Polycentric Dimensions of Economic Growth: Evidence from Spatial, Economic and Social Effects*

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Abstract

In this paper we examine the multi-dimensional role of externalities in regional growth. We employ two structural growth models (endogenous and exogenous) and make use of a spatial econometric framework to test the significance and impact of the various growth determinants. We utilise three types of regional proximity measures based on spatial, economic and social criteria, for seven EU countries' regions, during 1990-2005. Our findings robustly demonstrate that interregional externalities do matter for European regions, regardless of the definition of proximity.

Keywords: regional growth rates, regional proximity.

1. Introduction

Many theoretical growth models (Solow, 1956; Romer, 1986; Tamura, 1991) emphasize the role of external effects for the accumulation of production factors. Externalities imply that increases in the production factor stocks improve technology with benefits extending to agents other than those directly involved in the investments (Lucas, 1993; Vaya et al., 2004). Usually, economists assume that externalities spread over an entire economy, but there are no interactions among economies. In this context, there is an extensive empirical literature which examines the predictions of theoretical models and a significant part of it relates to regional growth[1] (Neven-Gouyette, 1995; Sala-i-Martin, 1996; Carlino & Mills, 1996; Bernand & Jones, 1996). These studies do not consider interactions among regions.

Externalities are important for growth, but they exist not only within but also across economies according to theoretical and empirical literature (Lucas, 1993; Kubo, 1995; Rey & Montouri, 1999; Lopez-Baso et al., 1999; Fujita et al, 1999; Fingleton, 1999; Fingleton & McCombie, 1998). External effects may be due to market size, forward and backward linkages, technology diffusion, factor mobility etc. If there are externalities across regions, studies that do not account for them produce biased results, leading to erroneous conclusions (Vaya et al., 2004). At the same time, we think that that there are limits to the spread of externalities. Specifically, we believe that externalities exist among economies with common characteristics, e.g. those which share borders (Durlauf-Quah, 1999; Fingleton & Lopez-Bazo, 2006). In most empirical studies external effects are modelled in an ad hoc manner emphasizing that the preferred spatial specification depends on regions and time period examined (Rey & Montouri, 1999, Le Gallo et al, 2003, Fingleton, 2001, 2004, Rey-Janikas, 2005, Abreu et al., 2005).

In this work, it is assumed that externalities across regions take the form of growth effects of neighbouring regions. These effects incorporate the influence of factor accumulation (physical capital, human capital and labour), TFP growth, technology diffusion, initial conditions and production function parameters of the neighbour regional economies. In this context, we analyze two structural growth

[1] Increasing evidence suggests that regional rather than national economies are the decisive units at which growth takes place (Ohmae, 1995; Storper, 1997; Cheshire and Malecki, 2004).

models (exogenous and endogenous) with across-region externalities and employ a spatial econometric framework to test the significance of the various growth determinants accounting for externalities and estimate their strength. The main contribution of our study is that we employ simultaneously three types of regional proximity based on spatial, economic and social criteria. We make the estimations for each of seven EU member-states at regional level, during 1990-2005 and then for the whole sample as a robustness check; most literature examines growth determinants in regions within individual countries (e.g. Broersma & Oosterhaven, 2009, Marquez, et al., 2010).

Our findings robustly demonstrate that interregional externalities do matter for European regions, regardless of the definition of proximity. Spatial, economic (based on output per capita) and social effects (based on population) imply strong spillovers across regions, in both the exogenous and endogenous growth models. Our estimations show that physical capital exerts a strong positive impact on growth. Additionally, human capital and R&D output enhance regional growth in the exogenous model, while growth of the lagging regions is positively affected by a catch-up effect through human capital in the endogenous model.

The structure of the paper is as follows. In Section 2 we summarize the theoretical and empirical literature on growth and externalities. In Section 3 we develop an exogenous and an endogenous growth theoretical model with cross regional externalities. Section 4 specifies the corresponding empirical model, presents the data and the econometric methodology we use. The analysis of the empirical findings is presented in Section 5 while, in the last Section we outline some concluding remarks and policy implications.

2. Growth models based on spatial, economic and social conglomerate effects.

Externalities play a central role in the theory of economic growth. In the neoclassical growth model, Solow (1956) assumed that all firms in the economy enjoy the same TFP level, which reflects technology accessible to all. So, there are disembodied knowledge externalities across firms. Later, Nelson-Phelps (1966) argued that technological progress reflects the rate of new discoveries, while total factor productivity growth depends on the implementation of these discoveries, and varies positively with the distance between the technology frontier and current productivity. The rate at which this distance is closed depends on human capital. So, disembodied technical know-how flows from the technology leader to the followers and augments their total factor productivity.

Romer (1986) modelled endogenous growth due to knowledge externalities, i.e. he argued that each firm is more productive the higher the average knowledge of other firms. He showed that, under certain conditions, constant returns to economy-wide knowledge generate endogenous growth, although there are diminishing returns to private knowledge. Lucas (1988) developed a model, where human capital accumulation generates spillover effects which increase the productivity of labour and physical capital. He argued that each person is more productive the more he/she is surrounded by other people with high levels of human capital. In Stokey (1988), learning by doing leads to the introduction of new higher quality goods over time, which eventually displace older goods. Learning is external to firms, and applies to new goods more than older goods. In Romer (1990), intermediate goods are imperfect substitutes in production. There is a stock of varieties, or ideas, and new ideas are invented using human capital and previous ideas. So, there are intertemporal knowledge spillovers. Tamura (1991) analyzed human capital externalities in the production of human capital, i.e. he implied that individuals learn from other individuals. These learning externalities are essential for long-run growth. Stokey (1991) argued that intergenerational human capital externalities, i.e. the young learn from the old generations, are critical for human capital accumulation. The latter makes the introduction of higher quality goods, which are intensive in human capital, easier.

Mankiw-Romer-Weil (1992, henceforth MRW) augmented the original Solow-Swan model to include human capital assuming there are knowledge externalities across firms within countries and across countries. They found that each country reaches a steady-state income that depends on its propensity to invest in human and physical capital. Romer (1994) considered a model in which knowledge about producing different varieties does not flow across countries, but each country can import the varieties that other countries know how to produce. Firms in the importing country enjoy higher labour productivity the more import varieties they access. If exporters cannot perfectly price discriminate and there is perfect competition among domestic final-goods producers, the higher labour productivity benefits domestic workers/consumers. If consumer varieties are imported, there is additional consumer surplus from import varieties.

Klenow-Rodriguez-Claire (2005) developed a model where: a) all countries grow at the same rate in the steady state thanks to international knowledge spillovers; b) differences in policies and country parameters imply differences in TFP levels, not growth rates. Their calibrated model indicated that countries benefit substantially from international knowledge spillovers, while the evidence seems to support models with externalities.

In this framework, employing simple unconditional convergence models (Barro-Sala-i-Martin, 1991) or a time series approach (Carlino-Mills, 1993) represent early attempts to model economic growth. Holtz-Eakin (1993) reinforced the link to theory by applying the neoclassical perspective due to MRW in an economic growth model pertaining to the US states. Although the MRW model performs reasonably well, it suffers from various restrictive assumptions and does not explain technological progress. Related to this, Griliches (1992) supported the existence of significant R&D spillovers. Coe-Helpman (1995) found that R&D abroad benefits domestic productivity, possibly through the transfer of technology through trade. Nadiri-Kim (1996) argued that the importance of research spillovers across countries varies between countries, i.e. domestic research seems important in explaining productivity in the US, while foreign research is more important for countries like Italy or Canada. Branstetter (2001), using disaggregated data, found research spillovers across firms that use similar technologies. The role of human capital in facilitating technology adoption was documented by Welch (1975), Bartel-Lichtenberg (1987) and Foster-Rosenzweig (1995). Following Nelson-Phelps (1966), Benhabib-Spiegel (1994) using cross-country data, concluded that technology spills over from leaders to followers and the flow depends on education levels. Benhabib-Spiegel (2005) obtained robust results supporting a positive role for human capital as an engine of innovation and as a facilitator of catch-up in total factor productivity using data for 84 countries in 1960-1995. Ertur-Koch (2005) extended the MRW model by assuming that technological progress is partly identical and exogenously determined for each spatial unit. In addition, they assumed that the level of technology is determined by the amount of physical capital per worker, which generates knowledge externalities that eventually spillover to neighbouring spatial units.

3. Theoretical models

3.1 Exogenous growth model

We study long-run growth using the framework suggested (among others) by MRW

(1992), de la Fuente (2002), Barro-Sala-i-Martin (2004) and Savvides-Stengos (2009). Thus, we specify an empirical model by employing a neoclassical aggregate production function. In this framework, we allow for spatial, economic and social spillovers among regions (see references in previous section and Nijkamp-Poot, 1998; Badinger et al, 2004; Gezici-Hewings, 2004; Eckey et al, 2007; Quah, 1996b).

