Knowledge Externalities, Agglomeration and Regional Development in the EU: Motivating Place-Based Regional Intervention

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Abstract

Human capital, knowledge accumulation and agglomeration externalities are indicated as prominent sources of increasing returns. Their simultaneous contribution to regional development is investigated in this paper accounting for non-linearity, threshold effects and spatial dependence. Based on EU25 regional data (1995-2007), results highlight differentiated growth patterns for less and more developed regions, the effect of externalities being considerable in the latter case. The evidence weakly relate externalities to agglomeration, suggesting it is neither necessary nor sufficient for regional growth. Externalities are, oppositely, related to knowledge accumulation and human capital. With this respect, existing gaps are identified as the most relevant cause of the economic disadvantage of lagging regions. This, in turn, strengthens the arguments in favour of a place-based approach to regional policy.

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Introduction

After Solow's model of growth (Solow, 1956) has dominated the academic scene in regional development for decades, New Growth Theory (NGT) (Romer, 1986; Lucas, 1988) and New Economic Geography (NEG) (Krugman, 1991; Krugman and Venables, 1995; Fujita et al., 1999) have readdressed the attention to endogenous factors driving regional development. Key elements of both NGT and NEG such as, for instance, human capital, innovation and agglomeration economies, have come to integrate traditional Barro-type empirical models of regional growth (Barro, 1991) where, in fact, a large amount of regional growth was left unexplained by the classical 2% estimate of the *speed-of-convergence* (Martin and Sunley, 1998).

The endogenous potential of regional development is also at the earth of the current academic and policy debate about regional intervention (Barca et al., 2012). Such debate has been shaped by a set of influential reports, the most important of which are the World Development Report (WDR) (World Bank, 2009), where traditional spatially-blinded policies are advocated, and two OECD reports (OECD, 2009a, 2009b) as well as the Barca report (Barca, 2009) claiming the importance of a place-based approach to regional development. According to Barca et al. (2012) development policies have been primarily aimed at the provision of important infrastructures, regardless of the effective impact on territorial development. While such spatially-blinded policies have, in fact, promoted agglomeration and development in same regions they have, at the same time, caused marginalization in more peripheral areas. In contrast, a place-based approach to regional policy is based on careful consideration of the territory-specific resources and needs, and pays attention to the interaction between geography and institutions. Advocates of places-based approach argue that agglomeration per se is neither necessary nor sufficient for growth (Garcilazo et al., 2010) and that, on the contrary, growth based on agglomeration is likely unsustainable in the long-run (Thissen and Van Oort, 2010). By the opposite, regional policy should work to exploit the endogenous potential by unveiling local externalities, such as those related to local human capital and local innovation.

The reduction of economic and social disparities within the European Union is explicitly set as a target in the European treaty (Art. 174). However, there has been agreement in academia that policies aimed at reducing inequalities may hamper efficiency and ultimately economic growth (Thissen and Van Oort, 2010). The WDR (World Bank, 2009) substantially shares this view arguing that economic development will be naturally spatially unbalanced and that policies should not incentive relocation of firms in less developed areas but, instead, should promote integration (Gill, 2010). In fact, the aim of EU regional policy is not that of reducing disparities by re-equilibrating production and income but that of providing place-specific answers to place-specific problems, in particular by removing the obstacles to and by creating favourable conditions to smart growth (European Commission, 2010).

In respect of this objective, successful implementation of European regional policy requires to carefully address two specific issues. On the one side the origins of spatial externalities and their contribution to economic development at the EU regional level need to be identified, detecting the precise role of agglomeration economies in relation to other endogenous factors of growth. According to the view expressed in WDR (World Bank, 2009) agglomeration is, in fact, the primary driver of economic development, triggered by urbanization economics in large and diversified cities and by localization economies in small and medium size specialized cities (Gill, 2010). Spatially blinded institutions and spatially connective infrastructure might, therefore, help spreading externalities to the benefit of all people (Deichmann et al., 2011). On the other side, concerning externalities not related to agglomeration, it will remain crucial to target regions where policy support is most needed due to structural barriers preventing, and possibly impeding the genesis and propagation of such externalities.

In spite of the large discussion involved in this policy debate, which is proved by the considerable number of journal articles which have eventually followed the World Bank and OECD publications and the Barca report (see, for instance, Buckley and Buckley, 2009; Harvey, 2009; Maringanti et al., 2009; Rigg et al., 2009; Rodríguez-Pose, 2010; Farole et al., 2011), few attention has been addresses to the related empirical analysis. The present paper analyses the origins of regional growth in EU in the period 1995-2007 emphasizing the role of externalities mediated by not only agglomeration economies, but also human capital and innovative activities. The aim is to ascertain the real contribution of agglomeration to overall regional growth by taking into account the different natures of endogenous growth. For this purpose a standard cross-regional Barro-type regression is extended by including proxy variables expected to indicate the presence of externalities. Following a consolidated literature in regional growth, spatial externalities and spillovers are properly considered in the empirical model. Finally semi-parametric estimators are employed to detect any non-linearity and threshold effect in the growth-externalities relation.

The result can be summarized in few points. Firstly, evidence corroborates previous empirical results, showing that regional growth in Europe is characterized by a convergence process. Regions, however, converge at difference speeds and toward different steady states. In particular, a faster speed of convergence is found in less-developed regions. The growth-agglomeration relation displays an inverse U-shaped curve. This evidences that the effect of agglomeration on regional development is not always positive and in some circumstances agglomeration might be even not desirable. By the opposite, the effect of both human capital and innovation on regional growth exhibits quasi-linear and U-shaped, respectively. In the latter case, evidence suggest that investments in the innovative capacity of regions might not be effective, if the region is poor in initial innovative capacity.

These results have important policy implications. Beyond demonstrating empirically that agglomeration per-se in neither necessary nor sufficient for regional growth, at least when accounting for other potential endogenous factors of regional growth, the evidence also suggest that regional policy intervention is crucial is sustaining the path of least-developed region to bridge the technological catch-up. In absence of regional intervention, these regions will likely remain marginalized by the smart development process that richer EU regions are already experiencing.

