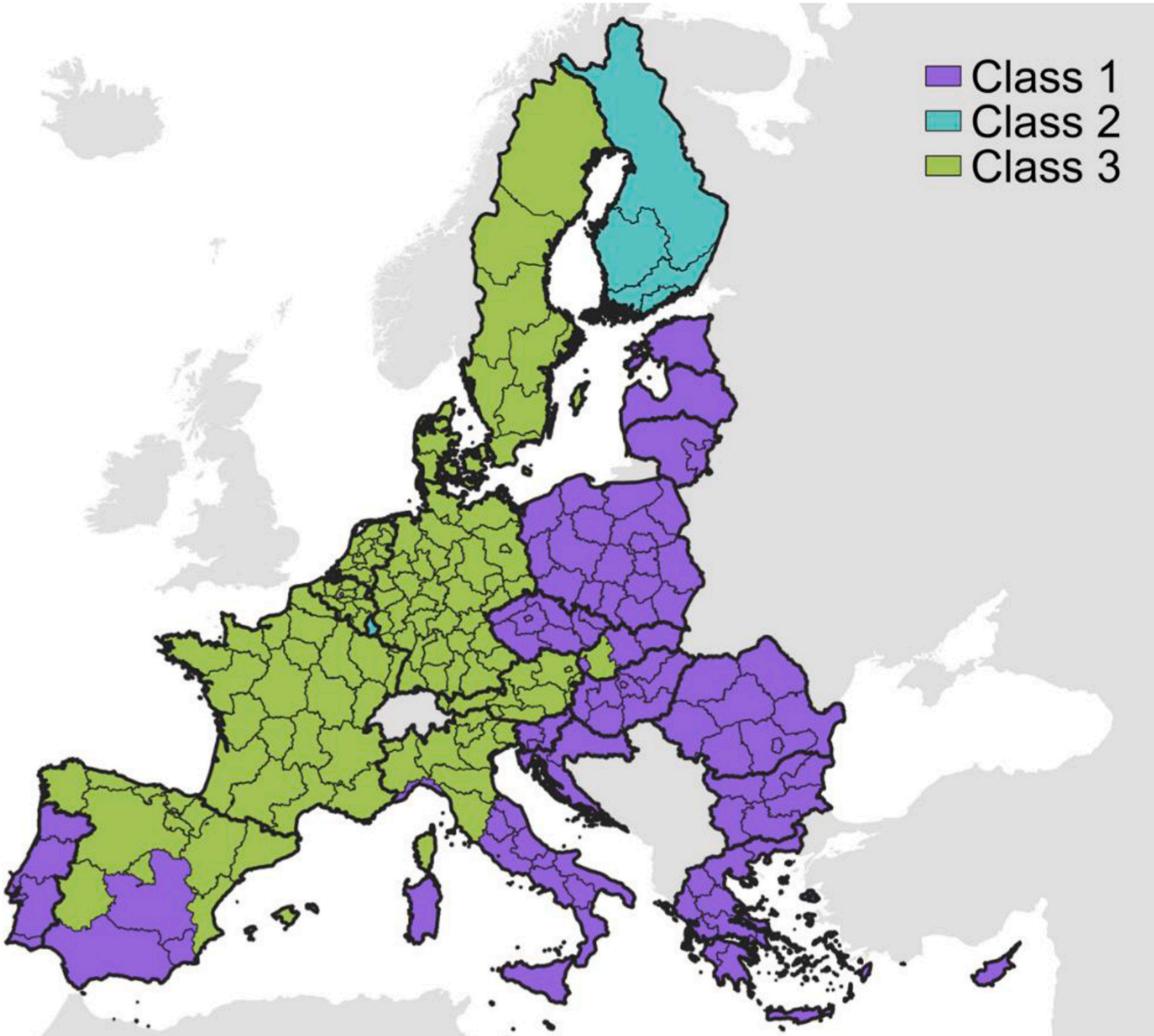

Fig. 4. Distribution of European regions among regimes.
Source: EuroGeographics for the administrative boundaries.

effectively growth drivers are leveraged. The latent class approach allows us to uncover the heterogeneous effects of institutional factors across regions, providing a deeper understanding of how different regions experience growth under varying institutional and economic conditions.

Table A6 in the Appendix complements these findings. It shows that regions in Classes 2 and 3 exhibit higher levels of income per capita, better institutions, and higher values for physical capital investment, R&D, and human capital. However, regions in Class 2 experience negative average growth in real GDP per capita and regions in Class 3 demonstrate positive economic growth. Class 1, which includes most lagging regions, receives more European funds relative to GDP and exhibits higher growth rates than regions in other classes.[28]

Fig. 4 shows the geographical distribution of European regions across the three classes.[29] Regions in Class 1 are primarily located in Southern and Eastern Europe, while Class 3 includes regions from Central and Northern Europe. Class 2, the smallest class, mainly consists of regions in Finland. By examining Table A5 and Fig. 4 together, we can conclude that central and northern European regions in Classes 2 and 3 are more developed and possess stronger institutional quality. Lagging regions are, in contrast, predominantly in Class 1, though some developed regions are also present in this class.

Regions are not restricted to remaining in the same class over time. Our LCM allows for some regions to switch from one class to another, as our likelihood function treats the cross-sectional and temporal dimensions symmetrically. Despite this flexibility, we find class allocations to be relatively stable, with only 21 % of regions switching classes over time. Figure A2 in the Appendix confirms this, showing that the distribution of class changes is heavily skewed towards zero, indicating that most regions remained in the same class throughout the study period.[30]

[28] The apparently strong economic growth performance of these regions can also be partially attributed to a decline in population, which mechanically increases per capita measures even absent substantial improvements in aggregate economic activity.

[29] We use the average posterior probabilities of each region to depict this map, smoothing over temporal variation to show the predominant class assignment for each region over the study period.

[30] As this result indicates that regions struggle to move beyond their initial economic conditions, our future research agenda includes developing a latent class model that accounts for regime persistence to identify the existence of poverty or development traps in Europe. Understanding what factors enable or prevent transitions between development regimes represents a crucial question for cohesion policy.

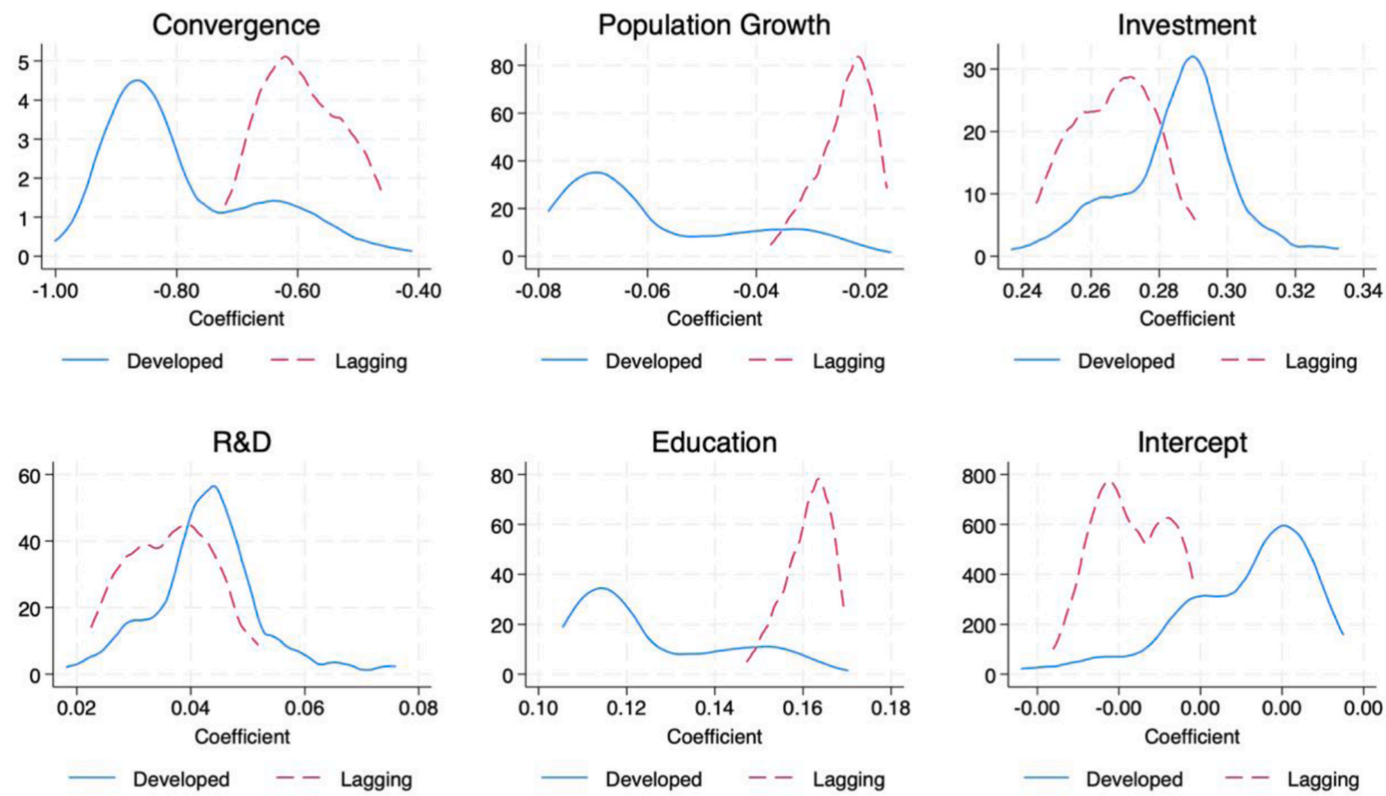

Fig. 5. Kernel density of heterogeneous coefficients.
Source: own elaboration

5.3.2. Heterogeneous-coefficient economic growth model

After determining the number of classes and identifying their characteristics, we summarise the returns of the traditional economic growth drivers for the three growth regimes in Table 4. The first column presents the parameter estimates from a one-class model that assumes common coefficients for all European regions, which corresponds to the model shown in the first column of Table 3. The next three columns present the class-specific returns of our LCEG model.

Across all classes, physical capital investment shows a consistently positive and significant impact on economic growth, particularly in Classes 2 and 3. Investments in R&D, though positive and significant in the overall model, are not significant in most latent classes. Moreover, the R&D coefficient in the one-class specification is statistically significant but relatively small, suggesting that although innovation contributes to growth, its economic relevance proves lower than other drivers. Educational levels positively impact growth in Classes 1 and 3, highlighting that human capital plays a more significant role in these regions. These results confirm that no uniform or representative effect of growth determinants exists across European regions. Instead, the LCEG model reveals distinct regional regimes, partially driven by variations in institutional conditions. As observed in Bos et al. (2010), the rate of convergence also differs across these regimes.

The key feature of the latent class model is its ability to produce heterogeneous parameters for traditional economic growth drivers across regions. Using Greene's (2005) approach, we estimate region-specific parameters by combining the posterior class membership probabilities with the estimated class-specific parameters, as outlined in equation (5). Fig. 5 illustrates the level and dispersion of these parameters —specifically, the speed of convergence and the impact of various growth determinants— across more and less developed regions. The results point to substantial variation in the parameters, particularly in more developed regions. This supports the conclusion that no 'average' effect of growth determinants exists, even within regions of the same country. More developed regions display a steeper convergence process and experience stronger effects from physical capital investment and R&D. In contrast, the effect of education proves more pronounced in less developed regions. Additionally, the negative impact of population growth on economic development is more substantial in more developed regions. The intercept, representing average economic growth, has a modest effect overall but is slightly higher in more developed regions.

