



The spatial dimension of ageing and growth in European regions

Rosella Nicolini¹ · José Luis Roig¹

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Abstract

This study aims to tackle the potential effects of population ageing on regional growth dynamics in the EU. We collected information at a NUTS2 level for EU countries from the years 2000 to 2020 to understand the extent to which the ageing of EU society might impact the EU convergence process. Our results emphasize that the ageing of EU society does not seem to harm the possibility of regional economic growth if we think that immigrants can fill openings in local labour markets (left by retired persons), as well as new jobs stemming from new services needed by retired persons (mostly in health and daily care). Our outcomes also stress the relevance of considering the spatial dimension of the analysis to detect the place-based dimension of this dynamic and, hence, the need for tailored policies.

JEL Classification J14 · J61 · R11 · R23

1 Introduction

The European Union (EU) is called to face important demographic challenges that could possibly harm the implementation of the full EU integration process, complicating the promotion of an inclusive growth process in the spirit of both the EU chart and the UN sustainable development goal (SDG 8). Similar to other industrialized countries, the fertility rate of natives inside the EU is dropping jointly with a structural ageing tendency in Western countries. An ageing society entails important structural changes and challenges. The drop in the size of the working-age population questions the productive capacity of an economy and challenges the sustainability of an intergenerational welfare system. In the EU framework, this type of

✉ Rosella Nicolini
rosella.nicolini@uab.cat

José Luis Roig
josepluis.roig@uab.cat

¹ Departament d'Economia Aplicada, Universitat Autònoma de Barcelona, Edifici B, Campus UAB, 08193 Bellaterra (Barcelona), Spain

issue is even more relevant for the long-term growth perspective at the subnational (regional) level. The EU is committed to reducing regional inequalities inside this territory: the long-standing EU Cohesion Policy is meant to provide tailored growth-enhancing investments to support regional development, but nothing is thought specifically to tackle the consequences of an ageing society.

In regional science, the debate on how to tackle the socioeconomic consequences of ageing at a regional level has been largely discussed (with insightful contributions by Plane 2012 and Newbold 2015, among others). Both Plane (2012) and Newbold (2015) focus on the association between ageing and migration as one of the preferential avenues to tackle the question and, possibly, grant sustainable growth to ageing regions. From a strict geographical viewpoint, Newbold (2015) stresses the evidence that retired persons show a tendency to cluster. Younger elderly people move to amenity areas (and hence generate a demand for services in the destination); however, there is also a general and dominant tendency for retired persons to not move from their last place of residence. In both cases, the clustering of ageing persons entails the rise of specific demands for services (mostly healthcare or homecare) to be provided in those places. The lack of native working-age persons settled in those areas to provide the required services can be compensated by the entry of international immigrants, whose entrance in the local labour market can be an effective source of economic growth, offsetting the effect of the exit of retired persons from the labour market.¹ Under these circumstances, the ageing process does not appear to harm the economic growth perspectives of regional clusters of ageing persons.

Starting in the 2000s, the EU registered important migration flows of the working-age population. Beyond the internal mobility of persons (mostly driven by internal migration from Eastern countries to Western countries after a group of ex-socialist countries joined in 2004 onward), EU countries have been selected as preferred destinations for worldwide immigration from Latin America, Africa and Southeast Asia.²

Our study aims to explore the extent to which ageing might not be a factor harming the economic growth of EU regions in the presence of inflows of working-age immigrants. Our contribution is twofold. On the one hand, we aim at providing an original empirical analysis to assess whether spatial dependence in ageing patterns can impact the existing convergence process across all EU regions (as discussed in the EU report, 2023, for instance). On the other hand, we are interested in providing an original quantitative approximation of the impact of immigration as a tool for fueling economic growth once more, taking into account the possible spatial

¹ Some evidence proposed by the *Regional Information Centre for Western Europe—United Nations* (<https://unric.org/en/migration-to-the-eu-facts-not-perceptions/>) helps explain this reality. At the beginning of 2022, 5.3% of the EU population were non-EU citizens; the percentage of citizens not residing in their country of birth raised to 12.5 if we also include EU internal migration. In terms of occupations, non-EU workers were more present in some sectors than EU workers: hotels and restaurants (9.1% compared to 4.2 for EU workers), construction (9.1% against 6.6%), logistics and distribution (7.6% against 3.9%) and domestic work (5.9% against 0.7%).

² Source: World Migration Report 2020—International Organization for Migration.

dependence of this effect. To provide results as that are as general as possible, we will be referring to all EU regions for the period 2000–2020.³

Our empirical strategy is to implement a conditional beta convergence-style framework. EU regions have experienced an overall convergence process since the beginning of the Union due to the differences in growth rates (roughly) between Western regions and Eastern ones (Monfort 2020, for instance). The rationale of our research strategy stems from empirical evidence. In the EU, the ageing phenomenon is mostly affecting Western regions: It is expected to exacerbate the convergence process as a result of the reduction of the relative size of the working-age population in the front-runner regions in Western areas. However, the consequences of the entry of immigrants, as well as the internal displacement of citizens from Eastern to Western regions, for filling up job vacancies are expected to interfere with the convergence process and, hence, imply that the economic impact of ageing in EU Western regions is compensated by the entry of new resources in the economy.⁴ We ran our estimations by approximating ageing with two indicators: median age and dependence rate for spatial units. The dependence rate is intended to be the ratio between the population below 14 and over 65 years of age, and the population between 15 and 64 years of age in each spatial unit. This indicator, as well as the median age, are both statistically significant in the expected direction. However, since the spatial dimension is crucial to feature the dynamics of ageing migration in the European setting, they are prominently centred in the Western regions. To this end, we embed the spatial dimension in our exercise by implementing a spatial econometric framework. This is effective: Ageing and immigration turn out to be statistically significant for growth only if we take into account the spatial dimension in the analysis. In our analysis, direct spillovers confirm the existence of positive effects inside each spatial unit, whereas indirect spillovers are barely significant. Thus, the possible offsetting effect of migration on ageing is mostly place-based. In this line, we posit some insights about the channels in which this effect takes place (following the anecdotal evidence discussed in footnote 1). On the one hand, new cohorts of immigrants entering the job market generally bring more human capital than retired persons, which fuels labour productivity and, hence, growth. On the other hand, the ageing of EU society yields the creation of new occupations or tasks (mostly for the health and daily care of retired persons), which can counterbalance the economic effect of the exit of aged natives from local labour markets.

³ Bandrés et al. (2017) assessed that the business-cycle patterns across European regions are quite heterogeneous. They identify five big clusters that share different business-cycle characteristics. Furthermore, they also detect that the spatial correlation of the different regional cycles has existed and increased since the beginning of the EMU. In the light of the previous results and to avoid bias in the selection of the business cycle, we consider the largest time period (according to data availability) to guarantee a minimum number of cycles for each region of our sample.

⁴ In this contribution, we are exclusively taking into account the immigration flows in EU regions for working-age individuals. In this respect, we are not taking into account the migration flow of young elderly persons to amenity places, as discussed in Newbold (2015). However, in the EU, this type of migration flow has preferred destinations in the southern regions of Western countries: Therefore, their expected impact would be to reinforce the ageing dynamics already in place there.

In this sense, our study provides novel quantitative evidence that could contribute to the planning of policies (in particular place-based policies given the relevance of the spatial dimension) to contrast the potential negative impact of ageing on local growth perspective and social cohesion.

This contribution is structured as follows: In Sect. 2, we present the literature review and formulate the research question. In Sect. 3, we discuss our data and propose preliminary statistics, whereas in Sect. 4, we run our empirical analysis. In Sect. 5, we present our policy discussion and conclusion. Finally, in the Appendix, we include additional empirical evidence and estimation results.

2 Literature review and research hypothesis

The socioeconomic impact of an ageing society has been widely studied under different perspectives: Two of them refer to the sustainability of the social welfare in an ageing society and to the direct implications of ageing for the economic growth process. In this contribution, we focus on the latter.