The remaining of the paper is structured as follows. In next section the theoretical and empirical literature relating externalities to regional growth is examined. In section three the dataset is described and the empirical specification of the model is discussed in detail. Results are summarized in section four. A discussion of emerging policy implications concludes the work.

Externalities and regional growth

The Barro-type regression approach (Barro, 1991) is considered as the reference toolbox for empirical analysis in the stream of regional growth. The approach is directly derived from Solow's (1956) growth model in which, under the simplifying hypothesis of decreasing returns to production factors, it is shown that economies will converge toward a unique steady-state per-capita income level at a declining growth rate. The test for this hypothesis relies on a cross-region regression of per-capita 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.

In a series of articles Quah (1993, 1996) contended that the approach was adequate to test convergence, inasmuch evidence of converge were found also in the case of increasing trends in economic disparities. New methods based on transitional analysis are then suggested (Quah, 1996a). Despite results of several cross-sectional analysis agree on the estimate of the speed of convergence between 1% and 3% in EU regions (see, for instance, Fagerberg and Verspagen (1996)), in fact, Magrini (1999) studies distributional dynamics in EU and finds evidence of polarization and even multimodality.

Martin and Sunley (1998) review the theoretical and empirical debate on regional convergence, discussing to what extent empirical models of regional development have been influenced by endogenous growth theories. Indeed both NGT and NEG oppose to neoclassical growth models assuming endogenous mechanisms of development mediated by either knowledge spillovers (Lucas, 1988) or investments in innovative activities (Aghion and Howitt, 1992) or by the spatial concentration of economic activities (Krugman, 1991; P. Krugman and Venables, 1996). The predicted long-run outcome, in NGT, is divergence or conditional convergence. Galor (1996) extensively discusses the implication of different theoretical growth models on the convergence hypothesis. Likewise the predicted outcome of NEG models is divergence, in the form fo core-periphery patterns. Baldwin and Forslid (2000), for instance, integrate NEG in a model of endogenous growth finding that the long-run equilibrium is characterized by core-periphery patterns. In European regions, such outcomes are more likely confirmed by the empirical evidence of club-convergence in Quah (1996) and even by evidence of core-periphery patterns in the spatial distribution of income and production (Le Gallo and Ertur, 2003).

The empirical literature associating regional development to endogenous factors of growth is large and still expanding. In what follows this literature will be reviewed, paying attention to the different hypothesis implicit in models of endogenous regional development and to empirical testing of predicted outcome.

Human Capital

Lucas (1988) was among precursors of endogenous growth and most of the importance acknowledged to human capital likely originates from his work. He proposed a model of growth in which production was characterized by human capital accumulation and externalities were generated on the job or through learning by doing (Lucas, 1988). Increasing marginal productivity of human capital implies that no convergence can be predicted and that the opposite might be true: variation in growth rates across economies might be prolonged over time. Cross country evidence presented in Mankiw et al. (1992) support this hypothesis. Authors propose an augmented Solow model including human capital variable and derive, accordingly, a modified convergence test. Their result indicate that differences in equilibrium per-capita income levels are explained by human capital endowments.

At the regional level, a similar test is proposed. Badinger and Tondl (2003) use an empirical specification derived from a growth accounting framework and consider trade, human capital and innovation as sources of endogenous growth. The effect of human capital is found positive and significant and there is evidence that higher levels of human capital facilitate technological catch-up. López-Bazo et al. (2004) extend the Mankiw et al. (1992) framework to account for inter-regional externalities and test the convergence hypothesis at the regional level in EU. It is found that both physical and human capital accumulation are responsible of non-negligible externalities and hence contribute significantly to regional growth. In a similar fashion Ertur and Koch (2006) explore the role of spatial externalities in regional growth using a revised version of Mankiw et al. (1992) for the analysis of regional growth in Europe and find evidence indicating positive correlation between human capital and growth.

Departing from growth regression Cheshire and Magrini (2000) analyze regional growth determinants by using distributional dynamics (Quah, 1996b; Magrini, 1999) and find similar results. In that case, evidence suggest that differences in the endowment of human capital can explain both the static and the dynamic of income disparities.

In general, empirical evidence on the relation between human capital and regional development corroborates the hypothesis that human capital positively impacts on regional development and, hence, drives regional growth. More recent evidence, however, put forward indications of a threshold effect on this relation (Basile, 2008). Such evidence is consistent with theoretical models of growth based on human capital such as, for instance, that by Azariadis and Drazen (1990). In this framework, returns to investments in human capital turn positive only after sufficient knowledge starts accumulating. In addition the analysis in Basile (2008) concludes that the contribution of human capital to development is larger when both the region and its neighbours are well endowed in human capital.

Research and Innovation

Formal models of endogenous growth focus attention on the contribution of knowledge in production. In the case of human capital, it is assumed that knowledge is embedded in people and that it translates into productivity gains through the contribution of educated workers in production process. Obviously not all knowledge is embedded in people. A part of knowledge can be codified and formalized, and hence materialized in product and process innovations. At the heart of the endogenous models of growth based on innovation (Aghion and Howitt, 1992), it lies the hypothesis that new products and processes give a firm the monopolistic power. Firms, accordingly, have incentive to invest in the knowledge sector, since market returns are guaranteed by monopolistic power. At the aggregate level, production is characterized by increasing returns and long run income levels will likely differ across economies based on innovative capacity.

The empirical test for this hypothesis is based on an extension of the growth regression which includes a measure of innovation. Fagerberg and Verspagen (1996) first proposed a test of the hypothesis based on EU regional data, measuring innovative capacity by mean of R&D-related indicators. In the result, they conclude that technological gap indeed explains the persistence of disparities in per-capita GDP. Furthermore it is shown that the inclusion of R&D in the specification does contribute to improve statistical fitting of the model and to explain regional variation in per-capita income growth as well. Adopting a similar empirical specification Fagerberg et al. (1997) reach the same conclusion, based on a different sample of regions. More recently Rodríguez-Pose and Crescenzi (2008) have studied the issue using data covering all regions in EU25, finding evidence of a positive relation between regional growth and innovation. Sterlacchini (2008a), based on EU15 regional data, examines the contribution of both human capital and innovation, finding that the effect of human capital is constantly positive while a positive effect of innovation shows only in more developed regions. Evidence from a spatial descriptive analysis (Verspagen, 2010) puts forward a hierarchy in territorial innovation which likely resembles the spatial distribution of regional productivity.

