Increasing Returns, Decreasing Returns and Regional Economic Convergence in the EU

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Abstract

Regional economic development is driven by the accumulation of production factors. More traditional factors like labor and physical capital are accumulated under the low of diminishing returns. This, in turn, allows less developed regions to better perform. Recent branches of theoretical and empirical literature have payed attention the role of increasing returns in an attempt to explain the persistence in regional economic disparities. Increasing returns are commonly attributed either to the accumulation of non traditional inputs such as human and knowledge capital or to the presence of local externalities generated by the spatial concentration of economic activities. In this paper the economic performance of 186 European regions is analyzed by using the ordinary growth regression approach. An empirical specification which simultaneously accounts for the presence of both decreasing and increasing returns is derived. The study is intended to analyze the extent to which regional development originates from the (un)balancement between convergence, driven by diminishing returns and divergence, boosted by increasing returns. Results indicate that the accumulation of traditional inputs leads the economic development of less favoured areas while the presence of increasing returns plays a more crucial role in developed regions. Furthermore the use of a non-linear specification for the growth equation highlights evidence of important threshold effects in entering the stage of development characterized by increasing returns. Accordingly, the regional development process is depicted as a far more

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complex process than what the simple dualism between increasing and decreasing returns may help to figure out, with very important implications for policy.

1 Introduction

Models of regional economic growth have traditionally emphasized the hypothesis of diminishing returns to labor and physical capital, allowing higher productivity in less developed regions. This, in turn, is expected to conduce to a convergence between regions in the economy. The growth regression framework proposed by Barro [9] is considered the workhorse of the empirical literature on the topic of regional convergence. In short the annual average growth rate of per-capita income over a certain period is regressed on the initial income level. The relation is expected to be negative and a significant estimate corroborates the theoretical hypothesis according to which all regions will converge to the same per-capita income level in the long run (Barro and Sala-i-Martin [8]).

As Martin and Sunley [32] note, the neo-classical approach presents several shortcomings. At the theoretical level the hypothesis of diminishing returns seems to be a very restrictive one. At the empirical level the estimated value of the so-defined speed of convergence, the rate at which disparities annually decrease, is found to be quite small (around 2%) and the amount of regional growth which is left unexplained by the model is also very high. Endogenous growth theories integrating the neo-classical growth models by introducing increasing returns in the production have actually solved much of these shortcomings.

However, when the growth rate is endogenously determined within the model, the prediction about the long-run equilibrium completely differs. While economic convergence, in either its absolute or conditional form, is the equilibrium associated to decreasing returns, divergence is predicted in presence of increasing returns. The understanding of the extent to which the regional development is driven by either decreasing or increasing returns thus appears as a key issue, especially in Europe.

In Europe regional convergence is expected to take place as a result of not only the integration process, but also and even as a consequence of the large investment programs within the Cohesion Policy to boost growth in less developed regions. There are several studies that, indeed, have empirically investigated convergence at the European regional level taking into consideration possible sources of increasing returns. In the work by Ertur and Koch [16] the role of human capital accumulation is emphasized. Similarly, Rodriguez-Pose and Crescenzi [36] study the effect of innovation on growth through investments in research and development. Some studies have also focused the attention on agglomeration economies, like in the case of Bosker [12] and, more in general, on interregional spillovers (Dall'erba and Le Gallo [15]). In all of the mentioned studies there is evidence that, notwithstanding the convergence process, regional growth is affected by the presence of increasing returns in the production.

In the present paper a similar approach is adopted and regional growth is studied by using the growth regression framework. Alongside the standard convergence hypothesis the existence of increasing returns is also accounted for in the model specification and tested upon a sample of 186 regions in the period 1995-2007. Building on the existing theoretical and empirical literature, three main determinants of increasing returns are identified, namely the orientation of the regional economy toward innovation, the importance of human capital and skilled workers in the production and, lastly, agglomeration economies. However, differently from the existing empirical literature, these determinants are concurrently related to regional growth.

The model specification further allows for non-linearities in the relation in such a way that the contribution of both decreasing and the increasing returns can be evaluated in the different stages of development. The results idicate that a process of economic convergence drives regional growth in less developed areas more than in already developed ones where, by the opposite, production is characterized by increasing returns. More specifically the agglomeration externalities positively contribute to regional growth in only very agglomerated regions and the positive effects of innovation and human capital are noticeable only over a thresholds of, respectively, regional innovative capacity and presence of skilled workers in the economy. These evidence have some very important policy implications. It is shown that regional development is determined by the composition of several factors and that the contribution of each varies along the development path of the region. Accordingly regions follow different development trajectories and, thus, the *"one size fits all"* policy approach to regional development proves to be inappropriate. On the contrary, more attention is claimed toward a more place-based approach.

The remaining of the paper is organized as follows. In the next section the theoretical and empirical literature on the relation between increasing returns and regional growth is reviewed. The various determinants of increasing returns are discussed and, for each, the issue of non-linearity is addressed. In section three the dataset is presented and three syntetic measures for the determinants of increasing returns are derived by using multivariate data analysis. The empirical model and the results are presented in section four. Follow conclusion.