In the EU, the ageing process takes place in a particular environment. Hayward and Zhang (2001) discuss the economic perspective of the demographic evolution of developed economies (including EU) experiencing decrease in fertility, but also in mortality and an increase in life expectancy. The combination of these demographic conditions nurtures the ageing trend of the population of natives for which the share of population above 50 years of age is expected to be 31.2% (on average in 2050). This important change in the demographic composition entails relevant issues from the social–economic perspective referring to the economic foundations to fuel economic growth. In this line, Börsh-Supan et al. (2014) elaborated an OLG framework to study the effect of population ageing on the interaction between economic growth, ageing, pension reforms and the target to maintain living standards despite the decline of the *support ratio* due to the reduction of the number of workers in the population. Their study approximates that a decline of the support ratio by 20% involves a reduction of 15% for the GDP per capita in comparison with a non-ageing economy. Similarly, in 2006, an empirical study proposed by Brunow and Hirte (2006) already concluded that a higher share of children and retirees would produce a drop in the current growth of GDP per capita.⁵

A way to limit this negative effect of the impact of ageing on economic perspectives is connected to the enhancement of human capital linked to migration flows (e.g. the discussion put forward by Servillo et al. 2011). But this movement generates further territorial disparities. In the case of the EU, Kashnitsky et al. (2017) concluded that EU regions experienced a convergence process during the period of 2003–2012; similar results are also discussed in Monfort (2020). This convergence seems mainly due to changes in the population demographic structure in East European regions. However, the projections show that the net migration flows

⁵ At regional level, the effect entailed by ageing on growth also generate some impacts on the evolution of regional inequality: de Menezes et al. (2012) discussed that ageing can harm the potential income convergence across generations and across regions.

across the EU tended to converge, and the consequence of this result would be that migration does not continually contribute to the convergence in population ageing places.⁶ This type of result relies on the basic hypothesis that urbanized regions tend to attract working-age populations who leave rural regions behind. The issue of the crucial consequences of outgoing migration from rural regions (fueling economic divergence) is well studied for the case of Spain. Collante et al. (2014) provided evidence about the striking impact of ageing and migration outflows from Spanish rural areas on the economic growth perspectives of these areas. At the same time, these authors include value regarding the crucial relevance of the international migration to redress their economic growth perspectives. Their analysis allows for concluding that potential rural areas that can retain international migrants (with middle-low level of human capital) are medium-large size municipalities with diversified economies and larger housing stock.⁷ Still addressing the problem to revert the consequences of ageing and depopulation dynamics, Alamà-Sabater et al. (2022) concluded that a primary mechanism to fight against the economic consequences of depopulation is to favour employment in the service sector in rural areas even if it is important to be aware that this could generate negative spillovers towards other sectors. Instead, Prenzel and Iammarino (2021) suggest that the investment in human capital is a sustainable policy measure to cope with ageing due to demographic change across the EU and, at the same time, guaranteeing economic growth conditions. Their argument is that to implement economic growth strategies, it is important to cope with demographic change by increasing labour productivity. This last outcome could be achieved by different channels: expanding the working-age population (with migration), postponing retirements or encouraging labour market access of woman or minorities, but, at the same time, there could be also room to impact productivity via technology adoption or job training. If this type of channel should be effective, ageing and economic growth could have a positive association. Acemoglu and Restrepo (2017) concluded that the positive association between ageing and growth could be due to a technological adjustment, particularly the progressive adoption of automation technology in the productive processes. To this end, these authors discuss statistical evidence for which—though it must not be taken for granted—there is a negative relationship between ageing and GDP per capita; however, this relationship is often positive. Referring to a sample of 169 countries, the authors argue that when the ageing phenomena takes place in capital abundant places, the adoption of new technologies can overcome (that is, neutralized or reverse) the negative effect on economic growth of the shrinking of the working-age population (*ibid*).

When translating this setting of analysis to the EU region, it is not so evident to detect so important differences (in terms of technological endowment) across the EU regions. Rather, EU regions experience important differences in the level of human capital and in the composition of the labour force. Therefore, our idea is to explore to which extent the positive growth in an ageing society could be also associated with a change in the composition of the labour force by considering that immigrants

⁶ This effect is also witnessed in the study proposed by Carbonaro et al. (2018).

⁷ Unfortunately, gender composition of this migration flows records numerical inferiority of woman.

can revert the general tendency for which ageing place are expected to experience a decrease in their economic growth rate. Hence, we formulate the following research hypothesis:

H₁ The entry of immigrants in ageing regions is effective to contrast the economic downturn of those locations.

3 Data and descriptive statistics

Our aim is to provide a relatively general quantitative study referring to European regions. Our scope is to propose insights under a spatial perspective that are as general as possible and going beyond the possible limitation of country or regional studies. Our data sources are the statistics published by EUROSTAT. Although, these statistics are often incomplete, their comparative advantage is to provide comparable data across EU territories over time. Referring to the NUTS2 composition of the EU in 2020, we collected all information referring to the EU regions from 2000 to 2020. Our strategy was driven by the concern of being able to deal with the same spatial units over time. Therefore, we kept the 2020 spatial layout, and we applied it to all the waves of data to get to 2000. To this end, we began with the full sample of EU NUTS2 regions (242 units) with the correspondent geographical 2020-NUTS2 layout.⁸ In addition, from the initial sample of 242 NUTS2 units, we excluded Croatia (which joined the EU in 2013) due to missing several data, as well as the overseas territories, Ceuta, Melilla, Guadalupe, Martinique, Guyana, La Réunion and Mayotte up to getting our final sample of 231 NUTS2 spatial units. Then, we applied the selected layout to all the previous annual waves of data. In the past 20 years, the NUTS2 structure of the EU experienced changes in terms of the administrative identification of the NUTS2 spatial units according to the changes in the EU regulation, but EUROSTAT statistics manage this issue and allow for handling the whole sample of 231 NUTS2 spatial units over time.⁹ Of course, identifying a unique spatial layout across data waves does not guarantee that one has all the data for all units in any data wave. The lack of data for some units and some variables means that the sample that we will deal with in the different estimations may vary between 132 observations and 231.

On average, the spatial units included in our sample experienced a positive growth rate. According to the literature discussed in Sect. 2, there was an overall increase in the dependence rate across all NUTS2 regions. The median age passed from 38.3 years to 44.2 years (on average) and the EU South-Western countries

⁸ In our initial sample, we did not include the UK and its territories because there had not yet been an agreement made between with the UK government for the diffusion of statistical data in the EUROSTAT.

⁹ More information about the different EU NUTS regulations can be found at: <https://ec.europa.eu/eurostat/web/nuts/history>

experienced the highest increase in the median age of the population (see Fig. 1 and Fig. 2).¹⁰

The target of this analysis is to emphasize the way immigration can counterbalance the ageing of the population in each spatial unit in terms of economic growth given a framework of analysis that takes into account the spatial dimension to control for effects of spatial dependence. To provide reliable statistics about the possible spatial association between ageing–immigration–growth, we performed a statistical exercise by referring to the local indicator of multivariate spatial association developed by Anselin (2017). This is a valuable tool because it identifies cluster locations for which the joint profile of two or more variables is similar to the one of the neighbours; something that is not necessarily true for an individual variable. Furthermore, the multivariate measure that is adopted by this indicator is not a simple extrapolation of univariate measures but rather a sophisticated combination of complex trade-offs for the attributes in all dimensions. The result of this index when combining the average growth rate for the period 2000–2020, the median age in 2000 and the share of immigrants over the population in 2000 (at regional level) is presented in Fig. 3.¹¹

The map presented in Fig. 3 emphasizes the existence of a quite important number of clusters for which there exists a statistical positive association among the three selected variables.¹² They are all located in the EU Western countries with a high concentration in the core of the EU. These statistics confirm the existence of a statistically significant association of the previous variables that deserve to be investigated.

Looking at data over time, the association between median age and share of immigrants, conditional on the level of GDP per capita consolidated over time (Fig. 9 and 10), leads to a certain degree of polarization across regions. In 2020, regions registering low level of GDP per capita are mostly experiencing low shares of immigration and low levels of median age, whereas the high values of GDP per capita are mostly associated with high shares of immigrants and relatively high levels of median age.

4 Empirical analysis

Our framework of analysis is modelled by following a conditional beta convergence approach: Hence, our dependent variable will be the average growth rate for each selected spatial unit and the value of selected determinants at the initial time point

¹⁰ The pyramid of the demographic composition of EU countries (Fig. 8 in the Appendix) emphasizes that the age distribution is skewed. Therefore, we include in our analysis the median age (rather than the average age) because the value of the median will not be distorted by outliers.

¹¹ In our analysis, we consider data about the share of immigrants in 2000 to avoid possible causal association between the potential attractiveness of a spatial unit (represented by the rate of growth) and the cumulated inflow of immigrants in the different NUTS2 units over time.

¹² Figure 7 in the Appendix illustrates the statistical significance of this indicator.

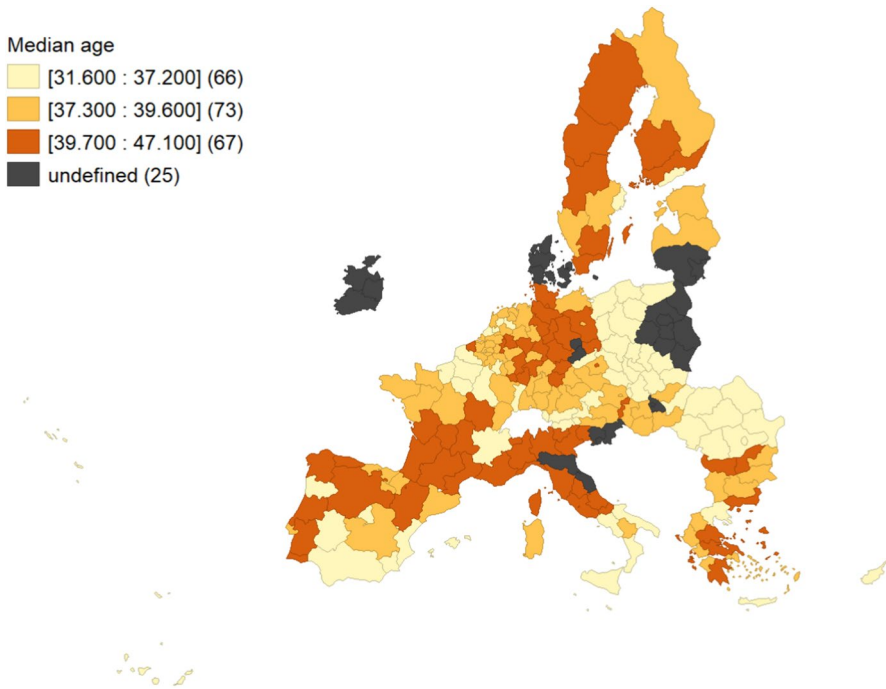


Fig. 1 Median age in Europe (2000)

of our analysis.¹³ Our principal variable of interests are the ones associated with the measurement of the economic growth and demographic composition of each of the spatial units. In our sample, we include information on the GDP per capita in purchasing power parity (PPS): These data allow for computing the average growth rate for each territory from 2000 to 2020 (*Average growth rate GDP-pc₂₀₀₀₋₂₀*) and having information of the level of GDP per capita in 2000 (here in logarithm—*Log GDP-pc₂₀₀₀*—to stabilize the variance of the series).¹⁴ As for demographic features, we consider the median age of the population in 2000 (*Median age₂₀₀₀*), and the dependence rate (*Dependence ratio₂₀₀₀*) for each NUTS2 spatial unit intended as the ratio between the population aged below 15 and above 65, over the total population