Fig. 6 maps the region-specific convergence parameters, estimated using the latent class specification. The map reveals significant heterogeneity in regional convergence patterns. Central and Northern European regions, as well as some northern regions in Southern Europe, converge at a stronger pace. In contrast, regions in Eastern Europe, particularly less developed ones, show slower convergence rates. In a standard latent class framework, regions converge to their respective steady states, which are class-specific. However, as the primary purpose of the latent classes in our application is to derive region-specific coefficients, regions converge to their respective steady states at region-specific rates. In this sense, it should be noted that the steady state function of each region not only possesses different intercepts as we are using a specification with individual effects, but also different slopes because, after performing a within transformation to control for

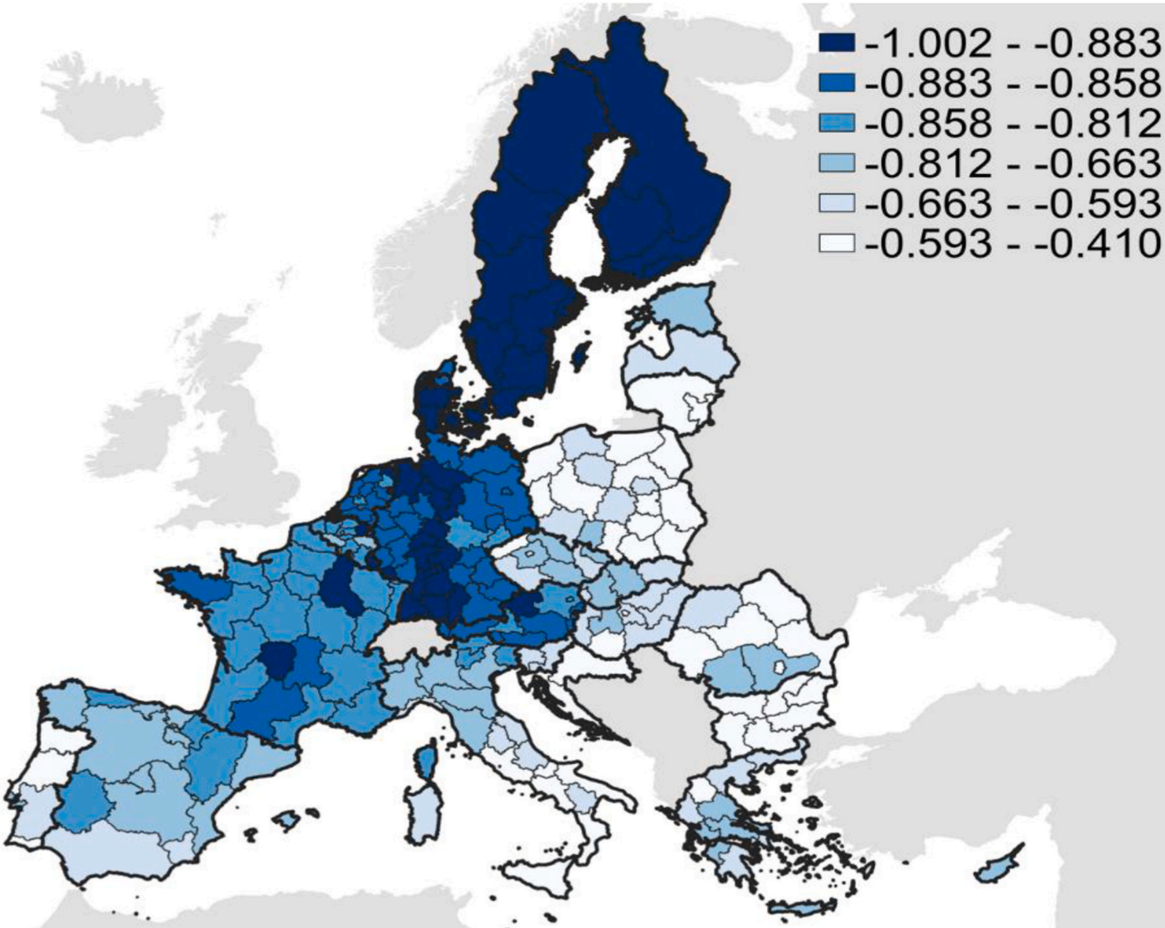

Fig. 6. Map of convergence coefficients.
Note: regions are classified in six equal count intervals. Average coefficient overall years. Source: EuroGeographics for the administrative boundaries.

unobserved individual effects, the respective steady states are region-specific weighted averages of three different class-specific steady states in line with Bos et al. (2010). This yields results that differ from the corresponding results obtained from a single class economic growth model. Therefore, our results indicate that persistent differences in regions' steady state functions represent a significant factor underlying cross-region economic growth. That is, if there had been no such differences in both intercepts and slopes, and regions only differed in terms of economic growth drivers, convergence would have proceeded at faster or slower rates.

In many countries, most regions belong to the same class, particularly in Eastern Europe, where regions generally share similar rates of growth in income per capita. Since the probability of belonging to a particular class is often high, the convergence process is largely determined by the characteristics of that class.[31] In contrast, while regions in Central and Northern Europe may experience slower growth overall, their less-developed regions are converging rapidly with wealthier ones. Interestingly, Class 3, which consists mainly of developed regions, has an average income per capita growth rate of 0.90 %, while Class 1, which includes most lagging regions, shows a slightly higher growth rate of 1 %. This indicates a slow convergence process between lagging and developed regions (Rodríguez-Pose and Ketterer, 2020). Our results suggest that income per capita convergence has been more pronounced within developed regions (Class 3) than within lagging regions (Class 1).

Figs. 7–9 map the distribution of the coefficients for physical capital investment, R&D, and human capital across regions. The highest returns on investment in physical capital and R&D are observed in Northern and Central Europe. However, some less-developed regions in Eastern Europe —notably in Romania, Czechia, and Hungary— also show relatively high returns on physical capital investment, as do some regions in innovation. This suggests that governments in these regions, along with the EU, should prioritise public investment in physical capital and innovation. In contrast, in Southern and South-eastern Europe, poor government quality significantly hinders the returns on investments in physical capital and innovation (Rodríguez-Pose and Di Cataldo, 2015). When it comes to education, Fig. 9 shows substantial regional differences, with education playing a particularly crucial role in less-developed regions and in some northern countries. This suggests that investing in human capital yields higher returns in less-developed regions with weaker government institutions and, except for Spain, lower regional autonomy. These findings are consistent with previous research showing heterogeneous effects of human capital and institutions across different European regions (e.g., Cutrini, 2023; Annoni et al., 2019).

The key policy recommendations based on these findings are: (a) public spending should prioritise investment in regions with higher economic returns; and (b) policymakers should focus on improving institutional quality, as local institutional ecosystems significantly influence the effectiveness of European and public investment at the local

[31] We use the term "mainly" because the regions assigned to a particular class often possess non-zero probabilities of belonging to other classes. This also explains why we do not observe significant heterogeneity in convergence rates within most countries, with the exception of Spain and Italy, both of which exhibit notable internal disparities.

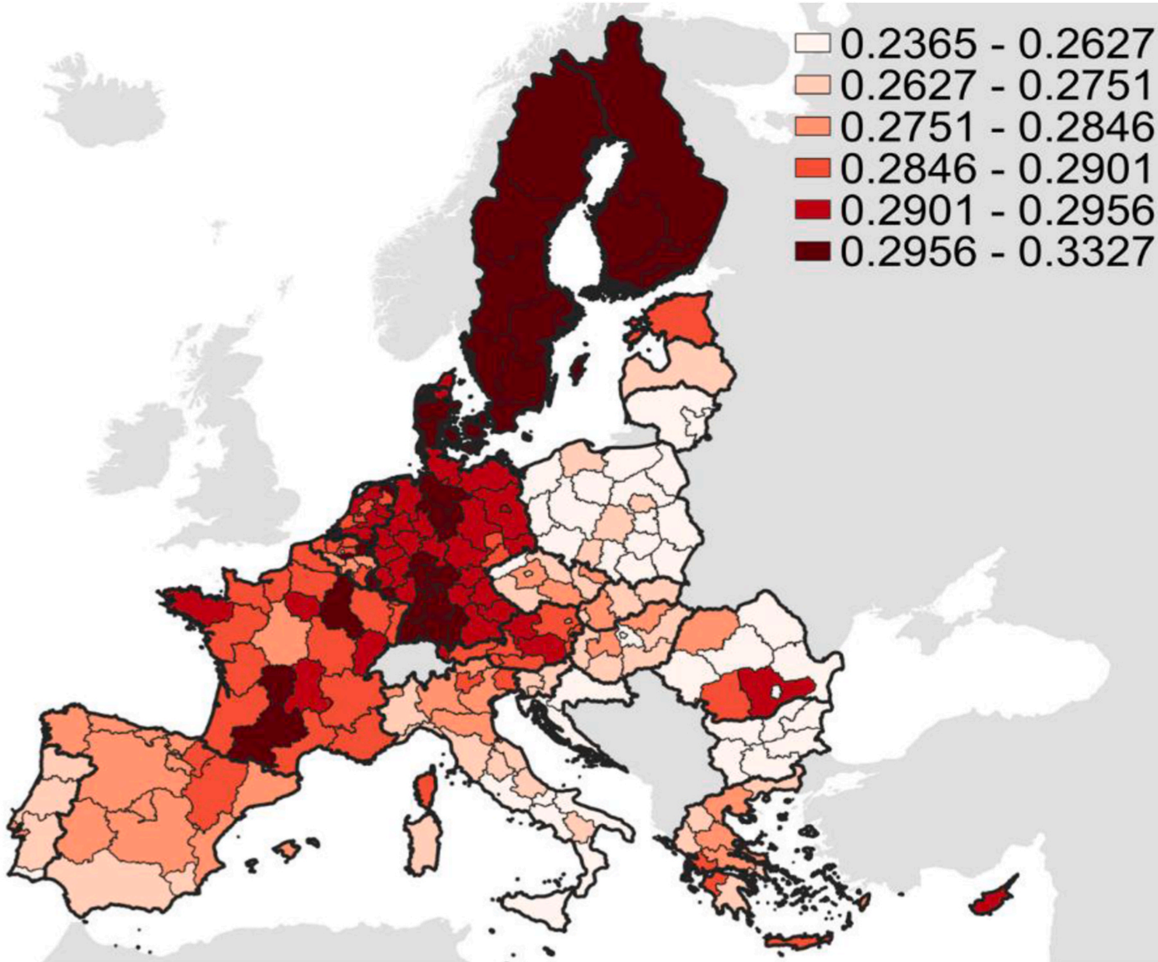

Fig. 7. Map of investment coefficients.
Note: regions are classified in six equal count intervals. Average coefficient overall years. Source: EuroGeographics for the administrative boundaries.

level.

In the following subsection, we explore how improving regional institutions can enhance the returns on investments in European regions.

5.4. How important are institutions for economic growth in European regions?

Our previous analysis shows that the economic returns of physical and human capital, as well as local innovation capacity, are influenced by the quality of government in each region (Rodríguez-Pose and Ganau, 2022). This implies that the parameters shown in Fig. 5 can change if the institutional quality or regional authority is modified. This provides an opportunity to calculate the marginal effects on the returns of education, physical capital investment, and innovation when institutional environments improve.

5.4.1. Marginal effects attributed to improvement in quality of institutions

In this subsection, we conduct a counterfactual analysis to examine the impact of changes in government quality (QI_{it}). Specifically, we simulate the effects of increasing institutional quality by one standard deviation for all regions on the returns of education, physical capital investment, and innovation. We also analyse the effects on the speed of convergence and other growth-related parameters. Figs. 10 and 11 display the distributions of both estimated and simulated coefficients for more and less developed regions, respectively.

Fig. 10 shows that a one-standard-deviation improvement in government quality in more developed regions leads to a significant increase in the elasticities of physical capital and R&D investment in most regions. These regions also experience faster convergence. However, the elasticities of education investment tend to remain low, even at higher levels of government quality, aligning with previous findings from a linear model that interacted QI_{it} with traditional growth drivers. Additionally, population growth has a more pronounced negative effect, while the intercept, representing average economic growth, exhibits a positive effect.

