



Is there a rainbow between crises? Lessons from thin-level convergence in an external assistance-intervened country

Margarida Catalão-Lopes¹ · Joaquim P. Pina²

Received: 26 June 2025 / Accepted: 30 January 2026
© The Author(s) 2026

Abstract

Anchored in the EU's objective of promoting territorial cohesion and reducing inequalities, as articulated in SDG 10 and the “Leave No One Behind” principle, our study analyzes economic convergence between the global financial crisis and the COVID-19 pandemic in Portugal, a country that underwent successful intervention through an external financial assistance program. Using municipal-level data—a fine-grained approach new to Portuguese growth empirics—we uncover clear signs of sigma and beta convergence, both unconditional and conditional, detailed through quantile estimation. Real per-capita income gaps narrowed most sharply in municipalities at the higher end of the conditional growth distribution. Education, market competition, and trade openness emerge as the strongest drivers of this progress, advising policies that prioritize human capital, competitive local markets, and deeper international integration.

Keywords Economic crises · Foreign aid intervention · Sigma convergence · Beta convergence · Portuguese municipalities · Determinants

JEL Classification Code C21 · O47 · R11 · R53

✉ Margarida Catalão-Lopes
mcatalao@tecnico.ulisboa.pt

Joaquim P. Pina
jagl@fct.unl.pt

¹ Instituto Superior Técnico, CEGIST, Universidade de Lisboa, Av. Rovisco Pais, Lisboa 1049-001, Portugal

² MARE - Marine and Environmental Sciences Centre, ARNET - Aquatic Research Network Associate Laboratory, Department of Applied Social Sciences, NOVA School of Science and Technology, NOVA University Lisbon, Caparica, Portugal

1 Introduction

Aligned with the United Nations' Sustainable Development Goals (SDG), particularly SDG10 on reduced inequalities, economic growth and convergence within and across countries and regions play an increasingly important role among the interests of academics and policymakers. Territorial cohesion is an objective of the European Union (EU), as defined in Article 174 of the Treaty on the Functioning of the European Union (TFEU) and included in the Lisbon Treaty, seeking to reduce disparities between the development levels of regions and mitigate internal asymmetries, within the context of the EU Cohesion Policy. However, the nexus between Cohesion Policy and interregional inequalities in different business cycle periods is complex.

In a common currency area, the region is a more meaningful unit of analysis than the country. It is generally accepted that convergence among regions may stimulate economic growth and that regional disparities do not favor it. If divergence is transitory, regions should grow towards a long-run common level of per capita income (steady-state), implying that the poorest would grow faster to catch up with the richest, or converge to their own or group-specific steady-state defined by a set of determinants. This is difficult to achieve across countries with different growth determinants and may also be difficult within countries and even within specific areas, as some recent analyses have shown for European cities and countries.

In this paper, we address convergence across Portuguese municipalities in the 2014–2019 period, between two extreme events that Portugal heavily experienced: the 2008 financial crisis, followed by a Financial Assistance Program from May 2011 to June 2014,¹ and the COVID-19 pandemic since March 2020, followed by the respective stringency measures. It is relevant to analyze how regional convergence was achieved (or not) during the non-crisis interval.

To the best of our knowledge, this is the first time that (i) this period is analyzed, with an emphasis on the possibility of convergence between crises, and (ii) the municipality is employed as the geographical unit of measure for Portugal in the realm of regional economic convergence. Other studies on regional convergence in Portugal have either used different periods and focused on convergence to EU levels or world convergence, or, if centered on the country level, have mainly employed NUTS III level data. The municipality is, in principle, a more homogeneous portion of space with a similar economic and social reality. Hence, growth determinants are more likely to be the same, which supports the interest in this novel, thinner analysis. By focusing on this period and this geographical unit, the current paper adds to Capello and Perucca (2015), who address the financial crisis period, and Benczes and Szent-Ivanyi (2015), who call for a deeper territorial analysis. Furthermore, the possibility of converging in the aftermath of a strict program of foreign financial assistance, and before a sanitary crisis, is explored for a small open economy.

¹ During the Troika intervention in Portugal (2011–2014), the country received external financial assistance from a consortium composed of the European Commission, the European Central Bank (ECB), and the International Monetary Fund (IMF). This assistance followed a deterioration of Portugal's public finances, mounting sovereign debt, and restricted access to international financial markets in the aftermath of the global financial crisis. The Troika closely monitored Portugal's progress, and the country successfully exited the program in 2014 without requiring additional assistance.

More specifically, we aim to empirically explore the possible existence of a catch-up effect for Portuguese municipalities, as well as the role of a battery of growth and economic cohesion determinants. These include intangible capital in its various forms, human and social factors, information and communication variables, science and technology activity, entrepreneurship, competition, public investment, and agglomeration effects. Our explanatory variables have been identified as key determinants in previous studies (e.g., Sala-i-Martin et al. 2004; Doré and Teixeira 2021) and are directly linked to several pillars of the Portuguese Recovery and Resilience Plan (RRP) and European targets, notably: (i) digital transformation; (ii) smart, sustainable and inclusive growth, including research, development and innovation; (iii) social and territorial cohesion; (iv) health and economic, social and institutional resilience; (v) policies for the next generation, including education.

We analyze Portugal's municipalities listed in PORDATA and inspect sigma convergence plus unconditional and conditional beta convergence, employing cross-section regression by Least Squares and Conditional Quantile approaches (e.g., Mello and Perelli 2003). These methods are appropriate for addressing our focus on the existence of convergence and also on its speed, providing a rich view of type of convergence and key determinants (Brock 2020). To this purpose, we take the cross-section of municipalities and employ Least Squares estimation (making sure that an Instrumental Variables estimator is not required). In turn, the use of Conditional Quantile approaches allows for richer heterogeneity.²

Concretely, we intend to answer 4 main questions:

Q1: Is there evidence in Portugal, in recent “normal” times, of catching up on real per capita income among municipalities?

Q2: Does the inclusion of the Azores and Madeira archipelagos in the analysis change results substantially?

Q3: Which are the significant determinants of real per capita income that characterize heterogeneity among municipalities?

Q4: Are municipalities in the left tail of the conditional distribution of real per capita income converging faster or slower than those in the upper tail?

Our main findings emphasize, on the one hand, the heterogeneity of municipalities regarding growth and convergence, challenging the view that the poorest ones grow faster and that public investment may have a positive contribution. On the other hand, we confirm that human capital, particularly education, is always and everywhere a key driver. Other determinants, like competition, are not ubiquitous, while openness always has a positive effect.

The findings on convergence speed call for targeted regional investment that reflects local development needs rather than uniform national policies, combined with strong and sustained commitments to education and skills as the central drivers of growth. Policies should also prioritize increasing openness and connectivity through improved infrastructure, trade links, and knowledge flows. At the same time, competition measures or regulation and public investment must be applied selec-

² Calegari et al. (2023) and Capello et al. (2024) also aimed at exploring differences across quartiles, the former for the Extended Regional Development Index and the latter according to regional vulnerability.

tively, ensuring that they are tailored to regional conditions to maximize effectiveness and avoid counterproductive outcomes.

The remainder of the paper is organized as follows. Section 2 briefly overviews the existing literature and state of the art concerning economic growth and regional convergence. Section 3 presents the data employed. Section 4 describes the empirical approach, derives the results, and interprets them. Section 5 concludes, acknowledges limitations, and suggests lines for future work. An Appendix contains detailed information about the variables employed.

2 Theoretical background and literature review

The theoretical and the empirical literature on economic growth reveal a long-standing effort to understand why regions diverge or converge in their development trajectories. Early empirical surveys (Durlauf and Quah 1999; Doré and Teixeira 2021) highlight not only the diversity of growth determinants but also the difficulty in establishing robust causal relationships. While persistent growth disparities generate welfare asymmetries, the mechanisms behind them remain multifaceted and context-dependent (e.g., Fan et al. 2013).