Initially, we assume a Cobb–Douglas production function**:**

$$Y_{iq} = K_{iq}^{a} H_{iq}^{\beta} \left(A_{iq} L_{iq}\right)^{1-a-\beta} \qquad (1)$$

where Y_{iq} denotes real output of region *i* (*i = 1, …, m*) during period *q* (*q = 1, …, k*), K_{iq} is the stock of physical capital, H_{iq} is the stock of human capital, L_{iq} is employment and A_{it} is a (labour-augmenting) TFP indicator. Furthermore, 0< $a+\beta$ <1 and there are constant returns to scale in all inputs, so we have a Solow-type model. We also assume that technological progress is given by $\frac{\dot{A}_{iq}}{A_{iq}} = B_i D_{iq}^{\gamma} G_y^{\zeta}$ (2), where $D_{iq} = D_{i0} e^{g_{D_i} t}$ (3) is R&D output and G_y is the average per capita growth of neighbouring regions. The latter represents regional spillovers due to technology diffusion, since it incorporates the effects of physical and human capital investment as well as R&D of neighbours on region *i* TFP growth. We assume that no region alone is large enough to affect in a significant way the average growth of its neighbour regions, so G_y can be considered exogenous to region *i*. Also, $0 < B_i, \gamma, \zeta, g_{D_i} < 1$, where *γ*, *ζ* denote the TFP growth elasticites wrt to R&D and neighbours' growth respectively, g_{D_i} is the growth rate of R&D in region *i* and $D_{i0} > 0$ is initial R&D in region *i*. Relative to the standard MRW model, (1) incorporates R&D and regional spillovers as determinants of technological progress in accordance with e.g. Romer (1990a), Aghion-Howitt (1998), Dinopoulos-Thompson (1998), Acemoglu (1998, 2009), Gancia-Zilibotti (2005) and Vaya et al. (2004).

We divide (1) by $A_{iq} L_{iq}$, so that all variables are expressed in efficiency units, and get:

$$\tilde{y}_{iq} = \tilde{k}_{iq}^{\alpha} \tilde{h}_{iq}^{\beta} \qquad (4)$$

Using (1)-(4) and after making the typical transformations in Solow-type models, the average growth rate of real per capita income between periods τ and τ+1 is as follows:

$$\left[\ln\left(\frac{Y_i}{L_i}\right)_{\tau+1} - \ln\left(\frac{Y_i}{L_i}\right)_{\tau}\right] =$$

$$= B_i D_{it}^{\gamma} G_y^{\zeta} + \left\{ \begin{array}{l} \exp\left[(1-\alpha-\beta)\left(\begin{array}{l} \dfrac{B_i D_{i0}^{\gamma} G_y^{\zeta}}{g_{D_i}\gamma} - \left(\delta + g_{L_i}\right)\tau - \\ -\dfrac{B_i D_{i0}^{\gamma} G_y^{\zeta}}{g_{D_i}\gamma}\exp\left(g_{D_i}\gamma\tau\right) \end{array}\right)\right] \\ \left[1-\exp\left(-(1-\alpha-\beta)\left(\delta+g_{L_i}\right) - \dfrac{(1-\alpha-\beta)B_i D_{i0}^{\gamma} G_y^{\zeta}\exp\left(g_{D_i}\gamma\right)}{g_{D_i}\gamma}\right)\right] \end{array} \right\} \quad (5)$$

$$\left[-\ln\left(\frac{Y_i}{L_i}\right)_0 + \ln A_i(0) + \frac{\alpha}{1-\alpha}\ln s_{ki} + \frac{\beta}{1-a}\ln \tilde{h}_i^* - \frac{\alpha}{1-\alpha}\ln\left(\delta + B_i D_{it}^{\gamma} G_y^{\zeta} + g_{L_i}\right)\right]$$

So, long-run growth per worker is determined by initial income per worker in region *i*, initial technology in region *i* $A_i(0)$, the saving rate for physical capital accumulation in region *i* ($s_{k\,i}$), steady-state human capital in region *i* ($\tilde{h}_i^*$), R&D in region *i* in period *t* (D_{it}), employment growth in region *i* (g_{L_i}) and average per capita growth of neighbour regions (G_y). Also, growth is a function of the output shares of physical capital and human capital, *α, β*, respectively, the common depreciation rate of physical and human capital *(δ)*, the elasticity of TFP growth wrt R&D *(γ)*, while $\lambda_{iq} = (1-a-\beta)\left(\delta + B_i D_{iq}^{\gamma} G_y^{\zeta} + g_{L_l}\right)$ is the rate of convergence to the steady-state. So, our model predicts that higher growth in neighbouring regions boosts growth and convergence rates in region *i*.

3.2 Endogenous growth model

Although the above Solow-type model performs reasonably well, it suffers from various restrictive assumptions, e.g. it does not emphasize technological progress. In light of that, we also estimate an endogenous growth model in the spirit of Benhabib-Spiegel (1994) (see also Nelson-Phelps 1966, Lucas, 1988, Romer, 1990a,b, Pede et al., 2007, Savvides-Stengos, 2009, Fleischer et al. 2010). Specifically, we assume a Cobb-Douglas production function:

$$Y_{iq} = A_{iq} K_{iq}^{a} L_{iq}^{\beta} \tag{6}$$

where Y_{iq} denotes real per capita output of region *i* (*i = 1, …, m*) during period *q* (*q = 1, …, k*), K_{iq} is the stock of physical capital, L_{iq} is employment, A_{iq} is the TFP indicator and 0< a, β <1. Also, we assume that TFP growth in each region depends positively on: a) the region's human capital stock, since the latter helps the improvement of its technological capabilities; b) the interaction between the human capital stock of the region and the distance from the technology leader, assumed to be the richest region. This stands for the ability of each region to adapt and implement technologies developed elsewhere (catch-up effect);[2] c) the average per capita growth of neighbouring regions, which corresponds to regional spillovers due to technology diffusion (see discussion in the previous subsection); d) other exogenous factors. As a consequence, the growth of total factor productivity is specified as follows:

$$\log A_{iq} - \log A_{i0} = c_i + b_1 H_{iq} + b_2 H_{iq} \left(\frac{Y_{\max,q} - Y_{iq}}{Y_{iq}} \right) + b_3 R G_y \tag{7}$$

where H_{iq} is human capital of region *i*, $Y_{\max,q}$ is per capita output of the richest region, Y_{iq} is per capita output of region *i*, G_y is the average per capita growth of neighbouring regions *j* with respect to region *i*, $j \neq i$, *R* is a weights matrix which determines how G_y affects growth of region *i* and c_i is exogenous technological progress. The term in brackets represents the distance between region *i* and the most technologically advanced (richest) region. So, the higher is the human capital stock of region *i*, the stronger its ability to use technologies developed elsewhere for a given size of the income gap between this region and the technology leader.

Taking log-differences in (6) and substituting (7) for TFP growth, we get:

$$\log Y_{iq} - \log Y_{i0} = c_i + (b_1 - b_2) H_{iq} + b_2 H_{iq} \frac{Y_{\max,q}}{Y_{iq}} + b_3 R G_y + a\left(\log K_{iq} - \log K_{i0}\right) + \\ + \beta\left(\log L_{iq} - \log L_{i0}\right) \tag{8}$$

As a result, output growth in each region depends on: a) the weighted average growth

[2] Human capital is considered exogenous, i.e. we do not examine the process of human capital accumulation.

of its physical capital and labour; b) the region's human capital; c) the interaction between the region's human capital and its income differential from the wealthiest region; d) the output growth of the neighbouring regions; e) exogenous technological progress.

4. Empirical framework

4.1. Econometric specification

In this paper we explicitly address the effect of regional externalities on the process of growth at the lowest possible level of spatial aggregation (NUTS 3).[3] As argued above, the reasoning behind such externalities is basically the diffusion of technology between regions caused by investments in physical and human capital as well as R&D. The externalities compensate the mechanisms of decreasing returns to scale to capital accumulation within each regional economy. Concretely, growth in the other economies enhances growth in a given economy.

The empirical evidence obtained from a broad sample of regions of European countries strongly supports such spillovers and the estimates are robust to the inclusion of other variables in the growth regression, to the consideration of spatial regimes in the sample, and to alternative measures of interactions between regions. Actually, we focus on spatial, economic and social externalities embodied in capital, extending the original work by MRW (1992) and Benhabib & Spiegel (1994) and by using the following equation:

$$g_{iq} = \zeta_i + \alpha_{iq} \sum_{\substack{j=1 \\ j \neq i}}^{m} w_{ij} g_{jq} + \gamma_{iq} \sum_{\substack{j=1 \\ j \neq i}}^{m} s_{ij} g_{jq} + \delta_{iq} \sum_{\substack{j=1 \\ j \neq i}}^{m} c_{ij} g_{jq} + \tau'_{iq} X_{iq} + \varepsilon_{iq} \qquad (9)$$

where $i = 1 \ldots m$ denotes a region, and $q = 1 \ldots k$ a time-period. Spatial weights are denoted by w, social weights by s and economic weights by c. So, W, S, C constitute the respective weight matrices. A detailed discussion about those weights follows at a subsequent section.