1.1 Increasing Returns and Regional Growth

The convergence debate has been dominated for decades by the Barro-type regression paradigm (Barro [9]). Such a framework is directly derived from the neo-classical growth model described by Solow [39] in which, under the hypothesis of perfect competition, homogenous agents and diminishing marginal returns, it is showed that economies folllow a path toward a steadystate per-capita income level. The far away from the steasy-state, the higher the rate at which the economy grows. Provided that economies have similar structural characteristics, they converge toward the same steady-state. The empirical test is based on a cross-country or cross-region regression of percapita income growth rate over a given time period on the initial level of per-capita income. A negative and significant coefficient related to the initial income is perceived as evidence of convergence.

Recently in a series of articles Quah ([34], [35]) has criticized such an approach to the empirical test of the convergence hypothesis. The main argument used in the critique is based on the inadequacy of the approach to explain the persitence, or in same cases the increase, in per-capita income disparities, despite the evidence of convergence. It is argued that, notwithstanding the evidence of convergence, economies in the long-run might not converge toward the mean of the distribution. By the opposite, the long-run income distribution might be characterized by bimodality.

Among the theoretical hypothesis behind the Solow-Barro framework, the one on the diminishing marginal returns of factor imputs has been pointed as the most unrealistic. More specifically, recent branches of literature have emerged releasing the assumption of diminishing returns and predicting non-converging long-run scenarios. This is the case of the New Growth Theory[1] (NGT) and of the New Economic Geography[2] (NEG) as well. Models belonging to the first of the two branches of literature emphasize the importance of production factors like human capital and knowledge capital which, thanks to knowedge spillovers, determine increasing returns to scale in the economy. In models belonging to the second branch, increasing returns are associated with the presence of pecuniary externalities arising from the spatial concentration of economic activities. In both the prediction on long-run equilibrium is similar. Economies will diverge and the long-run distribution of per-capita income will be characterized by club-convergence[3] as well as by core-periphery paterns[4].

Consequently this new literature proves to be more usefull in explain-

[1]For a comprehensive review of the literature see the work by Martin and Sunley [32].

[2]See Krugman [23].

[3]Galor [19] extensively discusses the implication of different theoretical growth models on the convergence hypothesis.

[4]An example of theoretical model of endogenous growth integrating NEG is provided by Baldwin and Forslid [7]. Consistently with more generic models of NEG, the long-run equilibrium is characterized by core-periphery patterns.

ing the empirical evidence of bimodality suggested by Quah [36]. In what follows this literature will be reviewed with a focus on the way the hypothesis of increasing returns is, on the one side incorporated in the theoretical modelling framework and, on the other side empirically tested.

1.2 Human Capital and the Knowledge Economy

The contribution of human capital to economic growth has been highlighted in the work by Mankiw et al. [31], who also provide empirical tests of the hypothesis, finding that human capital can actually explain a large part of cross-country variation in economic growth. The key element to be considered for the understanding of the role of human capital seems that, differently from labor, there is something more in human capital. And this is knowledge.

Knowedge is embedded in people and not necessarily shows decreasing marginal productivity. On the contrary, the more people work togheter the more easily they can exchange their knowledge and, accordingly, the higher will be the increase in productivity. Formal models of endogenous growth based on knowledge are proposed by Romer [37] and Lucas [30]. In these models the marginal productivity of knowledge is assumed to be increasing and the motivation for this relies on the externalities produced with the increase in the knowledge stock. The outcome associated to the predicted model equilibrium is distant from the convergence prediceted by the Solow model as, conversely, kwowledge can continuously increase generating persistent disparities between the economies.

The empirical test to assess the contribution of human capital on regional growth is based on an extension of the growth regression which includes a measure of human capital. In the study by Lòpez-Rodriguez et al. [29] a survey of the literature is provided together with a critical assessment of the measurement problems. At the EU regional level there is evidence that the long-run equilibrium level of the regional economy is strongly influenced by human capital. Tondl [39] argues that differences in human capital endowments are responsible for the persistence of the disparities between less developed Eurpean regions in the south and more developed northern regions. A similar conclusion is indicated also by Badinger and Tondl [6] and by Paci et al. [33] as well.

In a recent contribution, Basile [10] [10] has found evidence that the effect of human capital on regional growth becomes positive only after a certain threshold is passed. Furthermore he shows that the marginal returns from investments in human capital are higher if the region is located near to other regions with high levels of human capital as well. Following the author, such an evidence of a non-linear effect is consistent with some theoretical models, as for example that developed by Azariadis and Drazen

[4], in which social returns from human capital investments (externalities) appear only after a certain threshold of human capital is reached.

1.3 Innovation

Knowledge is not only embedded in people. Actually, the part of it which can be codified and formalized materializes in new products and processes. At the heart of the endogenous models of growth based on innovation (Aghion and Howitt [1]), it lies the hypothesis that these new products and processes give the firm a monopolistic power into the market. Increasing returns thus come from innovative activity which, in turn, is the result of specific investments made by the profit-maximizing firm. As a consequence, the growth pattern of the region might be importantly affected by the relative efforts put by firms in the activities of research and development.

Fagerberg and Verspagen [17] have tested this hypothesis empirically on a sample of European regions, assuming that the the technological gap, measured by mean of R&D related indicators, explains the persistence of disparities in per-capita GDP. They show that the introduction of R&D strongly improves the model fitting, contibuting to the explanation of the regional variation in per-capita income growth. A similar framework is also used by Fagerberg et al. [18], who provide analogous evidence but based on a different sample of regions. In a more recent past other studies have investigated the issue using larger samples of regions and more up-to-date datasets as well. The study by Rodriguez-Pose and Crescenzi [36], grounded on the sample of all the regions of EU25, finds converging evidence, witha clear positive contribution of innovation to regional growth. Likewise Sterlacchini [38] and Verspagen [40], among the others, reach to the same conclusion.