Why do some regions grow more than others? Should the regions in the growth frontier (i.e., those that grow faster, in the terminology of Jones 2016) grow so much? Are regions behind the growth frontier catching up? Cross-country studies consistently show that catching up is difficult when countries differ substantially in their structural growth drivers. Similar difficulties may arise within countries and even within smaller territories, as highlighted by recent analyses of European cities and regions (e.g., Kadi et al. 2022; Eyre et al. 2024). Moreover, the interaction between cohesion policy and regional inequalities is highly sensitive to the business cycle (Capello et al. 2024), raising important questions about policy timing, targeting, and effectiveness.

The world's spread of economic growth has clearly been very unequal across countries. The Great Divergence initiated in the 19th century has been magnified in the 20th century; technical change, institutional quality, and geography are recognized as key determinants of it (Crafts and O'Rourke 2014). Reducing economic disparities at the world, national, and regional levels is an aspiration to which quantitative models may contribute in several ways.

The well-known work of Sala-i-Martin et al. (2005) proposes a set of variables with strong evidence of correlation with economic growth, among which are primary school enrollment (a measure of human capital) and the initial level of real GDP per capita (a measure of conditional convergence). Based on the Schumpeterian view of economic growth driven by entrepreneurial innovations, the role of entrepreneurship in enhancing the production frontier or bringing economies closer to the world frontier is stressed in the work of Quadrini (2009). Firm size is pointed out by Pagano and Schivardi (2003) as an important determinant too, as the larger size allows companies to appropriate the increasing returns associated with R&D and, thus, fosters productivity.

The development of information technologies (IT) and their falling prices have importantly contributed to economic growth through increased productivity, and to differences in per capita income across world regions (Jorgenson and Vu 2005). Besides tangible assets, commonly and historically included in the production function, intangibles, which are knowledge-based, nonphysical assets such as organizational improvements, acquisition of new skills, ICT and R&D, may also impact productivity (Cincera et al. 2020) and, in modern economies, they must also be considered as capital and important contributors to economic growth (Corrado et al. 2022). The non-rival and weakly excludable nature of ideas (they may be easily copied) enhances economies of scale and scope (Crouzet et al. 2022; Jones 2005). Organizational capital is accumulated over the life cycle of firms, in a learning process, and entitles the owner of an older plant to rents that can be measured as part of the output distributed, apart from physical capital, workers, and managers (Atkeson and Kehoe 2005).

Social capital, understood as community relations that affect personal interactions, matters for group differences and has also been widely recognized as an engine of economic growth (see Durlauf and Fafchamps 2005, for a survey of theoretical and empirical research). The intense acceleration in the use of telecommunication technologies and interpersonal communication in the last decades has importantly affected the pattern of accumulation of social capital and changed the role of local density as a driver of economic growth (see Duranton and Puga 2014, for a review of theory and empirical evidence on the role of cities).

Despite its costs (namely in terms of crowding and pollution), agglomeration reduces travel needs and facilitates productivity, at the same time it fosters the exchange of ideas and innovation (Duranton and Puga 2020). The benefits of activity concentration arise mainly from human capital spillovers, promoting entrepreneurship and, again, higher productivity. More productive cities attract workers from less productive cities and rural areas, a movement that is responsible for increased output growth (Duranton and Puga 2022). Firms tend to be more productive in larger cities, which results more from the benefits of agglomeration than from stronger selection and left truncation of the sample of firms in the city (Combes et al. 2012). There is an earnings premium for working in bigger cities, for which an important explanatory factor is higher-skilled occupation (De La Roca and Puga 2017). This is in line with Storper (2018), according to which regional economic divergence includes the spatial distribution of skills and returns to education. City size thus stands out as a candidate determinant of growth differences. Agasisti and Bertolletti (2022) findings for European regions highlight the role of higher education systems, the quality of research, and specialization in STEM for economic development. Their contribution may further be seen as a call for planning to provide a favorable ecosystem for economic performance. Finally, one may also add that education is likely to have indirect effects on economic performance, through reduced violence (Poveda 2011).

In Portugal, the empirical literature mirrors these broader debates but has been relatively narrow in scope. Studies on regional convergence have typically examined convergence toward EU levels (e.g., Barros and Garoupa 1996) or global convergence (e.g., Ghoshray and Khan 2015). When the focus is on the national level, most analyses rely on NUTS III data—such as Viegas and Antunes (2013), Soukiazis and

Antunes (2006), and Braga (2003) for economic convergence, and Guerreiro and Caleiro (2015) for convergence in qualified human resources. More recent firm-level evidence suggests that exporting companies enjoy price-cost premia that may facilitate innovation and economic growth (Soares and Sousa 2023), while structural funds positively affect export performance (Cabral and Campos 2023), underscoring the importance of effective RRP implementation.

Lastly, the frameworks of beta and sigma convergence are central to empirical assessments. Beta convergence means that the poorest regions tend to grow faster than the richest (negative correlation between initial income and rate of growth), being a necessary (but not sufficient) condition for sigma convergence, which corresponds to a decrease over time of income dispersion across regions (Furceri 2005). In turn, sigma convergence is a sufficient condition for beta convergence.

The current paper employs these concepts to address the convergence of Portuguese municipalities during the most recent non-crisis period, that is, between the financial crisis and the COVID-19 pandemic, providing not just an assessment of the degree to which this convergence has occurred, but also new insights on which variables have influenced the most progress towards territorial cohesion. The results contribute to advancing the knowledge required for an accurate execution of RRP funds.

3 Data description and measurement

We draw on previous literature surveyed in the preceding section to select a battery of possible explanatory variables. We use annual data from 2014 to 2019 for 308 municipalities, including the Mainland, Azores, and Madeira, taken from the PORDATA platform (PORDATA 2023). The [Appendix](#) provides data definitions as downloaded from the PORDATA website.

Table 1 organizes data used according to the represented engines of growth and the concept being measured. The variables' definitions are shown. Following literature insights, the variables selected measure, for each municipality, the initial income level and respective average growth, public investment, human capital in the education and health dimensions, labor earnings signaling productivity, organization capital, social capital, ideas generation, innovation, information and communication, science and technology, agglomeration economies, competition, firm size, openness, entrepreneurship, and population as a measure for municipality size.

There are also dummy variables for NUTS II regions (North, Center, Alentejo, Algarve, Madeira, and Azores, with the Lisbon Metropolitan Area as default). As explained before, the variables chosen are aligned with the pillars of the Portuguese RRP and European goals (besides the United Nations Sustainable Development Goals).

Figure 1 shows the map of Portuguese regions, the Mainland and the Islands. Table 1 details the set of variables explored in the model specification search.

Table 1 Variables essayed at the municipality level. Source: Own elaboration.

Engines of growth	Concept measurement	Variable definition
	Initial income	Natural logarithm of real per capita income
Public investment	Public investment	Investment per capita
Human capital	Education	Primary education per capita Secondary education per capita
	Health	Inhabitants per doctor Inhabitants per pharmacist
Tangible capital labor ratio	Productivity, Capital labor ratio (capital intensity)	Earnings of employees (real)
Intangible capital	Organization capital	Percent firm survival 1 year
Social capital	Network	Students per computer with internet Home telephone access share per capita Job telephone access share per capita
Ideas	Ideas and productivity	Share of employees with Higher education Earnings of employees with Higher education (real)
Innovation	Leadership and innovation	Earnings of Supervisors, Foremen and Team Leaders (real) Earnings of highly skilled workers (real)
TFP	Information and Communication, Science and Technology	Share of firms in technology related sectors Share of firms related to Science and Innovation
	Agglomeration	Enterprises per 100 inhabitants
	Competition	Concentration of four major enterprises
	Scale	Firms with less than 10 employees Dummy for the existence of large firms
Openness	Outward looking	Real Exports of goods plus tourism per capita Real Exports of goods per capita
	Tourism	Tourism per capita Tourism output ratio
Entrepreneurship	Entrepreneurship	Birth rate of firms Share of individual owner firms
Size	Population	Population as measure for municipality size

4 Econometric approach and results

As explained before, we examine sigma convergence, as well as unconditional and conditional beta convergence, using cross-section regressions by Least Squares and Conditional Quantile approaches, which allow us to assess the existence and speed of convergence.

