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main determinants of regional economic resilience in the EU*

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** *The working paper was prepared while Neysan Khabirpour was a visiting economic analyst at the European Commission and postgraduate student at the Department of Economics, Ludwig-Maximilian University of Munich*

TABLE OF CONTENTS

ABSTRACT

The aim of this study is to empirically analyse the determinants of regional economic growth and resilience across European Union (EU) regions.

We will try to answer the following questions: Do regions vary in their ability to recover and bounce back from economic shocks? What internal and external factors are associated with the capacity of EU regions to cope with economic adversity and maintain economic well-being while others fall short? Are the determinants of economic growth and resilience the same across different groups of EU regions?

In order to answer the questions above, we have estimated a conditional growth model whereby economic growth across EU regions depends on a set of initial factors (i.e. human capital and investments) and proximity to other regions. In addition to the more traditional factors, this study also employs a subset of components of the Regional Competitiveness Index (2010) – RCI – to explain growth differentials across EU regions. Finally, we have grouped EU regions into two groups, according to their level of economic development – a north-west core of relatively high-income regions, and a south-east periphery of lower-income regions – and have tested whether our set of explanatory variables has a similar impact on the economic growth of the two groups of regions.

The econometric modelling approach incorporates complex spatial effects by considering both spatial heterogeneity and spatial dependence across geographical units, enabling us to account for spatial spillover among EU regions.

Empirical results indicate that while both groups of regions experience economic convergence, recent determinants of growth, as well as spillover effects, differ across the two. In the core regime, better institutions, higher shares of investment, and an economy specialising in higher-value-added sectors significantly spur domestic growth, with investment also inducing positive spillover effects to neighbouring regions. In the peripheral regime, low shares of lower-secondary educational attainment and high shares of tertiary educational attainment have a significant positive effect on domestic growth, with higher shares of tertiary educational attainment also inducing positive spillover effects. Moreover, technological readiness is also identified as an important factor in the peripheral regime creating positive spillover effects.

This is a critical time for the future of EU Cohesion Policy with the regulations for the post-2020 regional policy period currently under discussion. Several findings in this study are particularly relevant to this debate and should be factored into the ongoing discussions.

1. INTRODUCTION

Within the discipline of economics, a large amount of research has been devoted to the study of economic growth. Since Solow's seminal contribution in 1956, the examination of growth dynamics has been at the forefront of theoretical and empirical enquiry. Correspondingly, scholars have explored the causes and characteristics of national and regional growth processes and have studied the dynamics of economic convergence. Early studies were unable to determine whether or not slow- or fast-growing countries or regions were arbitrarily distributed over space or tended to cluster together. More recently, the literature recognised that space and location do indeed matter in shaping economic and, in particular, regional economic growth (Abreu et al., 2005, Ertur et al., 2006, Dall'Erba et al., 2008, Lim, 2016)[1].

As the 2008 economic and financial crisis revealed, some European regions were better equipped than others to deal with the crisis, reducing the degree of economic distress their region experienced and placing them on a swifter path to recovery. Therefore, a relevant area of enquiry is to discern what regions were more resilient to the 2008 economic shock and to identify the reasons why, which in turn could contribute to the existing literature on the concept of economic resilience (Martin, 2012, Brakman et al., 2015). Occurrences of economic shocks, such as the Great Recession in 2008, represent an important opportunity for researchers to empirically investigate the characteristics of resilient systems. As such, it is the principal aim of this study to empirically examine regional growth dynamics from 2008 to 2015 in two distinct spatial groups of EU regions. In so doing, the study intends to both discern the determinants of economically resilient regions and statistically assess the significance of spillover effects. The time period under investigation enables this paper to contribute to the literature on resilience, while the inclusion of spatial analysis enables it to test for spillover effects.

The study contributes to the literature in the following ways[2]. First, it groups EU regions (also defined as spatial regimes) according to patterns of economic development. Second, a spatial econometric model is used to determine growth dynamics within the two regimes in the EU, painting a picture of spatial dependence patterns and possible spillover effects. This study assesses the determinants of economic resilience using a subset of the Regional Competitiveness Index (RCI) components (Annoni and Dijkstra, 2017) as explanatory variables as well as other more classical growth factors. NUTS-2 level is the main spatial unit of analysis in this study and in the European literature on regional growth at large. However, this study also relies on functional urban areas (FUA) when functional economic areas are split into multiple parts by administrative borders.

In such cases, the economic territory would be misrepresented if considered only according to its NUTS-2 borders because of the significance of its commuting zones. Finally, this investigation focuses on the period just after the start of the Great Recession (2008-2015) which allows it to assess the determinants of resilient European regions, thereby informing the policy debate on the characteristics of regions that are better able to absorb economic shocks and return more swiftly to a path of economic prosperity.

The remainder of the study is structured as follows. Section 2 provides a succinct literature review on both spatial growth studies and the resilience discourse, whilst also serving to position this paper in the correct context. Section 3 presents the theoretical motivation of the analysis. Section 4 describes the data employed, and section 5 outlines the exploratory spatial-data analysis used to determine the spatial regimes. Section 6 outlines the empirical approach and presents and discusses results. Section 6 concludes by discussing implications that could serve to inform future regional resilience policy development.

[1] For a comprehensive literature review on the spatial effects, see Abreu et al., 2005.
[2] See Annoni et al. (2019) for a full analysis.

2. THEORETICAL FRAMEWORK

This section introduces the theoretical motivation underpinning this study's empirical analysis, which sets out to assess what factors are associated with more-resilient EU regions in the years following the economic crisis. This study considers regional economic resilience as the ability of a regional economy to absorb and rebound from an economic shock, measured in this analysis by a region's annual gross domestic product (GDP) per capita growth rate. Martin and Sunley (2015) explain that differences in resilience across regions are of paramount importance as they 'can contribute to the process of uneven regional development' across economies. In this context, this study aims to contribute to the existing literature on regional resilience in the EU by assessing what factors affect regional GDP per capita, the dependent variable, and to what extent such variables create spillover effects.

This study is theoretically guided by the neo-classical theoretical growth framework pioneered by Solow (Solow 1956, Barro and Sala-i-Martin, 1992), which assumes that all regions feature the same structural characteristics. However, this is clearly implausible since whatever convergence is found is conditional, as it depends on policies, institutions and other country-specific circumstances (Rodrik, 2012, Barro and Sala-i-Martin, 1991, Mankiw et al., 1992). In line with the existing literature on conditional convergence (Mankiw et al., 1992), this study assumes that regions differ from each other as regards their structural characteristics and endowments. As such, this analysis supplements the basic Solow-type growth framework with a number of regional explanatory factors that seek to explain the observed differences in EU regions' growth rates between 2008 and 2015. Those factors range from human to physical capital, from population growth to the quality of institutions, from technology uptake to the specialisation of the regional economy (Mankiw et al., 1992, Rodrik et al., 2004, Kwok and Tadesse, 2006, Crescenzi, Rodriguez-Pose, 2008, Mohl and Hagen, 2010, Rodriguez-Pose, 2013, Rodriguez-Pose and Garcilazo, 2013, Pescatori et al,. 2014, Annoni and Catalina Rubianes, 2016). Conventional growth regressions assume that variables observed at the regional level are independent, although there is an established consensus that regional economic growth rates exhibit spatial dependence (Abreu et al., 2005, Ertur et al., 2006, de Dominicis, 2014, among others). Spatial regression models, described in detail in section 5, enable this study to account for such dependence among observations that are likely to occur when they are collected at the level of territorial units (i.e. EU regions).

The following introduces and motivates the explanatory variables employed in the empirical model.

Human capital is a factor of economic growth that finds strong consensus in both the theoretical and emprirical literature on economic growth (Solow, 1956, Mankiw et al., 1992, Lucas, 1988, Barro, 1991). Higher levels of basic skills and competencies increase an individual's ability to excel in his/her workplace while, at the same time, allowing for greater flexibility in adapting to labour-market changes. Various studies have found a significant positive association between quantitative measures of schooling and economic growth (see Sianesi and Reenen, 2003, Krueger and Lindahl, 2001, Hanushek, E. and Wößmann, 2007 for an overview).