Also, we include at the model a vector of region specific controls X_{iq} and region fixed effects ζ_i, where the latter captures factors affecting growth which are specific to each region, but do not vary over time (see section 3 for a discussion on

[3] Le Gallo & Kamarianakis (2010) conclude that EU regional inequality is mainly due to region-specific productivity differentials, not differences in the industry-mix across regions, providing justification for regional level analyses similar to the one presented in this paper.

region-specific effects). We use population density growth instead of employment growth in the estimation of the exogenous growth model following the suggestion of Lockwood & Migali (2008). This is because the spatial economics literature argues that agglomeration boosts regional productivity[4], while congestion dampens productivity, so it is not clear theoretically which of the two opposing forces dominates in practice. Population density has been employed as a proxy for such effects, so its expected sign is not known a priori (Arellano & Fullerton, 2005; Ciccone & Hall, 1996; Wheeler, 2003; Broersma & Oosterhaven, 2009; Combes et al., 2010).

The expanded autoregressive model[5] (9) is estimated as the standard spatial autoregressive model, provided that the above formulations of weights are sufficiently different and that do not contain entirely overlapping information. For empirical estimation, the specification of equation (9) raises a number of issues. Those issues are explicitly discussed at a following subsection.

4.2 Data

Our sample includes regional data at NUTS-3[6] level for seven EU member-states, namely United Kingdom, France, Germany, Sweden, Italy, Spain and Netherlands over the 1990-2005 period. Our data source is Eurostat's Regio database. Tables 1 and 2 (available in the Appendix) provide the definitions and the descriptive statistics respectively of the variables employed in our estimations. Regional real GDP per capita growth is used as the dependent variable. R&D activity is proxied by patents granted to the European Patent Office[7]. Human capital is approximated by human resources employed in science and technology.[8] Also, physical capital is taken into account in the form of gross fixed capital formation, in line with theoretical specifications in Eq's (5) and (8). Additional independent variables include population density and infrastructure measured by km of motorways per region.

[4] Evidence for that is the concentration of population in high-income urban areas without exogenous sources of heterogeneity in spatial productivity (Glaeser & Gottlieb, 2009).
[5] The choice of the lag formulation is based on spatial diagnostic tests (LM-Error and LM-Lag).
[6] Some missing values of variables were replaced by using the extrapolation method for their generation (Reggiani & Nijkamp, 2006).
[7] Patents have been used extensively as an indicator of innovation output and its relation with economic growth has been examined in the literature (e.g. Barrell & Pain, 1997; Falvey, Foster & Greenaway, 2006). For an overview on the use of patents as economic indicators see Griliches (1990) and Mokyr (2009).
[8] We can argue that the latter variable could also be perceived as an R&D input proxy, as it focuses on human capital with enhanced knowledge and competences employed in knowledge-based industries.

4.3 Weight Specification

An important decision in model estimation is the choice of the connectivity weights. Exploratory data analysis typically provides a possible way of getting information about the structure of the data. However, a method that is often used in practice and suggested by the existing literature is to apply some weight matrices in regression analysis and test for the presence (if any) of dependence with each of the matrices[9]. We employ in the regression analysis weighted averages of tax rates in competing regions, following the standard spatial regression literature as summarized by Anselin et. al. (1996). The spatial weight matrix for region *i* takes the form, W_i. Its elements w_{ij} specify a "neighborhood set" for each observation *i*. In more detail, w_{ij} is positive if *j* is a "neighbor" of *i*, and zero otherwise. Indeed, this structure is given by what is known as the "connectivity matrix", which specifies the degree of connectivity (weights) between any two observations[10]. We implemented the empirical model using a negative exponential distance decay function given by $d_{ij} = \exp(-d_{ij}/p)$, *p* is a scaling parameter determining the spatial range over which the distance decay occurs. The value we used for the latter is 850, which makes that the distance decay is close to complete at a distance of approximately 850 miles (which is approximately the average distance between any city and the capital of any country in our sample).

In our model, we consider many forms of the weighting matrix besides the spatial one; i.e. based on economic and social criteria, provided that the matrices are sufficiently different and do not contain entirely overlapping information[11]. First, regions are assigned to be "neighbours" if they have a similar level of GDP per capita. In a non-geographic context, the notion of "distance" is determined by the relative magnitude of GDP per capita and a region is connected to all other regions. The GDP connectivity matrix differs from any distance matrix in two notable ways. First, the GDP matrix consists of weights where the importance of another region *j* to region *i* is given by the relative magnitude of GDP per capita. Second, the GDP connectivity matrix weighs high type partners much more heavily than low type partners, whereas in the distance matrix, any neighbour of *i* must always have *j* as a non-trivial neighbor. Therefore, the elements of the GDP per capita connectivity matrix are defined as:

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[9] For alternative specifications of weight matrices see Anselin et al. (1996).

[10] The assumption that these weights are known a priori is strong, although it is crucial for the method to work. Of course, it is no stronger than the typical implicit assumption that all weights are zero, that is, all observations are spatially independent.

[11] For further details see Brueckner (2003).

$$c_{ij} = 1 - \left| \frac{GDP_j - GDP_i}{GDP_j + GDP_i} \right|$$

and by construction, this index ranges from 0 to 1. In particular, if GDP per capita is the same between the two regions, then $c_{ij} = 1$. The elements of the GDP connectivity matrix take the value of 0 if the magnitude of GDP per capita of region *j* is dissimilar with region *i,* should the difference in GDP values is really significant. Notice that this definition of similarity is symmetric in that $c_{ji} = c_{ij}$.

A second form of the economic weighting matrix is based on R&D output, i.e. regions with similar R&D output are considered neighbours. Moreover, we define weighting schemes based on population density and the level of infrastructure (social criteria) according to e.g. Rodriguez-Pose (1999). The algebraic definitions of those weights are similar to the one with the GDP specification. One interesting feature of the GDP matrix is that more-open countries have the bulk of their economic activities with large, wealthy, countries, which more often depict a higher demand for capital. As a result, these countries will tend to have a higher "connectivity lag" (neighbours with many other countries) than the distance based "connectivity lag". In other words, the magnitude of the discussed weight is greater than the corresponding distance based weight.

Before proceeding to the estimation of equation (9), we must deal with three econometric issues. We use an instrumental variable approach to address endogeneity issues of control variables. A common approach in the literature is to generate instruments as the weighted average of the control variables in other countries (Devereux, Lockwood, & Redoano, 2008). That is for each element of X_{iq}, it is possible to construct a weighted average for other countries. These weighted averages can be used directly as instruments for our model and generate better instruments in the sense that they are more highly correlated with the endogenous variables (Kelejian & Prucha 1999, 2005). As a result the standard errors tend to be smaller.

A second issue is that in practice, our error terms are serially correlated, perhaps because changes at the level of growth require costs of adjustment for the private and public sector, or because such changes may be driven at the political or economic level by various interest groups. Thus, we present t-statistics based on clustered standard errors (Devereux et al., 2004) which are robust to both spatial correlation and serial correlation (Bertrand et al., 2004). A third issue is that we include region-specific fixed effects, to capture shocks which are not common to all regions. As a robustness check, we have used these effects in different model specifications.

5. Estimation Results

In this section, we present empirical evidence that supports our hypothesis on the role of externalities across regions in the process of growth by estimating the empirical counterpart of Equation (9). In so doing, we use gross domestic product per capita growth, as a proxy for economic growth and a number of explanatory variables to capture the fundamental considerations of the theoretical models presented before. It should be stressed that when selecting the above mentioned conditioning variables, we had in mind that observations for each one of them do not differ markedly across nearby regions, so that their inclusion can be considered as a test of robustness for our hypothesis on the role of externalities. This is so, because it could be argued that the spatial lag of the growth rate in equation (9) captures the effect of omitted factors within each region that are spatially, economically and socially correlated depending on the connectivity measure used..

5.1 Spatial neighbouring effects.

This section describes the MRW-type model estimates across seven European Union Countries (UK, France, Germany, Sweden, Italy, Spain, Netherlands). Table 1 presents the outcome of this empirical approximation using spatial neighbouring criteria along with some test statistics. Initially, we study the impact of neighbouring GDP growth on regional growth within each of the selected countries. The impact of neighbouring GDP growth is significant, positive and substantial in magnitude across all sample countries, in line with the literature (Ertur et al, 2006). Germany presents the lowest estimate of 0.38 and Italy shows the maximum one at 0.71. So, the economic dynamics of each region's neighbourhood seems to influence the growth prospects of the region.