At both the theoretical and the empirical levels there are however arguments suggesting that innovation non-linearly relates to growth. On the theoretical side it is argued that the rate of technological change, which is made in part by new innovations and in part by imitations, is likely to be higher in regions with an already substantial knowledge base. As it is claimed by Cohen and Levinthal[13] [13], not only the probability to realize a new innovation but also the probability to successfully replicate an existing innovation positively depends on the level of investments in research. To some extent, it can be argued that R&D investments are necessary to innovate and also represent a pre-condition to imitate (Fagerberg et al. [18]). Shifting this argument to the regional growth and convergence debate it would be possible to assume that less technological developed regions are likely to experience slower technological catch-up and, equally, if the technological gap is wide, some regions might not catch-up at all. Moving the attention to the empirical side, several works have found evidence of non-linearity and threshold effect in the relation between growth and innovation. For instance such a result is indicated by Fagerberg and Verspagen [17], Sterlacchini [38] and Crescenzi [14]. Very recently, the hypothesis that a smaller technological gap facilitates the absorption of new innovation has been included into a model of regional growth which, consequently, predicts club-convergence (Alexiadis and Tomkins [2]). The evidence in the paper supports the theoretical hypothesis.

1.4 Agglomeration

Aggolomeration economies are at the origin of NEG models (Krugman [23], Krugman and Venables [25]). Externalities arise in precence of multiple co-location of economic activities and are characterized as pecuniary externalities and, more precisely, are related to labor market pooling. Manufacturing goods are produced under a Dixit-Stiglitz monopolistic competition framework and is subject to economies of scale. It follows that the higher the concentration of economic activities in the area, the higher the profits for each single firm. The long-run equilibrium is determined by two forces: agglomeration economies boost divergence and high trasportation costs promote spreading. Given an initial even distribution of economic activities aross regions/countries and high transportation costs, once transportation costs start declining, it becomes more and more convenient for firms to co-locate in one area to benefit from agglomeration economies.

The original Krugman's framework has been readapted to accomodate the study of several economic cases. Among the others, the Krugman and Venables [24] model is an example of NEG model which interprets the process of European integration and the relative decline in transportation costs consequent to the abolition of trade barriers between member states. At the empirical level, the predicted core-periphery pattern in the spatial distribution of economic activities seems to be capable to explain the geographical shape of the production in Europe. In their exploratory spatial data analysis of production and income in EU regions, Le Gallo and Ertur [27] provide robust evidence of the concentration and of a core-periphery pattern as well. The first attempt to empirically measure the effect of agglomeration economies on regional performance has been made by Ciccone [3], relating total factor productivity to employment density, a standard measure of agglomeration. The effect of agglomeration is positive and sizable but the analysis, in this specific case, is not further extended to regional growth. The effect of agglomeration economies on regional growth is conversely studied by Bosker [12] for a sample of 208 EU16 regions over the period 1977-2002, differentiating the internal, within the region, effect from the external, between regions, effect. It is found that, for both, the effect is negative. More densely populated regions have lower growth rates and beeing located near densely populated regions also negatively impacts on growth. Interpretation of this result is straightforward. The negative effects of agglomeration, for instance diseconomies caused by congestion or higher housing prices, are larger than the benefits of agglomeration. As one cannot assume that the agglomeration effect is continosly negative, a natural question arises on what is the critical level of agglomeration at which diseconomies start prevailing on economies. A question which, according to Bosker [12], is not easy to disentangle.

1.5 A Comprehensive Framework

Different attempts have been made to develop empirical models which include testable hypothesis on the effect of innovation, human capital and agglomeration on regional growth. Most of the works suveyed in this section focus on each single determinant of increasing returns, and none of them has considered all the determinants simultaneously. This is probably the consequence of the lack of a theoretical backgroung pinpointing the way externalities from the accumulation of innovation and human capital and externalities from the concentration of economic activities relate to each other. One possible interpretation of this relation lies in the concept of knowledge spillovers. Knowledge, in theoretical models and in the reality as well, is classified in two broad cathegories, explicit and tacit, the second beeing transmitted exclusively via face-to-face contacts and frequent interactions (Von Hippel [41]). It follows that while on the one hand externalities arising as a consequence of the accumulation of knowledge in one region are, by definition, bounded in space, on the other hand there is no reason to believe that these externalities cannot cross the regional administrative boundaries.

Building on this view different studies have applied spatial econometric tecniques to the regional growth equation and interpreted the evidence in light of spillovers between neighboring regions (Lopez-Bazo et al. [28], Le Gallo et al. [26], Badinger et al. [5], Erthur and Koch [16], Dall' Erba and Le Gallo [15], Guastella and Timpano [22]). It is however worth noting that localized externalities due to knowledge spillovers are not predicted by NEG models since the latters consider, as already remarked, only pecuniary externalities. This means that spatial econometric extensions of the growth regression at the regional level only in part accounts for externalities, unless agglomeration economies are not explicitely included.