Fig. 11 shows the effects of improved government quality on the elasticities in less developed regions. The effects are generally smaller compared with more developed regions. But improvements in institutional quality still lead to better outcomes in terms of convergence, investment, and R&D expenditure. A significant positive effect on the constant term indicates an increase in average economic growth for less developed regions.

We also perform a counterfactual analysis (not shown) to assess the impact of changes in the RAI_{it}.[32] Specifically, we simulate the effect of increasing the RAI_{it} index by one standard deviation for both more and less developed regions, following a similar procedure as for government quality. The absence of significant changes in these simulations, coupled

[32] The detailed results of these analyses are available upon request from the authors.

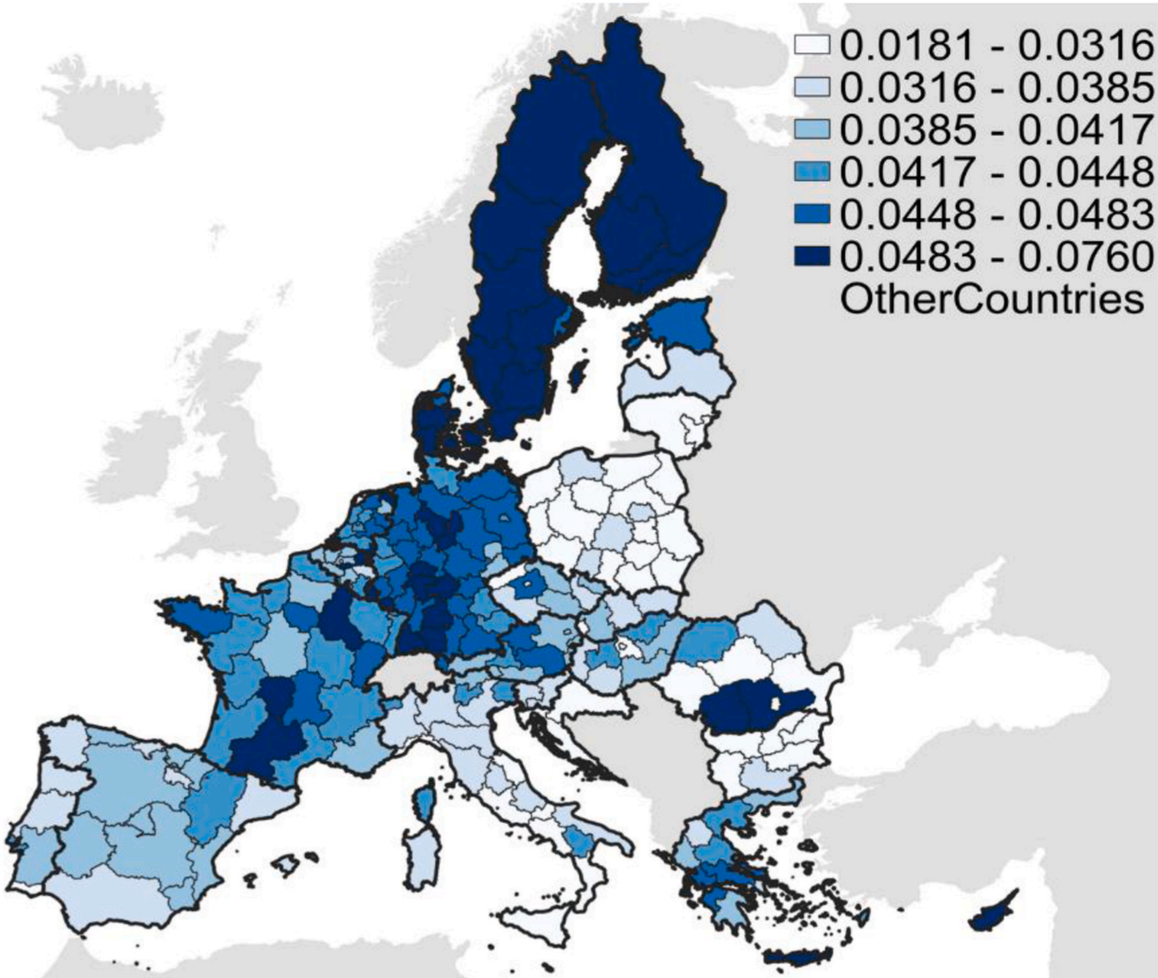

Fig. 8. Map of R&D coefficients.
Note: regions are classified in six equal count intervals. Average coefficient overall years. Source: EuroGeographics for the administrative boundaries.

with insignificant Kolmogorov-Smirnov tests, suggests that the elasticities of economic growth drivers in both groups of regions are less responsive to changes in RAI_{it} compared to changes in QI_{it}.[33]

Tables A.7 and A.8 in the Appendix further investigate both average and catching-up effects in the elasticities of traditional economic growth drivers after improving quality of government in both more and less developed regions. Kolmogorov-Smirnov tests indicate that for more developed regions, the changes in elasticities for all drivers except the constant term are statistically significant, confirming the importance of the shifts observed in the kernel density curves in Fig. 10. Conversely, for less developed regions, shifts in all kernel curves are statistically significant.

In addition, Table A.8 presents beta-convergence tests, based on equation (9). For more developed regions, these tests show a greater concentration in the parameters related to investment, innovation, human capital, population growth, and the speed of convergence, while heterogeneity in the parameters for the constant term has slightly increased. This suggests that even more developed regions could benefit from a process of territorial cohesion if government quality improves. In contrast, the beta-convergence tests for less developed regions reveal greater dispersion in parameters related to speed of convergence, investment, innovation, and the constant term. However, improvements in education and population growth contribute to reducing regional heterogeneity in these regions.

In summary, our results suggest that improving government quality can help reduce the heterogeneity of investment, innovation, and human capital parameters, especially in more developed regions. Weak institutional quality not only hinders economic growth but also affects territorial cohesion, particularly within more developed regions during the period under analysis.

5.4.2. *Combined marginal effects*

In this subsection, we focus on changes in both types of institutional factors (QI_{it} and RAI_{it}) in less developed regions. We increase the values of QI_{it} and RAI_{it} in all less developed regions by the average difference between more and less developed regions. The results of this counterfactual analysis are presented in Fig. 12, while Tables A.7 and A.8 in the Appendix provide tests of average and catching-up effects in elasticities between the original and counterfactual coefficients.

Our findings indicate that most less developed regions could significantly enhance their economic growth by increasing investments in physical capital and R&D expenditure, leading to faster convergence. However, the role of education in these regions deteriorates, and the

[33] This result is likely caused by the limited variation in the RAI index at the regional level within European countries as well as the little temporal variation of this index. Since the model is estimated after performing a within transformation to control for unobserved individual effects, much of the already-limited variation in regional authority is eliminated, leaving insufficient identifying variation to detect strong effects on investment returns.

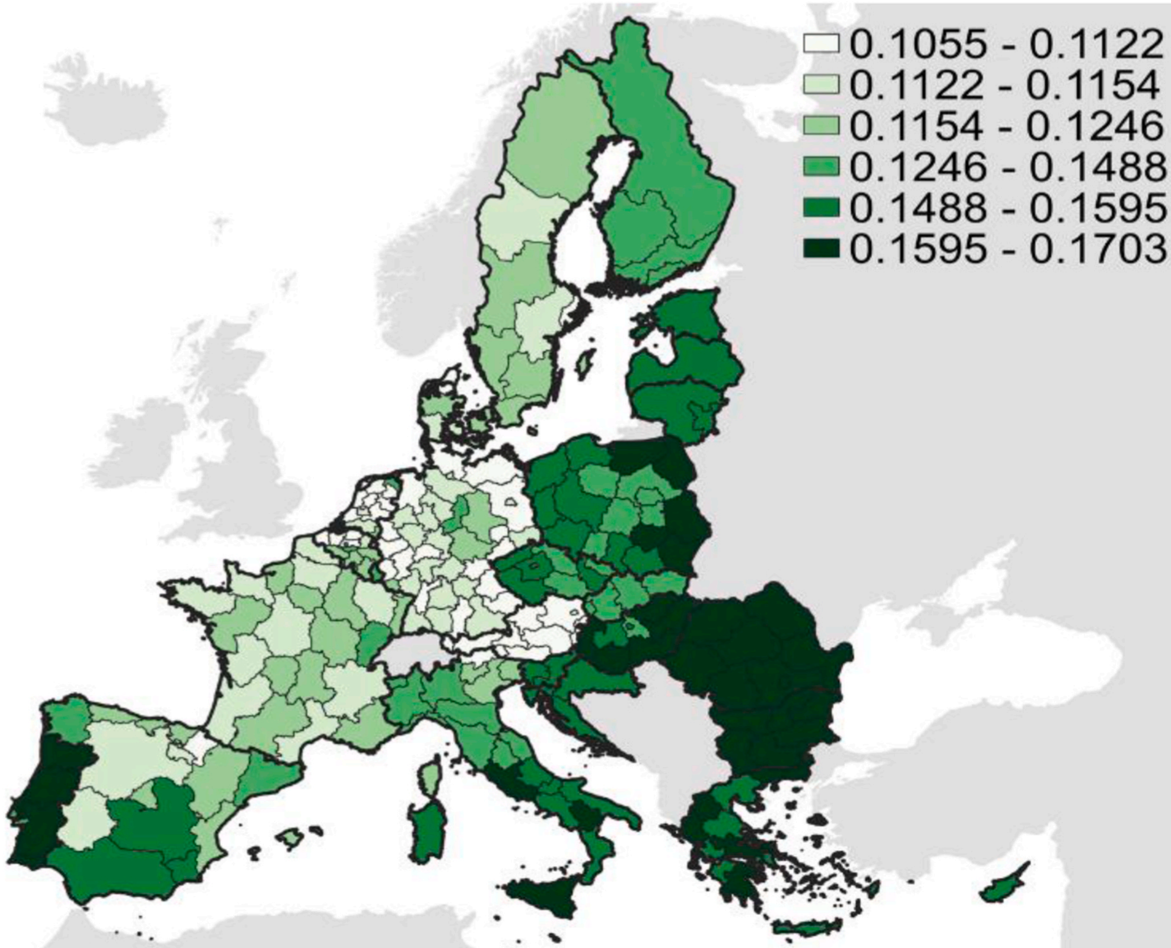

Fig. 9. Map of education coefficients.
Note: regions are classified in six equal count intervals. Average coefficient overall years. Source: EuroGeographics for the administrative boundaries.

negative effect of population growth intensifies. The beta-convergence test in Table A.8 suggests that changes in QI_{it} and RAI_{it} exacerbate the differences in economic growth rates, given the positive and statistically significant coefficient found for population growth, human capital and constant term. However, a simultaneous increase in QI_{it} and RAI_{it}, enhances the elasticities of physical capital and R&D investment without significantly affecting their dispersion.

5.5. Robustness analyses

In this subsection, we examine the robustness of our previous latent class model. It includes three analyses. In the first one, we present the results of an SLX latent class model. In the second analysis, we incorporate European Funds into the economic growth equation, interacting them with the traditional growth drivers. Finally, in the third analysis, we examine whether the spatial spillover effects and the European Funds are relevant for our analyses of the marginal effects attributable to (changes in) the institutional environment.

5.5.1. SLX latent class model

In the previous subsection, we did not account for potential interregional spillover effects, which may affect regional economic growth. These spillovers arise due to factors such as firms operating across multiple regions, worker mobility and commuting, and trade in goods and services (see Rodríguez-Pose and Crescenzi, 2008; Ozyurt and Dees, 2018; Wagner and Zeileis, 2019). In this subsection, we introduce an SLX latent class model, incorporating local spillover effects, to examine whether these spatial effects alter the results of our latent class model and to test the robustness of the non-spatial specification.