As pointed out by Hulten-Isaksson (2007), two general explanations have been offered to account for the observed growth patterns. One view stresses differences in the efficiency of production as the main source of the observed gap in output per worker. A competing explanation reverses this conclusion and gives primary importance to capital formation. Both of them are examined in Table 1 and the rest of our analysis. Specifically, both physical and human capital enter as important determinants of economic growth with a positive sign (e.g. Fischer et. al., 2009; LeSage & Fisher, 2008). However, we should note that growth spillovers seem to have a stronger effect on growth than human and physical capital. Moreover, the impact of human capital on growth is stronger than that of physical capital in all countries. Furthemore, R&D has a positive growth effect across all sample countries, which is stronger than the effect of both types of capital; this points to the very important role of TFP growth on overall economic growth (Ciccone, 2002). Moreover, population density growth is mostly not statistically significant except in France and Germany, where the impact is negative. So, positive agglomeration effects are mostly offset by negative congestion effects (see discussion in section 4). Finally, initial GDP has a strong negative impact on regional growth, which is evidence of conditional convergence within each of the sample countries (Barro-Sala-i-Martin, 1991; Chessire-Carbonaro, 1995).

Diagnostics examine some interesting features of the model. First, Pagan and Hall's (1983) test is a test of heteroskedasticity for instrumental variables (IV) estimation. This statistic is distributed as chi-squared under the null of no heteroskedasticity, and under the maintained hypothesis that the error of the regression is normally distributed. When we find heteroskedasticity, we report the corrected standard errors using a robust variance estimator. Second, the F-test, in the first stage of the estimation, examines the null hypothesis of whether the instruments are not correlated with the endogenous variable. A rejection means that there is such a correlation; the latter is the case in our results.. Third, the Anderson canonical correlations likelihood-ratio tests whether the equation is identified. The statistic provides a measure of instrument relevance, and rejection of the null indicates that the model is identified, which holds for all countries. In our model, we reject the null hypothesis. Finally, the Chow test rejects the null hypothesis for equality of coefficients across groups (regions) within each country. All countries in our sample follow a rejection pattern for the equality of coefficients across regions.

The results for the endogenous growth model specifications are presented in Table 2. The estimations of the impact of neighbouring GDP growth on regional growth present some interesting results. The impact of neighbouring GDP growth on regional growth within the selected countries is found to be significantly positive, coupled with a substantial magnitude, in line with the exogenous growth estimations.

So, we can conclude that the economic dynamics of each region's neighbourhood seems to influence the growth prospects of a region regardless of the underlined structural. With respect to the specific estimates, Italy presents the highest and Spain the lowest one (0.63 and 0.28 respectively).

Employment growth is estimated to have a modest negative effect on regional growth in all examined countries. Netherlands and Sweden present the strongest impact (0.16 and 0.14 respectively), where France and U.K. the lowest (0.09 and 0.07 respectively). This might be due to the inefficient allocation of the labour force in terms of space and industries (Rodriguez-Pose & Tselios, 2010; Azzoni and Silveira-Neto, 2005). Hence, the estimated relation could be pointing to negative congestion effects, which dominate positive agglomeration externalities (Broersma-Oosterhaven, 2009, Brunow-Hirte, 2009, Combes et al., 2010). Human capital is estimated to be insignificant in all countries examined. The effect of human capital on economic growth is ambiguous in the empirical literature, as it is often estimated as not significant, sometimes null, or even negative (Islam, 1995; Barro, 2001)[12]. One of the reasons behind this negative result might be associated with the fact that human capital is a concept that is not straightforward to measure given that it is not usually exchanged in markets like other economic goods (Coulombe & Tremblay, 2006). Also, returns to education tend to be higher in economies with a better educated labour force, which makes accurate estimates of the growth impact of education difficult to obtain (Azariadis and Drazen, 1990). Nevertheless, a statistically significant, albeit weak, catch up effect is estimated within all sample countries (ranging from 0.02-0.05). We conclude that relatively poor regions enjoy a stronger human capital enhancing effect compared to richer ones; thus human capital seems to work principally through the catch-up mechanism. This offers a pessimistic view for the growth prospects of lagging regions, since it means that when they attain the income level of the wealthy ones, their growth rate will fall and it will be permanently lower than that of the wealthy regions. As a consequence, they will diverge again from the affluent regions (Savvides-Stengos, 2009; Benhabib-Spiegel, 1994). Finally, with regards to physical capital, a positive and significant relation is once more estimated in all sample countries.

[12] As some authors note (e.g. Barro 2001; Hanushek & Kimko, 2000), human capital might be better measured using quality and not quantity measures. Nevertheless, the human capital proxy we introduced has never been used before in the literature. We believe it's an appropriate human capital indicator since it includes skilled labour force employed in science and technology industries.

Table 1: MRW model specification

	United Kingdom	France	Germany	Sweden	Italy	Spain	Netherlands
w_gdp	0.45* (0.21)	0.57* (0.28)	0.38* (0.16)	0.62** (0.25)	0.71* (0.36)	0.51* (0.23)	0.68* (0.32)
gdp1990	-0.81*** (0.12)	-0.73*** (0.15)	-0.52* (0.26)	-0.89*** (0.03)	-0.48** (0.18)	-0.43*** (0.09)	-0.51* (0.28)
Growth rate of popdensity	0.23 (0.77)	-0.01* (0.00)	-0.03* (0.00)	0.11 (0.45)	0.23 (0.52)	0.04 (0.15)	0.19 (0.86)
Physical Capital	0.12* (0.06)	0.15* (0.08)	0.14* (0.07)	0.09* (0.05)	0.08* (0.03)	0.08* (0.04)	0.07* (0.03)
Human Capital	0.23* (0.11)	0.49* (0.19)	0.61* (0.28)	0.22* (0.09)	0.41** (0.15)	0.37* (0.17)	0.18* (0.09)
R&D	0.48* (0.26)	0.59* (0.28)	0.79* (0.34)	0.82* (0.43)	0.78* (0.38)	0.56* (0.25)	0.65* (0.33)
Intercept	2.29* (1.22)	1.97** (0.95)	2.52* (1.28)	3.14 (2.41)	4.27** (1.85)	3.65** (1.38)	1.56 (1.41)
R^2 adjusted	0.64	0.68	0.73	0.71	0.59	0.62	0.72
F-test	305.11	296.67	327.02	107.43	496.7	388.02	159.02
Chow	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o
Anderson	19.85 (0.00)	32.64 (0.00)	65.84 (0.00)	45.11 (0.00)	57.63 (0.00)	78.92 (0.00)	52.72 (0.00)
Pagan-Hall	18673 (0.39)	19884 (0.34)	17003 (0.28)	24762 (0.11)	28003 (0.00)	14522 (0.26)	28005 (0.15)

Notes:

1. Standard errors are given in parentheses, p-values for the tests. Standard errors are robust to heteroscedasticity and are clustered by year to allow for spatial correlation in the errors. Also, *, **, and ***, respectively, indicate statistical significance at the 0.10, 0.05, and 0.01 levels.
2. Neighboring explanatory variables are used as instruments for spatial, economic and social weights.

Table 2: Endogenous growth model specification

	United Kingdom	France	Germany	Sweden	Italy	Spain	Netherlands
w_gdp	0.58* (0.28)	0.39* (0.17)	0.46* (0.29)	0.42* (0.19)	0.63** (0.39)	0.28* (0.16)	0.51* (0.31)
Employment growth	-0.07* (0.03)	-0.09* (0.04)	-0.12* (0.05)	-0.14* (0.08)	-0.09* (0.04)	-0.11* (0.05)	-0.16* (0.09)
Human Capital	0.01 (0.04)	0.17 (0.28)	0.03 (0.43)	0.15 (0.49)	0.07 (0.38)	0.14 (0.63)	0.23 (0.71)
Physical Capital	0.28* (0.15)	0.34** (0.13)	0.53* (0.27)	0.18* (0.09)	0.41* (0.23)	0.24* (0.11)	0.27* (0.14)
Catch up effect	0.02* (0.00)	0.03* (0.01)	0.05* (0.02)	0.01* (0.00)	0.02* (0.00)	0.04* (0.02)	0.01* (0.00)
Intercept	12.03 (26.81)	9.93 (19.88)	26.08 (32.01)	8.85 (12.45)	11.39 (32.45)	8.78 (18.32)	6.75 (19.02)
R^2 adjusted	0.54	0.57	0.61	0.65	0.53	0.58	0.62
F-test	407.24	302.18	418.02	447.02	532.52	217.66	338.67
Chow	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o
Anderson	74.55 (0.00)	87.97 (0.00)	74.05 (0.00)	68.81 (0.00)	94.63 (0.00)	89.14 (0.00)	72.08 (0.00)
Pagan-Hall	45621 (0.32)	54392 (0.41)	76441 (0.48)	37801 (0.31)	19883 (0.28)	47802 (0.39)	45993 (0.33)

Notes:

1. Standard errors are given in parentheses, p-values for the tests. Standard errors are robust to heteroscedasticity and are clustered by year to allow for spatial correlation in the errors. Also, *, **, and ***, respectively, indicate statistical significance at the 0.10, 0.05, and 0.01 levels.
2. Neighboring explanatory variables are used as instruments for spatial, economic and social weights.