In this we contribute to the existing empirical literature by proposing an unified framework in which the hypothesis of convergence due the presence of diminishing returns is tested jointly with the hypothesis of increasing returns following the accumulation of human capital and innovation and the concentration of economic activities. Furthermore, spatial heterogeneity and spatial externalities are separately considered.

2 Data

All the data used in this work come from the Eurostat regional database. The sample under study is composed by all the regions belonging to countries in the EU25 group. Regions are defined based on the NUTS classification and, for all the countries but Belgium, Greece, Germany and the UK, for which the level I has been taken as reference, the level II is used. The choice to rely on the statistical level I for the four aformentioned countries is motivetad by the availability of some of the data at only this level. More generally, for the same countries, the statistical level I seems to be more important than the level II for the definition of relevant administrative units. Overall, the regional classification used here is very close to that used by the OECD[5] in the definition of the territorial level T3.

By following the theoretical literature presented in the previous section, it is derived a list of relevant variables which can proxy the presence of increasing returns at the regional level. In what follows the variables are described[6].

RED is the percentage of research expenditure made by both private firms and public institutions located within the region relative to the regional Gross Domestic Product (average in years 1997-1999);

PA is the number of applications for patents made at the European Patent Office divided by the number of inhabitants of the region (average in years 1997-1999);

KIS is the share of workers in Knowledge Intensive Business Services[7] relative to the total number of workers in all NACE activities (average in years 1997-1999);

HTM is the share of workers in High and Medium-High Tech Manufacturing[8] relative to the total number of workers in all NACE activities (average in years 1997-1999);

[5]For more information on the territorial classification adopted by OECD please refer to the following documentation: http://www.oecd.org/dataoecd/35/60/42392313.pdf.

[6]In the growth regression framework investments and population change are usually included as controls. However, given the cross-section nature of the dataset, the inclusion of these variables might have produced simultaneity bias in the estimates. According to Grossman and Helpman [21] investments tend to follow GDP growth more than the opposite and, moreover, Fagerberg and Verspagen [18] have shown that differences in physical capital accumulation do not explain regional variation in per-capita GDP. Likewise Fagerberg and Verpagen [17] [17] show that population growth at the regional level is driven by migration flows which, in turn, depend on the economic opportunities in the destination region.

[7]A detailed definition is provided in the appendix.

[8]A detailed definition is provided in the appendix.

HRST is the percentage of regional population employed in Science and Technology (average in years 1997-1999);

ROAD is the total number of kilometers which compose the road network of the region (year 2000) divided by the area of the region in square kilometers;

INTERNET is the percentage of households having access to internet (average in years 2007-2009);

EMPD is the employment density, measured as the ration between the the number of employees (average in years 1997-1999) and the area of the region in square kilometers.

Table 1: Factor Analysis - Varimax Rotation

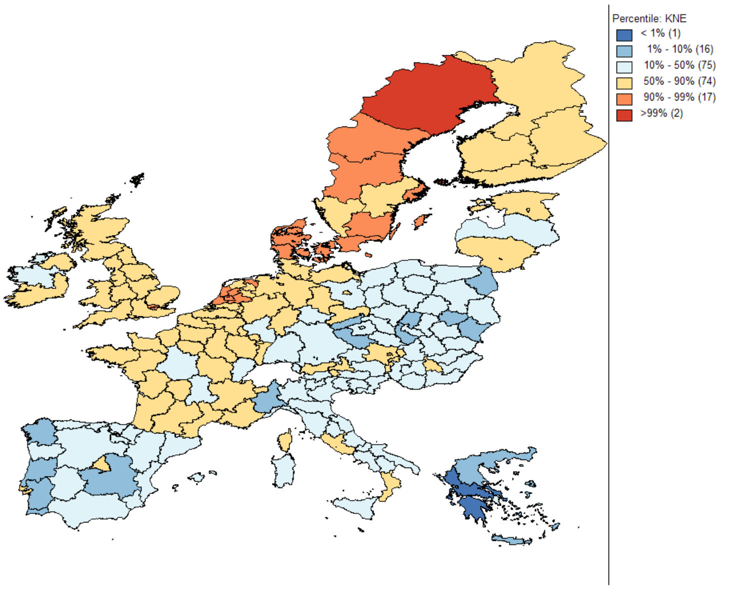
	Factor 1	Factor 2	Factor 3	Factor 4
RED	0.354	0.846		-0.200
PA	0.385	0.733		
KIS	0.896	0.208	0.267	-0.278
HTM		0.555		0.103
HRST	0.637	0.381	0.288	
ROAD	0.300		0.505	
INTERNET	0.834	0.398	0.116	0.357
EMPD		0.993		
Proportion	0.284	0.239	0.179	0.032
Cumulative	0.284	0.523	0.702	0.734

Admittedly, most of these variables show high correlation between them and this prevents the use of all of them in a regression framework because of the possible collinearity. Such correlations are detected by using factor analysis, on the base of which four factors are obtained. Correlations of these factors with the origin variables are summarized in the table 1. All together the four factors explain 73.4% of the total variance in the data.

The first factor is highly correlated with KIS and $HRST$. High sores in this factor thus indicate a service-based regional economy with a production system prominently oriented to knowledge. The high correlation of the factor with the $INTERNET$ variable also indicates that the production in high-scoring regions is grounded on a good ICT network infrastructure. For this reason the name of knowledge economy (KNE) is attributed to this factor. Its spatial distribution is shown in the figure 1 and it appears that regions reporting the highest scores are spatially concentrated in the nort-western part of Europe and mostly in Scandinavia.