¹³ This type of approach allows to control for potential endogeneity due to simultaneous effect between the dependent variable and selected covariates. This is the type of strategy exploited in the literature to address this type of questions as, for instance, in Bisciari et al. (2020), Llorens i Jimeno and Mestres Domènech (2020), Monfort (2020) or Maestas et al. (2023).

¹⁴ Figures 4 and 5 in the Appendix present the spatial distribution of GDP per capita in PPS (in 2020) and the average growth of the GDP per capita in PPS, respectively. In performing our analysis, we follow the same strategy applied by Monfort (2020) or Bisciari (2020). According to the accounting methodology adopted by EUROSTAT, GDP per capita in PPS eliminates the differences in price levels between countries allowing reliable volume comparisons of GDP between countries (source: <https://ec.europa.eu/eurostat/databrowser/view/tec00114/default/table?lang=en>).

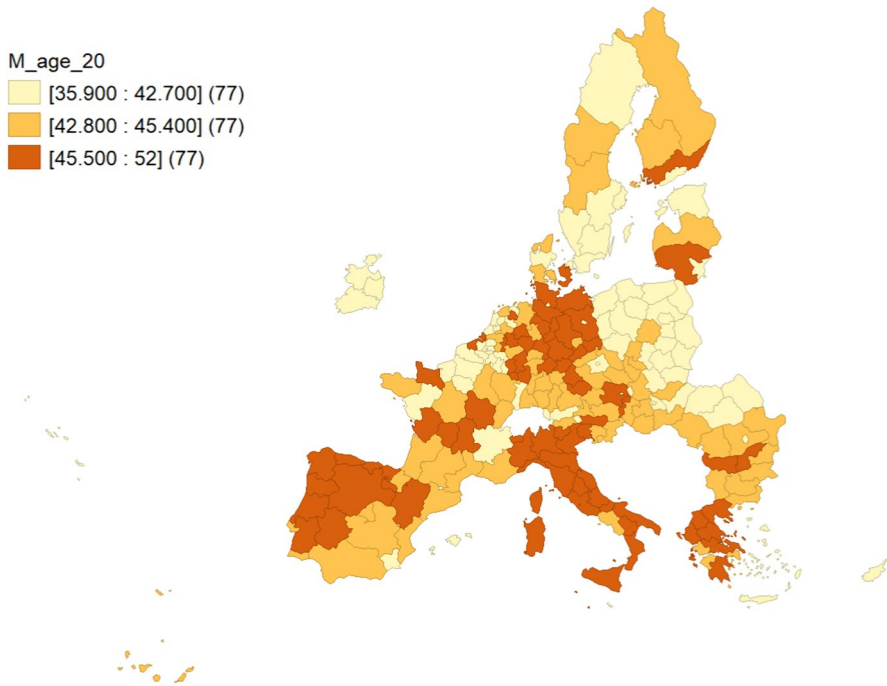


Fig. 2 Median age in Europe (2020)

between 15 and 64.¹⁵ Finally, we consider share of the stock of immigrants in working age between 15 and 64 (over the total population) in the host spatial units in 2020 (here in logarithm—*Share Immigrants*₂₀₀₀—to stabilize the variance of the series).¹⁶

First, we implement an econometric estimation to assess the relationship between growth and demographic change. Then, we augmented our setting to embed the spatial dimension by taking into consideration the spatial proximity of the different spatial units.

For each spatial unit, s , our baseline estimation is:

$$\begin{aligned} \text{Av growth rate GDPpc}_{s2000-20} = & \beta_0 + \beta_1 \text{Log GDPpc}_{s2000} \\ & + \beta_2 \text{LogMedian age}_{s2000} \\ & + \beta_3 \text{LogDepend ratio}_{s2000} + \beta_4 \text{LogShare immigrant}_{s2000} + \epsilon_s \end{aligned} \quad (1)$$

¹⁵ This indicator aims at embedding the proportion of persons that are retired or too young to have regular employment over the total population with the proper age to be active in the labour market; it is also an approximation of the capacity of the employed persons to sustain the no-active population. In an ageing society, this indicator is expected to increase over time.

¹⁶ As is quite common in the literature, immigrants are classified according to the place (country) of birth.

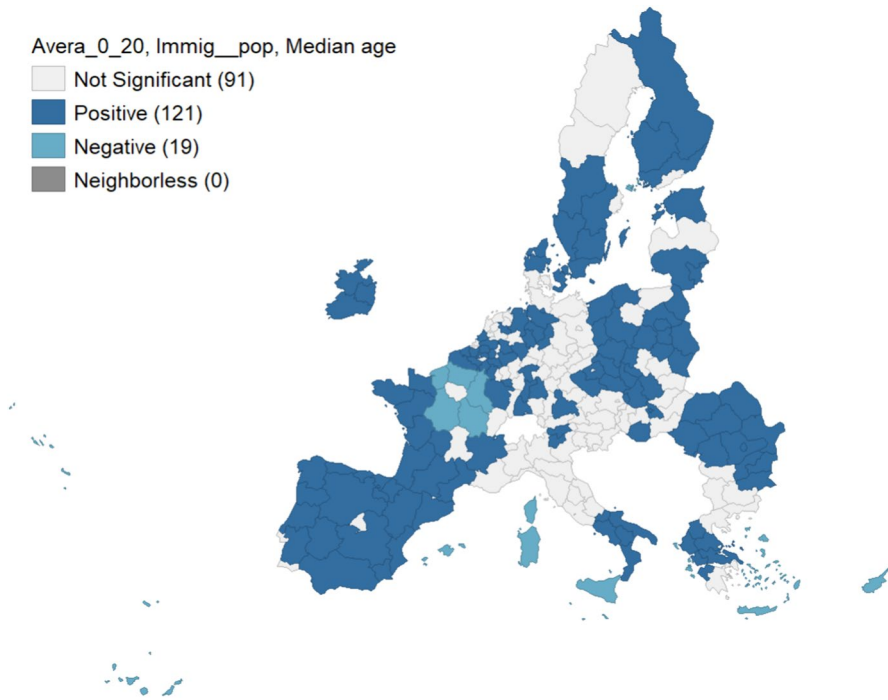


Fig. 3 Local indicator of multivariate spatial association

According to Eq. (1), the conditional beta convergence process takes place when the estimated coefficient β_1 is negative, and this tendency can be exacerbated if the estimates of the coefficients β_2 or β_3 turn to negative and statistically significant emphasizing that the ageing process in richest EU regions (the Western ones) drops their rate of growth and, hence, favours the catch-up of the Eastern ones. Instead, immigrants can play a counterbalancing role if β_4 turns to be positive (H_1).

Descriptive statistics referring to our variables are included in Table 1.

The results of our estimations for our selection of EU regions are presented in Table 2. It is worth noting that all observations in our sample shared an identical institutional dimension given by the general umbrella to be members of the EU, but each local spatial unit shared national institutional features changing over the two decades, as well, which could have an impact, for instance, on social policies like the age of retirement or the health services to retired people. To take into account this particular dimension, we correct the error of our estimation by clustering them by (EU) country.