By and large, empirical evidence asserts the positive effect of innovation on growth at the territorial level, as predicted by theory. Nonetheless scale effects need to be taken into account in considering the contribution of innovation to local development. On the one side, knowledge itself is an input for knowledge production (Dosi, 1988). Regions with a more substantial knowledge base and with a longer experience in innovative activity have higher opportunities to innovate, and may eventually experience higher rates of growth. On the other side, when considering innovation by imitation, a certain absorptive capacity is indeed necessary in order to successfully replicate other's innovation as well as to benefit from knowledge externalities (Cohen and Levinthal, 1989).

Accordingly R&D investments, at the regional aggregate level, are deemed necessary to innovate and also represent a pre-condition for prosperous knowledge diffusion (Fagerberg et al., 1997). Deep technological gaps slower and sometimes impede knowledge spillovers between regions and threshold effects have been identified in a number of empirical studies (Fagerberg and Verspagen, 1996; Crescenzi, 2005; Sterlacchini, 2008). Alexiadis and Tomkins (2010) proposed a theoretical growth model in which the regional absorptive capacity is negatively related to the technological gap and tested the hypothesis over the sample of EU27 regions, finding evidence in support of the hypothesis.

Agglomeration

While in NGT literature much concern is expressed for the role of knowledge-based externalities, in NEG literature (Krugman, 1991; Krugman and Venables, 1995) the attention is oriented more to benefits associated to the multiple co-location of economic activities. These benefits are characterized as pecuniary externalities and, more precisely, they are related to labour market pooling. Goods are produced in a Dixit-Stiglitz monopolistic competition framework with scale economies. This allows profits of each firm in the area to grow with the increasing number of firms localizing production in the same area. The equilibrium is concurrently determined by two forces in the model: agglomeration economies promotes co-location of activities in one single area and eventually divergence between territories while increasing transportation costs promote spreading of economic activities and hence a more even distribution of production. With the decline in transportation cost it becomes more and more convenient for firms to collocate in one single area.

The case of EU is discussed under the light of NEG models in Krugman and Venables (1996): it is argued that national barriers in Europe have discouraged the extension of industrial districts beyond national borders. According to Krugman and Venables (1996) the manufacturing sector in Europe is, in fact, much less spatially concentrated compared to the US and the decline in transportation costs which has followed the abolition of trade barriers is expected to significantly promote agglomeration in the long run. Although the long run welfare effect of integration is predicted positive, the level of inequality, in particular between regions, is expected to increase with the rise of economic agglomeration poles. On this point, Gardiner et al. (2011) have examined the national growth vs regional inequality trade-off for Europe and reported mixed evidence, primarily depending on the spatial scale unit used to measure agglomeration as well as on the definition of agglomeration itself.

The core-periphery pattern suggested by NEG seems overall capable of interpreting the geographical shape of the productivity in Europe. Using exploratory spatial data analysis to study the distribution of production and income in Europe, Le Gallo and Ertur (2003) find evidence of spatial concentration of economic activities at the regional level compatible with a generic core-periphery pattern. Ciccone (2002) studied the link between regional agglomeration, as proxy by employment density, and regional performance, as measured by total factor productivity. The empirical evidence in Ciccone (2002) suggests that the relation is positive and sizable.

Notwithstanding the evidenced correlation between agglomeration and territorial development, there is still much debate concerned with the effect of agglomeration on growth at the regional level. Crozet and Koenig (2005) analyse the effect of spatial concentration within regions on growth founding evidence of a positive relation, but the case of spatial concentration between regions is not discussed. Dall'erba and Hewings (2003) present a theoretical and empirical analysis for the case of infrastructure investments in European regions and study both, within region and between regions, effects. Their result suggest that a decline in transport cost induced by improvements in the inter-regional infrastructure network benefits aggregate country growth at the price of divergence whereas investments in the intra-regional infrastructure network stimulate regional growth in depressed areas but have limited impact on country growth. Petrakos et al. (2011) estimate a growth model using agglomeration and accessibility as covariates in the model and find that the coefficient estimates related to both variables are positive and significant. In this work, however, prominent characters of regional growth in Europe such spatial heterogeneity and spatial spillovers (Dall'erba and Le Gallo, 2008; López-Bazo et al., 2004; Pfaffermayr, 2012; Sardadvar, 2012) are not accounted for in estimation. By the opposite spatial effects are considered in Bosker (2007) studying regional growth for a sample of 208 EU16 regions over the period 1977-2002. This study estimates the direct effect of agglomeration on growth as well as the indirect (spillover) effect of agglomeration on neighbouring regions growth. It is found, relative to both effects, a negative relation between agglomeration and growth, suggesting that negative externalities and agglomeration diseconomies prevail over benefits of agglomeration, on average.

A Comprehensive Framework

A widespread empirical literature has attempted to bridge the gap between predictions from various theoretical models of regional development and empirical evidence, proposing testable hypothesis to be embraced in the cross-regional growth regression framework. These hypothesis have largely directed on either one or more divers of regional growth suggested by theories but rarely have considered all different theories in a comprehensive manner. It might be argue, in fact, that the lack of a theoretical background pinpointing the relation between the different springs of economic externalities is responsible for this.

On the one side, externalities related to human capital and research investments are usually considered to be pure externalities, meaning that benefits deriving from an unintended transfer of knowledge are not mediated by market mechanisms. NGT models indeed are not concerned with the mechanism of knowledge diffusion, which is instead considered a kind of black box. Nonetheless advances have been made in this literature starting from the seminal contribution by Hippel (1994), who first defined knowledge as *sticky*, up to the more recent stream of literature which goes under the name of *Geography of Innovation* (Audretsch and Feldman, 2004). On the other side, externalities in NEG models are modelled as pecuniary externalities, hence mediated by markets. According to Krugman (1991) it is worth focusing attention on pecuniary externalities since, by the opposite, *"knowledge flows are invisible, they leave no paper trail by which they may be measured and tracked"* (p. 53).