Beta convergence refers to the tendency of poorer municipalities to grow faster than richer ones, allowing them to catch up over time. Unconditional (absolute) beta convergence occurs when all economies converge toward the same steady-state income, assuming identical structural characteristics. Conversely, conditional beta convergence recognizes that municipalities differ in factors such as human capital, firm dynamics, and openness, among others, and therefore converge toward their own steady states.



Fig. 1 Portuguese regions. Source: NUTS_level_2_maps_of_Portugal

https://commons.wikimedia.org/wiki/Category:NUTS_level_2_maps_of_Portugal

Table 2 Sigma convergence for log of real per capita income. Source: Own elaboration.

Years	Mean		Standard deviation		Coefficient of variation	
	Whole Portugal	Portugal mainland	Whole Portugal	Portugal mainland	Whole Portugal	Portugal mainland
2014	1.253	1.307	0.620	0.606	0.495	0.464
2015	1.328	1.385	0.620	0.606	0.467	0.438
2016	1.396	1.447	0.611	0.602	0.438	0.416
2017	1.482	1.532	0.607	0.599	0.410	0.391
2018	1.548	1.598	0.599	0.589	0.387	0.369
2019	1.614	1.663	0.588	0.579	0.364	0.348

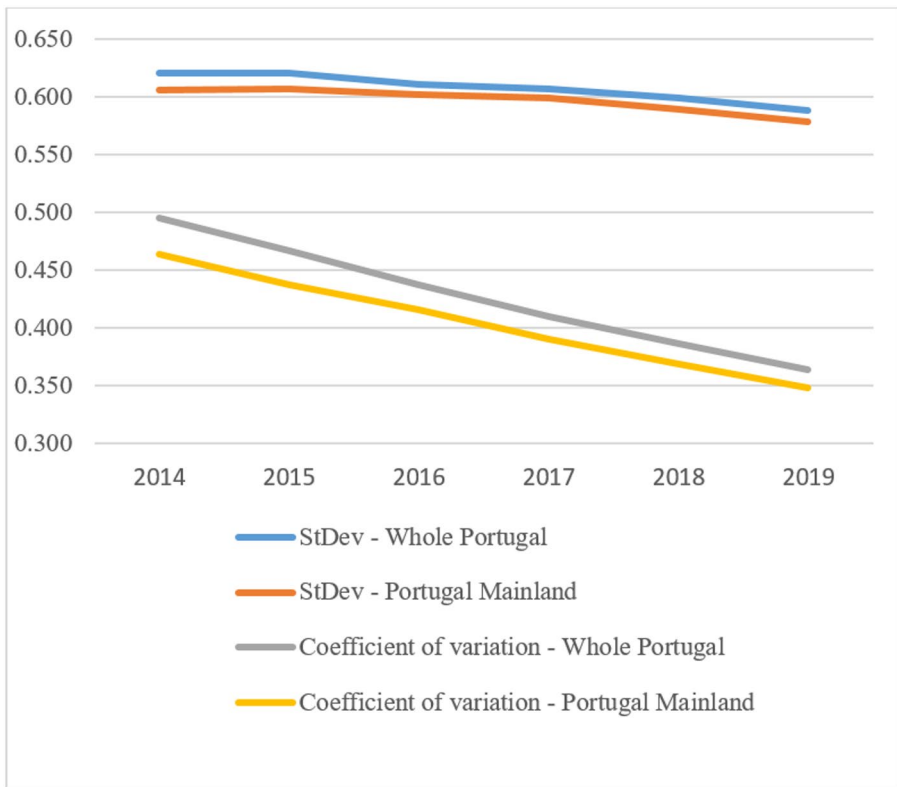
**Fig. 2** Sigma convergence for log per capita real income. Source: Own elaboration.

Table 2; Fig. 2 show that the standard deviation of the logarithm of real per capita income has decreased over time, a sign of sigma convergence. In other words, real per capita income dispersion across municipalities has been reduced in the 2014–2019 period. This is true for the 308 municipalities of “Whole Portugal” (Mainland, plus the Azores and Madeira), as well as for only “Portugal Mainland” (278 municipalities). Since real per capita income has grown over the sample period, we also compute the coefficient of variation, providing additional evidence of convergence.

As expected, dispersion (measured both by standard deviation and coefficient of variation) is consistently higher when the Whole Portugal (Mainland, the Azores, and Madeira) is considered than when the analysis is restricted to Portugal Mainland, which puts in evidence existing asymmetries in terms of real per capita income between the Mainland and Autonomous Regions (Azores and Madeira).

According to these results, regional convergence at the municipality level has occurred across the period 2014–2019. Taking into account a slightly higher real per capita income growth in Autonomous Regions during the period analyzed, the coefficient of variation points towards an approximation of both samples (with and without the Autonomous Regions).

Having shown the existence of sigma convergence and recalling that sigma convergence is a sufficient condition for beta convergence, we next show the existence of beta convergence. Furthermore, we look for significant determinants of growth and steady-state (which is eventually heterogeneous across municipalities), exploring existing PORDATA information and computing conditional beta convergence, besides the unconditional version. We further provide the implied speed of convergence and half-life.

To assert unconditional beta convergence, we estimate the following cross-section regression:³

$$\frac{1}{T} \ln \frac{y_{i,T}}{y_{i,0}} = a + b \ln y_{i,0} + \epsilon_i, \quad \epsilon_i \text{ i.i.d. } (0, \sigma_\epsilon^2) \quad (1)$$

To assert conditional beta convergence, we estimate the cross-section regression (2), which includes a battery of explanatory variables, to be selected according to significance:

$$\frac{1}{T} \ln \frac{y_{i,T}}{y_{i,0}} = a + b \ln y_{i,0} + \sum_{i=1}^N c_i X_{i,0} + \epsilon_i, \quad \epsilon_i \text{ i.i.d. } (0, \sigma_\epsilon^2) \quad (2)$$

We conduct the estimation of Eqs. (1) and (2) using Least Squares (LS) and provide heteroskedastic consistent estimators (MacKinnon and White 1985) for the purpose of robustness, as suggested by the White test results obtained in some of the regressions run while searching for significant determinants. To ensure consistency of the estimates, besides examining collinearity using Variance Inflation Factors (VIF), we also run Hausman test instrumenting with lagged variables (Durlauf et al. 2005).⁴ We did not find evidence of collinearity, and the Hausman test indicated the consistency of LS.

We first perform the analysis for the Mainland plus the Azores and Madeira (Whole Portugal, 308 municipalities) and then restrict it to the Mainland (278 munic-

³ The econometric work is conducted using Gretl (Gretl, 2023).