5.2 Economic neighbouring effects

This section analyzes the exogenous and endogenous growth models estimates across the same EU countries incorporating economic neighbouring criteria in addition to spatial neighbouring criteria (Tables 3-4). In the MRW-type specification (Table 3), the effect of neighbours, in terms of GDP, on regional growth is positive and significant across all countries.[13] Dutch regions exhibit the weakest impact (0.27), while German ones present the strongest (0.57). Regarding economic proximity on the basis of R&D, positive and significant spillovers on regional growth are found only in Germany, Italy and Spain. Moreover, these are substantially weaker compared with the case of neighbours according to GDP pc (0.17-0.28).

However, whether the economic neighbour is defined on the basis of GDP or R&D, the spatial correlation coefficient remains always positive and significant implying robust geographical spillovers. So, the more a region is surrounded by dynamic regions, the stronger its growth will be. The spatial effects are stronger when economic neighbours are defined according to GDP in the UK, Italy and Netherlands and when economic proximity is based on R&D for France, Germany, Sweden and Spain. Besides these, physical capital boosts regional growth in all but two cases, as theory would predict. Also, human capital exerts a positive effect on regional growth in all countries except UK and Netherlands when economic proximity is defined with regard to GDP pc. The positive impact persists when economic neighbourhood is based on R&D in Sweden, Italy and Spain. (Marquez et al, 2010).

Additionally, R&D influences positively growth irrespective of the way economic proximity is defined, in accordance with theory and empirics (Broersma-. Oosterhaven, 2009). This shows the important role innovation plays as a growth driver (see among others Griliches, 1988, 1990; Hall-Mairesse, 1995)

Furthermore, population density growth has a negative impact on regional growth in France and Germany and a non-significant effect in the other countries independent of the definitions of neighbour regions. This means that the positive agglomeration effects are neutralized by negative congestion effects within regions due to high population density, except in France and Germany where congestion dominates agglomeration (Broersma-Oosterhaven, 2009; Carlino, 1985; Moomaw, 1985). Finally, initial GDP pc dampens regional growth in all countries, so the evidence is in favour of conditional convergence within countries in accordance to some of the

[13] The diagnostic tests confirm that our results are reliable in all following estimations.

literature (Eckey et al. 2006; Chessire & Carbonaro, 1995).

In the endogenous growth specification (Table 4), the effect of neighbours, based on GDP, on regional growth is positive and significant within all countries. The strongest impact is estimated in Italian regions (0.56) and the weakest in Spanish ones (0.21). If we define economic proximity on the basis of R&D, positive cross-regional growth spillovers, although weaker compared to the case where neighboring effects are based on GDP pc, are estimated for all countries except the UK. Moreover, whether economic proximity is defined according to GDP or R&D, stronger neighbour growth has a sizeable impact (0.09-0.34) on regional growth, i.e. positive interregional externalities exist in all but two cases (Le Gallo & Dall'erba, 2006). The spatial spillovers are stronger when neighbours are defined according to GDP rather than R&D in all countries except Sweden, possibly implying that in the former case part of the geographical spillovers is due to technology diffusion related to R&D.

In addition, physical capital enhances regional growth irrespective of the way economic proximity is defined, which confirms its importance. The biggest impact is estimated for Italian regions (0.39) and the weakest impact for Swedish ones (0.05). Human capital exerts a positive but insignificant, impact on regional growth in all countries irrespective of how regional neighbourhoods are defined. Here, we should note that a statistically significant, but quantitatively weak (0.02-0.06), catch up effect is estimated within all sample countries. This means that the growth impact of human capital in relatively poor regions is stronger compared to richer regions. So, human capital seems to work principally through the catch-up mechanism. This offers a pessimistic view for the growth prospects of lagging regions, since it means that when they attain the income level of the wealthy ones, their growth rate will fall and it will be permanently lower than that of the wealthy regions. As a consequence, they will diverge again from the affluent regions (Savvides-Stengos, 2009; Benhabib-Spiegel, 1994).

Employment growth exerts a small negative effect on growth, pointing to negative congestion effects, which dominate positive agglomeration externalities, possibly reflecting the absence of the population density growth variable from the endogenous growth estimations (Broersma & Oosterhaven, 2009; Brunow & Hirte, 2009, Combes et al., 2010).

Table 3: MRW model specification

	United Kingdom		France		Germany		Sweden		Italy		Spain		Netherlands	
Criterion Variables	*GDP*	*R&D*	*GDP*	*R&D*	*GDP*	*R&D*	*GDP*	*R&D*	*GDP*	*R&D*	*GDP*	*R&D*	*GDP*	*R&D*
c_gdp	0.34*	0.14	0.42*	0.07	0.57*	0.17*	0.44*	0.53	0.55*	0.28*	0.38*	0.26*	0.27*	0.05
	(0.16)	(0.46)	(0.19)	(0.84)	(0.31)	(0.08)	(0.19)	(3.21)	(0.31)	(0.16)	(0.17)	(0.12)	(0.12)	(0.85)
w_gdp	0.22*	0.18*	0.12**	0.45*	0.08*	0.14*	0.28*	0.54*	0.39*	0.25*	0.32*	0.39*	0.16*	0.12*
	(0.09)	(0.09)	(0.04)	(0.22)	(0.03)	(0.07)	(0.15)	(0.26)	(0.18)	(0.14)	(0.17)	(0.19)	(0.08)	(0.07)
gdp1990	-0.41*	-0.32*	-0.59*	-0.71*	-0.22*	-0.84*	-0.73*	-0.68*	-0.08*	-0.12*	-0.17*	-0.18*	-0.26*	-0.16*
	(0.23)	(0.14)	(0.31)	(0.36)	(0.13)	(0.43)	(0.37)	(0.34)	(0.03)	(0.07)	(0.09)	(0.08)	(0.12)	(0.07)
Growth rate of popdensity	0.09	0.18	-0.03*	-0.04*	-0.04*	-0.05*	0.05	0.09	0.71	0.44	0.17	0.38	0.05	0.09
	(0.38)	(0.76)	(0.00)	(0.02)	(0.01)	(0.02)	(0.78)	(1.45)	(2.29)	(1.03)	(1.94)	(2.01)	(0.17)	(0.96)
Human Capital	0.04	0.01	0.26*	0.10	0.12*	0.13	0.38*	0.21*	0.27*	0.18*	0.28*	0.24*	0.09	0.05
	(0.87)	(0.45)	(0.12)	(0.07)	(0.05)	(0.05)	(0.17)	(0.09)	(0.13)	(0.0.09)	(0.15)	(0.12)	(1.11)	(0.77)
R&D	0.12*	0.05*	0.28*	0.32*	0.34*	0.38*	0.48*	0.51	0.41*	0.12*	0.24*	0.35	0.18*	0.12*
	(0.07)	(0.02)	(0.15)	(0.17)	(0.18)	(0.18)	(0.28)	(0.35)	(0.19)	(0.05)	(0.13)	(0.26)	(0.09)	(0.06)
Physical Capital	0.07**	0.04*	0.09**	0.06**	0.14**	0.09**	0.05*	0.04*	0.05*	0.03*	0.05*	0.01	0.05*	0.02
	(0.01)	(0.02)	(0.03)	(0.02)	(0.05)	(0.03)	(0.02)	(0.02)	(0.03)	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)
Intercept	7.78*	3.44*	5.42**	6.97***	4.48*	2.11*	4.63*	4.89*	3.39*	4.27*	2.11***	2.78***	3.44*	5.78*
	(3.92)	(1.77)	(2.15)	(1.16)	(2.31)	(1.03)	(2.32)	(2.45)	(1.38)	(2.08)	(0.08)	(0.15)	(3.92)	(2.56)
R^2 adjusted	0.68	0.65	0.71	0.70	0.72	0.68	0.74	0.74	0.62	0.65	0.67	0.65	0.63	0.59
F-test	387.23	337.23	631.18	527.12	709.45	586.11	879.02	879.02	544.92	608.75	474.11	399.29	459.11	408.97
Chow	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o
Anderson	21.83	23.16	48.11	79.01	54.39	72.04	74.09	74.09	94.01	83.11	53.61	71.05	34.56	45.89
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)
Pagan-Hall	21345	27331	54023	29003	62002	38444	45749	45749	37770	54442	28091	34078	23489	32008
	(0.39)	(0.25)	(0.42)	(0.18)	(0.42)	(0.24)	(0.11)	(0.11)	(0.16)	(0.17)	(0.42)	(0.35)	(0.43)	(0.48)

Notes:

1. Standard errors are given in parentheses p-values for the tests. Standard errors are robust to heteroscedasticity and are clustered by year to allow for spatial correlation in the errors. Also, *, **, and ***, respectively, indicate statistical significance at the 0.10, 0.05, and 0.01 levels.
2. Neighboring explanatory variables are used as instruments for spatial, economic and social weights.