Nonetheless, the same Krugman (2011), almost 20 years after *Geography and Trade* (Krugman, 2011), recognized that NEG theories have become popular at the end of that period in which economic development was driven exactly by market forces described in NEG models. Nowadays spatial concentration of economic activities in developed economies is mostly driven by intangible sources of externalities, such as knowledge spillovers, and less by market forces. Such externalities, by definition, are not bounded in space and, by the opposite, are likely to cross administrative borders, causing cross-regional externalities. This argument clears up the reason why a large body of regional growth literature, under the influence of new developments in spatial econometric methods (LeSage and Pace, 2009), has readdressed the attention on inter-regional spillovers (Lopez-Bazo et al., 1999; Le Gallo et al., 2003; Badinger et al., 2004; Ertur and Koch, 2006; Dall'erba and Le Gallo, 2008; Guastella and Timpano, 2010) while only to a minor extent the effect of agglomeration on regional growth has been considered in empirical works.

Despite the prominence gained by knowledge spillovers in the academic debate on regional growth, it is surprising to note how the policy debate about regional development, which is described in the introduction, is still confined to the role of agglomeration economies. And it is, in its largest part, centered on the policy implications derived from NEG models, in spite of the constrains set by the questionable plausibility and credibility of those models (Martin and Sunley, 2011).

The aim of this work is to fill this gap in the empirical literature by testing the role of agglomeration on growth, considering also the influence of non –market externalities such those related to human capital and innovative activity. As suggested by previous literature the role of spatial externalities is appropriately considered in the model framework. Most importantly, instead of estimating the average effect of externalities on growth, non-linear relations are estimated to understand in which regions externalities are more important.

Data

The data used in this work are part of the Eurostat regional database. The sample under study considers territories part of EU25. Statistical units are defined based on the NUTS classification. More in detail, in the case Belgium, Greece, Germany and the United Kingdom, NUTSI units have been considered, since most of the data come at this level from Eurostat. In the case of all other countries NUTSII units are considered. Overall, the regional classification used in this work is very close to that used by the OECD[1] in the definition of the territorial level T3.

Based on the theoretical and empirical literature reviewed in the previous section, a list of influencing variables to proxy regional externalities is derived. This is presented in table 1. Notably, in more than one case, different indicators have been included to describe the same phenomenon. This is considered a strength of this procedure, provided the multidimensionality of phenomena related to externalities. For instance, in the case of innovation, it is well known that R&D expenditures and patent applications are both good proxy of innovation. Nonetheless they account for different aspects of the same phenomenon, hence input and output, respectively. So, working with either one or the other of the two variables might imply an a-priori exclusion of relevant information, while the use of a synthetic indicator allows accounting for such multidimensionality.

Table 1: Description of variables used as proxy for externalities

<Table 1 about here>

Based on the correlation matrix in the appendix, a factor analysis has been applied to the list of variables. Factor analysis brings forth four indicators, whose loadings are reported in table 2 alongside the share of variance explained by each factor.

Table 2: Factor Analysis Loadings – Variamax Rotation

<Table 2 about here>

The analysis of loadings indicate a high correlation of the first factor with *KIS* and *HRST*. Additionally there is high correlation between this factor and *INTERNET*. The factor hence describes regions where human capital and technology infrastructure play a key role in the regional economy. Regions with high scores in this factor are characterized not only by the extensive use of human capital in the production of goods and services but also by the availability of a network structure facilitating the diffusion of knowledge and information among firms and workers both in the region and with other regions. Being human capital and knowledge diffusion key elements of a knowledge-based economic system, the name of *Knowledge Economy (KNE)* is assigned to this factor.

[1] 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.

Loadings in the second column of table 2 show that the second factor is highly correlated with *RED* and *PA* as well as with *MHT*. Therefore high scores in this factor are given to highly innovative regions whose economic activity is based on R&D investments and whose economic structure is specialized in R&D intensive manufacturing industries. These regions, in addition, over-perform also in terms of economic output since high scores in this factor also indicate an intensive patenting activity. Accordingly the name of *Innovation (INNO)* is assigned to this second factor.

Finally, loadings in the third column indicate that this factor is highly correlated with *EMPD* and *ROAD*. These two variables point to two very important aspects of spatial agglomeration. On the one side the density of employment measures the result of the geographical concentration of firms in every region n, as a result of market forces attracting firms and workers in most productive places of Europe. On the other side the density of road infrastructure could be considered a proxy for transportation cost, as the latter is expected to decrease following improvements in the infrastructure network. Being spatial concentration of employment and transport costs the most prominent elements of NEG models, the name of *Agglomeration (AGG)* is assigned to this factor.

Altogether these three factors explain 70% of the total variance in the data. The usual Bartlett's test is used to verify the hypothesis that four factors are sufficient and, in fact, the null is rejected at a 5% confidence level. Nonetheless, concerning the fourth factor, it is not possible to give a clear interpretation to it and, provided that only a 3% of the total variance is explained by this factor, it is considered as residual and omitted from the empirical analysis accordingly. [2]

Empirical Model And Results

The empirical model used to test the contribution of externalities to regional economic growth in Europe is the standard cross-regional growth regression. The dependent variable, the log of annual average growth of per-capita Gross Domestic Product[3] (GDP), is measured over the period 1995-2007. The main independent variable is the log of per-capita GDP in 1995. This base model is extended including the three measures of agglomeration, human capital and innovation derived from factor analysis presented in previous section. The complete linear model is presented in equation 1.

[2] The decition to exclude this factor is taken after veryfying that the same factor has no explanatory power on the dependent variable. In both linear and non linear models presented in next session the inclusion of the factor in model specification does not improve the model fit.

[3] Milions of Euro at 2000 prices.