Table 1 Descriptive statistics

Variable	Obs	Mean	Std. Dev	Min	Max
Average growth rate GDP-pc ₂₀₀₀₋₂₀	231	0.51	0.31	-0.021	1.54
Share immigrants ₂₀₀₀	132	0.08	0.06	0.003	0.30
Dependence ratio ₂₀₀₀	209	49.34	4.77	38.7	64.2
GDP-pc ₂₀₀₀	231	17,933.77	7784.884	3400	47,800
Median age ₂₀₀₀	206	38.3	2.52	31.6	47.1

Table 2 Basic estimations. Dependent variable: Average growth rate GDP per capita (2000–2020)

	OLS	OLS	OLS	OLS	OLS
Constant	4.58*** (0.73)	7.74*** (1.48)	6.61*** (0.90)	2.40* (1.4)	0.10 (1.70)
Log GDP-pc ₂₀₀₀	-0.42*** (0.07)	-0.40*** (0.09)	-0.39*** (0.08)	-0.13 (0.11)	-0.12 (0.14)
Log depend ratio ₂₀₀₀		-0.87** (0.13)		-0.21 (0.14)	
Log median age ₂₀₀₀			-0.64 (0.011)		0.36 (0.27)
Log share immig ₂₀₀₀				0.07* (0.03)	0.08* (0.04)
Mean VIF	1	1.01	1.17	1.40	1.36
Obs	231	209	206	132	132
R-squared	0.47	0.54	0.51	0.13	0.13
AIC	-26.58	-61.74	-50.84	-131.56	-131.30
BIC	-19.69	-51.72	-40.85	-120.02	-119.77

Level of significance: *** 1%, ** 5% and * 10%. Standard errors are shown in brackets. Error correction: Clustered by country

In Table 2, the VIF statistics assess that the regressors included in the selected specifications do not suffer from multicollinearity problems.¹⁷ First, in the period of 2000–2020, the EU NUTS2 territory followed an economic convergence process (the coefficient β_1 is negative), and our results are conclusive about the role of ageing when considering the dependency rate as proxy for ageing (β_3 is negative), but the estimates referring to the other proxy (*Median age₂₀₀₀*) are inconclusive.¹⁸ In terms of economic convergence among EU regions, our results are in line with the discussion proposed by Monfort (2020) and Bisciari et al. (2020) according to which the convergence among the EU region is still

¹⁷ According to the rule of thumb discussed in Theil (1971), VIF coefficients equal or larger than 10 confirms that there exists important multicollinearity among regressors and needs to be corrected. Values for VIF lower than 3 do not create concerns for multicollinearity.

¹⁸ Figure 6 in the Appendix shows the spatial distribution of local clusters of convergence. In this line, Auciello and Puente (2023) identify that ageing in areas with the highest income per capita is acting as a factor pushing towards economic convergence in Spanish regions.

present even if at a different pace, but not reversed. The estimates for the share of immigrants (β_4) are positive and statistical significant as one could expect from the discussion presented in Sect. 2 (H_1); however, the introduction of this variables pushes the estimates of the other components of Eq. (1) to lose their statistical significance.¹⁹ In terms of goodness-of-fit, beyond the value of the R-squared, we include the Bayesian Information Criterion (BIC) and the Akaike Information Criterion (AIC) statistics. The AIC and BIC statistics inform about the statistical quality of the different estimated models.²⁰ According to these statistics, when including all regressors, the quality of the model improves a lot.

Having estimated the baseline models, we proceeded to perform some additional estimations to explore additional results that can stem from this first set of estimations. The models proposed in Table 2 stem from the general idea to take into account a whole business cycle knowing that the expansion and recession period are not identical for all regions.²¹ However, we performed an additional analysis by splitting our sample into two subsamples: the former focusing on the period 2000–2010 and the latter from 2011 to 2020. According to Monfort (2008) and Bisciari (2020), the former period will mostly include an expansion period in the EU (our statistics for the average growth rate of the GDP per capita in PPS_{2000–2010} is about 0.33), whereas the latter includes part of the recession and a recovery period (according to our statistics, the average growth rate of the GDP per capita in PPS_{2011–2020} is about 0.15). Estimations of outputs are included in Table 5. As for the convergence issue, the two sets of estimations confirm that the convergence process was much more robust during the period 2000–2010 than in 2011–2020 (as in Monfort 2020 or Bisciari 2020). However, the estimation of the impact of the demographic determinants in the two subperiods is rather inconclusive: The only consistent statistically significant effect is the one referring to the negative impact of the increase in the dependence ratio on the average growth.

Another interesting question to explore is the extent to which the convergence-style model should be preferred to a panel model. A convergence-type model is expected to control for the endogeneity problem, but the same issue could also be addressed by lagging regressors in a panel fixed-effect estimation. To implement a panel fixed-effect analysis, first we proceeded to perform a few tests on the structure of the panel as well as assessing the existence of the potential endogeneity between GDP per capita and dependence rate. These tests were performed on our sample of 231 regions (covering the period from 2000 to 2020) and are presented in Table 6 in the Appendix. The Granger test for panel data (in the version for panels with small T and large N) confirms the existence of the double causality between GDP per capita and the dependence rate, but it can be controlled by lagging the regressors for five periods. Hence, we performed the panel

¹⁹ It is also important to underline that not all variables are available for the all regions in the original sample (231 observations): This is the reason for dealing with a reduced sample of observations in the last columns in Table 2. We are aware of this limitation of our database but, still, our data source provides homogeneous and comparable information across regions and time that is a valuable information that deserve to be exploited.

²⁰ The AIC and BIC criteria allow for comparing different models: The preferred models are generally those with the lower BIC or AIC statistics.

²¹ In this sense, the lack of regional co-movement during the business cycle makes it convenient to adopt the standard perspective proposed by Baumol (1986) and Barro and Sala-i-Martin (1992) according to which the convergence-type models have to be elaborated under a long-term perspective.

estimation by introducing lagged regressors, and the correspondent output is included in Table 7. Estimates in Table 7 include region (NUTS2) and time fixed effects. The quality of the estimations (according to the AIC and BIC criteria) is much worse than the one presented in Table 1. Once more, these estimations detect the convergence movement across regions for the overall period and a somewhat positive effect of ageing on the growth rate. However, the size of the estimated coefficients varies noticeably across the different specifications suggesting that some heterogeneous effects are not properly identified, thus affecting the reliability of these estimations. In addition, the AIC and BIC statistics confirm that the quality of the convergence-style estimations (Table 2) is definitely better than the ones obtained with the panel fixed effects (Table 7).

Next important step in the analysis is the implementation of the spatial dimension in our empirical analysis. The preliminary evidence discussed in Sect. 3 stresses the relevance of the spatial dimension to understand the potential (statistically significant effects) between migration inflows and growth: The destination of migration flows is basically concentrated in the Western part of the EU. It could be that the reason for not getting statistically significant estimates for mostly of the covariates in the last set of estimations in Table 2 is the potential existence of spatial dependence among observations that had not being taken into consideration in those equations.

To take it into account, we implement a second set of estimations whose results are presented in Table 3. When including the spatial dimension in our framework, we introduce a weight matrix $\mathbf{W}$. The spatial weight matrix $\mathbf{W}$ is computed as a first-order contiguity matrix.

The equation we are referring to for this set of estimation is:

$$\begin{aligned} \text{Av growth rate GDPpc}_{s,2000-20} = & \beta_0 + \beta_1 \text{Log GDPpc}_{s,2000} + \beta_2 \text{LogDepend ratio}_{s,2000} \\ & + \beta_3 \text{LogShare imm popul}_{s,2000} + \theta_1 W \text{Av growth rate GDPpc}_{s,2000-20} \\ & + \theta_2 W \text{Log Depend ratio}_{s,2000} + \theta_3 W \text{Log Share imm popul}_{s,2000} + \epsilon_s \end{aligned} \quad (2)$$

In Eq. (2), the coefficients θ_1 , θ_2 and θ_3 are aimed to capture the potential spillovers effects of surrounding area for each NUTS2 spatial unit of our sample.

Table 3 includes, first, baseline estimations performed with OLS, and then, spatial estimations run with SLX and SDM models. The SLX model is the point of departure to take into account spatial dependence since it considers spatial lagged regressors only (and, hence, shaping spatial spillovers as exogenous). Instead, the SDM model is a more general specification, since it embeds spatial dependence both for the dependent variable and regressors (here, spatial spillovers are modelled as endogenous). The SDM model has the advantage to produce more stable estimations even in the case the number of neighbours used to build $\mathbf{W}$ varies. Once more, we refer to the BIC and AIC statistics to compare the quality of the different specifications.

Referring to the econometric estimations in Table 3, the introduction of the spatial dimension makes the changes in the demographic composition of the spatial units (here approximated by the change of the rate of dependence) that were statistically significant as a determinant for the average growth rate in the period 2000–2020. The Wald test for spatial terms confirms that it is relevant to implement this estimation strategy; the AIC

Table 3 Estimations. Dependent variable: Average growth rate GDP per capita (2000–2020)

	OLS	OLS	SLX	SDM	
Constant	4.58*** (0.312)	7.74*** (0.03)	7.96*** (0.67)	4.80*** (0.69)	Direct effects
Log GDP-pc ₂₀₀₀	−0.42*** (0.032)	−0.39*** (0.034)	−0.32*** (0.04)	0.22*** (0.04)	−0.23*** (0.04)
Log depend ratio ₂₀₀₀		−0.87*** (0.16)	−0.91*** (0.15)	−0.58*** (0.14)	−0.61*** (0.14)
θ					
Average growth rate GDP-pc ₂₀₀₀₋₂₀				0.57*** (0.05)	Indirect effects
Log GDP-pc ₂₀₀₀			−0.14** (0.06)	−0.04 (0.06)	−0.23*** (0.07)
Log depend ratio ₂₀₀₀			0.39** (0.17)	0.05 (0.16)	−0.40 (0.30)
Wald test spatial terms			10.51**	58.48***	
Obs	231	209	209	209	
R-squared/Pseudo R-squared	0.47	0.54	0.56	0.56	
AIC	−26.58	−61.74	−65.99	−100.05	
BIC	−19.69	−51.72	−45.94	−76.65	

Level of significance: *** 1%, ** 5% and * 10%. Standard errors are shown in brackets. Error correction: Robust

(or BIC) criterion confirms the existence of endogenous spatial spillovers (being the fit of the SDM model better than the one of the SLX). The detected spillover effect is rather a direct effect since the selected covariates matter only when it refers to the own spatial units and its coefficient is negative being the size of the ageing effect more important than the one associated to the level of GDP. The only statistically significant indirect spillover effect is the one associated with the level of GDP per capita in neighbouring spatial units whose tendency replicates the one of the own spatial unit and, hence, reinforces the spatial pattern of the convergence process.²²

In a second step of our analysis, we augment our models by integrating information about the share of immigrants in the total population (*Log Share*₂₀₀₀) in the spatial unit *s*. Our target is to include a proxy for the economic impact of incoming workers (mostly in working age in 2000) on the economic performance of a selected spatial unit *s* and always taking into account the ageing effect incurred in the same unit.