Table 4: Endogenous growth model specification

	United Kingdom		**France**		**Germany**		**Sweden**		**Italy**		**Spain**		**Netherlands**	
Criterion Variables	*GDP*	*R&D*	*GDP*	*R&D*	*GDP*	*R&D*	*GDP*	*R&D*	*GDP*	*R&D*	*GDP*	*R&D*	*GDP*	*R&D*
c_gdp	0.42*	0.27	0.31*	0.12*	0.42*	0.27*	0.36*	0.12*	0.56**	0.33*	0.21*	0.14*	0.27*	0.18*
	(0.22)	(0.48)	(0.16)	(0.05)	(0.19)	(0.14)	(0.16)	(0.07)	(0.17)	(0.15)	(0.11)	(0.07)	(0.14)	(0.09)
w_gdp	0.34*	0.26*	0.12*	0.09*	0.18*	0.09	0.19*	0.27*	0.23*	0.15*	0.14*	0.11*	0.11*	0.07
	(0.17)	(0.14)	(0.06)	(0.04)	(0.09)	(0.07)	(0.09)	(0.14)	(0.11)	(0.07)	(0.07)	(0.06)	(0.06)	(0.04)
Employment growth	-0.11*	-0.05*	-0.08*	-0.02*	-0.12*	-0.06*	-0.12*	-0.09*	-0.03*	-0.06*	-0.09*	-0.12*	-0.06*	-0.02
	(0.05)	(0.02)	(0.04)	(0.00)	(0.05)	(0.03)	(0.05)	(0.04)	(0.01)	(0.03)	(0.05)	(0.06)	(0.03)	(0.02)
Human Capital	0.19	0.38	0.11	0.28	0.03	0.01	0.03	0.11	0.19	0.47	0.03	0.01	0.31	0.44
	(0.93)	(1.82)	(0.74)	(0.32)	(0.45)	(0.89)	(1.02)	(1.28)	(0.79)	(0.91)	(0.93)	(1.84)	(1.77)	(1.32)
Physical Capital	0.17*	0.29*	0.15*	0.08*	0.24*	0.14*	0.05*	0.07*	0.39*	0.27*	0.16*	0.12*	0.08*	0.06*
	(0.08)	(0.15)	(0.08)	(0.03)	(0.11)	(0.06)	(0.01)	(0.04)	(0.22)	(0.14)	(0.08)	(0.05)	(0.04)	(0.03)
Catch up effect	0.02*	0.03*	0.04*	0.03*	0.06*	0.04*	0.02*	0.03*	0.05*	0.04*	0.03*	0.02*	0.02*	0.03
	(0.00)	(0.01)	(0.01)	(0.01)	(0.03)	(0.02)	(0.00)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.02)
Intercept	4.93*	2.17*	1.33*	2.03*	2.88*	3.67*	3.39*	3.81*	4.27*	4.03*	2.28*	3.03*	4.02*	2.03
	(2.50)	(1.05)	(0.71)	(1.05)	(1.41)	(1.91)	(1.58)	(1.91)	(2.11)	(1.93)	(1.12)	(1.55)	(2.06)	(1.15)
R^2 adjusted	0.58	0.61	0.63	0.62	0.68	0.67	0.67	0.65	0.59	0.61	0.63	0.61	0.64	0.62
F-test	503.11	448.6	481.37	377.99	553.49	483.09	304.07	359.89	186.93	203.56	495.11	432.27	387.03	342.05
Chow	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o
Anderson	82.02	95.04	35.67	52.54	54.04	63.07	39.23	55.31	65.01	74.43	47.89	58.75	67.05	63.78
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.04)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Pagan-Hall	78099	67089	63002	89001	57705	68097	18997	28956	38031	56673	36803	47892	45246	54009
	(0.38)	(0.31)	(0.22)	(0.45)	(0.29)	(0.32)	(0.48)	(0.48)	(0.42)	(0.27)	(0.28)	(0.28)	(0.29)	(0.37)

Notes:

1. Standard errors are given in parentheses p-values for the tests. Standard errors are robust to heteroscedasticity and are clustered by year to allow for spatial correlation in the errors. Also, *, **, and ***, respectively, indicate statistical significance at the 0.10, 0.05, and 0.01 levels.
2. Neighboring explanatory variables are used as instruments for spatial, economic and social weights.

5.3 Social neighbouring effects

This section examines the MRW and endogenous type growth models estimates across the sample countries incorporating spatial and social neighbouring criteria. In the MRW specification (Table 5), the effect of neighbors on the basis of population density on regional growth is positive and significant within all countries. Dutch regions exhibit the weakest impact (0.04), while Swedish ones present the strongest (0.25). However, if we define social proximity on the basis of infrastructure, which facilitates communication between regions, positive and significant externalities on regional growth exist only in Italy (0.07) and Spain (0.05) and they are weaker than neighbouring effects according to population density. These findings may be due to the fact that the growth impact of infrastructure comes mainly through geographic proximity, while the same is not true for population density.

However, whether the social neighbour is defined on the basis of population density or infrastructure, higher growth of neighbours has a strong positive effect on regional growth (0.17-0.57), i.e. positive social externalities exist. The cross-regional spillovers are stronger when neighbours are defined according to population density in the UK, Germany, Italy and Netherlands and when proximity is based on infrastructure in France, Sweden and Spain. Also, spatial externalities are much stronger than social ones in all sample countries. This is perhaps the case, because spatial effects account for various interactions due to technology diffusion, trade and capital flows among neighbours. Such interactions have a stronger cumulative growth influence compared to spillovers among regions with similar social characteristics (Acemoglou, 2009).

Additionally, physical capital enhances regional growth when neighbour regions are considered those with similar population density (0.03-0.14). This effect no longer exists when social proximity is based on infrastructure. This is due to the fact that infrastructure is highly correlated with physical capital (insert correlation coefficients), so there is no significant additional information in the data when physical capital is included in a regression containing weights based on infrastructure.

Furthermore, human capital exerts a positive effect on regional growth in all countries except UK and Netherlands when social proximity is defined with respect to population density (0.09-0.52). The positive impact persists when social neighbourhood is based on infrastructure in Sweden, Italy and Spain. Additionally, R&D boosts regional growth in all countries irrespective of the way social neighbours are defined, which points to the importance of innovation activities for growth in addition to human capital. The strongest impact is estimated for Italy (0.62) and the weakest impact for the UK (0.14).

Population density growth has a negative impact on regional growth only in France and Germany when proximity is based on population density. In the remaining countries the impact is non-significant irrespective of the definition of neighbour regions. This means that the positive agglomeration externalities are neutralized by negative congestion effects within regions, except in France and Germany where congestion dominates agglomeration; this is in line with findings in the previous sub-section (see also discussion in section 4). Finally, initial GDP pc hinders regional growth within all countries, so there is strong evidence in favour of conditional convergence within countries.

In the endogenous growth model specification (Table 6), the impact of neighbours, based on population density, on regional growth is positive and significant within all countries. German regions exhibit the strongest impact (0.41), while in the UK the effect is weakest (0.17). If we define social proximity on the basis of infrastructure, positive and significant spillovers on regional growth are estimated within France, Sweden, Italy and Spain and they seem to be weaker compared to the case when neighbouring effects are based on population density similarly with the exogenous growth model.

Moreover, whether the social neighbour is defined according to population density or infrastructure, stronger geographic neighbour growth has a sizeable impact on regional growth, i.e. positive interregional externalities exist (0.19-0.53). The spatial spillovers seem stronger when neighbours are defined according to population density in Germany, Sweden, Italy and Netherlands and when proximity is based on infrastructure in UK, France and Spain.

Likewise, physical capital enhances regional growth in all countries irrespective of the way social neighbourhoods are examined, which points to the importance of physical capital formation for growth. The strongest effect is estimated for German regions (0.45) and the weakest impact for Swedish ones (0.12). In most countries, the impact is stronger when social proximity is based on population density rather than infrastructure, which may have to do with the high correlation of infrastructure with physical capital (see discussion in the context of the exogenous growth model above).

Regional human capital exerts a positive, though insignificant, influence on regional growth in all countries irrespective of the way social proximity is defined, as was the case in the endogenous growth model with spatial and economic spillovers. However, a statistically significant, but quantitatively weak (0.02-0.07), catch up effect is detected within all sample countries. So, the growth impact of human capital in backward regions seems to be stronger than in relatively rich regions, which confirms the findings in the context of the endogenous model with economic and spatial externalities (see discussion in the above sub-section). Employment growth has a negative impact on regional growth reflecting congestion effects, which dominate agglomeration externalities (Broersma & Oosterhaven, 2009; Glaeser & Gottlieb, 2009). This evidence is in line with previous results in the context of the endogenous growth model (Tables 2, 4 and discussion in respective sub-sections).