The *quality of institutions* is increasingly believed to be an essential factor in explaining economic growth differentials across countries and regions (Rodrik et al., 2004, Kwok and Tadesse, 2006, Rodriguez-Pose, 2013). Analyses at the regional level have shown that, in part, sub-national divergences in the quality of institutions can account for within-country disparities in economic growth (Charron et al., 2012, Charron and Lapuente, 2013, Rodriguez-Pose, 2013). The importance of human capital and good governance for economic development is also underlined by a recent OECD report on business demography (OECD 2017), which finds that the combination of better local governance and higher human capital fosters higher levels of entrepreneurship in a region. The significance of environments that are conducive to business creation cannot be underestimated since they create new employment opportunities and enhance productivity through innovative production processes – both of which contribute to regional growth.

The significance of *investment* as a factor of economic growth has been widely recognised in the literature (Anderson, 1990, Romer, 1990, Barro, 1991). An increase in a nation's capital stock leads to improved productivity by developing both fixed assets, such as machinery and equipment, and through intangible assets, such as investment in research and development (R&D) as well as knowledge creation (EIB, 2013). As stated in a report from the European Investment Bank: 'A sustained decline of investment in fixed assets may have important consequences for the medium- and long-term economic growth potential. It may lead to a permanent reduction in the level of potential output or, if the decline continues, it may lead to a permanent reduction in the rate of growth of potential output.' (EIB, 2013)

In recent years, *technological readiness*, characterised in this study as the digitisation of households, has emerged as a key economic driver, thanks to its effect of boosting growth in both more- and less-developed economies and its positive impact on job creation (Bilbao-Osorio et al., 2013, van Ark, 2015). A 2013 report by the World Economic Forum estimates that an increase of 10% in a country's digitisation score can contribute up to 0.75% growth in the GDP per capita (Bilbao-Osorio et al., 2013).

Finally, a factor that in recent years has been found to be relevant for economic development as a whole, and for regional growth specifically, is the degree of an economy's *specialisation* in *higher-value-added activities* (referred to in this study as business sophistication). High-value-added activities can trigger higher efficiency in the production of goods and services. At an advanced stage of development, sophisticated business practices are particularly important given that the more basic sources of productivity improvements have probably already been fully exploited (Sala-i-Martin et al., 2014).

Furthermore, certain classical determinants of economic growth – such as population growth, innovation, infrastructure and labour-market efficiency – are also included in the empirical analysis.

3. DATA

The variables introduced and discussed above are statistically captured as follows. The empirical analysis is based on cross-sectional data from 2008 to 2015, the latter being the most recent year for which regional GDP data was available across the EU. Please note that hereafter the study refers to regional as synonymous with NUTS-2 level[3].

Regional GDP data is from Eurostat and, where necessary, is supplemented by estimations from the European Commission's Directorate-General (DG) for Regional and Urban Policy[4]. Initial GDP per capita in 2008 is measured in purchasing power standards (PPS). Population growth is measured as average growth over the period of analysis (2008-2015, Eurostat); private and public investment are proxied by gross fixed capital formation as a share of GDP (average 2009-2015, Cambridge Econometrics); and the low-educated workforce is measured as the share of the population aged 25-64 with at most lower-secondary educational attainment, International Standard Classification of Education (ISCED) levels 0-2 (average 2006-2008; Eurostat). The quality of the regional institutions is described by the European Quality of Government Index (EQI) (Charron et al., 2014), which is a composite index developed by the Quality of Government Institute at Gothenburg University, and measures corruption, impartiality and the quality of the main public services. The 2010 edition is included in the analysis.

For the remaining variables, this study employs a subset of components of the 2010 EU RCI (Annoni and Kozovska, 2010). Published by the European Commission every three years since 2010, the EU RCI is a composite indicator which provides a synthetic picture of territorial competitiveness for each of the EU's NUTS-2 regions. The RCI builds on the Global Competitiveness Index by the World Economic Forum which comprises 11 components, each one an aggregate index of basic indicators describing different aspects of territorial competitiveness. Over 70 publicly available indicators from various official sources, mainly Eurostat but also from the World Bank, the World Economic Forum, the Organisation for Economic Co-operation and Development (OECD) and the European Commission's Regional Innovation Scoreboard, are split into the different RCI components. For the analysis in this study, the following six components are employed as explanatory factors of recent economic growth: the level of potential accessibility of motorways, railways and airports (infrastructure); the working-age population's level of higher education and lifelong learning (human capital); labour-market efficiency; households' technological readiness; the business sophistication of the economy; and the level of innovation in a region.

RCI 2010 is used in the analysis since its indicators all refer to the 2006-2008 period and are thus close to the starting year of this analysis (2008). Appendix A.1 provides a brief description of the RCI components used in this analysis and denotes the indicators included in each of these components (more information in Annoni and Kozovska, 2010, Dijkstra et al., 2011). The inclusion of RCI components enables the authors of this study to gain a more nuanced understanding of the causes of recent economic growth within each spatial regime. In fact, each RCI component is an aggregate measure of observable proxies all related to the concept which that component is expected to describe. Employing RCI components as explanatory variables rather than single, basic indicators is an important element of the analysis because it allows this study to provide a more holistic measurement of the latent concepts used as explanatory factors.

Finally, as mentioned above, the spatial unit of analysis in this study consists of both NUTS-2 regions and FUAs. As Lim (2016) points out, the question of which are the most appropriate spatial units to use has received little attention so far. Among studies on European regions, the NUTS-2 region is a prominent choice due to a vast quantity of data available and the fact that this is the territorial level at which funds are allocated by the European Regional Development Funds. However, it remains uncertain whether such administratively defined regions are most suitable since sometimes they are 'neither economically homogeneous entities nor are they self-contained with respect to labour markets' (Lim, 2016) and thereby may cause nuisance spatial dependence[5]. Using functionally rather than administratively defined regions can help to reduce nuisance spatial dependence (Magrini, 2004). In a first step to address this issue, this study employs FUAs for six major capital regions and their commuting belts, which would be particularly misrepresented if assessed strictly according to their NUTS-2 classification, due to the significance of the impact of their commuting zones on economic activity. Jointly defined by the EU and the OECD, this analysis uses six FUAs, namely the following capital regions and their commuting belts: Amsterdam, Berlin, Brussels, London, Prague and Vienna (Dijkstra and Poelman, 2014). This is an initial effort to better consider the suitability of spatial units in regional growth analyses.

3. The NUTS classification (Nomenclature of Territorial Units for Statistics) is a hierarchical system employed by the European Statistical Office – Eurostat – to divide up the EU's economic territory for the collection, development and harmonisation of European regional statistics. There are different levels of NUTS regions: NUTS-0 corresponds to the country level, while levels 1, 2, and 3 correspond to sub-national levels of smaller and smaller territorial units in terms of population.

4. In some countries, NUTS-2 level growth rates are not readily available and thus are estimated internally by the European Commission's DG Regional and Urban Policy. This is performed by regionalising national gross value added (GVA) at constant prices with regional GVA at current prices by sector. A combination of Eurostat's real growth rates with those estimated internally is applied to the current GDP to obtain the GDP in constant prices at the NUTS-2 level.

5. Nuisance spatial dependence is defined by Lim (2016) as the result of a mismatch between the geographical boundaries of the economic processes and the boundaries of the observational units.

4. IDENTIFICATION OF SPATIAL REGIMES THROUGH EXPLORATORY SPATIAL DATA ANALYSIS

Moran's I and Geary's C indexes are employed to test for global spatial autocorrelation (Geary, 1954, Moran, 1950). They both compare the value of the variable of interest, in this case the starting GDP per capita, in any one region with the value in all other neighbouring regions, within a pre-defined neighbouring area. If neighbouring regions over the entire area of observation have similar (dissimilar) values, then both statistics indicate a strong positive (negative) spatial autocorrelation.

The two indexes are related but not identical. Moran's I varies between -1 (perfect dispersion) and +1 (perfect spatial correlation)[6]. The value of Geary's C lies between 0 and 2 where 1 means no spatial autocorrelation[7]. For both indexes, inference is based on the permutation approach, assuming that, under the null hypothesis, each observed value could have occurred at all locations with equal likelihood. A reference distribution can be empirically generated and significance values can be computed.