The results of this new set of estimations are presented in Table 4.

Referring to the AIC and BIC statistics, the quality of this second set of estimations greatly improved with respect to the one in Table 3, and, hence, it delivers more reliable results. Once more, the Wald test suggests the importance of including spatial terms in the analysis and spatial spillovers keep being endogenous. Both in the SLX and SDM specifications, the introduction of the spatial dimension makes the estimates of the coefficient of the GDP per capita regain statistical significance jointly with the ones of the share

²² The estimations including the median age instead of the dependency rate provide the same type of results, and they are presented in Table 8 in the Appendix.

Table 4 Estimations. Dependent variable: Average growth rate GDP per capita (2000–2020)

	OLS	SLX	SDM	
Constant	2.40* (1.4)	2.36*** (0.79)	2.05*** (0.73)	Direct effects
Log GDP-pc ₂₀₀₀	−0.13 (0.11)	−0.14*** (0.05)	−0.13*** (0.05)	−0.14** (0.05)
Log share immig ₂₀₀₀	0.07** (0.03)	0.05** (0.02)	0.05** (0.02)	0.05*** (0.02)
Log depend ratio ₂₀₀₀	−0.21 (0.14)	−0.18 (0.14)	−0.12 (0.13)	−0.14 (0.13)
θ				
Average growth rate GDP-pc ₂₀₀₀₋₂₀			0.58*** (0.13)	Indirect effects
Log GDP-pc ₂₀₀₀		0.14 (0.09)	0.03 (0.09)	−0.08 (0.16)
Log share immig ₂₀₀₀		0.01 (0.04)	−0.001 (0.03)	0.04 (0.05)
Log depend ratio ₂₀₀₀		−0.34 (0.22)	−0.11 (0.21)	−0.28 (0.28)
Wald test spatial terms		11.00**	32.55***	
Obs	132	132	132	
R-squared/ Pseudo R-squared	0.13	0.20	0.19	
AIC	−131.56	−134.12	−146.66	
BIC	−120.02	−111.06	−120.72	

Level of significance: *** 1%, ** 5% and * 10%. Standard errors are shown in brackets. Error correction: Robust

of immigrants. They both are statistically relevant for shaping the average growth rate of each spatial unit and the share of immigrants counterbalance the convergence process (*H.I*). However, this second set of estimations emphasizes that effect is self-contained in each spatial unit (only direct effects are statistically significant).

The insights one can deduct from these results referring to the literature discussed in Sect. 1 are twofold. First, we can suppose that immigrants in 2000 could have set the conditions for the entry of new cohorts of migrants (for instance, exploiting network effects), and each new cohort could have brought (on average) more human capital than the one of retired persons. In this sense, the channel proposed by Prenzel and Iammarino (2021) would work, and, hence, more human capital would contribute to fuel labour productivity and, hence, growth. Second, the positive association between ageing society and economic effect via migration inflows can be linked to the creation of new jobs in the sector of services (and, hence, going back to the conclusions of Alamà-Sabater et al. 2022). The ageing of the EU society yields the creation of new occupations or tasks (mostly for health and daily care of retired persons), and this effect can counterbalance the economic effect of the exit of aged natives from the local labour markets. The fact that this effect turns to be statistically significant only when considering the spatial structure of the EU, it

is a signal that the matching effect between ageing, new tasks for employment and immigration flows are concentrated in specific places.

5 Conclusions and policy discussion

This study aims to investigate the impact of the change in the demographic composition of NUTS2 spatial units inside the EU on their convergence process in the period 2000–2020.

The literature emphasizes that all developed countries are experiencing an increase in the dependency rate as a consequence of the ageing population and the reduction of the working-age population (between 15 and 64 years). Consequently, the economic growth of places clustering aged persons is expected to be hindered. A valuable strategy to escape this trap is to either impose new technological adoption or fuel human capital accumulation to increase labour productivity and recover growth. Under these circumstances, we provide evidence that immigration can trigger economic growth.

From 2000 to 2020, the EU experienced important internal migration and an influx of external migration. Given the asymmetrical impact of migration flow in sending and receiving countries, the literature has been inconclusive regarding this question and, in particular, for EU regions. Hence, our research strategy targeted quantifying the extent to which immigration could be a tool to sustain economic growth in an ageing society.

Our results confirm the previous hypothesis that the inflow of migration can help to shape the growth perspectives of ageing territories. They also confirm the relevance of the spatial dimension in the empirical analysis. In doing so, we can conclude that the positive association between growth, immigration and ageing takes place inside each spatial unit, and, therefore, there are no spillover effects. This last outcome emphasizes two major considerations. First, place-based policies are extremely relevant. Problems associated with ageing and growth need to be tackled at a local level and require tailored policies for each specific spatial unit. Llorens i Jimeno and Mestres Domènech (2020) identify two main axes of intervention to offset the economic impact of an ageing population. There are initiatives impacting *extensive-margin* factors promoting growth in a context of ageing population: increasing the length of working time, the immigration and the participation of population in the labour force.²³ Another strategy would be focusing instead on factors driving the *intensive margin*: fostering labour productivity—primarily through education—but also tasks should be reallocated so that older workers can continue to be productive at work.

As for the extensive margin factors, the most debated ones are definitely the potential effects stemming from incoming immigrants, but the relevance of the spatial dimension in approximating those effects call for the specificity of tailored initiatives at the local level in line with the ones discussed in the European Commission report (2023). The benefits of the immigration inflows in a spatial unit pass through the attractiveness of those spatial units and their capacity to retain such an asset: natural immigration trends

²³ In this group of initiatives, Daniele et al. (2019) discussed how reducing the gender participation gap in the labour market can be another valuable tool to contribute to the increase in the size of the labour force.

mostly go to urban areas (as discussed in Backman and Karlsson 2023). Ageing reinforces the divide between more productive, younger regions and those lagging within a country that often coincide with rural areas (Daniele et al. 2019). This landscape is the one identified by the EU (European Commission report, 2023). In European countries, there coexists less developed rural regions facing difficulties in developing, retaining or attracting the talents needed to mitigate the impact of the demographic transition. But also, there are two other groups of regions: a group with a low and stagnating share of tertiary-educated people and, hence, with a rapidly shrinking working-age population, while the other group has signals of experiencing a clear talent development trap by registering net out-migration of younger cohorts who tend to be more educated than the average. These regions are usually less developed and rural and the persistence of this outflow of human capital, if not solved, could harm their growth and their potential convergence capacity. Under these circumstances, there is definitely room for policy interventions. But, as discussed in Pinilla (2023), these policies need to follow a mixed top-down and bottom-up interdisciplinary and highly coordinated combination. Short-run policies like monetary transfer can help to maintain living standards in ageing regions, but they are not effective in unlocking a region's development potential (Daniele et al 2019). Instead, some interventions should be provided by the central government (physical and digital infrastructures) to support local initiatives for local development and retain talents—including immigrants—in selected locations (Pinilla 2023).

Beyond creating infrastructure as a way to retain working-age population in ageing regions, the job creation is crucial as well. An ageing society usually creates a demand for services. From a spatial perspective, the socioeconomic consequences of an ageing society will generate different expectations of public services that local and central administrations are expected to provide. Current evidence and case studies emphasize the lack of services (homecare, healthcare and transport) in areas (above all rural) concentrating aged persons. These areas are facing socioeconomic decline, indicating a need for corrective measures. On the other hand, an ageing society will question local administrations as to how they provide public services and encourage their leaders to explore coordinated synergies to improve these provisions (European Commission, 2023).

Implementing ad hoc place-based policies can mitigate the socioeconomic consequences of an ageing society, including pro-immigration policies (e.g. the contracting-at-origin model) to sustain established services for older locals in rural areas. By attracting new services, potential positive spillover effects on other sectors, such as the local housing market, can be expected. Policies that facilitate the recruitment of qualified workers by matching the tasks requested by elderly people could be an option to integrate immigrants into remote areas as a component of a precise development and sustainability plan, such as having the hiring occurring in the country of origin.²⁴

²⁴ This programme is quite common in the agricultural sector, but it can be easily extended to other sectors (e.g. services or industry). This programme allows management of a recruiting process of foreign workers tailored to the needs (vacancies) in a specific sector and task. This type of programme grants recruited workers temporal work permits. An example of implementation of this programme in the agricultural sector is in Spain where the hiring is allowed of temporary workers in agriculture mostly from Morocco and Colombia (source: <https://gsp.cgdev.org/legalpathway/collective-management-of-hiring-in-the-country-of-origin/>).