The second factor is highly correlated with RED, PA and MHT. To this factor it is attributed the name of innovation ($INNO$) as high-scoring regions are characterized by a large use of innovative inputs, both in terms of labor and investiments, and a large production of innovative output as well. The spatial distribution of this factor is shown in the figure 2. It is

Figure 1: Spatial distribution of KNE - percentiles



characterized by a generic core-periphery structure centered on the region of Baden-Wurttenberg. High scores in less central areas are also recorded in the Swedish region of Vastsverige, in East England and, to a lower extent in Paris and in the Dutch region of Noort Brabant.

The third factor shows high correlation with the $EMPD$ variable and with the $ROAD$ variable. Accordingly, high scores pinpoint agglomerated regions and the name attributed to the factor is agglomeration (AGG). The spatial distribution of this factor, in figure 3, has, however, a different pattern from the expected core-periphery one. It does not surprise that very high scores are registered by the capital regions in the majority of the member states. Nonetheless, according to the indicator, some of the more agglomerated regions appear to be in the eastern part of the Europe, expecially in Poland and Chez Republic. On the contrary Spanish and French regions, they are accounted as non agglomerated.

3 Empirical Model and Results

The empirical analysis starts by estimating the standard growth equation for the sample of regions, and adding the three measures derived before to the model (equation 1). The per-capita Gross Domestic Product[9] (Y_i) of the region is used to meaure the regional output and the period under study is that from the year 1995 (t) to the year 2007 ($t+T$).

[9]Milions of Euro at 2000 prices.

Figure 2: Spatial distribution of INNO - percentiles

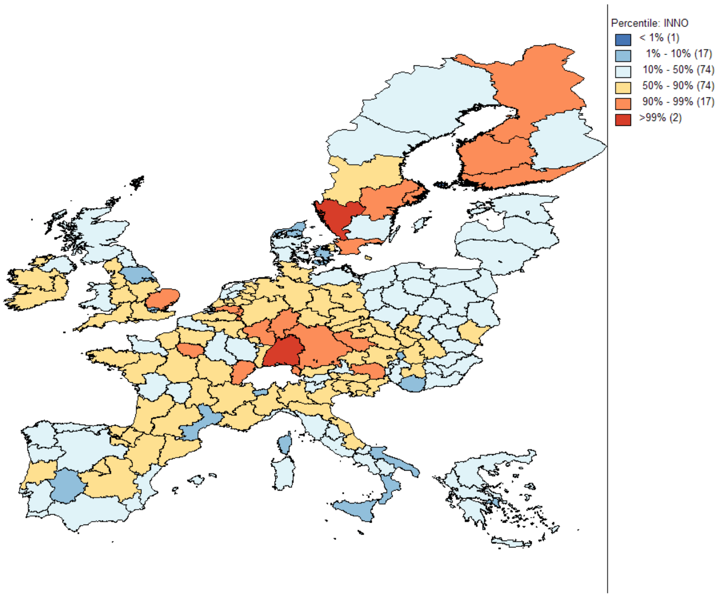
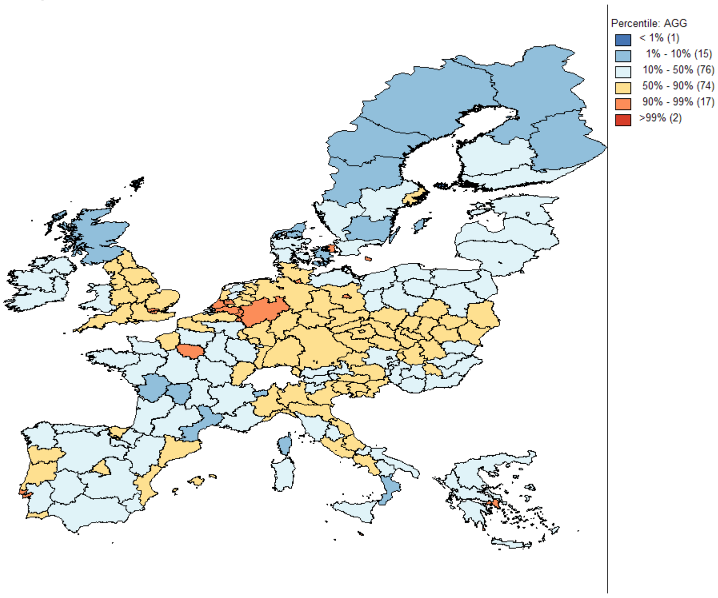


Figure 3: Spatial distribution of AGG - percentiles



$$\frac{1}{T}\log\left(\frac{Y_{i,t+T}}{Y_i,t}\right) = \alpha + \beta\log\left(Y_{i,t}\right) + \gamma_1 AGG + \gamma_2 KNE + \gamma_3 INNO + \varepsilon_i \quad (1)$$

As it is usual, the β coefficient is expected lower than zero. This implies that, as a consequence of the diminishing returns, poorer economies have higher growth rates. On the opposite, the values of γ_1 γ_2 and γ_3 are expected to be positive, so that higher regional growth might be related to the presence of increasing returns. Estimates using this linear specification are summarized in table 2. In the first three columns of the table estimates have been reported for the models with each factor added separately. In the last column, the three factors are included jointly.