Both indexes depend on the definition of the neighbouring area of each region k which, in turn, is defined on the basis of the spatial weight matrix $W(k)$. The specification of $W(k)$ is a much-debated issue in the literature (Abreu et al., 2005) since the choice of spatial weights can profoundly impact the results. In cases where the spatial weight matrix is not a contiguity matrix, which is when neighbouring regions are simply defined as those sharing a boundary, two elements are of key importance in the specification of $W(k)$: the type of distance and the limit to the range of spatial dependence, the so-called cut-off distance. This paper offers innovative solutions on both fronts.

First, the distance employed in this study is the estimated travel-time distance by road (ferry) which connects the regions along the actual road (ferry) network. Travel-time distances are derived from the TRANS-TOOLS road network tool, a European transport network model developed by the European Commission[8], and are computed between population-weighted NUTS-2 regions' centroids. This study considers this type of distance measurement more realistic than the classical Euclidean distance between regions' centroids, since urban areas in the EU are often located in highly congested networks.

Secondly, the cut-off distance, which is generally selected solely on the basis of theoretical consideration, is defined in this study by the variogram analysis, one of the most popular instruments in geostatistics (Cressie, 1984, Haining, 2003, Thompson, 1992).

VARIOGRAM ANALYSIS

The variogram is a function estimated on georeferenced observed data which describes their spatial dependencies. The shape of the estimated variogram function indicates the structure of spatial autocorrelation in the observed data. The variogram function is defined as the variance of the difference of the value of the variable of interest y at separate points (regions) across the area of interest:

$$2\gamma\,(h) = \mathrm{Var}\,[y_{i+h} - y_i] \qquad (1)$$

where y_i is the value of y at region i and y_{i+h} is the value of y in a region separated from region i by the distance h. The function $\gamma(h)$ is called semi-variogram and describes the spatial dependence structure. In this case, y_i is the value of GDP per capita in region i at the beginning of the period under investigation (2008) and the distance is the travel-time distance along the road network between regions.

Using the assumption of 'second-order stationarity' (Cressie, 1984), the semi-variogram is considered to be valid over the entire dataset and the relationship between the semi-variogram and the covariance of y is:

$$\begin{aligned}&\mathrm{Cov}[y_{i+h}, y_i] = \mathrm{E}[y_{i+h}\cdot y_i] - \mathrm{E}^2[y_i] = \mathrm{E}[y_{i+h}\cdot y_i] - \mu^2 \equiv C(h)\\&\gamma(h) = \mathrm{Var}(y) - C(h)\end{aligned} \qquad (2)$$

The estimated (semi-)variogram $\hat{\gamma}(h)$ is computed as:

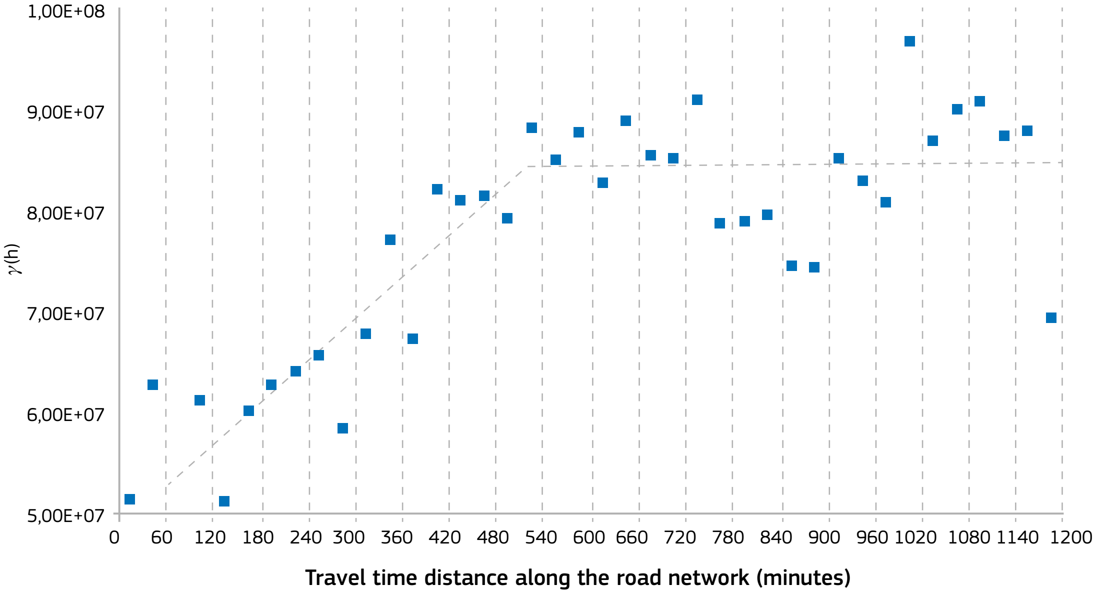
$$2\hat{\gamma}(h) = \frac{1}{n(h)}\sum_i (y_{i+h} - y_i)^2 \qquad (3)$$

where the summation is over all distinct pairs of regions that are h distance apart and $n(h)$ is the number of region pairs that are h distance apart. Values of $\hat{\gamma}(h)$ are close to zero if values in regions separated by distance h are highly correlated. Values of $\hat{\gamma}$ increase as the correlation among neighbouring regions decreases. The variogram is therefore a measure of spatial dissimilarity.

The variogram function is generally estimated by fitting the best curve to the observed data. The shape of $\hat{\gamma}(h)$ provides a graphical description of the structure of the spatial dependence at different distances. The shape generally shows a strong spatial dependence at short distances that decreases as h increases up to a certain distance, called the range, beyond which the level of spatial dependence levels off to nearly zero. The range of the empirical variogram specifies the maximum distance beyond which spatial correlation can be considered null, indicating the cut-off distance of the spatial weight matrix $W(k)$.

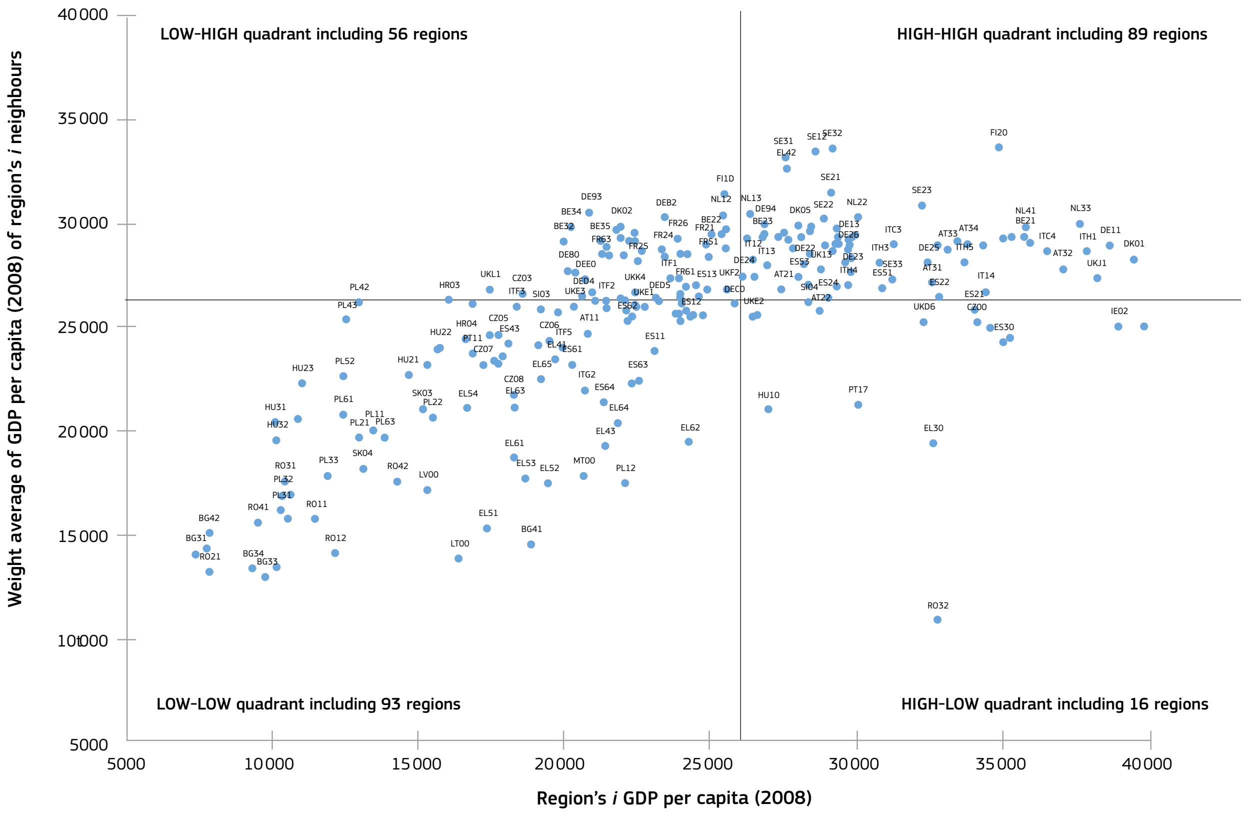
6. Perfect spatial dispersion means that high values are always surrounded by low values and vice versa. Perfect spatial correlation indicates that there is always a concentration of above- (below-) average values spatially close to other above- (below-) average values (high-high or low-low). Under the null hypothesis of no spatial correlation, the expected value of the Moran's I – $E[I]$ – depends solely on the number of regions (n). Values of I larger than $E[I]$ indicate positive spatial autocorrelation, while values smaller than expected indicate negative spatial autocorrelation.
7. Values lower than 1 demonstrate increasing positive spatial autocorrelation, whilst values higher than 1 illustrate increasing negative spatial autocorrelation.
8. http://energy.jrc.ec.europa.eu/transtools/