From this perspective, the other relevant question the local administration is called on to address is the financial feasibility and sustainability of different types of daily services requested by elderly individuals—especially related to healthcare, daily care, and public transport—the provision of which is the responsibility of local policymakers and have an important impact on the social standard of living in the next decades. In this sense, the European Commission report (2023) claims for a more coordinated action of all funds granted to this scope.

The immigration side is a possible tool to preserve productivity and fuel growth, but it is not unique. Initiatives on the intensive margin are relevant as well. Recent anecdotal evidence (in European countries) seems to offer new scenarios leading to a decrease in the dependency rate by a change in the size of the working population driven by older people postponing their retirement. In the EU, some countries debate institutional changes to the retirement age, such as extending it to 70.²⁵ However, just postponing retirement, if not coupled with other initiatives, can reduce average individual productivity (Daniele et al. 2019). Llorens i Jimeno and Mestes (2020) suggest the possibility that productivity in an ageing society can be preserved if a process of relocation of tasks for workers aged 65 or above can be put in place in a way to allow them to still be productive at work without losing their human capital. It has also been suggested that the labour force reattaches those workers over 65 due to personal monetary constraints or to overcome the lack of a proper welfare system supporting their needs (Kim and Hewings 2019).²⁶ From this perspective, the concern to preserve growth still involves fueling productivity and, under this hypothesis, the question of if and which type of investments in human capital for aged workers (over 50, for instance) might be suitable if the aim is to maintain their productivity and, indirectly, increase the return to the labour force. In the end, this channel is expected to be combined with migration inflows and reinforce productivity gain already triggered by it, but those results are subject to a deeper investigation.

All previous channels deserve to be addressed from a quantitative perspective, but a more complete set of data than the one we are handling would be beneficial. As discussed, even if we can handle homogeneous data, the data limitation of our sample not only allows for delivering quantitative results referring to a limited number of regions, but also prevents it from addressing interesting issues. One of these issues is the (potential) reverse causality between immigration and growth that could be valuable to explore by implementing an analysis setting different from the framework of convergence. In particular, it could be valuable to explore the extent to which regional growth prospects are attractive for immigrants, and how the location decisions for immigrants turn out to be a self-reinforcing process.

²⁵ A discussion concerning the increase in employment for older workers in Scotland is proposed by Loretto and White (2006).

²⁶ Kim and Hewings (2013) conclude that the investment in human capital is able to offset the negative effects of an ageing population on a regional economy. They also affirm that educational transfers (that individuals can use to finance their educational investments) are more effective than general money transfers in the long run in terms of per capita income growth.

Appendix

See Figs. 4, 5, 6, 7, 8, 9, 10 and Tables 5, 6, 7, 8.

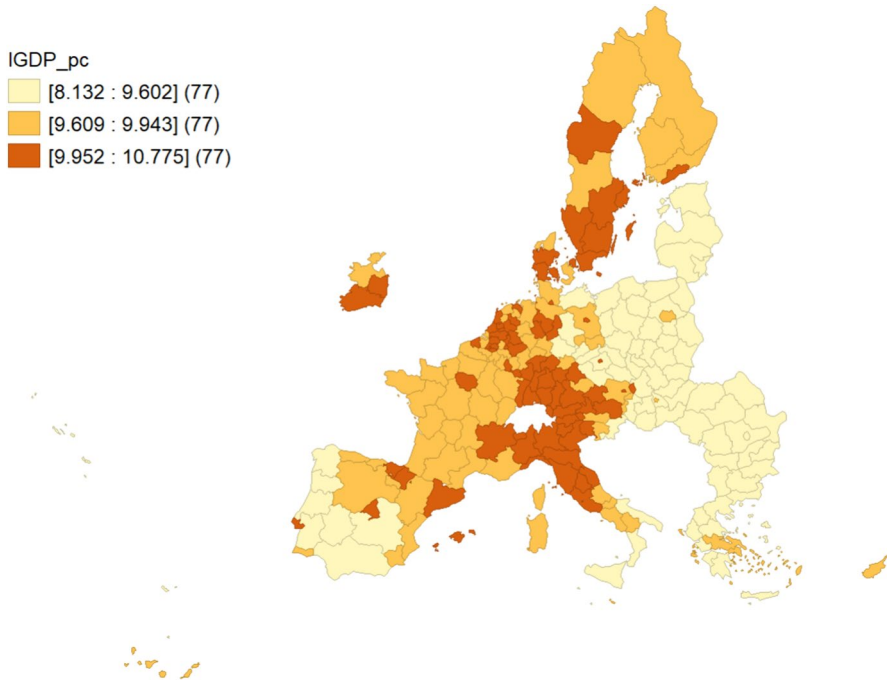


Fig. 4 Logarithm GDP per capita in ppp (2020)

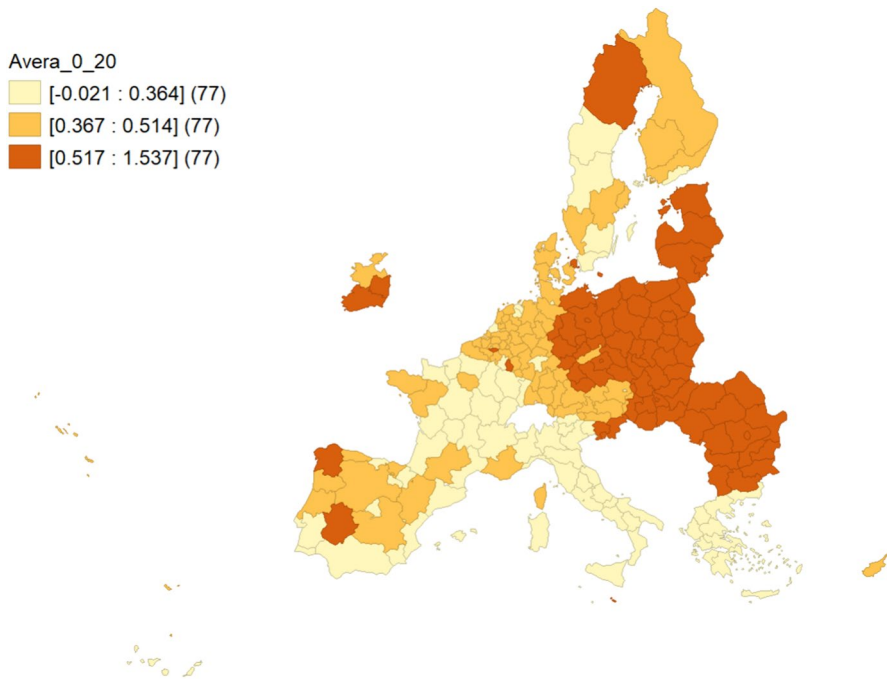


Fig. 5 GDP per capita average growth (2000–2020)

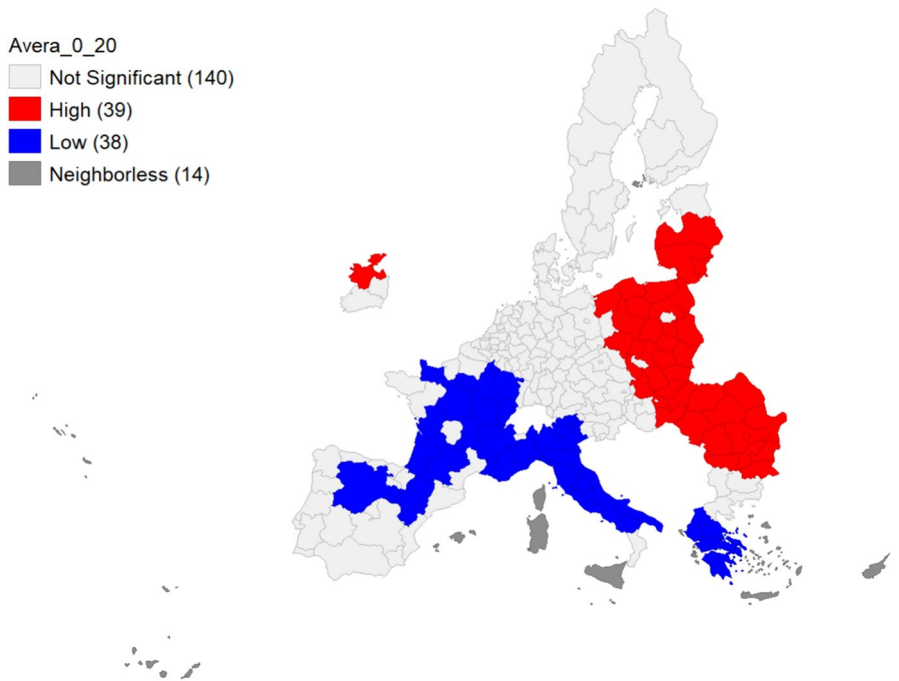


Fig. 6 Local clusters of GDP convergence (2000–2020). The label “Neighborless” refers to spatial units for which not all data are available