Table 2: Groth Regression - OLS Estimates

	(1)	(2)	(3)	(4)
Intercept	0.122***	0.161***	0.125***	0.186***
	(0.015)	(0.017)	(0.016)	(0.019)
log(gdp)	-0.010***	-0.014***	-0.011***	-0.017***
	(0.002)	(0.002)	(0.002)	(0.002)
agg	0.001			0.002**
	(0.001)			(0.001)
kne		0.005***		0.006***
		(0.001)		(0.001)
inno			0.001	0.003**
			(0.001)	(0.001)

Notes to table 2:

The estimated coefficient related to the initial income is always correctly sloped and highly significant. Its value ranges from -0.017 to -0.010, coherently with previous results in the empirical literature on European regions. Differently, the coefficients on the three factors have positive slopes but, exception made for the factor which interprets human capital and the knowedge economy, they are not significant when considered alone. Nonetheless, they turn out to be strongly significant when considered together. Among all of them, the coefficient related to KNE is the largest in magnitude.

The issues of spatial dependence and non-linearity are further introduced into the analysis. A first attempt is made by estimating a Spatial Error Model (SEM) specification of the equation 1 with the interaction terms between the logarithm of the initial income and each of the three factors. The choice of the SEM is made on the base of a battery of tests for spatial dependence on the residuals obtained from estimates reported in the column (4) of table 2. The results of spatial autocorrelation diagnostic tests and of the SEM estimates as well are reported in the tables B in the appendix and will not be discussed here. The reason is that the use of a

SEM specification with interaction terms, although it appears very effective in accounting for spatial relations between units, it shows some weaknesses in accounting for non linearities. Instead, a more flexible nonparametric specification, firstly applyed to the study of regional growth by Basile [10], is preferred. Covariates are introduced as smooth terms into the model formulation and the resulting Generalized Additive Model (GAM) is estimated with the methodology suggested by Wood [42].

Differently from Basile [10], however, spatial relations are taken into account by either including a spatial trend into the model or by using Moran Eigenvectors approach. The choice implies that the empirical model is basically specified as a non-spatial model, to which spatial heterogeneity and spatial relations are added only in a second step. Thus, no a priory assumptions are made concerning the contribution of interregional externalities to the regional growth. The spatial trend is added to the model as a smooth spline of the geographical coordinates. This seems to be the most suitable choice to handle spatial heterogeneity in a GAM framework, since the same methodology (smooth splines) is used to account for both non linearity and spatial relations. Instead, the Moran Eigenvectors approach (Griffith and Peres-Neto [20]) entails the inclusion of suitable eigenvectors extracted from the contiguity matrix so as the spatial dependence present in residuals[10] is moved into the model (Bivand et al. [11]). It is worth noting that both the approaches, differently from many others spatial regression approach, permit to include a spatial structure directly into the deterministic part of the model, and not in its random part.

The result of the GAM model are summarized in the table 3. The simplest model is estimated excluding the spatial component *(a)* from the model specification. It follows the model with the spatial trend *(b)* and that with the spatial filter *(c)*. Significance of each smooth term is evaluated through the vale of the related F statistic. In all the three models the smooth terms are strongly significant. In the model with the spatial trend, the $s(x, y)$ terms, identifies the smooth term relative to, jointly, latitude and longitude. Finally in the model with spatial filter, the filtering methodology has identified eighteen eigenvector. For the sake of simplicity the related coefficients and statistics have not been reported.

Goodness of fit is assessed by looking at the values of the adjusted R^2, at the percentage of the deviance explained and at the GCV score[11]. Moreover ANOVA tests have been carried out comparing each of the two models with the non spatial model. The results clearly indicate that, in both cases, the inclusion of spatial effects improves the model's fit. Overall,

[10]The procedure works in two steps. In the first the eigenvectors are selected which minimize the residual autocorrelation of the linear model with the inclusion of covariates. In the second the eigenvectors are included in the non linear model specification.

[11]In this case the lowest it is the value the better the model fits.