(1) $$\frac{1}{T}\log\left(\frac{y_{i,t+T}}{y_{i,t}}\right)=\alpha+\beta\log\left(y_{i,t}\right)+\gamma_1 AGG_i+\gamma_2 KNE_i+\gamma_3 INNO_i+e_i\,.$$

As it is usual in these models, the β coefficient is expected lower than zero, indicating conditional convergence. Following theoretical predictions, all values of $\gamma=[\gamma_1,\gamma_2,\gamma_3]$ are expected larger than zero, evidencing the positive contribution of all externalities on growth. e_i is the usual iid disturbance.

The model is estimated using the linear specification in equation 1 and estimation results are presented in table 3. Four linear models are estimated. In columns (a), (b) and (c) the model is estimated by adding one single explanatory variable to the base model and, finally, in column (d) all covariates are included.

Table 3: Estimation results - OLS

<Table 3 about here>

The estimated coefficient related to the initial income is always correctly sloped and highly significant. Its value ranges between -0.017 and -0.010, coherently with previous results in the empirical literature on European regions. In column (a) the coefficient related to agglomeration economies is larger than zero but not statistically significant. In column (b) the coefficient related to Knowledge economy is larger than zero and statistically significant. In column (c) the coefficient related to innovation is larger than zero but again not significant. Finally, in column (d), with all the variables pooled together, all coefficients maintain the expected sign and turn statistically significant.

This preliminary evidence indicate that misspecification problems arise when one or more of the sources of externalities are excluded from model regression. Nonetheless the main outcome cannot be considered satisfactory. Even in the case that all variables are included, the value of the adjusted R^2 is still quite low. The value of the F statistic makes clear the explanatory power of regressors, but, nonetheless, the model likely continues to be underspecified. The Moran's I statistic describes a situation in which model residual are spatially correlated and even if the degree of correlation declines for larger values of the cut-off distance, the test statistic continues to be highly significant[4]. Such high correlation in residuals might be related to the absence of country fixed-effects in the model specification. However, another reason for misspecification might be traced back in the

[4] A description of the contiguity matrix used to compute Moran's I is provided in the appendix.

hypothesis of linearity in the specification. In this respect Basile and Gress (2004) have shown that, considering cross-regional growth regression, a trade-off exist between spatial dependence and non-linearity. Furthermore, the use of a more flexible non-linear specification permits to identify any threshold effect in the relation between regional growth and its determinants.

Semi-parametric estimation of the growth equation at the regional level was initially proposed in Basile and Gress (2004) and subsequently applied also in Basile (2008) and in Basile et al. (2012). Following the methodology suggested by Wood (2006), some covariates are introduced as smooth terms into the model formulation in addition to the parametric part, resulting in a semi-parametric Generalized Additive Model (GAM). The suggested specification is described in equation 2. The only part of the model which is left parametric is the intercept while smooth functions $s(\cdot)$ are used to approximate the non linear relation between growth and initial income and between growth and the three factors responsible for externalities and increasing returns.

(2) $$\frac{1}{T}\log\left(\frac{y_{i,t+T}}{y_{i,t}}\right)=\alpha+s_1\left(GDP_i\right)+s_2\left(AGG_i\right)+s_3\left(KNE_i\right)+s_4\left(INNO_i\right)+e_i$$

In order to deal with spatial heterogeneity and spatial dependence in the data two different empirical strategies are used. On the one side the model is expanded by introducing a spatial trend as a smooth function of geographical coordinates $\left(s\left(long,lat\right)\right)$. The spatial trend is expected to capture the spatial heterogeneity which is left unexplained by other model covariates and hence to account for non-observable regional factors influencing growth. On the other side a spatial filter is included by mean of the Moran Eigenvectors approach (Griffith and Peres-Neto, 2006). Suitable eigenvectors are extracted from the contiguity matrix and included in the parametric part of the model in a way that any spatial dependence present in OLS residuals[5] is moved into the model (Bivand et al., 2008). It is worth noting that both the approaches, differently from many others spatial regression approaches, permit to include a spatial structure directly into the deterministic part of the model, and not in its random part.

Estimates of non linear semi-parametric models are presented in table 4. Column (a) reports estimates of the model in equation 2. The same model is extended including the spatial trend (column (b)) and the spatial filter (column (c)). In all models the estimated intercept is the same and

[5] 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.

is statistically significant. Significance of smooth trends is evaluated using F-tests on the null that the variable can be excluded from the model. All variables in the model (a) appear statistically significant at a minimum confidence level of 5%. The same significance appears also in estimates in column (b), where the spatial trend has been included. By contrary, when the spatial filter is added to the model the term related to agglomeration looses significance[6].

Comparing goodness of fit measures it appears that, in general, the model with a spatial component, either the spatial trend or the spatial filter, performs better than the base model. The values of the R^2 in both columns (b) and (c) is higher than the one in column (a). The improved performance of spatial models is also indicated by the percentage of deviance explained (the higher the better) and by the value of the Generalized Cross Validation indicator (the lower the better) (Wood, 2006). Finally ANOVA tests, comparing each model with the baseline model in column (a), reject in both cases the null that the spatial component can be omitted by the model specification. In addition, by focusing on the two spatial specification, there is evidence that the model with a spatial trend performs slightly better, if compared to the model with the spatial filter. Unfortunately, a direct test for which specification should be preferred cannot performed since the two models are non-nested. Nonetheless the evidence by the goodness of fit measures is deemed as sufficient to choice the spatial trend specification over the spatial filter.

Columns (d) and (e) report additional estimates for robustness check. In column (d) the share of workers in agriculture is added to the parametric part of the model to account for unobserved effects related to the industrial structure of the region. In column (e) this specification is further extended with the inclusion of a dummy for New Member States to control for group-wise heterogeneity. In both cases the previous results show robust. The share of agricultural workers is not significant when introduced alone but turns significant when included jointly with the NMS dummy. The latter is also highly significant even if the slope is negative, indicating that, all other things being equal, NMS have grown at a lower rate. According to all measures of goodness of fit the model in column (e) is the best performing model, explaining 83% of the total variance and with an R^2 of about 0.76.