⁴ VIF values are below 2 in every case analyzed. Hausman p-values are above the 5% significance level in every regression, and results from instrumental variables estimation reinforce LS estimates. We further computed Moran I. This test exhibits p-values smaller than the 5% critical level, thereby signaling possible spatial autocorrelation. However, regional dummies have shown little significance. Moreover, although efficiency may be affected, parameters' consistency is unaffected (see e.g., Conley 1999).

ipalities). The battery of variables indicated in Table 1 was essayed; the acronyms for the variables that showed explanatory power are presented in Table 3. The selection of explanatory variables followed a systematic econometric process that balanced theoretical relevance with practical constraints arising from data availability. Because some variables were not jointly observed across the full dataset, including them together would have reduced the usable sample to about two-thirds of its original size, potentially weakening the reliability of the estimates. To manage this trade-off, the model specification relied on both general-to-specific and specific-to-general strategies, testing numerous variable combinations. Variables were retained based on heteroskedasticity-robust p-values, the F-statistic, and overall explanatory power. This approach ensured that the final set of regressors achieved a sound balance between statistical robustness, theoretical justification, and maintaining the largest feasible sample. Additional experimentation with NUTS II regional dummies was also undertaken. Moreover, the final specification maximized comparability between Whole Portugal and Portugal Mainland.

The selected set of variables with explanatory power includes those pointed out by Sala-i-Martin et al. (2005) as having evidence of the strongest correlation with economic growth, namely the initial level of real per capita income (a measure of conditional convergence), primary school enrollment (a measure of human capital), and openness.

Tables 4 and 5 report the results of unconditional convergence LS, conditional convergence LS, and the Conditional Quantile approach. For inference regarding variables, a 10% significance level is considered (parameters in bold).

Table 4 shows that the conditional convergence LS regression adds explanatory power to growth performance when compared to the unconditional one, as documented by the individual significance of regressors and joint significance (F test p-value is near zero). Both regressions exhibit convergence of municipalities, which is faster in the conditional version. These results are similar for Whole Portugal and Portugal Mainland.

Regarding the determinants, we find that competition (C4), primary education (EducPpc) and openness (Xpc), measured by real exports of goods per capita, have a positive influence on municipality income performance. Evidence on public investment (PubInvpc), expected to be a positive driver, does not show up as statistically significant and exhibits a negative sign. This finding is actually consistent with many studies, as to the sign and to the non-significance (Bom and Lightart 2014; Sala-i-Martin et al. 2004). Pintera (2024) reports similar findings, focusing on European

Table 3 Variables acronyms-
Source: Own elaboration.

Acronym	Variable definition
lnInpc	Natural logarithm of real per capita income
PubInvpc	Public investment per capita (real)
C4	Concentration of four major enterprises (inversely related to competition)
EducPpc	Primary education per capita
Xpc	Exports of goods per capita (real)
DAlgarve	Dummy for the Algarve region
DCenter	Dummy for the Center region

Table 4 Convergence LS for Whole Portugal (Mainland, plus the Azores, and Madeira)Source: Own elaboration

	Whole Portugal				Portugal Mainland			
	Unconditional LS (N=299)		Conditional LS (N=299)		Unconditional LS (N=278)		Conditional LS (N=278)	
	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
const	0.0965	0.0000	0.0889	0.0000	0.0969	0.0000	0.0843	0.0000
lnIncpc	-0.0197	0.0000	-0.0290	0.0000	-0.01953	0.0003	-0.0291	0.0000
PubInvpc	–	–	-0.0036	0.7261	–	–	-0.0016	0.8845
C4	–	–	-0.0005	0.0085	–	–	-0.0005	0.0472
EducPpc	–	–	0.2853	0.0415	–	–	0.3153	0.1364
Xpc	–	–	0.0015	0.0001	–	–	0.0014	0.0014
DAlgarve	–	–	0.0522	0.0000	–	–	0.0516	0.0000
DCenter	–	–	0.0103	0.0137	–	–	0.0096	0.0253

Table 5 Conditional Quantile approach for Whole Portugal (Mainland, plus the Azores, and Madeira)Source: Own elaboration

Variables	τ (quantile)	Whole Portugal				Portugal Mainland			
		Unconditional (N=299)		Conditional (N=299)		Unconditional (N=278)		Conditional (N=278)	
		Coeff	p-value	Coeff	p-value	Coeff	p-value	Coeff	p-value
const	0.25	0.0721	0.0000	0.0633	0.0000	0.0721	0.0000	0.0715	0.0000
	0.50	0.0948	0.0000	0.0824	0.0000	0.0941	0.0000	0.0799	0.0000
	0.75	0.1187	0.0000	0.1024	0.0000	0.1191	0.0000	0.0939	0.0000
lnIncpc	0.25	-0.0145	0.0002	-0.0208	0.0000	-0.0145	0.0004	-0.0199	0.0000
	0.50	-0.0175	0.0000	-0.0255	0.0000	-0.0170	0.0000	-0.0241	0.0000
	0.75	-0.0226	0.0000	-0.0304	0.0000	-0.0227	0.0000	-0.0318	0.0000
PubInvpc	0.25	–	–	-0.0055	0.6252	–	–	-0.0022	0.8627
	0.50	–	–	-0.0106	0.3173	–	–	-0.0104	0.3191
	0.75	–	–	-0.0081	0.3823	–	–	-0.0072	0.6388
C4	0.25	–	–	-0.0006	0.0007	–	–	-0.0006	0.0015
	0.50	–	–	-0.0003	0.0471	–	–	-0.0002	0.1334
	0.75	–	–	-0.0001	0.5882	–	–	0.0000	0.9373
EducPpc	0.25	–	–	0.3118	0.0261	–	–	0.1959	0.2283
	0.50	–	–	0.2711	0.0118	–	–	0.2716	0.0192
	0.75	–	–	0.2258	0.0617	–	–	0.3162	0.0456
Xpc	0.25	–	–	0.0009	0.0170	–	–	0.0008	0.0013
	0.50	–	–	0.0009	0.0094	–	–	0.0008	0.0125
	0.75	–	–	0.0010	0.0005	–	–	0.0009	0.0100
DAlgarve	0.25	–	–	0.0517	0.0000	–	–	0.0526	0.0000
	0.50	–	–	0.0498	0.0000	–	–	0.0492	0.0000
	0.75	–	–	0.0549	0.0000	–	–	0.0546	0.0000
DCenter	0.25	–	–	0.0079	0.0685	–	–	0.0073	0.0912
	0.50	–	–	0.0054	0.1130	–	–	0.0045	0.2056
	0.75	–	–	0.0038	0.3502	–	–	0.0040	0.3807

regions and employing a different methodology. In particular, the author finds that investment is not significant, while business-related variables and education play a role. The size of municipalities does not appear as a determinant (a result in line with Giesen and Südekum 2011).

Two regions, Algarve (DAlgarve) and Center (DCenter), stand out as having specific characteristics, both with a positive impact on income performance, particularly the former. These regions do appear to have better growth performance, the former because of a greater recovery and the latter because it includes about 1/3 of the municipalities.

For Portugal Mainland we found similar significant determinants, except for primary education, which is not significant, although close to being significant on average at the 10% level. The overall similarity is eventually also influenced by the fact that the island municipalities are only about one-tenth of the full municipality set.

For the sake of robustness, we also employ the Conditional Quantile Regression, overcoming eventual deviations from Normality and, importantly, allowing us to capture heterogeneity. To ensure robust inference, and given the heteroskedasticity found in LS regressions, we also use robust standard errors (Koenker and Zhao 1994) and report the p-values that correspond to the implied t-ratios for the conditional quartile coefficients. The 1st quartile ($\tau=0.25$) of the conditional distribution corresponds to low-growth municipalities, whereas the 4th quartile ($\tau=0.75$) corresponds to high-growth municipalities. From Table 5, we observe some heterogeneity; determinants have varying significance across quartiles and show some differences between Whole Portugal and Portugal Mainland.