While the spatial specification nests the latent class model from Subsection 5.3, we still prefer the non-spatial model for both methodological and data-related reasons. First, spatial econometric models face criticism for identification issues (see Gibbons and Overman, 2012; Debarsy and Le Gallo, 2024). Second, there exists extensive literature on latent class and spatial econometric models but only Lee (2018) has attempted to combine both approaches. However, although the proposed model is econometrically rigorous, it lacks theoretical consistency.[34] As developing a theoretically consistent spatial latent class model lies beyond the scope of this paper, we instead present the results of an SLX latent class model, which incorporates local spillovers without

[34] The likelihood function of a spatial autoregressive model accounts for feedback effects that occur as impacts pass through neighbouring units (regions) and return to the unit (region) where the change originated. The implicit assumption in a standard (i.e., one-class) spatial model is that neighbouring regions will react in the same manner as the region where the change started. The spatial latent class model introduced by Lee (2018) makes the same assumption, even though the latent class structure suggests that regions in different classes may exhibit different reactions. This inconsistency between the model's latent structure and its spatial dependence structure represents a fundamental theoretical limitation that has not yet been resolved in the literature.

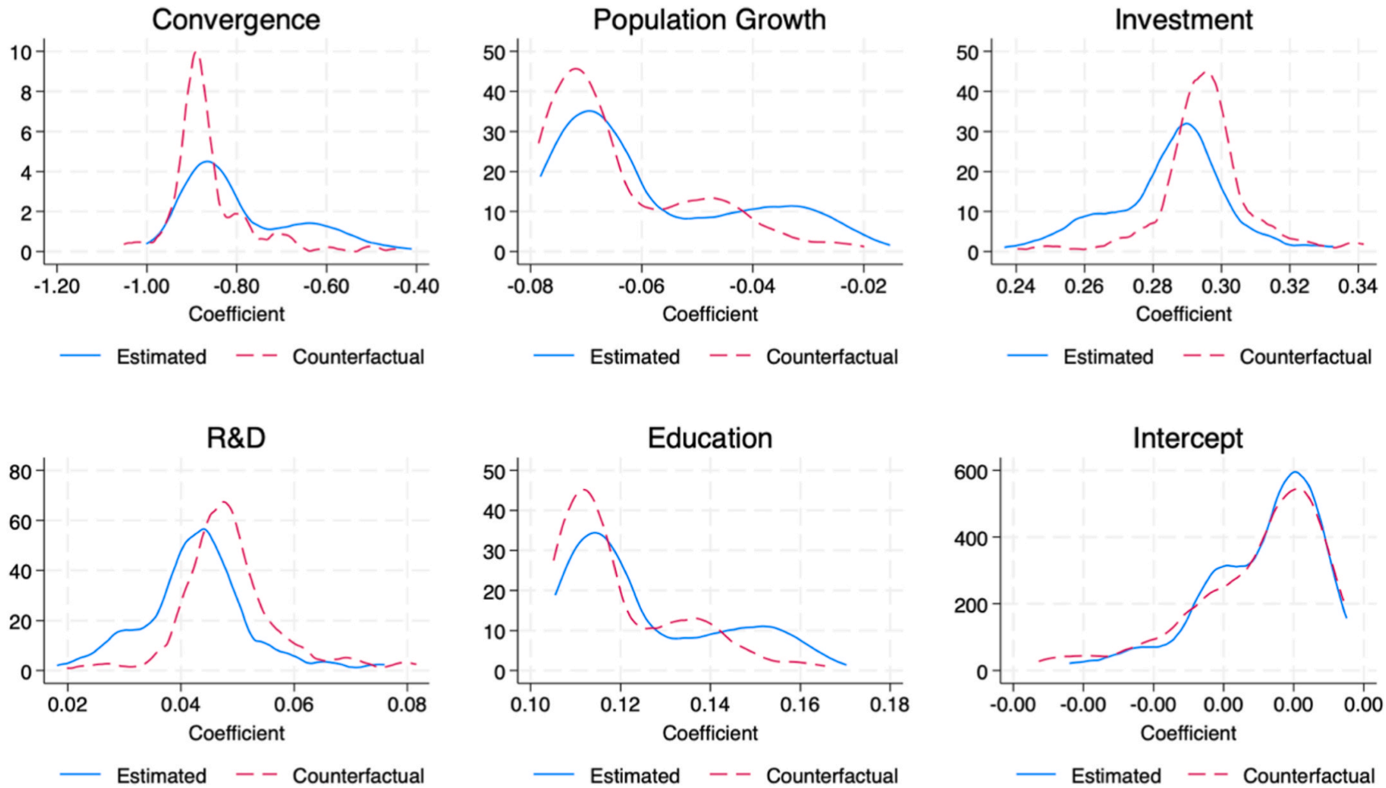

Fig. 10. The effect of government quality on elasticities in more developed regions.
Note: Counterfactual analysis of an increase in the institutional quality indicator by one standard deviation for all regions. Source: Own elaboration.

endogenous interaction effects, thus avoiding theoretical inconsistencies.

Table 5 displays the parameter estimates using the SLX latent class specification. Table A.9 in the Appendix shows the most probable class predictions for more and less developed regions.[35] The results for the economic growth equation are generally consistent with the non-spatial model, although there are some differences in class characteristics. For instance, the estimated coefficients in Table 5 reveal a significant convergence process in terms of income per capita, though the effect of population growth proves significant only when disaggregating by classes. Furthermore, investment in physical capital continues to positively contribute to regional development across all classes. Innovation exerts a particularly strong positive effect in the complete sample, while education significantly benefits all regions and classes.

We present the coefficients of the spatially lagged economic growth drivers in Table 5. Most of these coefficients are statistically significant, indicating that inter-regional spillovers play a relevant role in European economic growth. Evidence of local spatial spillover effects from neighbouring regions is found in all models, aligning with previous studies (e.g., Cantos et al., 2005; Álvarez-Ayuso et al., 2016), which also suggest that spatial spillover effects become more pronounced at finer territorial scales, such as regional or provincial levels, compared with national scales.

Across all regions, we observe significant spillover effects from convergence processes and population growth. Investment presents a positive spillover effect in all regions and mainly in classes 1 and 3, in which there are many developed regions and most of the less developed regions with high government quality. Furthermore, innovation exerts a positive spillover effect in class 1, a small sample of regions, but with high government quality, while education presents a negative spillover effect in developed regions (class 2), showing a competition effect of production factors, and a positive spillover effect in less developed regions with high government quality and in part of the sample of developed regions (class 3). These findings imply that a region's economic development benefits from its neighbouring regions, particularly those with substantial physical capital investment, consistent with Arrow-Romer's physical capital externalities (Arrow, 1962; Romer, 1986). Moreover, population mobility also appears to influence regional growth. However, the spillover effects related to neighbouring regions' population are negative across both the standard and latent class specifications of the SLX economic growth model. This negative coefficient could suggest the presence of Myrdal's backwash effects (Myrdal, 1957), where competition for production factors between regions results in negative impacts.[36]

When disaggregating the results by classes, we find that less developed and developed regions with high government quality benefit significantly from neighbouring regions' innovation. In our spatial

[35] As Fernández-Blanco et al. (2009) point out, a class-labelling issue arises in many LCMs as permutation of all the parameters corresponding to each class does not change the overall parameter estimates. What we obtain with this permutation is merely a relabelling of the classes. This explains why similar specifications (e.g., non-spatial versus spatial) of the LCM might allocate most of the observations in roughly the same classes, but they are labelled differently (e.g., Class 1 versus Class 3). The substantive interpretation focuses on the characteristics of each class rather than its numerical label.

[36] This would indirectly corroborate the existence of agglomeration economies, which attract production factors to areas with higher economic activity, reinforcing theories that explain core-periphery patterns (Barbero and Zoffo, 2016). The negative population spillovers suggest that peripheral regions may experience net outflows of productive workers to neighbouring more developed areas.

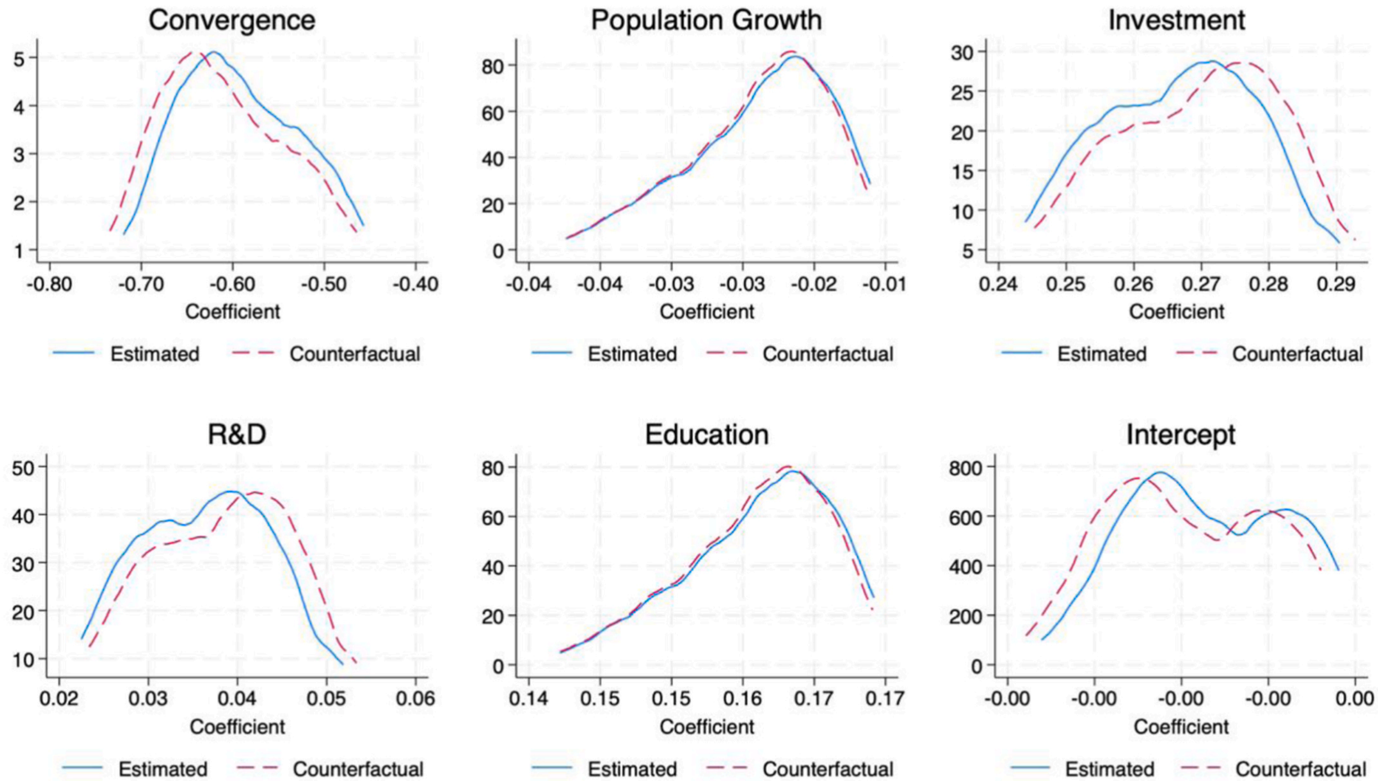

Fig. 11. The effect of Government quality on the elasticities of less developed regions.
Note: Counterfactual analysis of an increase in the institutional quality indicator by one standard deviation for all regions. Source: Own elaboration.