FIGURE 1: Empirical semi-variogram based on GDP per capita (2008) for all EU regions.



Source: Eurostat, DG REGIO elaboration

FIGURE 2: Moran's I scatter plot on GDP per capita (2008).

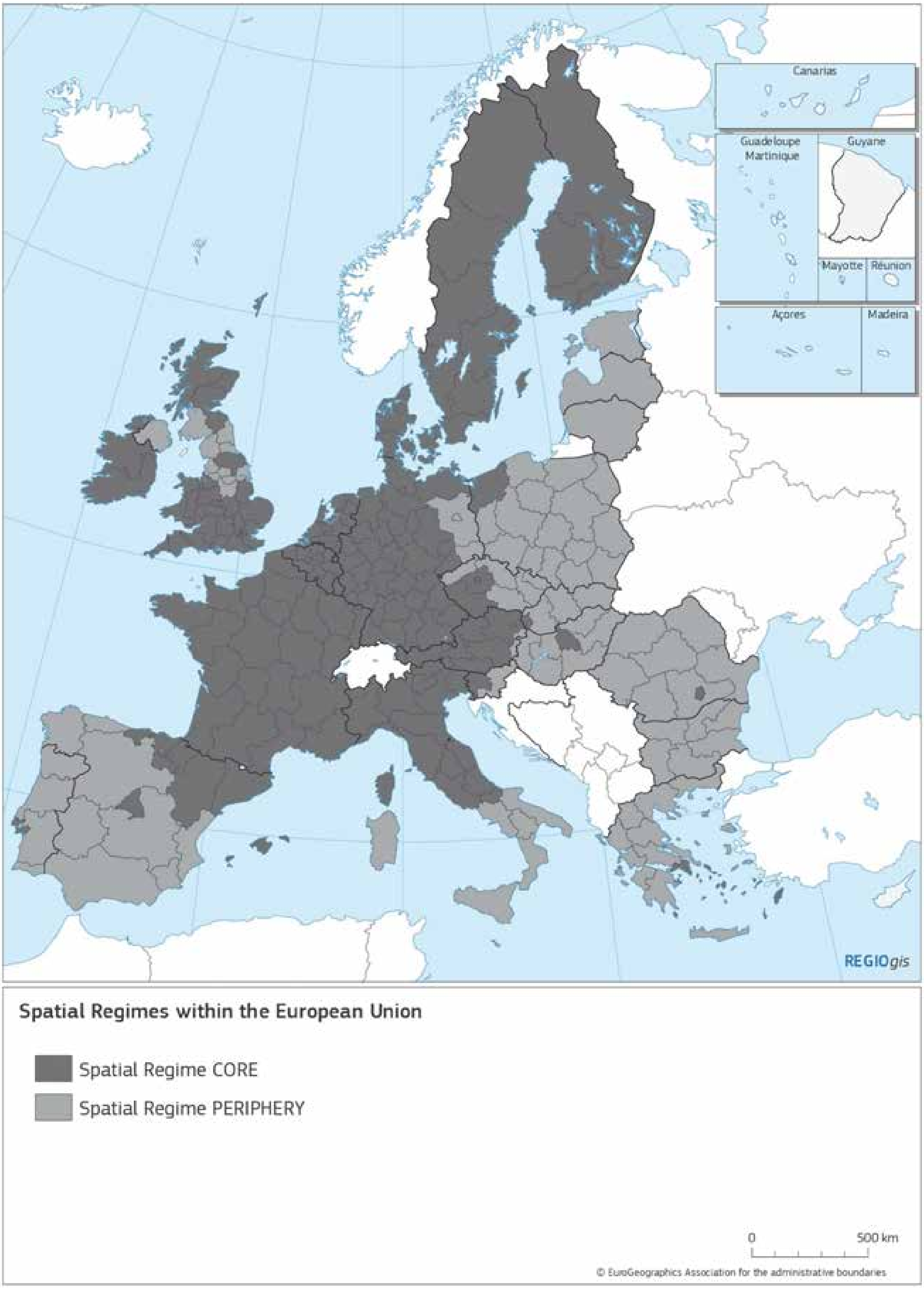


EU average GDP per capita (2008) = 26 082 euro

Note: Luxembourg region is an outlier and is not shown in the graph

Source: Eurostat, DG REGIO elaboration

FIGURE 3: The two spatial regimes identified by Moran's *I* scatter plot and ANOVA analysis.



Source: Eurostat, DG REGIO elaboration

Initial GDP per capita levels (2008) across all EU regions and travel-time distances across the road network are used to estimate the empirical variogram in this study (Figure 1). The shape found is typical, with the level of spatial correlation gradually decreasing as distances increase. The empirical cut-off distance is approximately 500 minutes, at which point the function levels off.

The weights used in the spatial weight matrix in the rest of the analysis are defined as the inverse of travel-time distances with a cut-off of 500 minutes.

The global spatial autocorrelation indexes, Moran's I and Geary's C, have been computed for the whole EU for the initial GDP per capita across all the years of the analysis, with a spatial weight matrix based on the inverse of travel-time distance with a cut-off of 500 minutes. The values of both indexes and their p-value, always less than 0.0001, indicate a significant spatial autocorrelation pattern across the EU for the entire period (2008-2015)[9].

Moran's I scatter plot (Figure 2) visualises the spatially weighted average GDP of all of region i's neighbours on the GDP of region i (Anselin, 1995, Ertur & Koch, 2006). The different quadrants correspond to four types of local spatial association: High-High (HH), Low-Low (LL), Low-High (LH) and High-Low (HL). HH regions are those with GDP per capita above the EU average surrounded by neighbouring regions with a spatially weighted average GDP also above the EU average. Similar logic follows for the other categories.

The most represented category of regions is LL which includes 93 regions, closely followed by the HH category which includes 89 regions. The LH category and the HL category include 56 and 16 regions, respectively. Most of the regions in the HL category are either FUAs (section 2) or capital regions: Vienna and Prague, with their respective commuting belts, in addition to Madrid, Lisbon, Athens, Helsinki, Budapest, Bucharest and Bratislava. These regions can be considered as 'ivory towers', representing anomalies rather than the mainstream pattern of spatial dependence across the EU.