Table 3: Growth Regression - Non-linear Models

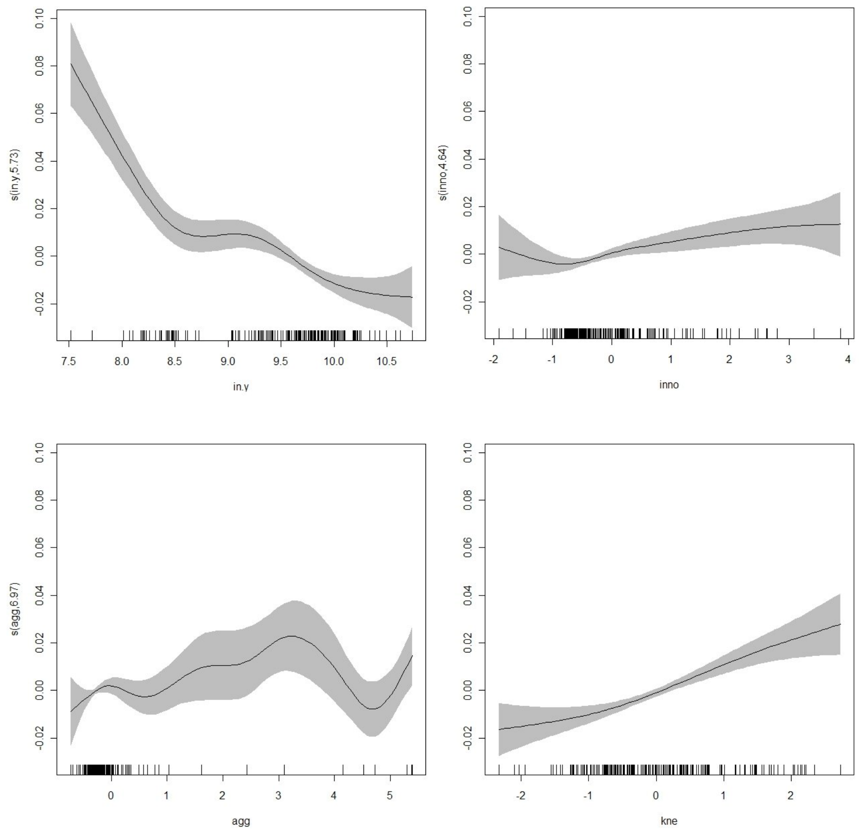
	(a)		(b)		(c)	
Coefficient						
Intercept	0.024^{***}	(0.0008)	0.024^{***}	(0.0006)	0.024^{***}	(0.0006)
F-statistic						
$s(gdp)$	20.046	[0.000]	16.200	[0.000]	29.580	[0.000]
$s(agg)$	4.229	[0.041]	2.818	[0.006]	3.459	[0.065]
$s(kne)$	8.550	[0.000]	11.149	[0.000]	35.388	[0.000]
$s(inno)$	3.067	[0.007]	3.383	[0.004]	4.259	[0.000]
$s(x, y)$			6.638	[0.000]		
Goodness of Fit						
$Adj.R^2$	0.443		0.746		0.721	
Devianceexp.	48.50%		80.90%		76.90%	
$GCV \cdot 100$	0.1415		0.0791		0.0792	
$ANOVA(\chi^2)$			0.000		0.000	

Notes to table 3:
SE in parenthesis, probabilities in square brackets
***, ** and * indicate significance at 1%, 5% and 10% confidence levels

all the indicators detect the best fitting in the case of the GAM with the spatial trend.

Relative to the only model with spatial trend, results are presented in figure 4 in the form of a multiple plot to allow easier interpretation of the effect of non-linearity. Each plot separately scatters the smoothed predicted value on the vertical axis against the original value on the horizontal axis. The value on the vertical axis has a straightforward interpretation. It indicates the predicted contribution of the variable to regional growth. For this reason, all the values on the four different vertical axis have been reproduced on the -.02/.10 range, which permits to compare results.

Figure 4: Plot of predicted smoothed values against variables - Non-linear model with Spatial Trend



Looking at the figure 4 it is possible to note that the contribution of initial income on growth shows a clear negative relation with the observed values of the initial income. Thus the convergence hypothesis is, on general, verified at the empirical level. A deeper look into the initial income plot, however, indicates that the rate of convergennce, graphically identified as the slope of the curve, is higher in regions with a lower initial income level. In greater detail, the income distribution in the initial period seems to be characterized by a strong bimodality. In the horizontal axis all the observations, each indicated by a small line in the axis, seem to concentrate around two major poles. The part of the curve relative to the observations in the first group of regions, likely the regions of eastern countries and, more generally, of the periphery, looks more sloped if compared to the part of the curve relative to the group of leading regions. The plot moreover shows that, for the majority of these leading regions, the value of the curve stands below the level of zero in the vertical axis. This means that for regions with very high levels of the initial income an increase in income itself has a negative impact on growth and, coherently with the convergence hypothesis, that rich regions have lower growth rates.

Interpetation of the agglomeration plot is more challanging. It is first worth to concentrate the attention on the characterizing feature of this plot. Looking at the distribution of the values which compose the factor, it is easy to detect a strong polarization in the neighbourhood of the value of zero. Only ten regions, in fact, have a score in this factor higher than one and these, of course, are capital regions. Relatively to the only group of non capital regions, the relation between agglomeration and its contribution to growth appear inverse U shaped. For low values of agglomeration, its increase has a positive effect on regional growth while, for already densely agglomerated areas an increase in agglomeration produces negative effects on growth. The evidence reinforces the hypothesis on the presence of agglomeration diseconomies or, at least, cast serious doubts on the validity of the opposite hypothesis, that according to which agglomeration is good for growth. Finally it is worth noting that the value of $s(agg)$ is higher than zero only in a very small intervall on the distribution of agg.

The plot of the innovation factor is characterized by two most important features. The first is the U-shaped pattern, which shows the existence of a first important threshold effect. The second is that the predicted value of the contribution of innovation to growth ($s(inno)$) turns to be positive only after a certain value of the factor, which value represents the second threshold effect. Thus, for very low levels of innovative capacity, an increase in it would have no positive effects on growth. Only when the innovative capacity of a region exceeds the first threshold effect, marginal increases in innovation make the contribution of innovation to growth increase. Scoring higher than the first threshold in innovation is necessary but not sufficient for having positive effects on growth. These effects are present in only regions scoring higher than the second threshold in the innovation factor. The result is consisten with previous evidence found by Sterlacchini [38] for European regions using R&D as a proxy for innovation.