Based on the Whole Portugal results, the speed of convergence is highest for high-growth municipalities, followed by median-growth municipalities, while low-growth municipalities converge the slowest. These results emerge from both conditional and unconditional regressions. Competition (C4) only stimulates low and median-growth municipalities, and public investment does not play a role across the quartiles. This result complements Calegari et al. (2023) by pointing out the heterogeneous role of public investment and adding the market organization determinant. In turn, primary education is always relevant, as found in Sala-i-Martin et al. (2004). Re-estimating the same regression but with secondary education instead of primary, interestingly yields a smaller impact from education but increases the estimated speed of convergence. Marquez-Ramos and Mourelle (2019) also find that education matters nonlinearly for growth in Spain and its respective regions, with impacts that differ across regions. Odoardi and Muratore (2019) results for regional convergence and growth after the financial crisis point out that human capital, namely education, is especially important for the southern (low-income) regions. Cutrini (2019) provides evidence of a divergence path in Europe after the crisis but shows that knowledge-intensive activities have a positive role in growth, thereby contributing to heterogeneous behaviour. Remarkably, openness (Xpc) also plays a significant role in every quartile. Finally, as to regional behavior, in the end only the Algarve (DAlgarve) survives the quartile splitting analysis, whereas the Center (DCenter) better performance is restricted to the first quartile.

For Mainland, education (EducPpc) shows up significant for the median and high-growth quartiles. Public investment remains non-significant and with a negative sign.

This evidence, from both Whole Portugal and from Portugal Mainland, is possibly due to contradictory effects resulting from stimulus on the one hand, and crowding-out on the other, or due to the nature of the investment itself. Competition (C4) and openness (Xpc) have a positive influence on municipality income performance. For competition, this influence is relevant just in the 1st quartile, while openness, as captured by the real exports of goods per capita, improves performance in all quartiles. The same two regions, Algarve (DAlgarve) and Center (DCenter), have specific characteristics, the former with an always positive impact on income performance and the latter with a positive one on average and only in the first quartile, as observed for Whole Portugal. We confirm that the speed of convergence is larger for the high-growth municipalities, followed by the median, while the low-growth municipalities are the slowest to converge. These results emerge from both conditional and unconditional regressions. Patel et al. (2021) further emphasise the presence of heterogeneity and report that middle-income economies tend to outperform their low-income counterparts.

A concise view of the speed of convergence and corresponding half-life from previous exercises makes clear the catching-up of municipalities for real per capita income in the aftermath of 2014 and before the 2020 pandemic outbreak (Table 6).

Regarding the speed of convergence, it is noticeable that municipalities in the upper tail of the conditional growth distribution present a faster rate than all others and the LS estimate (mean), for either conditional or unconditional growth regressions. In terms of magnitude, we do not observe meaningful differences between Portugal as a whole and the Mainland, but the magnitude of the speed of convergence when taking into account that not all municipalities converge to a common steady state (that is, conditional convergence speed) is consistently larger than obtained from the unconditional version (that is, assuming a common steady state). In other words, converging to one's steady state is faster than converging to a common one. Overall, the magnitudes match existing evidence on growth empirics, around 2%.

The respective half-lives point out values ranging from 20 to 46 years to overcome half the gap to steady state. These values are consistently larger when considering a

Table 6 Speed of convergence and half-lifeSource: Own elaboration

		Unconditional			Conditional	
			Whole Portugal	Portugal Mainland	Whole Portugal	Portugal Mainland
Speed of convergence	τ (quantile)	0.25	1.5%	1.5%	2.2%	2.1%
		0.50	1.8%	1.8%	2.7%	2.6%
		0.75	2.4%	2.4%	3.3%	3.5%
	LS		2.1%	2.1%	3.1%	3.1%
Half-life (years)	τ (quantile)	0.25	46	46	32	33
		0.50	38	39	25	27
		0.75	29	29	21	20
	LS		33	34	22	22

The speed of convergence is computed using the ln of initial real per capita income; the half-life is the number of years for a municipality to cover halfway to its steady-state level of real per capita income (e.g., Mello and Perrelli 2003)

common steady state (i.e., unconditional convergence, the minimum being 29 years) rather than the own steady state.

Interestingly, conditional regression results show stronger convergence, meaning that initial conditions are unequal and matter for growth. This points to an eventually strong recovery, possibly overcoming the crisis drop, and is in line with Sánchez de la Vega et al. (2019) findings for Spanish autonomous communities.

The evidence in Table 6 for the conditional quantiles is highlighted in Fig. 3. Remarkably, when displaying the conditional deciles estimates (with robust confidence intervals of Koenker and Machado 1999) along with the LS estimates, we verify their concavity and downward-sloping behaviour, in line with previous literature findings. This means that the scale of the Portuguese distribution of real per capita income across municipalities is shrinking over time, which can be seen as a refinement of the convergence definition, as provided by Koenker and Machado (1999). Succinctly, our results find support in previous evidence, including a reinforced view on the concept of convergence, which takes into account the reduction in the scale of the distribution.

We are now able to answer questions Q1-Q4. Regarding Q1 and Q2, our results show evidence of the catching up of real per capita income among municipalities, both for Portugal as a whole and for Portugal Mainland only. However, regarding Q3, these two samples differ in a determinant. While exports (Xpc) are a common determinant, playing a role across the spectrum of municipalities, primary education (EducPpc) shows relevance for median and high-growth municipalities and competition (C4) for the low-growth quartile. Public investment (PubInvpc) never helps explain the dependent variable. Concerning Q4, the results also show that municipalities in the left tail of the conditional distribution of real per capita income converge more slowly than those in the upper tail; in this way, the scale of the distribution shrinks, which further supports convergence. From a geographical point of view, two regions emerge from the analysis as statistically different from the rest – Algarve (DAlgrave) and Center (DCenter), with Algarve always standing out as a high grower.

Portugal is a country situated in the less developed part of the North-South Divide in Europe, thus affected by the existing asymmetry in the convergence stance, which is weaker for the poorest regions. This is a call for action, namely, fostering the growth determinants found significant at the municipality level.

Taking together the determinants found relevant and the pillars of the Recovery and Resilience Plan (RRP), two main strands of policy emerge. First, human capital-related issues are a driver of economic performance: fostering education and rewarding highly skilled workers promotes the generation of ideas, R&D, and innovation. On the other strand there are structural policies aimed at the organization of markets, outward-looking stance, and investment. Ensuring competition and free initiative is a *sine qua non condition* for providing incentives towards innovation and growth (but regulation and supervision are also indispensable). Moreover, an outward-looking view, supporting market openness, facilitates knowledge acquisition and business scaling. This finding reinforces Capello and Perucca (2015) at a finer territorial level and is in line with Bolea et al. (2018) findings which, while identifying a trend break in convergence in European Union countries with the 2008 crisis, reinforce the role of trade and knowledge-intensive activities as key determinants for growth. Invest-