There are several reasons why this study does not pursue a spatial econometric analysis with the four categories identified by the Moran's I scatter plot. Primarily, the number of regions in two of the categories, HL and LH, is not high enough to generate reliable model estimates. Furthermore, Moran's I scatter plot relies solely on GDP per capita and does not take into account all the other explanatory variables this study seeks to include in the model. Finally, most of the region i's in the LH quadrant have a GDP per capita very close to the EU average (Figure 2 shows how they are clustered towards the centre of the scatter plot, which represents the EU average of GDP per capita).

These observations led this study instead to define two regimes out of the four identified by the Moran's I scatter plot. To this aim, an analysis of variance – ANOVA (Morrison, 2005) – on all the explanatory variables is carried out with all possible combinations of the four regimes. The ANOVA results show that the highest polarisation of the explanatory variables is obtained by keeping the LL regime as a regime by itself while grouping the other categories into a single regime {HH, LH, HL}[10].

The two regimes, referred to from now on as *periphery* for the LL regions and *core* for the HH, HL, and LH regions, clearly divide the EU into a richer north-centre core and a poorer south-east periphery (Figure 3)[11]. Descriptive statistics of all the variables tested in the analysis are provided in Appendix A.2.

9. Detailed results are available from the authors upon request.
10. Results of the ANOVA analysis are available from the authors upon request.
11. Stability of the regimes over time has been checked by comparing the distribution of GDP per capita (in PPS) at the beginning, in the middle and towards the end of the period being analysed. Regions above (below) the EU-28 average tend to be consistent over time, suggesting an overall stability of the regimes over the period being analysed. The three maps of regional GDP per capita are available from the authors upon request.

5. EMPIRICAL ANALYSIS AND RESULTS

5.1 EMPIRICAL ANALYSIS

The dependent variable of the model is defined as the average annual growth rate of regional GDP per capita in constant prices (reference year 2010) in the period 2009-2015. Explanatory variables are measured at the beginning of the period (or close to the beginning) to avoid endogeneity issues.

Spatial regression models are necessary to account for spatial dependence between observations. The spatial econometric literature suggests a range of model specifications to account for the presence of spatial dependence across spatially correlated data. This study follows the argument proposed by LeSage and Fisher (2008) who state that the conjunction of two specific circumstances in applied regional growth regression models make the Spatial Durbin Model (SDM) specification a natural choice over competing alternatives: first, the presence of spatial dependence in the error terms of the Ordinary Least Square (OLS) regression model; and second, the existence of an omitted spatially dependent variable (or variables) that is (are) correlated with an included variable (variables)[12].

The SDM (Anselin, 1988, LeSage and Pace, 2009) allows this study to include two types of spatial dependence concurrently: the first one works through the dependent variable, whilst the second one works through the full set of explanatory variables.

The SDM model takes the form:

$$\mathbf{g}_{nx1} = \rho \mathbf{W}_{nxn} \mathbf{g}_{nx1} + \alpha \mathbf{I}_{nx1} + \mathbf{X}_{nxk} \beta_{kx1} + \mathbf{W}_{nxn} \mathbf{X}_{nxk} \theta_{kx1} + \varepsilon_{nx1} \tag{4}$$

where:

g_{nx1} : average annual growth rate of GDP per head (in PPS) in the n regions in the period being analysed (2009-2015);

W_{nxn} : non-negative spatial weight matrix, based on the inverse of the travel-time distance, with cut-off at 500 minutes;

X_{nxk} : set of k explanatory variables: initial GDP per capita, investment, population growth; infrastructure; quality of institutions; human capital (both as low and highly educated), labour market efficiency, technological readiness, business sophistication and innovation;

ε_{nx1} : normally distributed error term.

The model in (4) enables regional growth rates to depend on its own set of regional characteristics, on the same characteristics observed in neighbouring regions, and on the level of spatial dependence across regional growth rates captured by the parameter ϱ. The terms Wg and WX represent the spatial lag of the dependent and of the explanatory variables, respectively. The term Wg is the spatially weighted linear combination of the initial growth rates in neighbouring regions, while WX represents a spatially weighted combination of characteristics in neighbouring regions.

All the potential factors of growth listed in section 2 have been tested in both the OLS and the SDM specifications. As expected, the data features high levels of multi-collinearity which makes it particularly difficult to specify the correct model. To estimate the model, this study follows two criteria: (i) the significance value (p-value) for both the factor and its spatial lag, and (ii) the OLS variance inflation factor value.

Neither the infrastructure nor the labour market efficiency[13] component has been found to be statistically relevant in almost any of the model specifications. Although the reason for this could certainly be ascribed to the analysis' limited time span, interestingly, both results are in line with recent economic analyses on regional growth in the EU (Crescenzi and Rodriguez-Pose, 2012, Rodriguez-Pose and Garcilazo, 2013, Annoni and Catalina Rubianes, 2016).

The authors also find the role of innovation to be rather limited across the different models. As expected, the RCI components that play a key role in innovation-driven economies – technological readiness, business sophistication and innovation – are deeply intertwined. Of the three, the models indicate the impact of the innovation component on economic growth to be the weakest. As striking as this may seem, this finding is once again in line with recent analyses on regional growth (OECD, 2012, Annoni and Catalina Rubianes, 2016). In particular, the *innovation paradox* introduced by the OECD (2012) gives possible reasons for the weak support the model provides for the link between innovative activities and regional growth. One reason relevant to this analysis is that research and technological innovation matter more as regions approach the productivity frontier. For regions further away from the frontier, other strategies can be more viable than trying to be innovative themselves, such as adopting technology from more advanced regions. Another reason is that cutting-edge innovation does not necessarily generate growth where it takes place. This is surely valid at the national level and is likely to be even more accurate at the regional one: local innovation and local growth are not necessarily linked.

Thus, the OECD analysis provides this study with a compelling rationale as to why the innovation component is not found to be relevant in explaining recent growth. It is worth noting that, among the three innovation-related RCI components included in this analysis, innovation is deemed to be the most advanced of the three on the spectrum of regional innovativeness (see the indicators included in the innovation component in Appendix A.1). Thus, infrastructure, labour-market efficiency and innovation components have been excluded from further analysis.

12. The procedure proposed by Elhorst (2010) is applied here to test the appropriateness of the SDM specification. First, this study estimates the OLS model. Second, by using the classic Lagrange Multiplier (LM) test and its robust version (RLM), performs a test on the regression residuals to determine whether the results from the OLS can be accepted (Anselin, 1988 and Anselin et al., 1996). Since this study finds that the OLS model is rejected in favour of both the spatial lag and the spatial error models (Table 2), the authors have estimated an SDM. As a final step, this study employs a likelihood ratio (LR) test to examine whether the SDM can be simplified to the spatial lag or to the spatial error model. As both assumptions are rejected, the authors assume that the SDM is the model that best describes this study's data.

13. Long-term unemployment was also tested as a simpler version of the labour market efficiency component of the RCI, but was never found to be statistically relevant.

As opposed to an OLS model or other spatial models that do not contain the spatial lag of the dependent variable (i.e. spatial error model, SEM), SDM models allow one to estimate both the direct and indirect effects of the different explanatory variables on the dependent one (in our case regional growth rates; see LeSage and Pace, 2009, Elhorst, 2010). In the SDM, which includes the spatial lag of both the dependent and the explanatory variables, the direct effect refers to the extent to which regional growth in one region is affected by a change in the region's explanatory variables. The indirect effect measures the extent to which a change in the explanatory variables in neighboring regions affects regional growth in the region itself, but also how a change in the explanatory variables in the region affects the region itself through feedback effects from its neighbours (Abreu et al., 2005, LeSage and Pace, 2014). Given that the empirical modelling approach includes spillover effects from neighbouring regions through the spatially lagged dependent and explanatory variables, the drivers of economic growth will also include such external factors.

In addition, this study extends the existing empirical literature on the determinants of regional growth across EU regions to allow for parameter estimates to differ across the two spatial regimes identified in section 4. In this respect, this investigation enriches the work of Özyurt and Dees (2015) who, in a similar fashion, estimate a regional SDM model for the EU[14].