Table 5: MRW model specification

	United Kingdom		France		Germany		Sweden		Italy		Spain		Netherlands	
Criterion Variables	*Pop Dens*	*Infrast*	*Pop Dens*	*Infrast*	*Pop Dens*	*Infrast*	*Pop Dens*	*Infrast*	*Pop Dens*	*Infrast*	*Pop Dens*	*Infrast*	*Pop Dens*	*Infrast*
s_gdp	0.08* (0.04)	0.02 (1.75)	0.12* (0.06)	0.09 (1.09)	0.14* (0.07)	0.02 (1.23)	0.25* (0.12)	1.17 (4.29)	0.17* (0.08)	0.07* (0.03)	0.22* (0.12)	0.05* (0.02)	0.04* (0.02)	0.01 (2.25)
w_gdp	0.32* (0.15)	0.29* (0.14)	0.18* (0.09)	0.39* (0.22)	0.38* (0.19)	??0.27*?? (0.13)	0.38* (0.22)	0.57* (0.28)	0.47* (0.22)	0.39* (0.21)	0.43* (0.23)	0.44* (0.22)	0.17* (0.08)	0.32 (0.79)
gdp1990	-0.48* (0.23)	-0.53* (0.26)	-0.64* (0.33)	-0.65* (0.34)	-0.89* (0.47)	-0.76* (0.38)	-0.87* (0.43)	-0.85* (0.39)	-0.27* (0.14)	-0.18* (0.09)	-0.36* (0.19)	-0.25* (0.14)	-0.42* (0.21)	-0.41* (0.20)
Growth rate of popdensity	0.11 (0.74)	0.87 (1.69)	-0.12* (0.06)	-0.11 (0.7)	-0.09* (0.05)	-0.02 (0.31)	0.64 (1.09)	0.02 (2.77)	0.19 (1.78)	0.03 (1.74)	0.45 (3.01)	0.53 (2.69)	0.19 (0.96)	0.17 (0.69)
Human Capital	0.28 (1.73)	0.45 (2.09)	0.09* (0.04)	0.29 (1.91)	0.12* (0.06)	0.42 (1.08)	0.52* (0.27)	0.28* (0.15)	0.35* (0.17)	0.29* (0.15)	0.12* (0.06)	0.22* (0.11)	0.37 (1.99)	0.48 (2.63)
R&D	0.18* (0.09)	0.14* (0.07)	0.47* (0.28)	0.52* (0.28)	0.58* (0.32)	0.39* (0.18)	0.41* (0.22)	0.59* (0.28)	0.62* (0.29)	0.27* (0.13)	0.39* (0.19)	0.39* (0.19)	0.24* (0.11)	0.19* (0.09)
Physical Capital	0.11* (0.05)	0.09 (0.17)	0.07* (0.03)	0.06 (0.26)	0.14* (0.07)	0.03 (0.57)	0.04* (0.02)	0.12 (0.08)	0.07* (0.03)	0.15 (0.71)	0.03* (0.01)	0.01 (0.01)	0.08* (0.03)	0.16 (1.19)
Intercept	5.03* (2.52)	4.78* (2.27)	1.42* (0.75)	2.75*** (1.16)	1.97* (0.98)	2.75 (2.16)	0.89 (0.99)	1.03 (3.01)	5.52* (2.59)	5.89* (2.44)	2.89* (1.51)	3.67* (1.58)	4.67** (2.09)	3.55* (1.79)
R^2 adjusted	0.65	0.63	0.68	0.70	0.71	0.70	0.59	0.55	0.63	0.64	0.65	0.67	0.64	0.62
F-test	347.25	452.89	259.19	527.12	387.11	442.09	442.56	523.45	198.89	274.93	330.02	483.92	388.97	330.96
Chow	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o
Anderson	32.09 (0.05)	45.67 (0.04)	53.46 (0.07)	68.78 (0.04)	59.49 (0.08)	54.11 (0.06)	28.87 (0.05)	39.93 (0.05)	67.71 (0.07)	43.89 (0.08)	67.91 (0.09)	62.38 (0.00)	28.98 (0.07)	37.89 (0.05)
Pagan-Hall	58931 (0.32)	78902 (0.45)	34498 (0.25)	29003 (0.18)	54664 (0.34)	49903 (0.27)	39756 (0.19)	33775 (0.25)	48098 (0.28)	42051 (0.38)	67689 (0.49)	45098 (0.42)	39071 (0.39)	43506 (0.49)

Notes:

1. Standard errors are given in parentheses p-values for the tests. Standard errors are robust to heteroscedasticity and are clustered by year to allow for spatial correlation in the errors. Also, *, **, and ***, respectively, indicate statistical significance at the 0.10, 0.05, and 0.01 levels.
2. Neighboring explanatory variables are used as instruments for spatial, economic and social weights.

Table 6: Endogenous growth model specification

	United Kingdom		France		Germany		Sweden		Italy		Spain		Netherlands	
Criterion Variables	*Pop Dens*	*Infrast*	*Pop Dens*	*Infrast*	*Pop Dens*	*Infrast*	*Pop Dens*	*Infrast*	*Pop Dens*	*Infrast*	*Pop Dens*	*Infrast*	*Pop Dens*	*Infrast*
s_gdp	0.17*	0.74	0.38*	0.24*	0.41*	0.05	0.19*	0.05*	0.29*	0.17*	0.28*	0.19*	0.29*	0.47
	(0.09)	(1..89)	(0.19)	(0.11)	(0.18)	(1.19)	(0.09)	(0.02)	(0.16)	(0.08)	(0.15)	(0.09)	(0.14)	(0.33)
w_gdp	0.45*	0.53*	0.29*	0.42*	0.24*	0.17	0.38*	0.35*	0.35*	0.32*	0.23*	0.28*	0.19*	0.87
	(0.23)	(0.27)	(0.15)	(0.23)	(0.11)	(0.75)	(0.19)	(0.18)	(0.17)	(0.17)	(0.12)	(0.15)	(0.08)	(1.99)
Employment growth	-0.15*	-0.11*	-0.14*	-0.17*	-0.11*	-0.19	-0.05*	-0.12*	-0.09*	-0.11*	-0.14*	-0.09*	-0.05*	-0.07*
	(0.08)	(0.06)	(0.08)	(0.00)	(0.05)	(0.35)	(0.02)	(0.06)	(0.05)	(0.06)	(0.07)	(0.04)	(0.02)	(0.03)
Human Capital	0.01	0.11	0.53	0.78	0.18	0.55	0.01	0.02	0.49	0.89	0.11	0.19	0.06	0.02
	(2.01)	(3.01)	(1.28)	(2.12)	(1.49)	(2.09)	(1.89)	(2.45)	(1.09)	(1.09)	(0.77)	(1.23)	(1.29)	(2.77)
Physical Capital	0.15*	0.22*	0.28*	0.31*	0.45*	0.24*	0.12*	0.19*	0.42*	0.18*	0.22*	0.18*	0.16*	0.31
	(0.08)	(0.09)	(0.15)	(0.16)	(0.21)	(0.11)	(0.06)	(0.09)	(0.24)	(0.1)	(0.12)	(0.08)	(0.08)	(0.56)
Catch up effect	0.06*	0.05*	0.03*	0.04*	0.07*	0.05*	0.04*	0.05*	0.02*	0.03*	0.05*	0.03*	0.03*	0.01
	(0.03)	(0.02)	(0.01)	(0.01)	(0.03)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.04)
Intercept	2.23*	2.17*	4.75*	5.27*	2.12*	3.39*	2.45*	3.15*	5.59*	5.39*	6.78	5.78*	1.28	1.17
	(1.23)	(1.05)	(2.37)	(1.05)	(1.02)	(1.91)	(1.09)	(1.64)	(2.82)	(2.93)	(7.34)	(6.55)	(1.89)	(1.05)
R^2 adjusted	0.61	0.59	0.61	0.59	0.66	0.64	0.65	0.62	0.57	0.58	0.57	0.55	0.62	0.60
F-test	289.44	327.09	119.78	377.99	229.01	330.08	772.89	359.89	491.78	427.09	115.78	198.78	443.67	501.34
Chow	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o	Rej H_o
Anderson	35.57	45.76	87.93	73.82	38.11	43.76	96.72	87.98	29.53	38.98	89.92	67.89	74.56	60.17
	(0.00)	(0.00)	(0.00)	(0.02)	(0.00)	(0.00)	(0.01)	(0.07)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.03)
Pagan-Hall	45007	52854	25723	32719	43009	45009	45923	58977	96900	87601	43451	51021	55008	48017
	(0.41)	(0.35)	(0.22)	(0.58)	(0.39)	(0.47)	(0.28)	(0.39)	(0.55)	(0.38)	(0.38)	(0.42)	(0.29)	(0.45)

Notes:

1. Standard errors are given in parentheses p-values for the tests. Standard errors are robust to heteroscedasticity and are clustered by year to allow for spatial correlation in the errors. Also, *, **, and ***, respectively, indicate statistical significance at the 0.10, 0.05, and 0.01 levels.
2. Neighboring explanatory variables are used as instruments for spatial, economic and social weights.

5.4 Robustness

In this section, we examine the MRW type growth model estimates across countries in a unified sample incorporating spatial, economic and social neighboring criteria (Table 7). We do that in order to verify if the findings of the individual countries' estimations are robust. Country dummies as well as dummy variables indicating country participation in the Eurozone were introduced in order to control for country-specific effects due to e.g. historical and cultural factors and the impact of the common European currency in the regions belonging to the Euro area respectively. Countries dummies are significant and have a positive sign. Dummies are included or excluded per column of Table 7 to account for all potential cases.