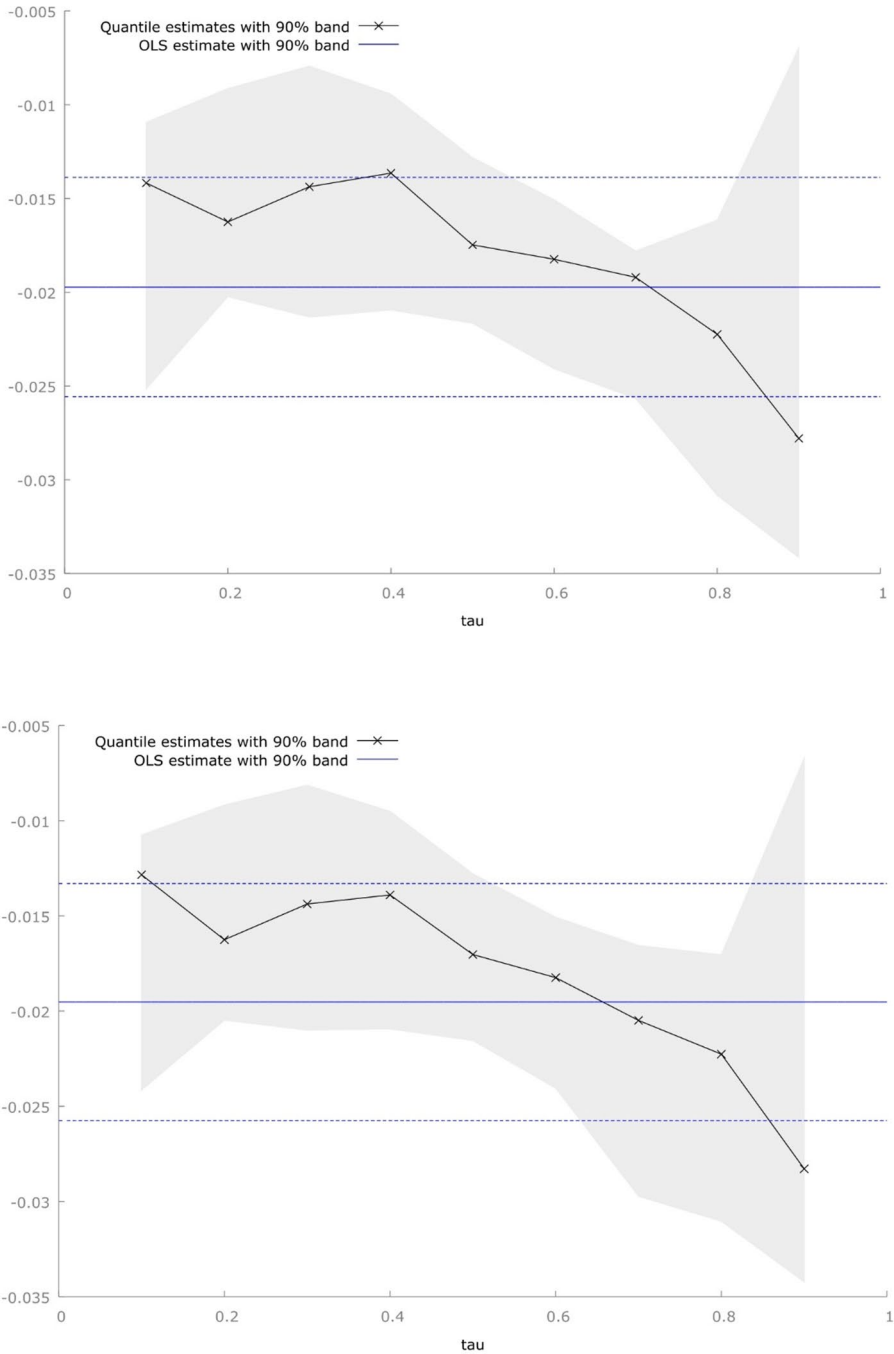


Fig. 3 Unconditional convergence for Whole Portugal (up) and the Portugal Mainland (down).Source: Own elaboration.

ment, as capacity building, technology enhancement and including public capital, may also be a key driver. Results from Perez-Montiel and Manera (2022) indeed support a positive but heterogeneous role for public investment in infrastructure as an instrument to foster growth. Capello et al. (2024), too, find effectiveness of Cohesion Policy funds for convergence, as these contributed to the recovery of European Regions that occurred in 2014–2019. Eventually, private investment also has a role, possibly benefiting from public investment. Not all kinds of public capital are fitted (Pereira 2000).

5 Concluding remarks, limitations, and extensions

Since its creation in 1993, Europe's cohesion policy has been concerned with ensuring a level playing field by addressing regional growth disparities. Recent events like the COVID-19 pandemic and, before that, the financial crisis, may have delayed this desired convergence. But to what extent did convergence occur between these two crises, in particular in the countries located in less developed geographies and that most heavily experienced the referred extreme events, such as Portugal?

Employing municipality data extracted from PORDATA for the inter-crisis period of 2014–2019 and applying cross-section growth regressions estimated by LS and by Conditional Quantiles, this paper inspects the existence of sigma and beta convergence in Mainland and Portugal's full territory. Sigma convergence is shown to exist, and beta convergence details that this convergence is faster for municipalities in the upper tail of the conditional growth distribution. Exports (Xpc) exhibit explanatory power for the entire spectrum of municipalities, while competition (C4) and primary education (EducPpc) stand as important determinants of this convergence, the former for the low-growth municipalities and the latter for the median and high growth quartiles, although with heterogeneous magnitude, in line with Cuestas et al. (2021). In turn, public investment (PubInvpc) does not have a role in explaining convergence, perhaps due to contradictory effects resulting from stimulus on the one hand, and crowding-out on the other. These issues are twinned with some RRP pillars. Interestingly, the size of municipalities does not play a role in the growth regressions; that is, Gibrat's law (growth rates are independent of size) holds for Portuguese municipalities.

Concerning heterogeneity across municipalities and the limited local government influence, our results reinforce the differential and mild effect of institutional reforms, namely decentralization (Hammond and Tosun 2011; Tosun and Yilmaz 2010). This calls attention to the supporting and incentive management role of planning as a coordinating and supporting tool to promote development in its several dimensions, in line with recent views about planning that focus on motivations, governance, and interaction of players at various scales (e.g., Purkarthofer et al. 2021).

The policy implications derived from our findings emphasize (i) tailored programs; (ii) continually improving pathways, such as education and openness, and (iii) policy stances and actions that warrant particular attention (namely competition and public investment).

Municipalities should have development strategies tailored to their specific conditions, combining investments in innovation for dynamic regions with basic infrastructure for structurally weaker ones. Central to all cases is strengthening education—through expanded access, higher teaching quality, and better-aligned vocational training—alongside improving external integration via transport links, digital connectivity, and support for firms engaging with broader markets. Reforms in competition and public investment also need to be context-specific. Competition measures should be introduced where local entrepreneurial capacity can respond, while weaker municipalities may first require institutional and capacity-building support. Public investment must be better targeted and monitored, with stronger administrative capabilities and rigorous project evaluation to ensure that spending yields real productivity gains.

Conducting empirical work always presents limitations. We focused on cross-section econometrics, parametric and nonparametric, but did not explore spatial modeling alternatives or dataset group splitting. A deeper look into regions, club convergence, and potential differences is an avenue for future research, with spatial econometrics and the Phillips and Sul (2007) approach. A possible approach may consider measures of inequality and spatial dependence that account for the associations between real per capita GDP in neighbouring regions (as in Panzara and Postiglione, 2020). We also plan to develop a regression tree approach, resorting to alternative clustering methods inspired by the results of König and Ohr (2013), besides applying dynamic panel data and dealing with structural breaks that allow for broadening the time span. Last but not least, a study on the period after the pandemic would be advisable to inspect the COVID-19 effects, as well as the impact of the Recovery and Resilience Plan.

Appendix

List of PORDATA series with the original definition:

- Gross value added of non-financial enterprises: total and by sector of economic activity, Euro - Constant Prices, CPI - Base=2016 - Thousands.
 - Total.
- Resident population: total and by age group.
 - Total.
- Town council expenditure: total, current and capital; Euro - Constant Prices, CPI - Base=2016 - Thousands.
 - Capital expenditure.
- Inhabitants per doctor and pharmacist, Ratio.