Following the literature on club convergence initiated by Durlauf and Johnson (1995), then applied to the European case by Ertur et al. (2006) and Le Gallo and Dall'Erba (2003), the authors assume that regions in the EU converge to distinct multiple, locally stable, steady-state equilibria (i.e. two spatial regimes) – according to their level of economic development – where the estimated parameter values associated to the conditioning variables differ significantly across the two regimes.

This study starts its empirical analysis with the estimation of a simple OLS model with one and two spatial regimes, respectively. Results of the OLS estimations of the model are only presented here to test whether spatial dependence is present in the OLS residuals[15], as well as to show that the estimated coefficients are significantly different across the two spatial regimes.

The results of the spatial model diagnostics, presented at the bottom of Table 1, clearly indicate the presence of spatial autocorrelation. The Moran's I statistic for spatial autocorrelation applied on the residuals of the OLS is positive and highly significant, indicating that the model is misspecified, although no indication can be inferred as to which alternative specification should be used. The result of the spatial Chow test in Table 1 clearly confirms the rejection of the null hypothesis, suggesting significantly different coefficients for each of the two regimes.

The Spatial Durbin Model is then estimated with both one and two spatial regimes (Table 2). Results of the spatial Chow test shown in Table 2 point once again to the significant differences between the coefficients estimated in each regime. The existence of spatial externalities is strongly supported by the estimated coefficient of the lagged dependent variable, highlighting the presence of spatial dependence between regional growth rates, and indeed confirming that OLS is not suitable for this study's dataset. To correctly interpret the model, direct and indirect impacts in the two spatial regimes have been estimated together with their standard error (Table 3)[16].

5.2 RESULTS

This study has found that regardless of the spatial regime to which a region belongs, spatial effects are important for any region, leading to the conclusion that: *location matters*. If a region is surrounded by high-growth regions, this positively affects its own growth, in both the core and peripheral regimes. Further, in agreement with the conventional empirical literature on convergence, the direct effect of the initial level of GDP is negative and highly significant in both regimes, which suggests a 'catching-up' process (Solow, 1956) in which poorer economies grow faster than richer ones.

Human capital is found to be a significant growth factor in both spatial regimes. In both the core and the periphery, the results infer that a high share of low-educated people in the workforce (at most lower-secondary education) is detrimental to regional growth. As recent contributions (Annoni and Catalina Rubianes, 2016, OECD, 2012) find, a higher proportion of low-educated people are in fact even more of an impediment to growth than a lower proportion of highly educated ones, which serves to underline the significance of ensuring sufficient levels of education.

In the periphery, the relevance of human capital as a growth factor is observed at both ends of the spectrum since, in addition to the negative effect of a low-educated workforce, higher education is also found to be positively associated with regional growth. These results are supported in the literature, which highlights the indispensable role that human capital plays in the earlier stages of economic development (Barro 1991). In this regime, the results also suggest the existence of spillover effects for the higher education component, indicating that the presence of a highly educated workforce positively affects growth in neighbouring regions. As such, policy initiatives aimed at increasing levels of higher education in a region not only promote growth within but also across regional borders – contributing to cross-regional development. The findings suggest that in difficult economic periods, regardless of the stage of economic development, investing in human capital, which can spur economic growth by increasing the productivity of the labour force, remains an integral component of more resilient economies.

14. Özyurt and Dees (2015) use a panel setting and look at differences among income levels instead of rates of income growth.
15. That is, this study assumes that parameters ρ and $\beta 2$ in equation (4) are equal to zero.
16 Simulations have been carried out using the software @R, with Markov chain Monte Carlo estimation of standard errors, 1 000 replications.

Table 1: Estimated results of the OLS

	(1) OLS All regions	(2) OLS Core	(3) OLS Periphery
Constant	23.30*** (3.70)	24.70*** (5.81)	2.47 (7.40)
Initial GDP per head (natural logarithm, ln)	-2.26*** (0.37)	-2.41*** (0.56)	-2.74*** (0.61)
Investment	3.80* (2.17)	4.13* (3.14)	3.26 (3.23)
Population growth	-0.01 (0.02)	-0.00 (0.02)	-0.02 (0.03)
Infrastructure (RCI component)	-0.28 (0.12)	-0.31** (0.14)	-0.24 (0.37)
Quality of institutions	0.27* (0.15)	0.43** (0.20)	–0.04 (0.27)
Lower-secondary education	-0.03*** (0.01)	-0.03*** (0.01)	-0.02* (0.01)
Higher education and training (RCI component)	-0.00 (0.18)	-0.38* (0.23)	1.10*** (0.33)
Labour market efficiency (RCI component)	0.01 (0.16)	0.11 (0.23)	–0.23 (0.28)
Technological readiness (RCI component)	0.42** (0.16)	0.12 (0.20)	1.17*** (0.28)
Business sophistication (RCI component)	1.16*** (0.21)	1.24*** (0.27)	0.36 (0.36)
Innovation (RCI component)	-0.30 (0.21)	0.08 (0.26)	-0.89** (0.37)
Adj R-squared	0.48	0.52	
Chow test		2.76 (p-value <0.001)	
Spatial diagnostics			
Moran's I (residuals)	0.22***	0.16***	
LMerr	124.0***	66.34***	
RLMerr	30.47***	12.15***	
LMlag	103.99***	65.25***	
RLMlag	10.52***	11.06***	
Number of observations	254	254	

*Note: the dependent variable is the average annual growth rate of GDP per head between 2009 and 2015 (as the percentage change). Standard errors are shown in parentheses and statistical significance levels are labelled with ***, **, and * referring to the 1, 5 and 10% significance levels, respectively.*

Furthermore, the results suggest that among core regions, which generally experience higher average incomes, the quality of institutions is an essential determinant of growth, thereby endorsing previous findings in the literature which highlight that good institutions are vital to economic development. However, the results do not indicate the existence of spillover effects associated with the regional quality of institutions. Good governance – which generally implies higher productivity from production factors, lower rent-seeking behaviour, accelerated administrative processes, stronger citizen-state relationships, and reduced corruption – will do much to improve conditions for augmented economic activity in a region although it is often bounded by jurisdictional borders and thus has little positive effect on adjoining administrative realities.

The confined nature of this growth factor, as the absence of spillover effects suggests, underlines the importance of targeted regional efforts to enhance the quality of governance in an attempt to spur economic growth. However, among the peripheral regions, this analysis finds a negative spillover effect, possibly inferring that neighbouring regions with good governance structures attract physical and human capital, thereby inducing the said negative effect on the economic growth of the region with weaker institutions.

Table 2: Estimated results of the Spatial Durbin Model

	Spatial Durbin All regions	Spatial Durbin Core	Spatial Durbin Periphery
Constant	2.80 (8.24)		
Initial GDP per head (ln)	-1.54*** (0.32)	-1.62*** (0.44)	-1.82*** (0.52)
Investment	1.89 (1.86)	4.35* (2.54)	2.59 (2.73)
Population growth	0.01 (0.02)	0.03 (0.02)	-0.01 (0.02)
Quality of institutions	0.42*** (0.15)	0.55*** (0.18)	-0.01 (0.22)
Lower-secondary education	-0.02** (0.01)	-0.03** (0.01)	-0.03*** (0.01)
Higher education and training (RCI component)	0.05 (0.16)	–0.16 (0.19)	0.54** (0.26)
Technological readiness (RCI component)	0.12 (0.16)	-0.00 (0.18)	0.35 (0.27)
Business sophistication (RCI component)	0.44*** (0.17)	0.49** (0.21)	-0.12 (0.29)
GDP per head (ln) in neighbouring regions	1.06 (0.83)	-1.71 (2.48)	-4.49* (2.46)
Investment in neighbouring regions	9.75 (6.92)	28.64** (11.73)	-21.62 (15.44)
Population growth in neighbouring regions	-0.05 (0.05)	-0.24*** (0.09)	0.07 (0.10)
Quality of institutions in neighbouring regions (RCI component)	-1.24*** (0.45)	0.11 (0.86)	-1.69*** (0.63)
Lower-secondary education in neighbouring regions	0.02 (0.02)	0.03 (0.05)	0.14*** (0.04)
Higher education and training in neighbouring regions (RCI component)	0.13 (0.44)	-0.76 (0.61)	3.56** (1.55)
Technological readiness in neighbouring regions (RCI component)	0.68 (0.52)	0.30 (0.82)	2.92*** (1.10)
Business sophistication in neighbouring regions (RCI component)	-0.23 (0.40)	0.20*** (0.59)	-4.20*** (1.58)
Growth rate in neighbouring regions	0.81***		0.58***
Spatial Chow test: 48.34 (p-value <0.001)			