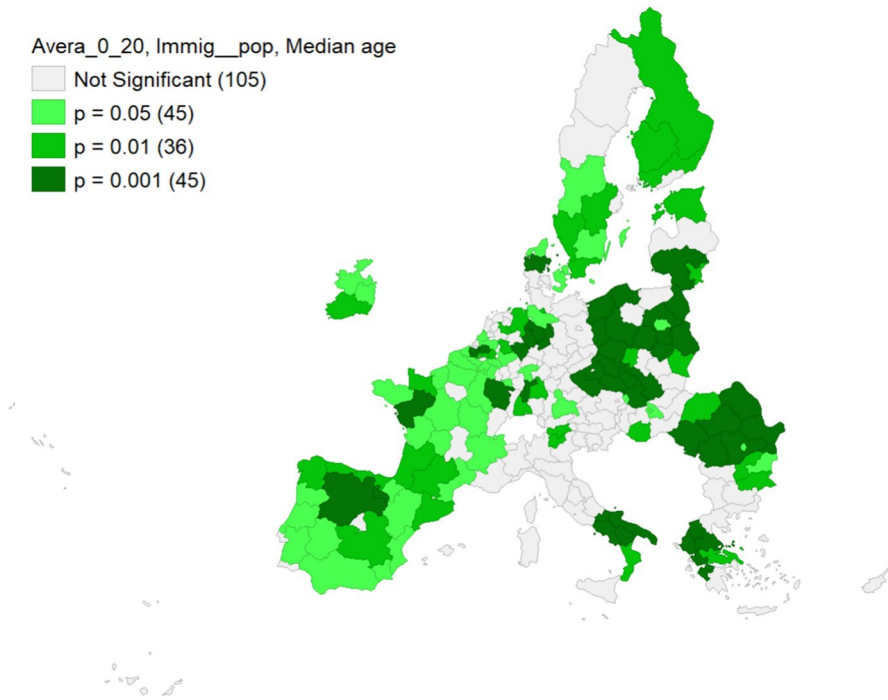
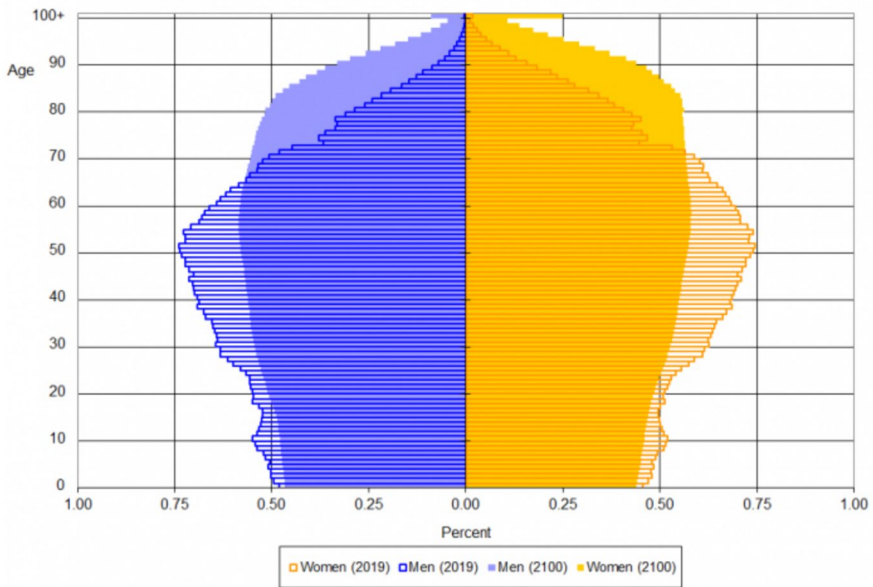


Fig. 7 Statistical significance local indicator of multivariate spatial association

Population pyramids of the European Union
(% of total population)



Note: Population projections, base year 2019
Source: Eurostat (online data codes: proj_19np)

eurostat

Fig. 8 Age composition EU regions. Source: Eurostat; Available at https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Population_pyramid&oldid=490696

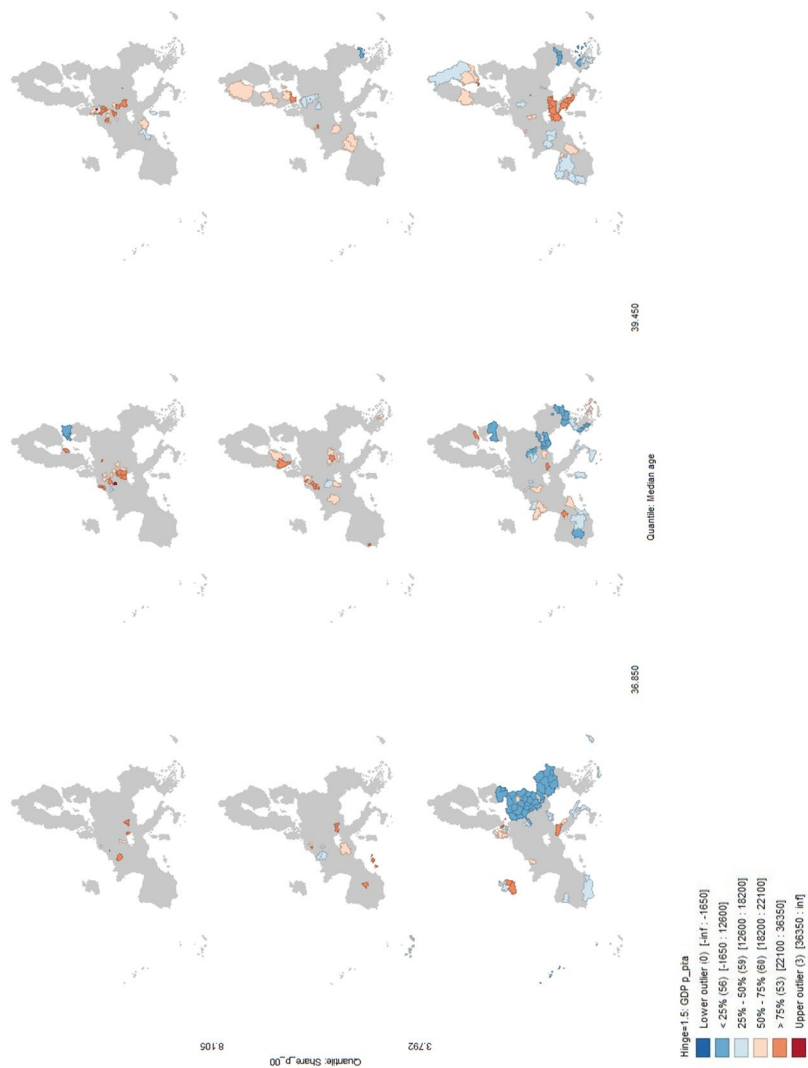


Fig. 9 Conditional map 2000. Variable of interest: GDP per capita 2000. Vertical axis: Share of immigrants in working age (over total population) in 2000. Horizontal axis: Median age population in 2000



Fig. 10 Conditional map 2020. Variable of interest: GDP per capita in 2020. Horizontal axis: Median age population in 2020. Vertical axis: Share of immigrants in working age (over total population) in 2020

Table 5 Basic convergence estimation by subperiod

A. Dependent variable: Average growth rate GDP per capita (2000–2010)

	OLS	OLS	OLS	OLS	OLS
Constant	2.86*** (0.40)	4.73*** (0.87)	4.31*** (0.80)	4.92** (1.3)	3.57** (1.27)
Log GDP-pc ₂₀₀₀	−0.26*** (0.04)	−0.24*** (0.04)	−0.23*** (0.04)	−0.25*** (0.06)	−0.25*** (0.05)
Log depend ratio ₂₀₀₀		−0.52*** (0.14)		−0.57** (0.23)	
Log median age ₂₀₀₀			−0.48** (0.18)		−0.23 (0.26)
Log share immig ₂₀₀₀				0.01 (0.01)	0.01 (0.01)
Obs	231	209	206	118	118
R-squared	0.53	0.60	0.55	0.62	0.58
AIC	−301.65	−315.42	−283.10	−131.56	−131.30
BIC	−294.77	−305.39	−273.12	−120.02	−119.77

B. Dependent variable: Average growth rate GDP per capita (2011–2020)

	OLS	OLS	OLS	OLS	OLS
Constant	1.42** (0.06)	2.81*** (0.82)	2.60* (1.31)	0.50 (0.76)	0.15 (1.70)
Log GDP-pc ₂₀₀₀	−0.13** (0.07)	−0.11** (0.05)	−0.13** (0.05)	0.02 (0.06)	0.03 (0.07)
Log depend ratio ₂₀₀₀		−0.39** (0.16)		−0.14 (0.13)	
Log median age ₂₀₀₀			−0.31 (0.27)		−0.00 (0.19)
Log share immig ₂₀₀₀				0.03 (0.02)	−0.04* (0.02)
Obs	231	221	221	194	194
R-squared	0.13	0.29	0.20	0.13	0.13
AIC	−280.24	−348.10	−321.98	−373.87	−369.54
BIC	−273.35	−337.91	−311.78	−360.79	−356.47

Level of significance: *** 1%, ** 5% and * 10%. Standard errors are shown in brackets. Error correction: Clustered by country