- Inhabitants per doctor.
 - Inhabitants per pharmacist.
- Enrolled students in pre-school, primary, lower secondary and upper-secondary education: total and by level of education, Individual.
 - 1 st cycle plus 2nd cycle plus 3rd cycle.
 - 1 st cycle plus 2nd cycle plus 3rd cycle plus upper-secondary education.
- Analogue main lines telephone stations: total and by type, Telephone access/station.
 - Residential.
 - Professional.
- Average number of students by computer with Internet connection in primary, lower secondary and upper-secondary education: total and by level of education, Ratio.
 - Total.
- Employees: total and by level of education, Individual.
 - Total.
 - Higher.
- Average monthly earnings of employees: total and by level of education; Euro - Mean - Constant Prices, CPI - Base=2016.
 - Higher.
- Average monthly earnings of employees: total and by qualification level; Euro - Mean - Constant Prices, CPI - Base=2016.
 - Supervisors, Foremen and Team Leaders.
 - Highly skilled workers.
- Total incomes of tourist accommodations: total and by type of establishment, Euro - Constant Prices, CPI - Base=2016 – Thousands.
 - Total.
- Proportion of foreign guests in tourist accommodations, Individual - Proportion - %.
 - Total.

- Value of goods imported and exported by enterprises, Euro - Constant Prices, CPI - Base=2016.
 - Exports.
- Non-financial enterprises per 100 inhabitants.
 - Enterprises per 100 inhabitants.
- Concentration of turnover and of gross value added of the four non-financial enterprises, %.
 - Concentration indicator of turnover of the four major enterprises.
- Non-financial individual business: total and by sector of economic activity, Enterprise.
 - Total.
- Non-financial enterprises: total and by sector of economic activity, Enterprise.
 - Total.
 - Information and communication activities.
 - Professional, scientific, technical and similar activities.
- Non-financial enterprises: total and by size, Enterprise.
 - Small- and medium-sized enterprises.
 - Large enterprises.
- Non-financial enterprises with fewer than 10 personnel employed as a % of total non-financial enterprises, Proportion - %.
 - Enterprises with fewer than 10 personnel employed as a % of total enterprises.
- Birth, death, and survival rates of non-financial enterprises, Rate - %.
 - 1-Year survival rate.
 - Birth rate.

Author contributions All authors contributed to the study conception. Original draft preparation, review, and editing were performed by Margarida Catalão-Lopes. Methodology, data collection, and econometric analysis were implemented by Joaquim P. Pina. Results interpretation was carried out by both authors. All authors read and approved the final manuscript.

Funding Open access funding provided by FCT|FCCN (b-on). Margarida Catalão-Lopes acknowledges financial support from FCT – Foundation for Science and Technology, I.P., under project UID/97/2025

(CEGIST). Joaquim P. Pina acknowledges funding by national funds through FCT - Fundação para a Ciência e a Tecnologia, I.P. (Portugal), through the projects UID/4292/2025 and UID/PRR/4292/2025 granted to MARE - Marine and Environmental Sciences Centre, and the project LA/P/0069/2020 (<https://doi.org/10.54499/LA/P/0069/2020>) granted to the Associate Laboratory ARNET - Aquatic Research Network.

Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

References

- Agasisti T, Bertolletti A (2022) Higher education and economic growth: a longitudinal study of European regions 2000–2017. *Socio-Econ Plann Sci* 81:100940. <https://doi.org/10.1016/j.seps.2020.100940>
- Atkeson A, Kehoe P (2005) Modeling and measuring organization capital. *J Polit Econ* 113(5):1026–1053. <https://doi.org/10.1086/431289>
- Barros PB, Garoupa N (1996) Portugal-European Union convergence: some evidence. *Eur J Polit Econ* 12(3):545–553. [https://doi.org/10.1016/S0176-2680\(96\)00015-8](https://doi.org/10.1016/S0176-2680(96)00015-8)
- Benczes I, Szent-Ivanyi B (2015) The European economy in 2014: fragile recovery and convergence. *J Common Mark Stud* 52(S1):162–180. <https://doi.org/10.1111/jcms.12266>
- Bolea L, Duarte R, Chóliz J (2018) From convergence to divergence? Some new insights into the evolution of the European union. *Struct Change Econ Dyn* 47:82–95. <https://doi.org/10.1016/j.strueco.2018.07.006>
- Bom P, Lightart J (2014) What have we learned from three decades of research on the productivity of public capital? *J Econ Surveys* 28(5):889–916. <https://doi.org/10.1111/joes.12037>
- Braga V (2003) Regional growth and local convergence: Evidence for Portugal. ERSA conference papers, European Regional Science Association
- Brock G (2020) The real Oaxaca decomposition: convergence within Mexico's Oaxaca region in the twenty-first century—do types of crime and religious belief matter? *Econ Change Restruct* 53:543–569. <https://doi.org/10.1007/s10644-019-09255-7>
- Cabral S, Campos MM (2023) European structural funds and the performance of Portuguese firms. *Banco de Portugal Economic Stud*, IX(1)
- Calegari E, Ferrara AR, Freo M, Reggiani A (2023) The heterogeneous effect of European Union cohesion policy on regional well-being. *Eur Urban Reg Stud* 30(4):311–318. <https://doi.org/10.1177/09697764231188304>
- Capello R, Perucca G (2015) Openness to globalization and regional growth patterns in CEE countries. *J Common Mark Stud* 53(2):218–236. <https://doi.org/10.1111/jcms.12157>
- Capello R, Ciappei S, Lenzi C (2024) EU Cohesion Policies and interregional inequalities in disruptive times. *Eur Urban Reg Stud* 32(2):124–145. <https://doi.org/10.1177/09697764241284416>
- Cincera M, Delanote J, Mohnen P, Santos A, Weiss C (2020) Intangible investments and productivity performance. GEE Papers 145, Gabinete de Estratégia e Estudos, Ministério da Economia, revised Mar 2020
- Conley TG (1999) GMM estimation with cross-sectional dependence. *J Econ* 92(1):1–45. [https://doi.org/10.1016/S0304-4076\(98\)00084-0](https://doi.org/10.1016/S0304-4076(98)00084-0)
- Corrado C, Haskel J, Jona-Lasinio C, Iommi M (2022) Intangible capital and modern economies. *J Econ Perspect* 36(3):3–28. <https://doi.org/10.1257/jep.36.3.3>