The inclusion of social (using population density criterion) and economic (using GDP criterion) neighbouring effects (column 2), shows that the impact of neighbours on regional growth is positive and significant; actually it is much stronger when neighbours are defined in terms of economic criteria (0.35 vs 0.11). This is evidence that regions with similar economic structure are closely linked with each other through e.g. technology diffusion, trade and capital flows. When spatial, economic (using GDP) and social (using population density) criteria are included simultaneously (column 3), only neighbours according to the first two criteria affect regional growth, while the economic neighbouring effect is approximately the same as before. This implies that when geographic proximity is taken into account, social proximity does not have a separate growth impact any more due to the similarity of neighbouring regions in terms of population density and infrastructure. However, when spatial and social criteria are used (column 4), the growth impact of adjacent regions on regional growth is positive in both cases, though the spatial correlation is much stronger than the social one (0.28 vs 0.06) indicating the importance of geographic proximity for regional spillovers. Also, in case all three types of weights are used and economic weights are based on GDP (column 5), there are positive cross-regional externalities for all neighbour types, where the effects are stronger for economic and then geographic neighbours confirming the previous findings qualitatively.

When we estimate only spatial and economic neighbouring effects (column 7), both are positive and strong, 0.32, 0.39 respectively, pointing to the distinct roles of spatial and economic proximity in the growth process. This is robust both qualitatively and quantitatively to the inclusion of social proximity, which plays a smaller role (column 8) or is not significant (column 9). The latter two columns imply that population density is a better indicator of social proximity compared to infrastructure. Furthermore, physical capital enhances growth in most cases (0.07-0.13). This effect is in line with previous findings, noting that the range of estimates is smaller compared with the country regressions. This is expected due to the averaging of the relevant country estimates that takes place when the data is pooled.

Furthermore, human capital boosts regional growth whatever combination of neighbouring weights we use (0.09-0.22). This confirms the results found when we run estimations on countries separately, although the range of estimates is again narrower now. So, human capital seems to be more important for growth than physical capital in line with the individual country evidence.

Moreover, R&D has a positive but insignificant impact on growth in the whole sample irrespective of the way neighbours are defined. This, combined with the findings presented in Tables 3 & 5, implies that the strong heterogeneity of the growth effects of R&D between countries makes it impossible to estimate these effects with relative accuracy for the whole sample. Thus, it shows the necessity for separate country estimations.

Population density growth has a small positive influence on regional growth whatever the definition of proximity is. This means that the positive agglomeration externalities outweigh the negative congestion effects within regions when we consider the whole sample (see discussion in Section 4). Again, the difference with the country findings points to the need for individual country regressions to uncover country-specific growth patterns. Finally, initial GDP hampers growth in the unified sample, so there is still strong evidence in favour of conditional convergence as was the case in the country level estimations. We should note that the convergence rate for the whole sample is smaller than the same rate within individual countries, which is expected because the regions considered as a whole are much more heterogeneous relative to the regions within each country.

Table 7: All countries -model specification

	Spatial Criterion		Economic Criteria			Social Criteria		
Criterion Variables	*No spatial*	*Spatial*	*No economic*	*GDP*	*R&D*	*No social*	*Pop Dens*	*Infrast*
w_gdp		0.17* (0.09)	0.28* (0.14)	0.21* (0.10)	0.14* (0.08)	0.32* (0.15)	0.28* (0.13)	0.25* (0.2)
c_gdp	0.35** (0.11)	0.28* (0.15)		0.34** (0.11)	0.28* (0.14)	0.39* (0.19)	0.41* (0.23)	0.45* (0.21)
s_gdp	0.11* (0.04)	0.47 (0.96)	0.06* (0.03)	0.04* (0.02)	0.18 (0.85)		0.08* (0.03)	0.27 (1.07)
Human Capital	0.22* (0.10)	0.16* (0.07)	0.18* (0.09)	0.09* (0.04)	0.13* (0.07)	0.18* (0.09)	0.22** (0.06)	0.18* (0.09)
Physical Capital	0.09* (0.04)	0.18 (0.27)	0.07* (0.04)	0.11* (0.05)	0.04 (0.08)	0.13* (0.06)	0.11* (0.05)	0.08* (0.04)
gdp1990	0.17* (0.08)	0.12* (0.06)	0.14* (0.07)	0.14* (0.08)	0.48 (0.69)	0.12* (0.06)	0.18* (0.09)	0.12* (0.06)
Growth rate of popdensity	0.07* (0.03)	0.03* (0.01)	0.05* (0.02)	0.02* (0.01)	0.04* (0.02)	0.07* (0.03)	0.05* (0.02)	0.06* (0.03)
R&D	0.18 (0.89)	0.45 (1.38)	0.11 (1.56)	0.27 (1.97)	0.39 (1.97)	0.11 (1.07)	0.25 (1.75)	0.69 (0.97)
Intercept	2.47 (4.68)	3.09 (3.89)	0.95 (1.89)	1.34 (2.42)	2.06 (2.24)	2.56 (3.09)	2.19 (2.67)	1.69 (2.45)
Country Dummies	yes	yes	yes	no	no	yes	no	no
Euro Dummy	yes	yes	yes	no	no	yes	yes	Yes
R^2 adjusted	62	64	68	69	68	67	68	66
F-test	487.78	405.56	389.12	403.86	445.05	563.89	511.03	397.88
Anderson	47.09	38.99	28.11	37.85	32.11	57.09	58.76	49.48
Pagan-Hall	38005	47089	42309	47008	42804	51007	49065	58096

Notes:
1. Standard errors are given in parentheses, p-values for the tests. Standard errors are robust to heteroscedasticity and are clustered by year to allow for spatial correlation in the errors. Also, *, **, and ***, respectively, indicate statistical significance at the 0.10, 0.05, and 0.01 levels.
2. Neighboring explanatory variables are used as instruments for spatial, economic and social weights.

6. Concluding remarks

We consider the role that growth externalities play in the process of regional economic development. We develop two structural growth models where growth of neighbouring regions affects each region's growth, in seven European countries over the period 1990 to 2005. Relative to the previous literature, the present paper presents several elements of novelty. First, we consider three types of neighbours based on spatial, economic and social criteria, using spatial econometric methods. Second, both exogenous and endogenous growth models are estimated, in order to test for the existence and magnitude of interregional externalities in both specifications. Third, we analyse regions both within individual countries and in the context of the whole sample. Our estimates support earlier studies on regional growth and externalities (Vaya et al., 2004; Broersma & Oosterhaven, 2009; Fingleton & Lopez-Bazo, 2006).

Our results robustly demonstrate that interregional externalities do matter for European regions, regardless of the way neighbourliness is defined. Spatial effects, economic effects (based on output per capita) and social effects (based on population) imply strong cross-regional spillovers, in the context of both the exogenous and endogenous models. Both specifications exhibit a strong positive growth influence of physical capital. Regarding the exogenous model, human capital and R&D output enhance regional growth, while there is strong evidence of conditional convergence across all sample countries. In the endogenous model, growth of the lagging regions is positively affected by a catch-up effect through human capital accumulation.

A number of policy implications can be drawn from the above findings. Regional development policies should consider the externalities among neighbouring economies, i.e. the fact that regions surrounded by dynamic entities are likely to grow faster than otherwise. As a result, coordinated policy actions in the lagging regions should take priority, in order to maximise the growth benefits, given the scarcity of the available funds. This, in turn, justifies the need for a harmonised European regional policy.

Table A. Description of Variables*

Variable	Description	NUTS Level
GDP per capital	Regional Gross Domestic Product (GDP) at constant market prices (2000?) (in mil. of Euros)	NUTS 3
GDP 1990	Regional Gross Domestic Product (GDP) at 1990 (in mil. of Euros)	NUTS 3
Population Density	Inhabitants per km^2	NUTS 3
Physical Capital	Regional gross fixed capital formation at constant (2000) prices (in mil. of Euros)	NUTS 2
Human Capital	Percentage of total employment who have completed a tertiary level of education and/or are employed in a science and technology occupation where a tertiary level of education is normally required	NUTS 2
R&D	Patent applications to the European Patent Office per million inhabitants	NUTS 2
Infrastructure	Kilometres of motorways	NUTS 2
Country dummies	Each dummy variable takes the value of 1 for regions belonging to a specific country, which the dummy refers to, and 0 otherwise.	NUTS 3
Euro area dummy	The dummy variable takes the value of 1 if the region belongs to a Euro area member-state and 0 otherwise.	NUTS 3

******Note*: The source of our data is REGIO database available by Eurostat.

Table B: Summary Statistics

Variable	Mean	Std. Dev.	Min.	Max.
GDP pc	389.11	658.73	57.27	2546.39
Population density	287.17	298.11	2.07	978.88
Physical Capital	8091.78	9178.2	431.56	58902.9
Human Capital	89.67	17.89	22.09	134.78
Research & Development	1239.56	563.01	47.05	4078.92
Infrastructure	893.02	478.18	129.04	2975.05

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