*Note: the dependent variable is the average annual growth rate of GDP per head between 2009 and 2015 (as the percentage change). Standard errors are shown in parentheses and statistical significance levels are labelled with ***, **, and * referring to the 1, 5 and 10% significance levels, respectively.*

Table 3: Calculated total, direct and indirect impacts for the Spatial Durbin Model

	All regions			Core			Periphery		
	Direct effect	Indirect effect	Total effect	Direct effect	Indirect effect	Total effect	Direct effect	Indirect effect	Total effect
Initial GDP per head (ln)	-1.55***	-0.95	-2.50	-1.72***	-6.28	-8.00	-2.01***	-13.09*	-15.10*
Investment	2.72	58.24	60.97	5.43**	73.59*	79.01**	1.89	-47.49	-45.60
Population growth	0.01	-0.19	-0.18	0.02	-0.52*	-0.50*	-0.01	0.17	0.17
Quality of institutions	0.35**	-4.64	-4.29	0.56***	1.02	1.58	-0.07	-4.01**	-4.08**
Lower-secondary education	-0.02**	0.03	0.01	-0.03**	0.02	-0.01	-0.03**	0.29**	0.26*
Higher education and training (RCI component)	0.06	0.88	0.93	-0.19	-2.03	-2.22	0.68**	9.15*	9.83*
Technological readiness (RCI component)	0.18	4.02	4.20	0.01	0.70	0.71	0.46*	7.36**	7.82**
Business sophistication (RCI component)	0.45***	0.63	1.07	0.51**	1.15	1.66	-0.26	-10.10*	-10.32*

*Note: the statistical significance levels are labelled with ***, **, and * referring to the 1, 5 and 10% significance levels, respectively.*

In the core regime, specialisation in higher-value-added activities (proxied by business sophistication) is a significant determinant of growth and thus important to sustained economic growth, especially for the higher initial levels of economic development. In the peripheral regime, a negative and weak spillover effect is detected, suggesting that neighbouring regions with more sophisticated business environments attract physical and human capital, thereby producing a negative effect on the growth of the region specialised in lower-value-added economic activities.

While the above delineates common growth factors across EU regions, this study also finds distinct factors associated with each regime. Investment levels are found to be statistically significant only in the core regime. This suggests that among higher-income regions, which on average have a higher level of institutional quality, sustained investment has been essential for growth, in particular during the economic crisis years. Moreover, the results indicate that investment induces significant and strong positive spillover effects, suggesting that higher shares of investment in a region have positive effects on the growth rate of neighbouring regions.

Within the core regime, a weak indirect effect is detected for population growth, indicating that a region's economic growth is negatively affected by population growth in surrounding regions. While further research is necessary to better understand this dynamic, one possible explanation could be that higher population growth in surrounding regions leads to greater labour supply which, in turn, could attract physical capital.

Technological readiness is identified as an important determinant in the peripheral regime. Advances in information and communication technologies (ICT) generally increase productivity and accelerate commercial processes, both of which are essential for economic competitiveness. The results indicate that technological readiness is an important factor for growth in less-developed regions and also induces positive spillover effects. Presumably, the effect of technological readiness is less prominent in the core regime, where regions are generally richer than in the peripheral regime, and thus may have already reached an advanced technological frontier.

While this study's results are mostly in line with findings of similar recent studies, a note of caution on the interpretation of the results should be introduced here. As is common with most regression-based analyses, the aim of this empirical investigation is to reveal relationships among variables, *ceteris paribus*, without implying that the relationships can be interpreted as causal.

6. CONCLUDING REMARKS AND POLICY IMPLICATIONS

The aim of this study was to empirically examine recent regional economic growth in two distinct groups of regions across the EU. While a long-term study of growth is of relevance, this analysis focused on the crisis and post-crisis period (2008-2015) across and within different spatial groups of regions in the EU, in an effort to better understand the characteristics of resilient regions and to capture any potential spillover effects. Two groups of regions were identified – a richer north-centre core and a poorer south-east periphery – which enabled the analysis to be more pertinent to the respective realities. The authors hope that this study's findings can be used to inform future European regional policy development and thereby to better equip European regions for future economic shocks.

BOX 1: Summary of direct and indirect effects from the SDM. Green shading indicates significant positive effect; red shading indicates significant negative effect (in both the darker the colour, the more significant the estimated effect is); white indicates absence of statistically significant effect.

	Core regime		Peripheral regime	
	Direct	Indirect	Direct	Indirect
GDP _head_PPS_2008				
Investment				
Population growth				
Quality of institutions				
Lower-secondary education				
Higher education and training				
Technological readiness				
Business sophistication				

By employing a Spatial Durbin Model, this analysis was able to model spillover effects of both economic growth and its main determinants while taking into account higher-order spatial interactions among regions. The results, as shown in Box 1 below, indicate that within the core, higher amounts of investment, a better quality of institutions, more pronounced business sophistication and reduced shares of the low-educated all have a significant effect on higher GDP per capita growth in a region itself, whilst higher investment levels and lower population growth in a region have a positive effect on GDP per capita growth in surrounding regions. Within the periphery, a lower proportion of the low-educated and a higher share of higher education and training, as well as more advanced technological readiness significantly affect higher GDP per capita growth in a region, while the lower quality of institutions, a higher proportion of low-educated, greater shares of higher education and training, more advanced technological readiness and less pronounced business sophistication all have a positive effect on GDP per capita growth in the surrounding regions.

This is a critical time for the future of the EU's Cohesion Policy, with regulations for the post-2020 regional policy period currently under discussion. There are several findings in this study that are particularly relevant to this debate and should be factored into the ongoing discussions. First, the study confirms that a number of core tenets of the EU's Cohesion Policy remain valid. The significance of location and spatial effects has long been the fundamental principle underpinning Cohesion Policy, and the importance of these elements, as highlighted by this analysis, fully endorses this principle. Similarly, the confirmation that aspects such as human capital, the quality of institutions and value-added business are key determinants of economic growth confirms the approach under development for the post-2020 period. In particular, the significance of higher-value-added activities in the pursuit of sustained economic growth finds resonance in the European Commission's Smart Specialisation strategy, a policy instrument to spur economic growth across Europe's regions. Smart Specialisation encourages Member States to 'focus their efforts and resources on a limited number of ambitious yet realistic priorities, where as a result, they would be able to develop excellence as well as compete in the global economy in a sustainable manner' (European Commission, 2013). The results of this study underscore the relevance of this policy instrument and emphasise its future role in developing resilient and growing regions. Moreover, the results inform the debate on middle-income regions, as recently defined by Iammarino et al. (2018) and the EC (2017), and suggest how the 'middle-income trap' can be avoided. The findings indicate that sustaining levels of investment and moving up the value chain may offer a path out of or around the middle-income trap, the latter in line with the Smart Specialisation policy, too.

As shown by the above examples, the differentiated nature of some of the determinants of growth identified in this study has the possibility to provide significant added value for the post-2020 Cohesion Policy programmes. The results can potentially be factored into EU programme negotiations, taking into account the individual situation of the region concerned. The spillover effects identified have been insufficiently prioritised in many Cohesion Policy programmes to date as they are often more internally focused. This is a further area for potential development of EU policy.

In conclusion, this study aims to have contributed to the literature in two ways. It has employed innovative methods and a sound empirical framework to identify determinants of regional growth and resilience in two spatial regimes in the post-crisis EU and has highlighted those factors that have spillover effects. The results suggest some important policy implications. Therefore, the authors hope that future research and regional policy development can be pursued on the backdrop of these results, which could serve to inform and shape strategies, some of which have been suggested above, to better combat economic shocks in an increasingly interconnected European Union.