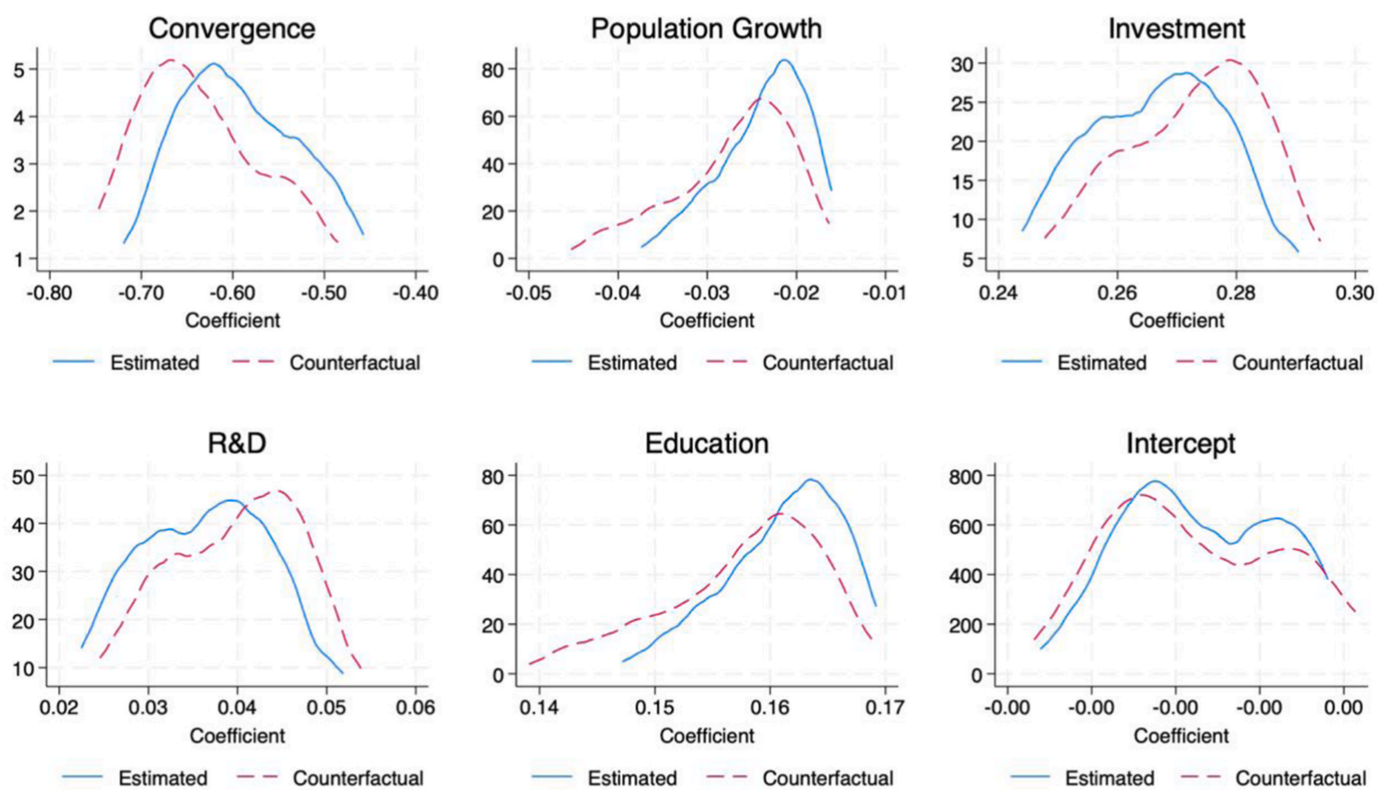

Fig. 12. The effect of Government quality and regional authority on the elasticities of less developed regions.
Note: Counterfactual analysis of an increase in the quality of the government indicator and regional authority index of less developed regions by the difference between the average of the more and less developed regions. Source: Own elaboration.

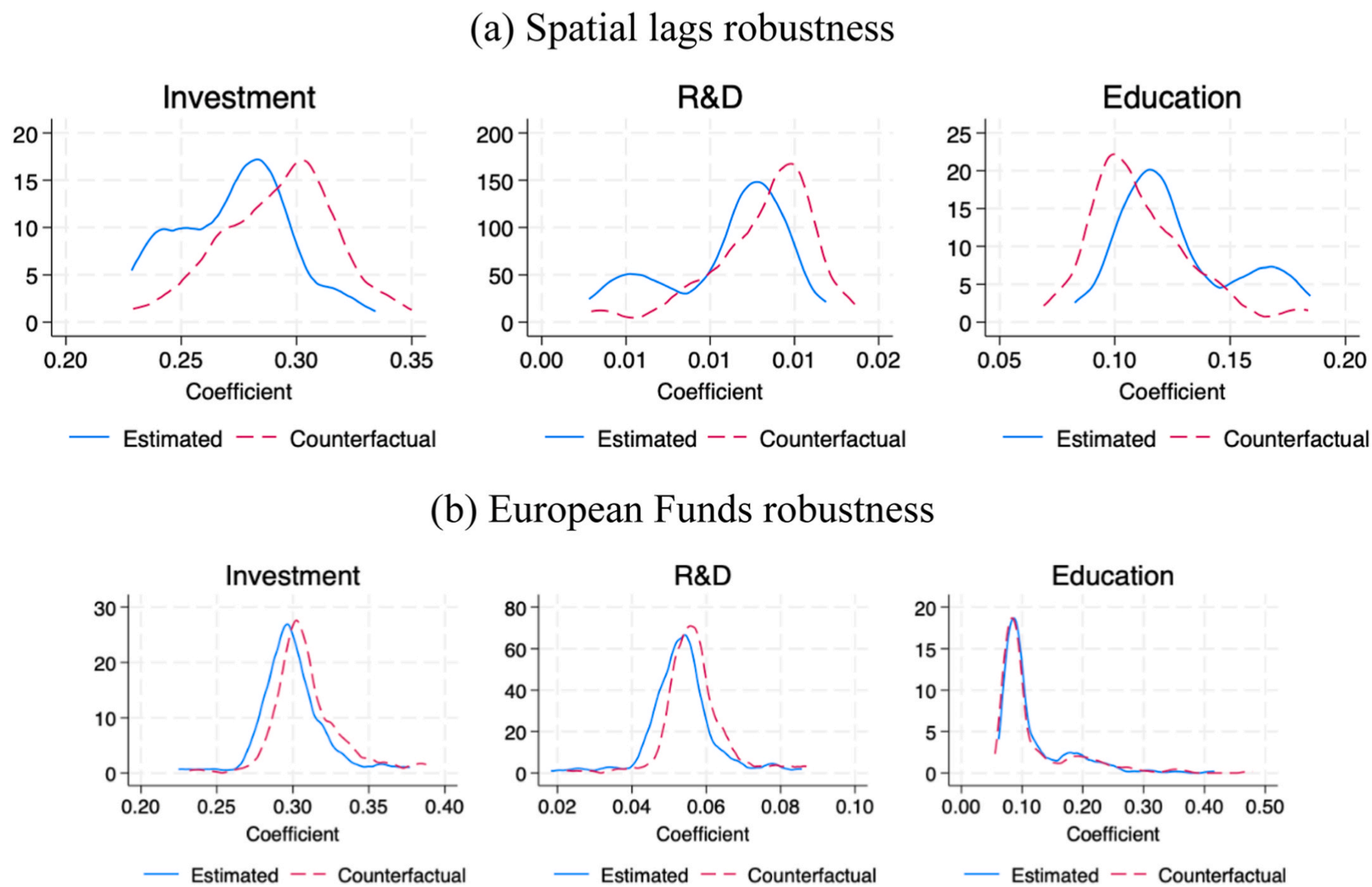

Fig. 13. The effect of Government quality on the elasticities in more developed regions.
Note: Counterfactual analysis of an increase in the institutional quality indicator by one standard deviation for all regions. Source: Own elaboration.

latent class model, economic growth spillovers are influenced not only by neighbouring regions' innovation but also by their capital and education levels. Lagging regions (Classes 1 and 3) and less development regions with high government quality (class 3) experience positive externalities from neighbouring regions' capital and education levels, consistent with the findings of Álvarez and Barbero (2016), who observed similar results in lagging Spanish regions. Conversely, in developed regions with weak institutions (Class 2), we observe a negative spillover effect from neighbouring regions' educational levels, because of the existence of competition for production factors.

In summary, despite some theoretical and data limitations, our spatial latent class model demonstrates that inter-regional spillover effects are far from negligible. These effects prove crucial for understanding regional economic performance and designing effective place-based development policies, regional innovation strategies, and smart specialisation initiatives. Notably, the influence of economic growth drivers remains consistent with the non-spatial model, where all regions benefit from investment, whilst innovation drives growth in the complete sample. Education also supports development in the complete sample of regions and all classes.

5.5.2. *Latent class economic growth model with European funds*

So far, we have assumed that the European funds can only affect economic growth if this funding is translated into concrete investments.[37] Previous studies, such as Rodríguez-Pose and Garcilazo (2015), interacted European funds with institutional factors like government quality in order to capture their effects on regional development. These papers thus assumed a different channel through which European funds might impact on regional development, i.e. by increasing the marginal effects of some of the economic growth drivers. In this subsection, we follow a similar methodology and incorporate European Funds into the economic growth equation, interacting them with the traditional growth drivers.

As shown in Table A.10 in the Appendix, developed regions are primarily located in Classes 1 and 2, while lagging regions are mostly concentrated in Class 3. The prior probabilities for each class are presented at the bottom of Table 6. The estimated coefficients indicate that Class 1 contains developed regions with high government quality. Class 3 includes regions with higher autonomy, most of which are lagging.

Table 6 presents the parameter estimates of the economic growth equation, incorporating European Funds through interactions with the growth drivers. As with previous estimations, we observe a convergence process, a negative effect of population growth, and a positive impact of investment across all classes. However, the introduction of European Funds amplifies the effects of innovation and education. Innovation positively affects all regions but exerts a stronger effect in developed regions (Classes 1 and 2). Education promotes economic growth across all regions and classes.

[37] We thank an anonymous reviewer for pointing out this important alternative specification and encouraging us to explore how European funds might affect growth through channels beyond their translation into concrete investments.

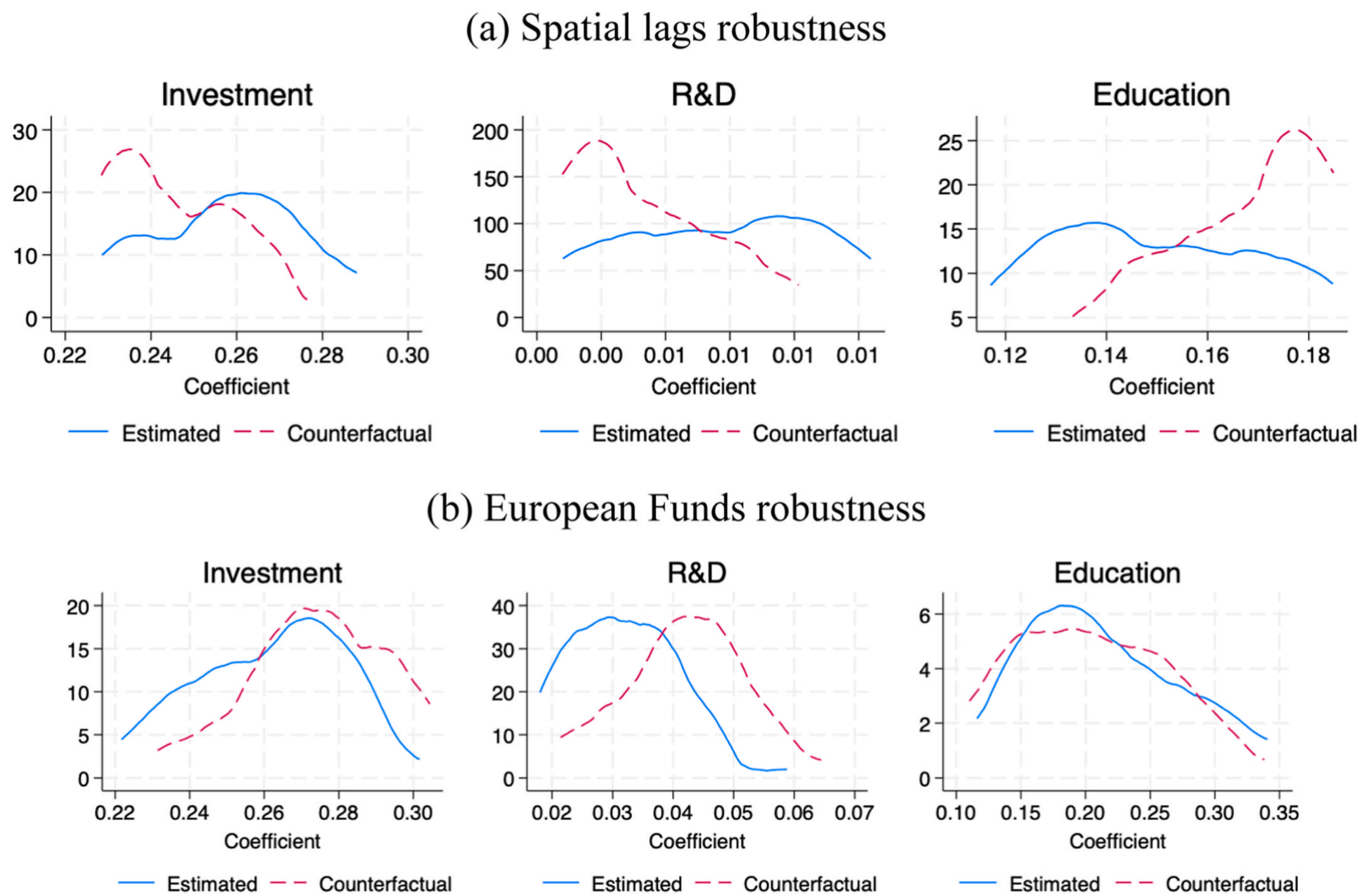

Fig. 14. The effect of Government quality on the elasticities of less developed regions.
Note: Counterfactual analysis of an increase in the institutional quality indicator by one standard deviation for all regions. Source: Own elaboration.