Finally, the interpretation of the knowledge economy factor is the most intuitive. The effect of a marginal increase of the factor is always grater than zero although, and again, the predicted effect on growth becomes positive after a given threshold. The value of $s(kne)$ ranges in between -.02 and .02, which means that, among all the sources of increasing returns, kne is the one that majorly contributes to growth.

4 Discussion and Conclusion

The assumption of non-linear patterns in growth-drivers used in this work allows a deeper understanding of the regional convergence. Overall it is found that there is convegence. The higher the income level, the lower the contribution of income to growth. Nonehteless, the per-capita income distribution appears characterized by bi-modality and, moreover, regions in the two groups converge at different speeds. This first group is principally made by regions with a per-capita income in 1995 lower than 10000 euros at 2000 prices.This roughly corresponds to regions eligible for Objective 1 funds under the Cohesion policy1[12]. An higher speed of convergence characterizes this group. In the second group, made of regions with an income level in 1995 higher than approximately 13500 euros (at 2000 prices), the speed of convergence is lower. For each region in this group the contribution of income to growth is lower than zero. Growth in these regions, if any, is thus driven not by convergence.

Among the three theoretical hypothesis concerning the way regional growth relates to the presence of increasing returns in the regional economy, the ones about knowledge and human capital and innovation are the ones most reflected in the empirical evidence. On the contrary the contribution of agglomeration seems to be, overall, negative, with an inverse U shape. Overall, results suggest that the relation between the factors highlighted by the theoretical literature as springs of regional growth and current regional performance is far more complex than predicted. Agglomeration might produce positive effects on regional growth, but the evidence suggest that this is true only for very agglomerated regions, like capital regions are. For all the other regions agglomeration does not rule and, on the opposite, the evidence suggests that, over a given agglomeration level, diseconomies become predominant. Innovation might produce positive effects as well but the presence of important thresholds has to be taken into account. Thep-

[12] Actually a larger number of regions can benefit from the eligibility to Objective 1 funds.

resence of such thresholds could be linked to the importance of externalities along the innovation process. Accordingly, an existing knowledge base is necessary to benefit from externalities, as long as new knowledge is built upon existing knowledge. The existence of a significant knowledge base therefore increases the productivity of innovative investments, which, on the contrary, could be ineffective in regions where knowledge is scarce. The same can be argued for human capital. Spillovers between skilled workers are usually ascribed as the source of increasing returns to investments in human capital, but a consistent pool of skilled workers is necessary for spillovers to take place.

Turning the attention to the policy implications, it can be concluded that growth in least developed regions is boosted by a convergence process. For regions which have entered an advanced stage of the economic development, growth is driven by other factors. Among these factors, agglomeration is nieghter necessary nor sufficient for regional growth, while innovation and human capital show their effect only after a threshold is passed. Thus cohesion-oriented measures should be focused on filling the gap that least developed regions have in terms of innovative capacity and use of human capital in the regional production system. On the opposite, targeting low-income regions might be a failing approach since these regions already have higher growth as a consequence of their higher factor productivity.

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A Definitions

A.1 KIBS

List of activities included in the definition of Knowledge Intensive Business Services: Post and Telecommunications, Computer and related activities, Research and development, Water transport, Air transport, Real estate activities, Renting of machinery and equipment without operator, and of personal and household goods, Financial intermediation, except compulsory social security, Activities auxiliary to financial intermediation, Education, Health and social work, Recreational, cultural and sporting activities.

A.2 HTM

List of activities included in the definition of medium/high-tech and high-tech manufacturing: Aerospace, Pharmaceuticals, Computers, office machinery, Electronics-communications, Scientific instruments, Electrical machinery, Motor vehicles, Chemicals, Other transport equipment, Non-electrical machinery.

B Additional Tables

Table 4: Spatial Autocorrelation Diagnostics

	d=700km	d=500km	d=300km
$Moran'sI$	0.3709 [0.000]	0.4167 [0.000]	0.4853 [0.000]
$logLik(SLM)$	575.41	578.05	574.97
$logLik(SEM)$	581.47	586.45	586.54
$logLik(SDM)$	582.23	582.33	582.75
$-LR(SDM-SLM)$			15.5643 [0.004]
$-LR(SDM-SEM)$			-7.5819 [0.108]

Notes to table 4:
Probabilities in square brackets

Table 5: Growth Regression - Spatial Error Model

	(1)	(2)	(3)	(4)
$Intercept$	0.185***	0.183***	0.192***	0.190***
	(0.026)	(0.026)	(0.026)	(0.026)
$\log(gdp)$	-0.017***	-0.017***	-0.018***	-0.017***
	(0.003)	(0.003)	(0.003)	(0.003)
agg	0.001*	0.009	0.001*	0.001*
	(0.001)	(0.013)	(0.001)	(0.001)
kne	0.008***	0.008***	0.048***	0.009***
	(0.001)	(0.001)	(0.015)	(0.001)
$inno$	0.003***	0.003***	0.003***	0.029*
	(0.001)	(0.001)	(0.001)	(0.018)
$\log(gdp) \cdot agg$	-0.001			
	(0.001)			
$\log(gdp) \cdot kne$		-0.004***		
		(0.002)		
$\log(gdp) \cdot inno$				-0.003
				(0.002)
λ	0.719***	0.716***	0.723***	0.716***
	(0.051)	(0.052)	(0.051)	(0.052)

Notes to table 5
SE in parenthesis
***, **, * indicate significance at 1%, 5% and 10% condifence levels.