Table 4: Estimation results – GAM

<Table 4 about here>

Contrary to the case of linear models, in which coefficient estimates are used for discussion, the results in table 4 cannot be directly considered. Wile in linear model the coefficient quantifies the

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[6] Estimation results related to the spatial filter variables are not reported in the table but are available upon request to the author.

average effect of a variable on the dependent variable, in non linear models marginal effects should be considered. These are plotted in figures 1 to 4 for the four non-parametric smooths.

Figure 1: GAM Marginal Effects – intial income

<Figure 1 about here>

As expected, the relation between growth and initial income is negative. In figure 1 it is possible to note two different slopes. A higher speed of convergence characterizes less developed regions, namely regions with the value of log income of 8.8, which is equivalent to a value of per-capita income of about 6600 euros at 2000 prices. A second lower speed describes the growth of the second group of regions, the group of most developed. Overall this result confirms previous evidence on the presence of club-convergence in Europe, since it is shown that regions converge towards different steady states and do at different speeds.

Figure 2 highlights the inverse U-shape relation linking agglomeration to regional growth. The contribution of agglomeration to regional growth is positive only for a selected group of regions characterized by poor infrastructure density and low population density. For these regions the value of the *agglomeration* factor is below -0.1. After this threshold the return to agglomeration becomes negative and finally indefinite in the case of very agglomerated areas.

Figure 2: GAM Marginal Effects - Agglomeration

<Figure 2 about here>

In figure 3 a smoother S-shape curve depicts the relation between knowledge economy and regional growth. The contribution of an increase in the *knowledge economy* factor is flat up to the threshold of -0.5 and grows at declining rates after that threshold. This result suggest that a primary knowledge base needs to be accumulated before knowledge turns to be productive for the regional economy.

Figure 3: GAM Marginal Effects - Knowledge Economy

<Figure 3 about here>

The same result is evidenced in the figure 4, which plots the contribution of innovation to growth. In this case it is possible to note an U-shaped pattern pointing to a threshold effect at the value of -0.8 of the *innovation* factor. Investments in innovative activity below this threshold are not only unproductive but might, on the contrary, produce negative effects on regional growth. Clearly the effect of innovation on growth turns positive after the threshold is passed.

Figure 4: GAM Marginal Effects – Innovation

<Figure 4 about here>

In an attempt to describe in a simple and meningful way the information content extrapolated from the empirical analysis, regions have been classified on the base of marginal effects plotted in figures 1 to 4. Regions with a growth potential grounded on the convergence process have been defined as convergence regions, as the speed of convergence for these regions appears higher in figure 1. Regions on the left of the highest pick in the inverse U curve in figure 2 are considered as regions with a potential for agglomeration and, by the opposite, regions on the right part of the graph are described as characterized by agglomeration diseconomies. On the contrary, regions with a value of either *knowledge economy* or *human capital* below the threshold in figures 3 and 4 respectively are considered as featured by structural barriers impeding regional growth. Based on this classification, six cathegories of region are identified in Europe and these are plotted in figure 5.

Figure 5: Map of EU regions based on econometric results

<Figure 5 about here>

In contrast with the EU definition of "convergence regions" adopted by European Commission, according to which southern Italy, Portugal and the majority of regions in Spain and Greece are included[7], regions in the convergence area, notably based on the definition provided in this paper, are located solely on Eastern Europe. In many of these regions, however, the potential for growth induced by convergence is hampered by structural barriers. In particular these regions lack the necessary amount of knowledge and innovative capacity to sustain smart growth and standard policy instruments to support reseach and education might have low impact. On the contrary, solutions designed to speed up smart growth need to be elebaorated at the territorial level, addressing appropriately the reasons for such structural distances in innovation and knowledge.

The geographical scope of agglomeration economies appears quite extended in Europe, suggesting that many regions can still benefit from increasing their potential accessibility. This is the case of Franch regions (excluding Paris), as well as of regions in Spain (excluding Madrid) and Portugal, in the central and southern Italy, in Austria, in northern Germany, in Ireland, in western and northern UK and in northern EU countries. Nonetheless, structural barriers apper also in many of these regions, most notably in Spain and Portugal, in Italy and in Greece. Any potential growth caused by agglomeration economies in these regions is likely moderated by the dearth od human capital and innovation in the regional economy.

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[7] See http://ec.europa.eu/regional_policy/atlas2007/index_en.htm for more information.

By the opposite, agglomeration diseconomies represent a characterizing feature of almost all other regions. It is not surprising to find, in fact, many of European capital regions within this category. Overall, in these regions, economic development is driven by human capital and innovation and is only in part moderated by diseconomies. Few exceptions are represented by Lombarida and Veneto (Italy) and Baden-Wuttenberg (Germany). In these regions, by the contrary, the relatively low innovative capacity and knowledge capital confine, or pehaps reduce, the potential for growth.

Discussion and Conclusion

Cross regional convergence in Europe has been deeply investigated in empirical literature, finding evidence of club-convergence or core-periphery patterns of growth. In this respect, the present study, based on 186 NUTS I and II regions in EU25, confirms this evidence by adding new results. Overall, the per-capita income distribution appears characterized by bi-modality. Regions in the two groups grow at different average rates and, in addition, converge at different speeds.

The analysis in this paper is innovative with respect to the existing literature inasmuch as the conditional convergence model is extended including more and different hypothesis about economic growth driven by increasing returns. More important, the different hypothesis suggested by economic theory are tested simultaneously. A second innovative aspect is the non-linear estimation. While linear estimation is particularly usefull in convergence models for the identification of steady states, its result, point elasticities, express the average effect of every variable on growth. Non-linear estimation, by the opposite, is a a powerful tool to reveal in which regions effects are larger (smaller) and ultimately to identify threshold effects. From a policy perspective, evidenced heterogeneity in drivers of regional growth underpins a territorial approach to regional policy.