Consistent with the indirect analysis of European funds through auxiliary regressions, the effect of investment remains unaffected by European Funds. Instead, European Funds contribute to raising educational levels in all regions, particularly in developed regions (Classes 1 and 2). Surprisingly, the interaction effect between European Funds and innovation is not significant across all regions and is even negative in Class 1, which includes some developed regions with lower government quality. This might be due to the aggregation of all European Funds into a single indicator, potentially masking more specific effects.

5.5.3. Are the marginal effects of institutional quality more relevant with spatial effects and European funds?

Our previous robustness analyses include spatial spillover effects and the role of European Funds in influencing investment, innovation, and education. In this subsection, we use the coefficients estimated in these two subsections to delve deeper into the counterfactual analysis of how improvements in government quality and autonomy affect the parameters of economic growth drivers and their dispersion.

Figs. 13 and 14 illustrate the impact of government quality on the elasticities of economic growth drivers in more and less developed regions, respectively. For more developed regions, Fig. 13 shows that the sign of the effects remains consistent with the previous model. However, considering spatial spillovers intensifies the positive effects of government quality on investment and innovation, amplifying the negative effect on education, although this effect proves less pronounced when European Funds are taken into account. The Kolmogorov-Smirnov tests in Table A.11 in the Appendix confirm the significance of these results. The beta-convergence test in Table A.12 shows that the dispersion of elasticities decreases, particularly when spatial spillovers are included, except in the case of investment.

In contrast, Fig. 14 and the Kolmogorov-Smirnov tests in Table A.11 show that in less developed regions, there exists a positive effect of government quality on education. This result contradicts that obtained without spillover effects. However, investment and innovation intensify their positive effects when European Funds are considered, though they are negative in the model with spatial spillovers. Considering European funds, no significant effect is observed on education. The beta-convergence test in Table A.12 reveals that the dispersion of elasticities decreases when spatial effects are included. This demonstrates that European Funds enhance the positive effects of government quality on the elasticities of economic growth drivers in lagging regions, reducing their dispersion, consistent with Crucitti et al. (2024), who highlight that regional disparities decrease with policy intervention.

Finally, following the same procedure than in previous analysis, we focus on changes in both types of institutional factors (QI_{it} and RAI_{it}) in less developed regions. We simulate an increase in QI_{it} and RAI_{it} by the average difference between more and less developed regions. Fig. 15 presents the results of this new counterfactual analysis, while Tables A.11 and A.12 provide Kolmogorov-Smirnov tests of significance and catching-up effects on elasticities. In the spatial model the effect of education —previously negative— is positive, which represents an improvement, although investment and innovation are no longer significant. On the other hand, this analysis reveals that the positive and significant effects on investment and innovation are intensified in models that include European Funds. These findings further confirm the results of earlier studies, which suggest that policy interventions exert particularly strong effects in lagging regions, which benefit more from European Funds.

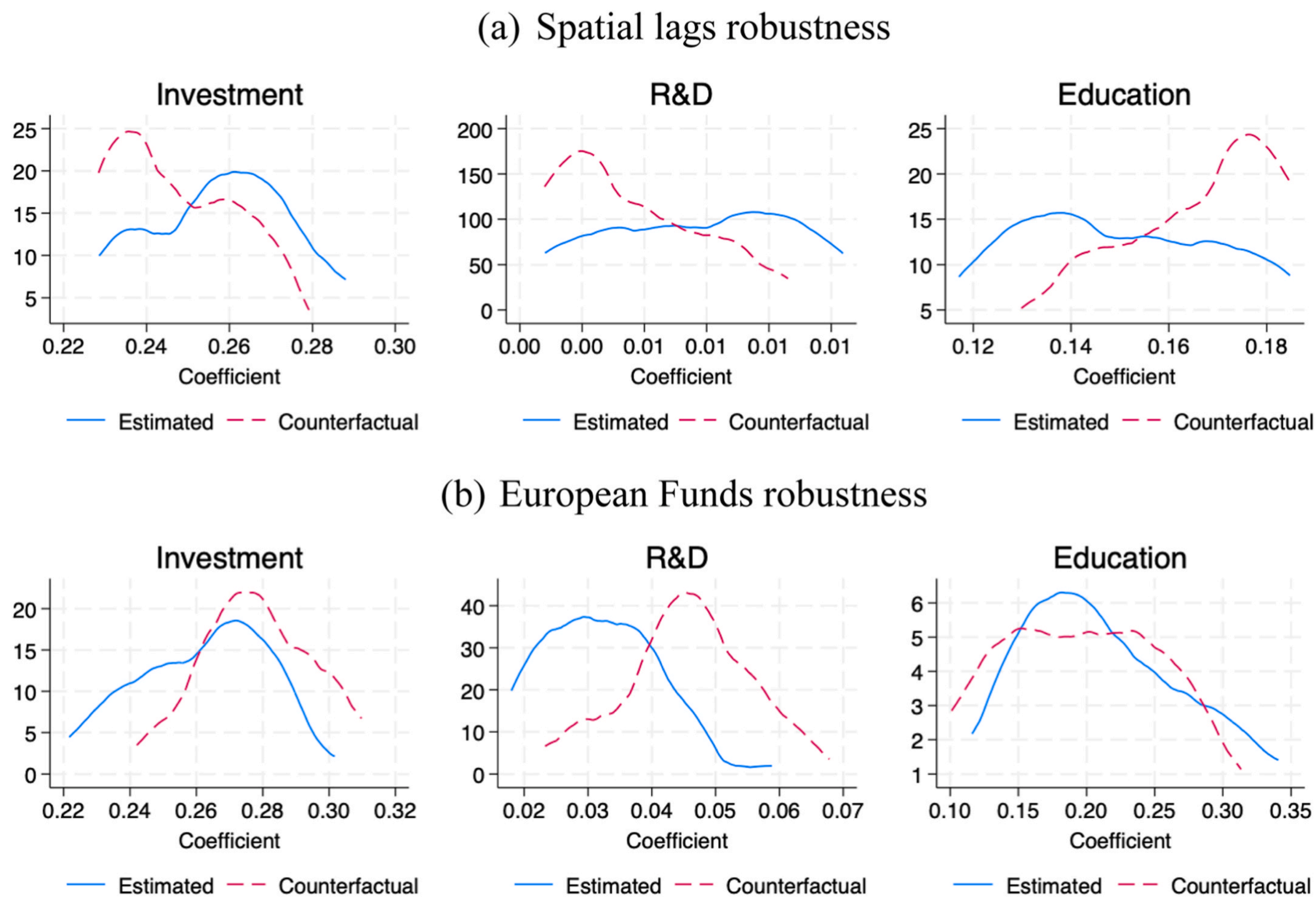

Fig. 15. The effect of Government quality and regional authority on the elasticities of less developed regions.
Note: Counterfactual analysis of an increase in the quality of the government indicator and regional authority index of less developed regions by the difference between the average of the more and less developed regions. Source: Own elaboration.

Our results highlight that improvements in institutional quality, combined with policy interventions via European Funds, prove particularly effective in boosting innovation and investment in lagging regions. Meanwhile, in more developed regions, improvements in institutional factors are amplified by inter-regional spillovers, particularly through education. These findings underscore the importance of both institutional quality and targeted policy interventions in promoting regional economic growth and reducing disparities across European regions.

6. Conclusions

Research on how institutions shape the drivers of economic growth in European regions often assumes a uniform effect across all regions. Most studies focus on the impact of government quality on the economic performance of EU regions as a whole or broadly classify them by development level (e.g., Iammarino et al., 2019; Rodríguez-Pose and Ketterer, 2020). Our research challenges this assumption by demonstrating that institutional effects vary significantly across regions. Using a latent class structure, we estimate region-specific effects of investments in physical capital, human capital, and innovation, revealing substantial differences in returns depending on government quality and regional autonomy. This highlights that the heterogeneous parameters observed across regions are fundamentally influenced by institutional factors.

The differentiated effects of economic growth drivers and varying rates of convergence indicate the presence of distinct regimes, shaped in part by institutional conditions. The latent class approach allows us to derive region-specific parameters. We observe that institutional weaknesses may limit the returns on traditional growth drivers such as innovation and education. Conversely, regions with higher government quality experience better returns on innovation and physical capital investment, which suggests that strong institutions play a key role in enhancing regional economic performance.

The results for individual regions reveal significant heterogeneity. For instance, regions in the Nordic countries and central Europe see the highest returns on investment in physical capital and innovation, whereas many less developed regions, including some in northern Europe, experience the greatest economic growth from investments in education. These region-specific parameters enable more tailored recommendations on the types of investments that yield the highest returns, informing public investment strategies and European cohesion policy. In summary, the LCEG model reveals that institutional quality significantly shapes regional economic outcomes by influencing how effectively growth drivers are leveraged. The latent class approach allows us to uncover the heterogeneous effects of institutional factors across regions, providing a deeper understanding of how different regions experience growth under varying institutional and economic conditions.

We explore how improving regional institutions can enhance the returns on public investments in European regions by conducting counterfactual simulations through increases in the quality of government (QI) and regional autonomy (RAI) indices, two key factors influencing economic growth patterns and heterogeneous parameters. We find that enhancing institutional quality has significant growth effects and increases the returns on physical capital, education, and innovation, facilitating convergence. We also observe an increase in the intercept parameter, indicating higher overall economic growth, alongside a reduction in the elasticities of human capital investment and an intensified negative effect of population growth on economic performance. These effects prove less pronounced in less developed regions. Moreover, improvements in government quality reduce parameter heterogeneity more in developed regions than in less developed ones, suggesting that institutional improvements can also drive convergence within developed regions. Thus, weak institutional quality not only hinders economic growth but also affects territorial cohesion, particularly within more developed regions during the period under analysis.

We also find that increasing the RAI index boosts the speed of convergence in more developed regions and contributes to average economic growth in both more and less developed regions. However, our simulations show that government quality exerts a more significant impact on economic growth than regional autonomy. This is consistent with the findings of Filippetti and Cerulli (2018), who argue that greater autonomy is not always beneficial for public service delivery and that decentralisation effectiveness depends on the institutional context, particularly institutional quality. These results suggest that, despite ongoing debates about regional autonomy in several EU countries, policymakers should focus on reducing public sector corruption, improving impartiality, and enhancing efficiency in public services.