Table 6 Basic panel statistics

	Test	Result
Cross-sectional dependence	Pesaran's test: 320.53*** Average absolute value of the off-diagonal elements: 0.587	The panel is cross-sectional independent
Heterogeneity test	F-test: $F(213, 4279) = 154.83$ ***	Panel fixed effects are statistically significant; the heterogeneity of effects at the panel-unit level exists
Unit roots	Series: GDP per capital annual growth Harris-Tzavalis unit root test: $\rho = 0.0366$ ($z = -65.8742$) ****	The series is stationary
Granger causality (Dumitrescu-Hurlin test, 2012)	Δ GDP per capita vs Δ Dependence rate H_0 : GDP per capita does not cause dependence rate	The double causality between <i>GDP per capita</i> and <i>dependence rate</i> can be rejected with 5 lags
	Δ Dependence rate vs Δ GDP per capita H_0 : <i>Dependence rate</i> does not cause <i>GDP per capita</i>	Optimal number of lags (AIC) = 5 Z -bar tilde = 5.861 *** H_0 is rejected with 5 lags
		Optimal number of lags (AIC) = 5 Z -bar tilde = 0.6862 H_0 cannot be rejected with 5 lags

In order to build a balanced panel of NUTS2 regions for a period from 2000 to 2020, we drop from the final sample spatial units that we are unable to track for the whole period. These units are the ones belonging to Denmark, Ireland and 2 units in Germany

Level of significance: *** 1%, ** 5% and * 10%

Table 7 Basic panel estimations. Dependent variable: Annual growth rate GDP per capita (2000–2020). Independent variables lagged 5 periods. Methods: Fixed-effects estimations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Constant	7.76*** (2.41)	1.13 (3.15)	−4.9** (2.08)	7.47** (3.17)	2.22* (1.29)	5.00 (6.69)	−7.9** (3.37)	5.00 (6.70)	1.96 (2.04)
Log GDP-pc	−0.68** (0.25)	−0.47* (0.24)		−0.61** (0.27)		−1.2* (0.66)		−1.2** (0.65)	
Log depend ratio		1.20** (0.54)	1.56*** (0.52)			1.99** (0.76)	2.29*** (0.80)		
Log median age				−0.08 (0.33)	−0.28 (0.34)			1.99** (0.76)	−0.24 (0.50)
Log share immig						0.08 (0.14)	0.14 (0.15)	0.08 (0.14)	0.09 (0.13)
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs	2824	2656	2656	2651	2651	2158	2158	2149	2149
R-squared	0.23	0.21	0.22	0.22	0.22	0.23	0.22	0.21	0.21
AIC	5315	5006	5014	5008	5025	4058	4079	4059	4094
BIC	5410	5106	5109	5108	5119	4161	4175	4161	4191

Level of significance: *** 1%, ** 5% and * 10%. Standard errors are shown in brackets. Error correction: Clustered by country

Table 8 Estimations. Dependent variable: Average growth rate GDP per capita (2000–2020)

	OLS	OLS	SLX	SLX	SDM	SDM
Constant	6.61*** (1.65)	0.10 (1.70)	6.13*** (0.86)	0.26 (1.07)	4.02*** (0.73)	0.59 (0.97)
Log GDP-pc ₂₀₀₀	-0.39*** (0.08)	-0.12 (0.14)	-0.33*** (0.05)	-0.12*** (0.06)	-0.21*** (0.05)	-0.12*** (0.05)
Log median age ₂₀₀₀	-0.65 (0.39)	0.36 (0.27)	-0.69*** (0.86)	0.33 (0.26)	-0.44** (0.21)	-0.25 (0.24)
Log share immig ₂₀₀₀		0.08** (0.04)		0.06* (0.02)		0.06*** (0.02)
θ						
Average growth rate GDP-pc ₂₀₀₀₋₂₀						
					0.66*** (0.08)	0.62*** (0.13)
Log GDP-pc ₂₀₀₀			-0.10 (0.07)	0.05 (0.11)	0.000 (0.08)	0.02 (0.10)
Log median age ₂₀₀₀			0.30* (0.18)	-0.13 (0.30)	-0.06 (0.21)	-0.11 (0.27)
Log share immig ₂₀₀₀				0.03 (0.04)		-0.002 (0.03)
Wald test spatial terms			11.50**	6.21	94.12***	33.73***
Obs	206	132	206	132	206	132
R-squared/ Pseudo R-squared	0.51	0.13	0.54	0.17	0.57	0.16
AIC	-50.84	-131.30	-56.03	-129.37	-109.75	-146.08
BIC	-40.85	-119.77	-36.06	-106.31	-86.46	-120.14

Level of significance: *** 1%, ** 5% and * 10%

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Declarations

Conflict of interest There are no conflicts of interest.

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References

- Acemoglu D, Restrepo P (2017) Secular stagnation? the effect of aging on economic growth in the age of automation. *Am Econ Rev*, p&p 107(5):174–179
- Alamà-Sabater L, Márquez MÀ, Tortosa-Ausina E (2022) Spatio-sectoral heterogeneity and population-employment dynamics: some implications for territorial development, *Regional Studies*, forthcoming.
- Anselin L (2017) A local indicator of multivariate spatial association: extending geary's c. *Geogr Anal* 51(2):133–150
- Auciello I, Puente S (2023) Cambios recientes en el patrón de convergencia entre regiones. *Boletín Económico* n. 2023/1, Banco de España, <https://doi.org/10.53479/29770>
- Backman M, Karlsson Ch (2023) Ageing places: convergence and the role of foreign population. *Reg Stud* 58(5):922–937. <https://doi.org/10.1080/00343404.2023.2228347>
- Bandrés E, Gadea-Rivas MD, Gómez-Loscós A (2017) Regional business cycles across Europe, *Documentos Ocasionales* n. 1702, Banco de España
- Barro RJ, Sala-i-Martin X (1992) Convergence. *J Polit Econ* 100(2):223–251
- Baumol WJ (1986) Productivity growth, convergence and welfare: what the long-run data show. *Am Econ Rev* 76:1072–1085
- Bisciari P, Essers D, Vincent E (2020) Does the EU convergence machine still work ?, *NBB economic review*, June 2020
- Börsch-Supan A, Härtl K, Ludwig A (2014) Ageing in Europe: reforms, international diversification and behavioral reactions. *Am Econ Rev*, p&p 104(5):224–229
- Brunow S, Hirte G (2006) Age structure and regional economic growth. *Jahrb Reg* 26:3–23
- Carbonaro G, Leanza E, McCann Ph, Medda F (2018) Demographic decline, population aging, and modern financial approaches to urban policy. *Int Reg Sci Rev* 41(2):210–232

- Collantes F, Pinilla V, Saéz LA, Silvestre J (2014) Reducing depopulation in rural Spain: the impact of immigration. *Popul Space Place* 20:606–621
- Daniele F, Honiden T, Lembecke AC (2019) Ageing and productivity growth in OECD regions: combatting the economic impact of ageing through productivity growth ?, OECD Regional Development Working Papers 2019/08
- de Menezes TA, Silveira-Neto RM, Azzoni CR (2012) Demography and evolution of regional inequality. *Ann Reg Sci* 49:643–655
- European Commission (2023) Regional trends for growth and convergence in the European Union. Commission staff working document (June, 1 2023)
- Hayward MD, Zhang Z (2001) Demography of ageing. a century of global change, 1950–2050. In: Binstock RH, George L (eds) *Handbook of ageing and the social science*, 5th edn. Academic Press, pp 69–85
- Kashnitsky I, de Beer J, van Wissen L (2017) Decomposition of regional convergence in population aging across Europe. *Genus* 73(2):1–25
- Kim T, Hewings GJD (2013) Endogenous growth in an aging economy: evidence and policy measures. *Annals Reg Sci* 50:705–730
- Kim K, Hewings GJD (2019) Bayesian estimation of labor demand by age: theoretical consistency and an application to an input-output model. *Econ Syst Res* 31(1):44–69
- Llorens i Jimeno E, Mestres Domènech J (2020) The impact of ageing on Spain's economic growth: a regional focus. *CaixaBank working paper series* 01/20, September 2020
- Loretto W, White P (2006) Population ageing and older workers: employees' perceptions, attitude and policies. *Popul, Space, Space* 12(5):341–352
- Maestas N, Mullen KJ, Powell D (2023) The effect of population aging on economic growth, the labor force, and productivity. *Am Econ J Macroecon* 15(2):306–332
- Monfort, Ph (2020) European commission, directorate-general for regional and urban policy, (2020): Convergence of EU regions redux- recent trends in regional disparities. EU directorate-general for regional and urban policy, WP 02/2020 Publications Office <https://data.europa.eu/doi/https://doi.org/10.2776/27556>
- Newbold KB (2015) Population aging: What role for regional science. *Ann Reg Sci* 55:357–372
- Pinilla V (2023) El Reto demográfico: políticas frente a la despoblación rural en España. *Papeles De Economía Española*, N 176:146–161
- Plane DA (2012) What about aging in regional science? *Ann Reg Sci* 48:469–483
- Prenzel P, Iammarino S (2021) Labour force ageing and the composition of regional human capital. *Econ Geogr* 97(2):140–163
- Servillo L, Atkinson R, Russo AP (2011) Territorial attractiveness in EU urban and spatial policy: a critical review and future research agenda. *European Urban Reg Stud* 19(4):349–365
- Theil H (1971) *Principles of Econometrics*. Wiley, New York

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