Results portray a a complex picture characterized by large regional heterogeneity. Evidence suggest that different factors contribute to regional growth in Europe, perhaps simultanously. Convergence drives growth in eastern Europe and, in general, in NMS, although growth and catch-up in many ragions is hampered by the structural gaps in human capital and innovative capacity. It seems the case that only a big boost in the innovative capacity of these regions, accompanied by economic restructuring oriented to the knowledge economy may help to speed-up the convergence process. The majority of regions in western Europe have a potential for growth linked to improvements in accessibility, but also in this case such potential is mitigated by poor innovative capacity and lack of human capital within the economy. This is the case of southern European regions in Spain, Portugal, Italy and Greece. Finally, only in few regions growth is driven by innovation and human capital, even in presence of agglomeration economies.

As growth patterns are heterogeneous across regions, regional policies for growth should be designed accordingly. There is evidence of a positive relation of growth with human capital and innovation across all regions but the presence of thresholds in both cases invites to an accurate consideration of the case for regions below the threshold. In such cases investments in innovation an knowledge may have considerably moderated effects of be ineffective at all.

Accordingly, evidence in this paper suggest that a territorial approach to regional policy might better suit the aim of promoting growth at both the EU level and the regional level. On the one side it is found that agglomeration is neither necessary nor sufficient for regional growth. In fact, many of the most developed regions in Europe are facing agglomeration diseconomies, while regions with a potential for growth caused by increasing agglomeration have registered relatively low growth. This indicates that improvements in spatially connective infrastructures might have very limited impact on regional growth in absence of other measures. On the other side evidence suggest that growth is actually hampered by structural barriers related either to the lack of sufficient innovative capacity or to the limited use of knowledge in the economy. In this respect, effectiveness of policy instruments depends on the ability to stimulate regional structural transformation toward a knowledge-based economy, removing structural barriers which obstacle growth.

Efforts in this direction have been made with implementation of the Smart Specialization strategy, summarized in a recent report by the European Commission (EC (2011)). According to the report, the Smart Specialization strategy should serve to coordinate efforts by public and private institutions for the identification of strategic knowledge areas at the regional level in an attempt to maximize the benefits originating from these efforts. For the specific purpose of identifying regional strategic knowledge areas, the strategy aims at promoting the specialization of leading regions in generic technologies opposed to specialization in sector-specific applications of these technologies in other regions. The same report (EC (2011)) however recognizes that most of the commitment to Research and Technological Development for the period 2007-2013 comes from already economically and technologically developed regions, with the perspective that these investments will help reinforcing the virtuous cycle of knowledge creation and growth. Benefits in less developed regions might be accordingly low.

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Appendix

Correlation Matrix

<Table A1 about here>

Contiguity Matrix

The generic element w_{ij} of the contiguity matrix W is defined using the critical cut-off distance criterion with $d^* = \{300, 400, 500\}$.Squared inverse distance between each pair of contigous regions is used in place of the simple binary option and elements are row standardized.

$$w_{ij} = \begin{cases} d_{ij}^{-2} / \sum_j d_{ij}^{-2} \text{ if } d < d^* \\ 0 \text{ otherwise} \end{cases}$$

Definitions

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.

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.

Table 1: Description of Variables

Variable	Description
RED	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	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	share of workers in Knowledge Intensive Services relative to the total number of workers in all NACE activities (average in years 1997-1999)
HTM	share of workers in High and Medium-High Tech Manufacturing relative to the total number of workers in all NACE activities (average in years 1997-1999)
HRST	percentage of regional population employed in Science and Technology (average in years 1997-1999)
ROAD	total number of kilometres which compose the road network of the region (year 2000) divided by the area of the region in square kilometres
INTERNET	percentage of households having access to internet (average in years 2007-2009)
EMPD	employment density, measured as the ratio between the number of employees (average in years 1997-1999) and the area of the region in square kilometres

Table A1: Correlation Matrix

	RED	*PA*	*KIS*	*HTM*	*HRST*	*ROAD*	*INTERNET*	*EMPD*
RED	-							
PA	0.760	-						
KIS	0.573	0.512	-					
HTM	0.455	0.428	0.104	-				
HRST	0.571	0.530	0.715	0.210	-			
ROAD	0.178	0.147	0.405	0.007	0.275	-		
INTERNET	0.572	0.625	0.762	0.285	0.731	0.324	-	
EMPD	0.090	0.061	0.333	-0.108	0.317	0.523	0.151	-

Table 2: Factorial Analysis – Varimax Rotation

	Factor 1	**Factor 2**	**Factor 3**	**Factor 4**
RED	0.354	0.846		-0.2
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	0.3		0.505	
INTERNET	0.834	0.398	0.116	0.357
EMPD			0.993	
Proportion of variance	0.284	0.239	0.179	0.032
Cumulative proportion	0.284	0.523	0.702	0.734

Table 3:

	(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)
Adj R^2	0.179	0.246	0.177	0.275
F statistic	21.000***	31.070***	20.740***	18.440***
Moran's I - 300				0.485***
Moran's I - 400				0.417***
Moran's I - 500				0.371***

Notes to table 3:
SE in parenthesis. ***, ** and * denote significance at 1%, 5% and 10% confidence levels respectively.

Table 4:

	(a)	(b)	(c)	(d)	(e)
			Coefficients		
Intercept	0.024***	0.024***	0.024***	0.014***	0.016***
	(0.001)	(0.001)	(0.001)	(0.006)	(0.006)
log(agri)				-0.005	-0.006*
				(0.003)	(0.003)
Dummy NMS					-0.0125**
					(0.006)
			F-statistics		
s(GDP)	20.046	16.200	29.58	14.611	13.584
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
s(AGG)	4.229	2.818	3.459	2.046	2.473
	[0.041]	[0.006]	[0.065]	[0.041]	[0.012]
s(KNE)	8.55	11.149	35.388	6.483	7.169
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
s(INNO)	3.067	3.383	4.259	3.432	3.696
	[0.007]	[0.004]	[0.000]	[0.004]	[0.002]
Spatial Trend		6.638		7.048	7.291
		[0.000]		[0.000]	[0.000]
Spatial Filter			YES		
			Goodness of Fit		
Adj. R^2	0.443	0.746	0.721	0.757	0.764
Deviance Explained (%)	48.50	80.90	76.90	82.30	83.00
*GCV * 100*	0.1415	0.0791	0.0792	0.0078	0.0077
ANOVA (p-value)		[0.000]	[0.000]	[0.000]	[0.000]

Notes to table 4:
SE in parenthesis. p-values in square brackets. ***, ** and * denote significance at 1%, 5% and 10% confidence levels respectively.