The policy implications of our analysis prove significant. Recognising the heterogeneous returns on investment across EU regions —contingent on government quality and autonomy— can enhance the efficiency of public spending. This knowledge allows for more targeted, place-sensitive interventions (Iammarino et al., 2019) that prioritise investments with the highest potential returns, tailored to the specific conditions of each territory. Our findings underscore the importance of institutional factors, particularly government quality, in shaping the returns on traditional drivers of economic growth and promoting territorial cohesion. Efforts to improve institutional quality should focus on regions where substantial increases in investment returns can be achieved, thus raising territorial cohesion through more effective investment. Poor institutions hinder the returns on public investments and diminish the effectiveness of European investment. Therefore, positive incentives for further institutional quality improvements should be integrated into EU Cohesion Policy. Twinning the allocation of European funds to improvements in public institutions could represent a worthwhile approach to ensure that regions with weaker institutions receive targeted support for institutional enhancement.

Finally, we introduce local spillover effects and European Funds into the economic growth equation, interacting them with the traditional growth drivers, to examine the robustness of our specification. It is worth mentioning that the influence of economic growth drivers remains consistent in both cases with the non-spatial model. Regarding the SLX model, we observe that spatial spillovers provide additional insights. In the model with spatial spillovers, despite some theoretical and data limitations, our spatial latent class model demonstrates that interregional spillover effects are far from negligible. Developed regions (especially those in Class 2 with high government quality and autonomy) benefit from innovation spillovers from neighbouring regions. Meanwhile, lagging regions (Class 1) gain from capital and educational externalities, while developed regions with strong institutions (Class 2) experience negative spillover effects from neighbouring regions' education levels.

The introduction of European Funds amplifies the effects of innovation and education. Consistent with the indirect analysis of European funds through auxiliary regressions, the effect of investment remains unaffected by European Funds. Instead, European Funds contribute to raising educational levels in all regions, particularly in developed regions (Classes 1 and 2). Surprisingly, the interaction effect between European Funds and innovation is not significant across all regions and is even negative in Class 1, which includes some developed regions with lower government quality. This might be due to the aggregation of all European Funds into a single indicator, potentially masking more specific effects.

The counterfactual analysis improving government quality and autonomy confirms that spatial spillovers intensify the positive effects of government quality on investment and innovation while amplifying the negative effect on education, although this effect proves less pronounced when European Funds are considered. European Funds enhance the positive effects of government quality on the elasticities of economic growth drivers in lagging regions, reducing their dispersion, consistent with Crucitti et al. (2024), who highlight that regional disparities decrease with policy intervention.

While this study highlights the heterogeneous returns on investment driven by institutional factors, a potential limitation is the exclusion of temporal dynamics. Future research could explore whether regions transition between different development groups over time or remain stable, and what factors influence these dynamics. This could help identify development traps, as discussed in the literature (e.g., Battisti and Parmeter, 2013; Diemer et al., 2022). Future studies could also contribute to this literature by analysing the factors that prevent regions from transitioning from poor to rich and reinforcing the poverty or development trap. Identifying the role of European funds in this process and evaluating whether their current design helps poor regions escape the development trap would provide valuable insights for policymakers.

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.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.econmod.2025.107445.

APPENDIX

Table A.1
Descriptive statistics for more and less developed regions.

	Mean	Std. Dev	Minimum	Maximum
More developed regions				
Growth of real GDP per capita (%)	0.786	3.362	−16.106	14.565
Real GDP per capita (€)	29,472.267	13,442.703	5989.369	98,748.211
Population growth (%)	0.242	0.778	−6.426	5.635
Investment (Million €)	1,1286.503	12,525.965	234.260	142,594.797
R&D (€ per capita)	603.755	611.122	6.641	3884.269
Human Capital (%)	27.721	8.704	8.300	57.100
ESIF Funds (% of GDP)	0.706	1.131	0.001	8.999
Quality of Government	0.366	0.859	−2.796	2.818
Regional Authority Index	16.404	8.988	0.000	27.000
Less developed regions				
Growth of real GDP per capita (%)	0.046	4.040	−14.319	12.921
Real GDP per capita (€)	12,537.492	5847.551	3755.248	25,617.303
Population growth (%)	−0.370	1.072	−11.046	3.583
Investment (Million €)	4411.206	5445.629	304.760	37,820.398
R&D (€ per capita)	87.775	65.225	3.905	242.314
Human Capital (%)	19.066	5.189	9.100	31.300
ESIF Funds (% of GDP)	2.587	1.953	0.060	10.545
Quality of Government	−1.020	0.693	−2.528	0.791
Regional Authority Index	9.136	7.640	1.000	24.500

Note: Descriptive statistics based on a sample of 1446 observations for developed regions and 367 for less developed regions. Source: own elaboration.

Table A.2
List of lagging regions.

Region code	Region name	Category
BG31	Severozapaden	Low income
BG32	Severen tsentralen	Low income
BG33	Severoiztochen	Low income
BG34	Yugoiztochen	Low income
BG42	Yuzhen tsentralen	Low income
EL51	Anatoliki Makedonia, Thraki	Low growth
EL52	Kentriki Makedonia	Low growth
EL53	Dytiki Makedonia	Low growth
EL54	Ipeiros	Low growth
EL61	Thessalia	Low growth
EL62	Ionia Nisia	Low growth
EL63	Dytiki Ellada	Low growth
EL64	Sterea Ellada	Low growth
EL65	Peloponnisos	Low growth
EL41	Voreio Aigaio	Low growth
EL43	Kriti	Low growth
ES42	Castilla-la Mancha	Low growth
ES61	Andalucía	Low growth
ES62	Región de Murcia	Low growth
ES64	Ciudad Autónoma de Melilla	Low growth
ES70	Canarias	Low growth
HU23	Dél-Dunántúl	Low income
HU31	Észak-Magyarország	Low income
HU32	Észak-Alföld	Low income
HU33	Dél-Alföld	Low income
ITF1	Abruzzo	Low growth
ITF2	Molise	Low growth
ITF3	Campania	Low growth
ITF4	Puglia	Low growth
ITF5	Basilicata	Low growth
ITF6	Calabria	Low growth
ITG1	Sicilia	Low growth
ITG2	Sardegna	Low growth
PL81	Lubelskie	Low income
PL82	Podkarpackie	Low income
PL72	Swietokrzyskie	Low income
PL84	Podlaskie	Low income
PL62	Warminsko-Mazurskie	Low income
PT11	Norte	Low growth
PT15	Algarve	Low growth

(*continued on next page*)

Table A.2 (*continued*)

Region code	Region name	Category
PT16	Centro	Low growth
PT18	Alentejo	Low growth
RO11	Nord-Vest	Low income
RO21	Nord-Est	Low income
RO22	Sud-Est	Low income
RO31	Sud - Muntenia	Low income
RO41	Sud-Vest Oltenia	Low income

Note: Region's NUTS codes correspond to the 2016 classification.

Table A.3
Auxiliary panel regression equations.

	(I) Government Quality	
Intercept	−10.996	***
	(2.287)	
Summer precipitation variability	0.000	
	(0.001)	
Spring precipitation variability	−0.003	***
	(0.001)	
Lagged GDP_{pc}	1.112	***
	(0.228)	
Population growth	−0.007	
	(0.010)	
Year-Effects	Yes	
Observations	1804	
Number of regions	229	
Model F-statistic	6.66	
Model test p-value	0.00	
F-stat. external instruments	3.91	
P-value	0.00	

Notes: Lagged GDP is defined as the regional real Gross Domestic Product (in logs) lagged one period (y_{it-1}) and population growth is defined as the log of the employment growth rate adjusted by the depreciation rate and the total factor productivity growth rate ($n_{it} + g + \delta$). Clustered standard errors by region in parenthesis. ***p < .01, **p < .05, *p < .1.

Table A.4
Parameter estimates. Basic economic growth models.

	(I)		(II)		(III)		(IV)	
Intercept	0.006	***	0.016	***	0.015	**	0.021	***
	(0.000)		(0.005)		(0.006)		(0.007)	
Lagged GDP	−0.642	***	−0.762	***	−0.656	***	−0.815	***
	(0.053)		(0.055)		(0.048)		(0.053)	
Population growth	−0.015	*	−0.094	***	−0.086	***	−0.078	***
	(0.008)		(0.011)		(0.009)		(0.011)	
Investment	0.224	***	0.184	***	0.226	***	0.187	***
	(0.027)		(0.026)		(0.025)		(0.024)	
R&D	0.096	***	0.070	***	0.074	***	0.063	***
	(0.021)		(0.017)		(0.017)		(0.017)	
Education	0.093	***	0.157	***	0.138	***	0.183	***
	(0.023)		(0.021)		(0.021)		(0.021)	
Government Quality interactions								
Intercept			0.205	***			0.204	***
			(0.032)				(0.034)	
Lagged GDP			−0.054	***			−0.054	***
			(0.013)				(0.014)	
Population growth			−0.043	***			0.003	
			(0.006)				(0.016)	
Investment			0.001				0.003	
			(0.004)				(0.004)	
R&D			0.021	***			0.022	***
			(0.005)				(0.005)	
Education			−0.021	**			−0.021	**
			(0.009)				(0.010)	
Regional Authority Index interactions								
Intercept					−0.043	***	−0.052	***
					(0.009)		(0.008)	
Lagged GDP					−0.048	*	−0.026	

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Table A.4 (*continued*)

	(I)		(II)		(III)		(IV)	
					(0.026)		(0.023)	
Population growth					−0.046	***	−0.043	***
					(0.006)		(0.015)	
Investment					0.010	*	0.007	
					(0.006)		(0.005)	
R&D					0.007		−0.002	
					(0.006)		(0.005)	
Education					−0.027	***	−0.014	**
					(0.008)		(0.007)	
Number of observations	1813		1804		183		1804	
Number of regions	230		229		230		229	
Model F-statistics	71.72		55.32		67.76		53.68	
Model test p-value	0.00		0.00		0.00		0.00	
F-statistics residuals	77.47		81.39		118.02		92.39	
P-value	0.00		0.00		0.00		0.00	
Adjusted R-squared	0.45		0.50		0.50		0.53	

Notes: The dependent variable is the log of real Gross Domestic Product (GDP) growth in all models ($\Delta ln\ y_{it}$). Lagged GDP is defined as the regional real Gross Domestic Product (in logs) lagged one period (y_{it-1}) representing the convergence process. Population growth is defined as the log of the employment growth rate adjusted by the depreciation rate and the total factor productivity growth rate ($n_{it} + g + \delta$). Investment is defined as the log of the Gross Fixed Capital Formation as the proxy of investment in physical capital (s_{it}^{K}), R&D represents the log of the gross domestic expenditure on R&D (s_{it}^{RD}) and the Education is the log of the percentage of population aged 25 to 64 with tertiary education as the proxy for human capital (s_{it}^{H}). All estimations include the residuals of the auxiliary equations for Investment, R&D, Education, and the Government Quality. Estimations based on a sample of 1813 observations for 230 regions. The region of the Canary Islands (ES70) and its 9 observations are lost in columns (II) and (IV) due to missing data in the precipitation variability instrument. Intercept in Government Quality (QI) and Regional Authority Index (RAI) interactions represents the direct effect (not interacted with any other variable) of both institutional factors. Clustered standard errors by region in parenthesis. ***$p < .01$, **$p < .05$, *$p < .1$.

Table A.5
Most probable class prediction.

Class	1	2	3	Total
More developed				
Frequency	320	132	994	1446
Percent	17.65 %	7.28 %	54.83 %	79.76 %
Less developed				
Frequency	325	41	1	367
Percent	17.93 %	2.26 %	0.06 %	20.24 %
Total				
Frequency	645	173	995	1813
Percent	35.58 %	9.54 %	54.88 %	100.00 %

Note: Clustered standard errors by region in parenthesis. ***$p < .01$, **$p < .05$, *$p < .1$. Source: own elaboration.

Table A.6
Characteristics of the regions by class.