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ANNEXES

APPENDIX A.1: RCI COMPONENTS TESTED IN THE ANALYSIS

RCI component	Indicators included	Source	Geographical level	Unit of measurement	Reference year
Infra-structure	1. Motorway potential accessibility	DG Regio	NUTS2	population living in surrounding regions weighted by travel time along motorways	2010
	2. Railway potential accessibility	DG Regio	NUTS2	population living in surrounding regions weighted by travel time along railways	2010
	3. Number of passenger flights (accessible within 90' drive)	Eurostat/ EuroGeographics/ National Statistical Institutes	NUTS2	daily no. of passenger flights	2010
Higher education & training	1. Population aged 25-64 with higher educational attainment (ISCED 5-6)	Eurostat (LFS)	NUTS2	% of total population of age group	2007
	2. Lifelong learning	Eurostat Regional Education Statistics	NUTS 2	% of population aged 25-64 participating in education and training	2007
	3. Early school leavers	Eurostat Structural Indicators	NUTS2	% of the population aged 18-24 having attained at most lower secondary school and not going further	average 2006/2007
	4. Accessibility to universities	Nordregio, EuroGeographics, GISCO, EEA ETC-TE	NUTS2	% of regional population at more than 60 minutes from the nearest university	2006
	5. Higher education expenditure	Eurostat Educational Statistics	country	total public expenditure as % of GDP at levels ISCED 5-6	2006
Labor market efficiency	1. Employment rate (excluding agriculture)	Eurostat Regional Labour Market Statistics (LFS)	NUTS 2	% of population 15-64 years	2008
	2. Long-term unemployment	Eurostat Regional Labour Market Statistics (LFS)	NUTS 2	% of labor force unemployed for 12 months or more	2008
	3. Unemployment rate	Eurostat Regional Labour Market Statistics (LFS)	NUTS 2	% of active population	2008
	4. Labor productivity	Eurostat Regional Labour Market Statistics (LFS)	NUTS 2	GDP/person employed in industry and services (€), Index, EU27 = 100	2007
	5. Gender balance unemployment	Eurostat, DG Regional Policy	NUTS 2	% difference between female and male unemployed	2008
	6. Gender balance employment	Eurostat, DG Regional Policy	NUTS 2	% difference between female and male unemployed	2008
	7. Female unemployment	Eurostat Regional Labour Market Statistics (LFS)	NUTS 2	% of female unemployed	2008

RCI component	Indicators included	Source	Geographical level	Unit of measurement	Reference year
Techno-logical readiness	1. Households with access to broadband	Eurostat Regional Information Statistics	NUTS2	% of total households	2009
	2. Individuals who ordered goods or services over the Internet for private use	Eurostat Regional Information Statistics	NUTS2	% of individuals	2009
	3. Household with access to internet	Eurostat Regional Information Statistics	NUTS2	% of total households	2009
Business sophisti-cation	1. Employment in the "Financial intermediation, real estate, renting and business activities" NACE sectors (J_K)	Eurostat Regional Labour Market Statistics	NUTS2	% of total employment	2007
	2. Gross Value Added (GVA) at basic prices for NACE sectors J_K (NACE)	Eurostat Regional Economic Statistics	NUTS2	% of total GVA	2007
	3. FDI intensity	ISLA-Bocconi	NUTS2	number of new foreign firms per mln. inhabitant	average 2005-2007
	4. Aggregate indicator for strength of regional clusters	European Cluster Observatory	NUTS 2	score (for more details see Appendix B)	2006
Innovation	1. Innovation patent applications	OECD REGPAT	NUTS2	number of applications per million inhabitants	average 2005-2006
	2. Total patent applications	OECD REGPAT	NUTS2	number of applications per million inhabitants	average 2005-2006
	3. Core Creativity Class employment	Eurostat (LFS)	NUTS 2	% of population aged 15-64	average 2006-2007
	4. Knowledge workers	Eurostat (LFS)	NUTS 2	% of total employment	2006
	5. Scientific publications	Thomson Reuters Web of Science & CWTS database (Leiden University)	NUTS2	publications per million inhabitants	average 2005-2006
	6. Total intramural R&D expenditure	Eurostat Regional Science and Technology Statistics	NUTS2	% of GDP	2007

RCI component	Indicators included	Source	Geographical level	Unit of measurement	Reference year
Innovation (continued)	7. Human Resources in Science and Technology (HRST)	Eurostat Regional Science and Technology Statistics	NUTS2	% of labour force	2008
	8. Employment in technology and knowledge-intensive sectors	Eurostat Regional Science and Technology Statistics	NUTS2	% of total employment	2008
	9. High-tech inventors	OECD REGPAT	NUTS2	number of inventors (authors of high technology EPO patent applications) per million inhabitants	average 2005-2006
	10. ICT inventors	OECD REGPAT	NUTS2	number of inventors (authors of ICT EPO patent applications) per million inhabitants	average 2005-2006
	11. Biotechnology inventors	OECD REGPAT	NUTS2	number of inventors (authors of biotechnology EPO patent applications) per million inhabitants	average 2005-2006

APPENDIX A.2:
DESCRIPTIVE STATISTICS OF ALL THE VARIABLES TESTED IN THE ANALYSIS

Core				Quantiles				
Variable	Number of regions	Mean	Standard Deviation	Min	0.25	Median	0.75	Max
Quality of institutions (EQI)	160	0.57	0.68	-2.84	0.34	0.73	0.97	1.76
Investment	160	0.19	0.03	0.12	0.17	0.19	0.21	0.34
Population growth	160	3.66	4.50	-9.00	0.90	3.21	6.91	21.85
Infrastructure (RCI component)	160	0.16	0.90	-1.36	-0.61	0.04	0.80	2.13
Lower-secondary education	160	27.11	11.04	4.43	18.47	25.15	33.48	60.13
Higher education and training (RCI component)	160	0.11	0.59	-2.15	-0.22	0.10	0.45	1.53
Labor market efficiency (RCI component)	160	0.36	0.57	-1.13	-0.03	0.37	0.83	1.76
Technological readiness (RCI component)	160	0.46	0.80	-1.74	-0.18	0.72	1.13	1.83
Business sophistication (RCI component)	160	0.03	0.61	-1.50	-0.33	-0.05	0.40	1.88
Innovation (RCI component)	160	0.31	0.62	-1.55	-0.09	0.23	0.74	1.92
GDP per head (in PPS), 2008	160	29295	7309	12978	24018	28379	32781	67605
Growth of GDP per head (2009-2015)	160	1.00	0.01	0.96	1.00	1.00	1.01	1.04

Periphery				Quantiles				
Variable	Number of regions	Mean	Standard Deviation	Min	0.25	Median	0.75	Max
Quality of institutions (EQI)	92	0.63	0.91	-2.65	-1.12	-0.86	0.01	1.31
Investment	92	0.19	0.04	0.11	0.17	0.19	0.21	0.34
Population growth	92	-1.66	6.28	-17.49	-4.44	-0.98	2.09	21.62
Infrastructure (RCI component)	92	-0.81	0.49	-1.34	-1.16	-0.93	-0.63	0.81
Lower-secondary education	92	32.42	19.19	3.40	15.38	28.13	49.63	77.90
Higher education and training (RCI component)	92	-0.45	0.63	-1.98	-0.91	-0.43	0.03	1.13
Labor market efficiency (RCI component)	92	-0.56	0.65	-2.04	-0.98	-0.60	-0.17	0.93
Technological readiness (RCI component)	92	-0.81	0.81	-2.19	-1.33	-0.84	-0.37	1.05
Business sophistication (RCI component)	92	-0.76	0.52	-1.60	-1.10	-0.85	-0.42	0.75
Innovation (RCI component)	92	-0.91	0.58	-2.00	-1.31	-0.94	-0.58	0.93
GDP per head (in PPS), 2008	92	17146	4903	7382	12876	17831	21360	25796
Growth of GDP per head (2009-2015)	92	1.00	0.02	0.95	0.99	1.01	1.02	1.04

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