- Crafts N, O'Rourke KH (2014) Twentieth century growth. Handbook of Economic Growth, vol 2A. ed. Philippe Aghion and Steven N. Durlauf (Elsevier)
- Crouzet N, Eberly J, Eisfeldt A, Papanikolaou D (2022) The economics of intangible capital. *J Econ Perspect* 36(3):29–52. <https://pubs.aeaweb.org/doi/pdfplus/https://doi.org/10.1257/jep.36.3.29>
- Cuestas J, Monfort M, Ordóñez J (2021) The education pillar of the Europe 2020 strategy: a convergence analysis. *Empirica* 48:1113–1129. <https://doi.org/10.1007/s10663-021-09504-x>
- Cutrini E (2019) Economic integration, structural change, and uneven development in the European Union. *Struct Change Econ Dyn* 50:102–113. <https://doi.org/10.1016/j.strueco.2019.06.007>
- De La Roca J, Puga D (2017) Learning by working in big cities. *Rev Econ Stud* 84(1):106–142. <https://doi.org/10.1093/restud/rdw031>
- Sánchez de la Vega J, Buendía Azorín J, Calvo-Flores Segura A, Yago M (2019) A new measure of regional competitiveness. *Appl Econ Anal* 27(80):108–126. <https://doi.org/10.1108/AEA-07-2019-0010>
- Doré NI, Teixeira AAC (2021) Empirical literature on economic growth, 1991–2020: Uncovering Extant Gaps and Avenues for Future Research. *Global J Emerg Market Economies* 15(1):7–37. <https://doi.org/10.1177/09749101211061626>
- Duranton G, Puga D (2014) The growth of cities. In: Handbook of economic growth, Vol. 2A, ed. Philippe Aghion and Steven N. Durlauf (Elsevier)
- Duranton G, Puga D (2020) The economics of urban density. *J Econ Perspect* 34(3):3–26. <https://pubs.aeaweb.org/doi/pdfplus/https://doi.org/10.1257/jep.34.3.3>
- Duranton G, Puga D (2022) Urban Growth and its Aggregate Implications, available at <https://diegopuga.org/papers/hcgrowth.pdf>
- Durlauf SN, Fafchamps M (2005) Social Capital. In: Handbook of Economic Growth, Vol. 1B, ed. Philippe Aghion and Steven N. Durlauf (Elsevier)
- Durlauf SN, Quah DT (1999) The new empirics of economic growth. In: Taylor JB, Woodford M (eds) Handbook of Macroeconomics, vol 1. North-Holland, Amsterdam
- Durlauf SN, Johnson PA, Temple JRW (2005) Growth Econometrics, in Handbook of Economic Growth, Vol. 1A, ed. Philippe Aghion and Steven N. Durlauf (Elsevier)
- Eyre PW, Grover D (2024) Regional divergence in France and international integration: is foreign direct investment attraction policy part of the problem? *Eur Urban Reg Stud*. <https://doi.org/10.1177/09697764241276196>
- Fan G, He L, Wei X, Han L (2013) China's growth adjustment: moderation and structural changes. *Econ Change Restruct* 46:9–24. <https://doi.org/10.1007/s10644-012-9135-2>
- Furcer D (2005) β and σ -convergence: a mathematical relation of causality. *Econ Lett* 89(2):212–215. <https://doi.org/10.1016/j.econlet.2005.05.026>
- Ghoshray A, Khan F (2015) New empirical evidence on income convergence. *Empir Econ* 49:343–361. <https://doi.org/10.1007/s00181-014-0869-8>
- Giesen K, Südekum J (2011) Zipf's law for cities in the regions and the country. *J Econ Geogr* 11(4):667–686. <https://doi.org/10.1093/jeg/btq019>
- Gretl (2023) Gnu regression, econometrics and time-series library, available at <https://gretl.sourceforge.net/>
- Guerreiro G, Caleiro A (2015) The Spatial Convergence of Knowledge in Portugal. CEFAE-UE Working Papers 2015_08, University of Evora, CEFAE-UE (Portugal)
- Hammond G, Tosun M (2011) The impact of local decentralization on economic growth: evidence from US counties. *J Reg Sci* 51(1):47–64. <https://doi.org/10.1111/j.1467-9787.2010.00683.x>
- Jones CI (2005) Growth and ideas, In: Handbook of Economic Growth, Vol. 1B, ed. Philippe Aghion and Steven N. Durlauf (Elsevier)
- Jones CI (2016) The facts of economic growth. Handbook of Macroeconomics, vol 2. ed. John B. Taylor and Harald Uhlig (Elsevier)
- Jorgenson D, Vu K (2005) Information technology and the world economy. *Scand J Econ* 107(4):631–650. <https://doi.org/10.1111/j.1467-9442.2005.00430.x>
- Kadi J, Banabak S, Schneider A (2022) Widening gaps? Socio-spatial inequality in the “very” European city of Vienna since the financial crisis. *Cities* 131:103887. <https://doi.org/10.1016/j.cities.2022.103887>
- Koenker R, Machado J (1999) Goodness of fit and related inference processes for quantile regression. *J Am Stat Assoc* 94(448):1296–1310. <https://doi.org/10.1080/01621459.1999.10473882>
- Koenker R, Zhao Q (1994) L-estimation for linear heteroscedastic models. *J Nonparametr Stat* 3(3–4):223–235. <https://doi.org/10.1080/10485259408832584>
- König J, Ohr R (2013) Different efforts in European economic integration. *J Common Mark Stud* 51(6):1074–1090. <https://doi.org/10.1111/jcms.12058>

- MacKinnon JG, White H (1985) Some heteroskedasticity-consistent covariance matrix estimators with improved finite sample properties. *J Econ* 29(3):305–325. [https://doi.org/10.1016/0304-4076\(85\)90158-7](https://doi.org/10.1016/0304-4076(85)90158-7)
- Marquez-Ramos L, Mourelle E (2019) Education and economic growth: an empirical analysis of nonlinearities. *Appl Econ Anal* 27(79):21–45. <https://doi.org/10.1108/AEA-06-2019-0005>
- Mello M, Perrelli R (2003) Growth equations: a quantile regression exploration. *Q Rev Econ Finan* 43(4):643–667. [https://doi.org/10.1016/S1062-9769\(03\)00043-7](https://doi.org/10.1016/S1062-9769(03)00043-7)
- Odoardi I, Muratore F (2019) The role of human capital after the crisis in Italy: a regional analysis. *Socio-Econ Plann Sci* 66:58–67. <https://doi.org/10.1016/j.seps.2018.07.002>
- Panzer D, Postiglione P (2020) Measuring the spatial dimension of regional inequality: an approach based on the Gini correlation measure. *Soc Indic Res* 148:379–394. <https://doi.org/10.1007/s11205-019-02208-7>
- Patel D, Sandefur J, Subramanian A (2021) The new era of unconditional convergence. *J Dev Econ* 152:102687. <https://doi.org/10.1016/j.jdeveco.2021.102687>
- Pereira AM (2000) Is all public capital created equal? *Rev Econ Stat* 82(3):513–518. <https://doi.org/10.1162/rest.2000.82.3.513>
- Perez-Montiel J, Manera C (2022) Government public infrastructure investment and economic performance in Spain (1980–2016). *Appl Econ Anal* 30(90):229–247. <https://doi.org/10.1108/AEA-03-2021-0077>
- Phillips P, Sul D (2007) Transition modeling and econometric convergence tests. *Econometrica* 75(6):1771–1855. <https://doi.org/10.1111/j.1468-0262.2007.00811.x>
- Pintera J (2024) Regional convergence in the European Union – factors of growth between the great recession and the COVID crisis. *Econ Syst* 48(1):101169. <https://doi.org/10.1016/j.ecosys.2023.101169>
- PORDATA (2023) Database of Contemporary Portugal. Francisco Manuel dos Santos Foundation, available at <https://www.pordata.pt/en/home>
- Poveda A (2011) Economic development, inequality and poverty: an analysis of urban violence in Colombia. *Oxf Dev Stud* 39(4):453–468. <https://doi.org/10.1080/13600818.2011.620085>
- Purkarthofer E, Humer A, Raine Mäntysalo R (2021) Regional planning: an arena of interests, institutions and relations. *Reg Stud* 55(5):773–777. <https://doi.org/10.1080/00343404.2021.1875128>
- Sala-i-Martin X, Doppelhofer G, Miller R (2004) Determinants of long-term growth: a Bayesian averaging of classical estimates (BACE) approach. *Am Econ Rev* 94(4):813–835. <https://www.aeaweb.org/articles?id=10.1257/0002828042002570>
- Soares AC, Sousa R (2023) Markup premium of Portuguese exporters. *Banco de Portugal Econ Stud* 9:52
- Soukiazis E, Antunes M (2006) Two speed regional convergence in Portugal and the importance of structural funds on growth. *Ekonomia* 9(2):222–241
- Storper M (2018) Separate worlds? Explaining the current wave of regional economic Polarization. *J Econ Geogr* 18(2):247–270. <https://doi.org/10.1093/jeg/lby011>
- Tosun M, Yilmaz S (2010) Decentralization, economic development, and growth in Turkish Provinces. *Emerg Markets Finance Trade* 46(4):71–91. <https://doi.org/10.2753/REE1540-496X460405>
- Viegas M, Antunes M (2013) Convergence in the Spanish and Portuguese NUTS 3 regions: An exploratory spatial approach. *Intereconomics: Rev Eur Econ Policy* 48(1):59–66. <https://doi.org/10.1007/s10272-013-0445-z>

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.