	Class 1	Class 2	Class 3
Growth of real GDP per capita (%)	1.001	−2.263	0.904
Real GDP per capita (€)	15,011	29,732	32,554
Population growth (%)	−0.150	0.125	0.290
Investment (Million €)	5722	7768	12,969
R&D (€ per capita)	153.740	609.155	704.218
Human Capital (%)	22.1	26.7	28.2
ESIF Funds (% of GDP)	2.08	1.23	0.41
Quality of Government	−0.848	0.427	0.631
Regional Authority Index	8.736	11.832	19.488
Less developed	0.504	0.237	0.001
Observations	645	173	995

Note: Mean values based on a sample of 1.813 observations for 230 regions.

Table A.7
Kolmogorov-Smirnov Tests.

QI	Convergence	Population growth	Investment	R&D expenditure	Education	Constant
More developed regions						
Counterfactual	−0.342***	−0.223***	0.000	0.000	−0.223***	−0.060
	(0.000)	(0.000)	(1.000)	(1.000)	(0.000)	(0.518)
Baseline	0.000	0.000	0.353***	0.337***	0.000	0.043
	(1.000)	(1.000)	(0.000)	(0.000)	(1.000)	(0.706)

(continued on next page)

Table A.7 (*continued*)

QI	Convergence	Population growth	Investment	R&D expenditure	Education	Constant
Less developed regions						
Counterfactual	−0.174	−0.109	0.000	0.000	−0.109	−0.217
	(0.249)	(0.581)	(1.000)	(1.000)	(0.581)	(0.114)
Baseline	0.000	0.022	0.217	0.217	0.022	0.000
	(1.000)	(0.978)	(0.114)	(0.114)	(0.978)	(1.000)
QI and RAI	Convergence	Population growth	Investment	R&D expenditure	Education	Constant
Less developed regions						
Counterfactual	−0.326***	−0.304**	0.000	0.000	−0.283**	−0.109
	(0.008)	(0.014)	(1.000)	(1.000)	(0.025)	(0.581)
Baseline	0.000	0.000	0.326***	0.283**	0.000	0.130
	(1.000)	(1.000)	(0.008)	(0.025)	(1.000)	(0.457)

Note: p-values in brackets. ***p < .01, **p < .05, *p < .1. The "Counterfactual" row tests the hypothesis that the heterogeneous coefficients are smaller in the counterfactual. The "Baseline" row tests the hypothesis that the heterogeneous coefficients are smaller in the baseline. Source: own elaboration.

Table A.8
Beta-convergence tests.

QI	Convergence	Population growth	Investment	R&D expenditure	Education	Constant
More developed regions	−0.376***	−0.235***	−0.301***	−0.201***	−0.242***	0.144***
	(0.022)	(0.017)	(0.032)	(0.036)	(0.017)	(0.016)
Less developed regions	0.026**	−0.020***	0.030**	0.030**	−0.019***	0.011
	(0.011)	(0.004)	(0.012)	(0.012)	(0.005)	(0.012)
QI and RAI	Convergence	Population growth	Investment	R&D expenditure	Education	Constant
Less developed regions	0.026	0.324***	0.003	0.003	0.313***	0.123***
	(0.028)	(0.029)	(0.022)	(0.020)	(0.030)	(0.027)

Note: Standard errors in parenthesis. ***p < .01, **p < .05, *p < .1. This table shows the estimated a_1 coefficient in equation (9). Source: own elaboration.

Table A.9
Most probable class prediction for more and less developed regions in the spatial SLX model.

Class	1	2	3	Total
More developed				
Frequency	224	895	327	1446
Percent	12.36 %	49.37 %	18.04 %	79.76 %
Less developed				
Frequency	44	92	231	367
Percent	2.43 %	5.07 %	12.74 %	20.24 %
Total				
Frequency	268	987	558	1813
Percent	14.78 %	54.44 %	30.78 %	100.00 %

Table A.10
Most probable class prediction for more and less developed regions in the model with European Funds.

Class	1	2	3	Total
More developed				
Frequency	201	1179	66	1446
Percent	11.09 %	65.03 %	3.64 %	79.76 %
Less developed				
Frequency	37	90	240	367
Percent	2.04 %	4.96 %	13.24 %	20.24 %
Total				
Frequency	238	1269	306	1813
Percent	13.13 %	69.99 %	16.88 %	100.00 %

Source: own elaboration.

Table A.11
Kolmogorov-Smirnov Tests robustness analysis.

QI	SLX model					
	Convergence	Population growth	Investment	R&D expenditure	Education	Constant
More developed regions						
Counterfactual	−0.391***	−0.391***	0.000	0.000	−0.391***	−0.342***

(*continued on next page*)

Table A.11 (*continued*)

QI	SLX model					
	Convergence	Population growth	Investment	R&D expenditure	Education	Constant
	(0.000)	(0.000)	(1.000)	(1.000)	(0.000)	(0.000)
Baseline	0.000	0.000	0.397***	0.391***	0.000	0.005
	(1.000)	(1.000)	(0.000)	(0.000)	(1.000)	(0.995)
Less developed regions						
Counterfactual	0.000	0.000	−0.348***	−0.391***	0.000	−0.326***
	(1.000)	(1.000)	(0.004)	(0.001)	(1.000)	(0.008)
Baseline	0.370***	0.348***	0.000	0.000	0.370***	0.000
	(0.002)	(0.004)	(1.000)	(1.000)	(0.002)	(1.000)
QI and RAI						
Less developed regions						
Counterfactual	0.000	0.000	−0.326***	−0.348***	0.000	−0.326***
	(1.000)	(1.000)	(0.008)	(0.004)	(1.000)	(0.008)
Baseline	0.326***	0.348***	0.000	0.000	0.348***	0.000
	(0.008)	(0.004)	(1.000)	(1.000)	(0.004)	(1.000)
QI	**Model with European Funds**					
	Convergence	Population growth	Investment	R&D expenditure	Education	Constant
More developed regions						
Counterfactual	−0.304***	−0.098	0.000	0.000	−0.120*	−0.152**
	(0.000)	(0.172)	(1.000)	(1.000)	(0.072)	(0.014)
Baseline	0.000	0.054	0.255***	0.239***	0.043	0.000
	(1.000)	(0.581)	(0.000)	(0.000)	(0.706)	(1.000)
Less developed regions						
Counterfactual	−0.413***	−0.543***	0.000	0.000	−0.109	0.000
	(0.000)	(0.000)	(1.000)	(1.000)	(0.581)	(1.000)
Baseline	0.000	0.000	0.326***	0.457***	0.043	0.478***
	(1.000)	(1.000)	(0.008)	(0.000)	(0.917)	(0.000)
QI and RAI						
Less developed regions						
Counterfactual	−0.609***	−0.652***	0.000	0.000	−0.152	0.000
	(0.000)	(0.000)	(1.000)	(1.000)	(0.345)	(1.000)
Baseline	0.000	0.000	0.348***	0.587***	0.022	0.630***
	(1.000)	(1.000)	(0.004)	(0.000)	(0.978)	(0.000)

Note: p-values in brackets. ***p < .01, **p < .05, *p < .1. The "Counterfactual" row tests the hypothesis that the heterogeneous coefficients are smaller in the counterfactual. The "Baseline" row tests the hypothesis that the heterogeneous coefficients are smaller in the baseline. Source: own elaboration.

Table A.12
Beta-convergence tests in the robustness analysis.

QI	Convergence	SLX model				
		Population growth	Investment	R&D expenditure	Education	Constant
More developed regions	−0.071***	−0.179***	−0.031	−0.209***		
	(0.026)	(0.024)	(0.026)	(0.023)	(0.023)	(0.046)
Less developed regions	−0.308***	−0.326***	−0.308***	−0.334***	−0.329***	−0.573***
	(0.054)	(0.048)	(0.057)	(0.047)	(0.048)	(0.038)
QI and RAI	Convergence	Population growth	Investment	R&D expenditure	Education	Constant
Less developed regions	−0.251***	−0.271***	−0.251***	−0.281***	−0.275***	−0.566***
	(0.055)	(0.048)	(0.058)	(0.046)	(0.047)	(0.039)
QI	**Model with European Funds**					
	Convergence	Population growth	Investment	R&D expenditure	Education	Constant
More developed regions	−0.212***	−0.229***	0.000	−0.089***	0.148***	0.076***
	(0.029)	(0.017)	(0.024)	(0.019)	(0.007)	(0.007)
Less developed regions	−0.200***	−0.030	−0.195***	−0.075***	−0.046	0.030
	(0.062)	(0.081)	(0.067)	(0.101)	(0.035)	(0.086)
QI and RAI	Convergence	Population growth	Investment	R&D expenditure	Education	Constant
Less developed regions	−0.420***	−0.266**	−0.366***	−0.257**	−0.098*	−0.171
	(0.076)	(0.102)	(0.083)	(0.125)	(0.050)	(0.107)

Note: Standard errors in parenthesis. ***p < .01, **p < .05, *p < .1. This table shows the estimated a_1 coefficient in equation (9). Source: own elaboration.

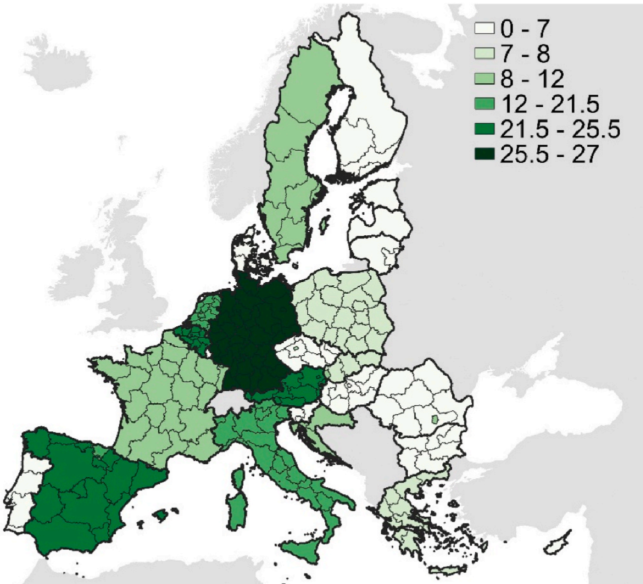

Fig. A.1. Regional Authority Index in European regions in 2017.
Source: own elaboration from Hooghe et al. (2016) and Shair-Rosenfield et al. (2020).

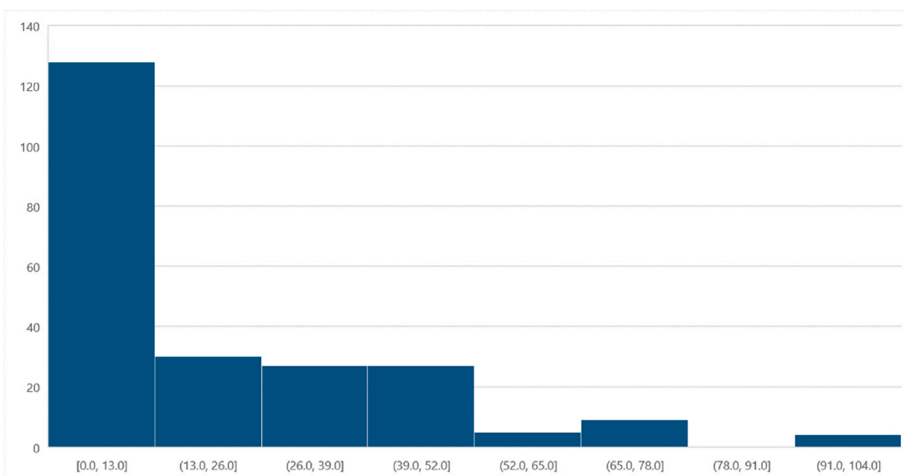

Fig. A.2. Distribution of class changes (in percentage).

Data availability

Data will be made available on request.

How institutions shape the economic returns to investment in European regions? (dataset and codes) (Reference data) (Mendeley Data)

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