Figure 1:

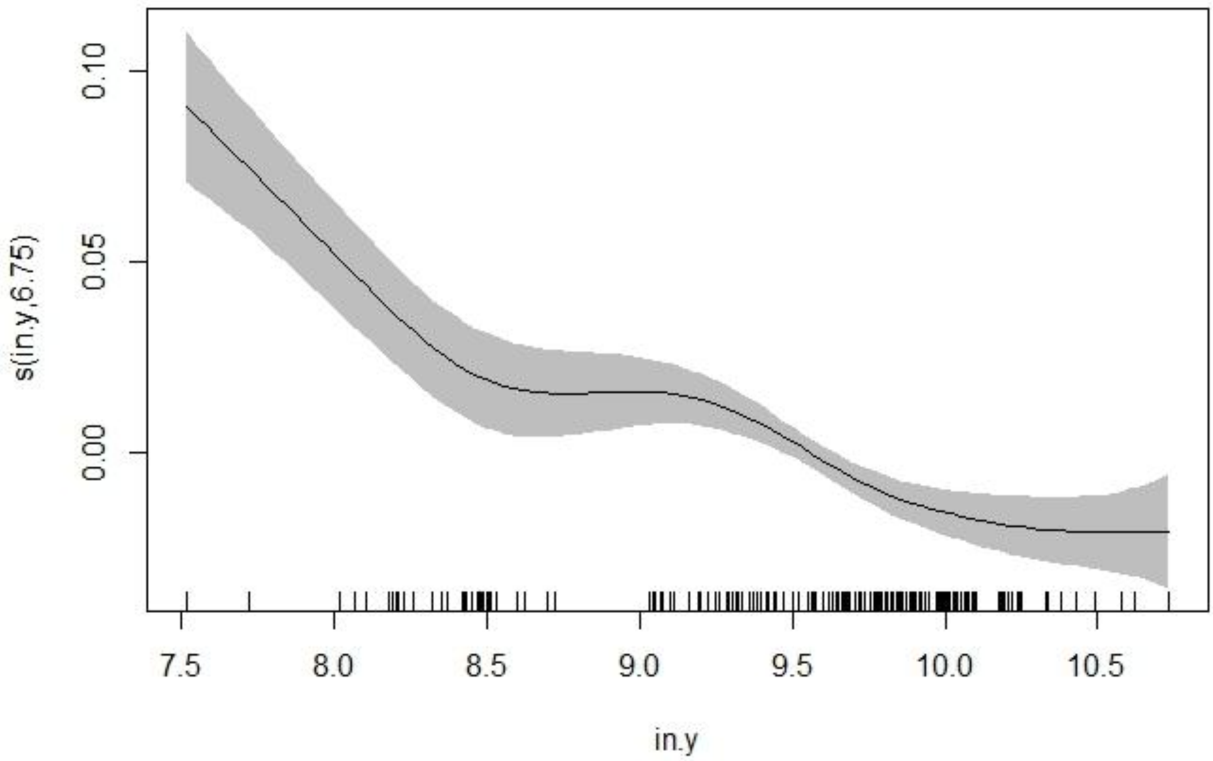


Figure 2:

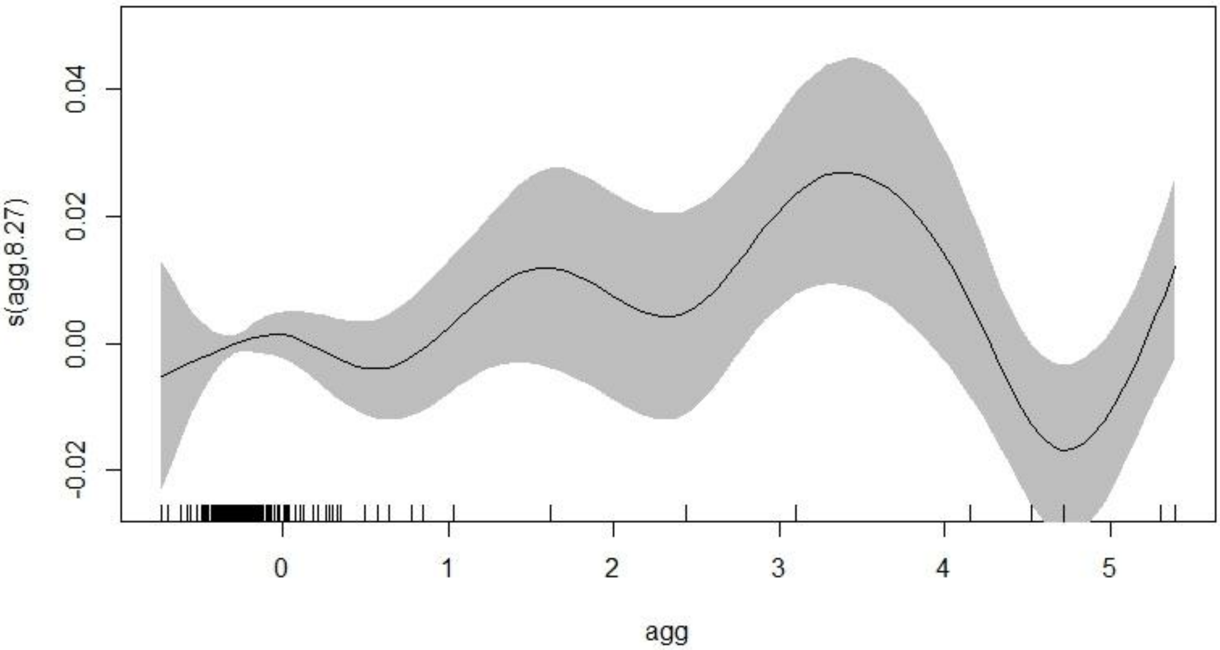


Figure 3:

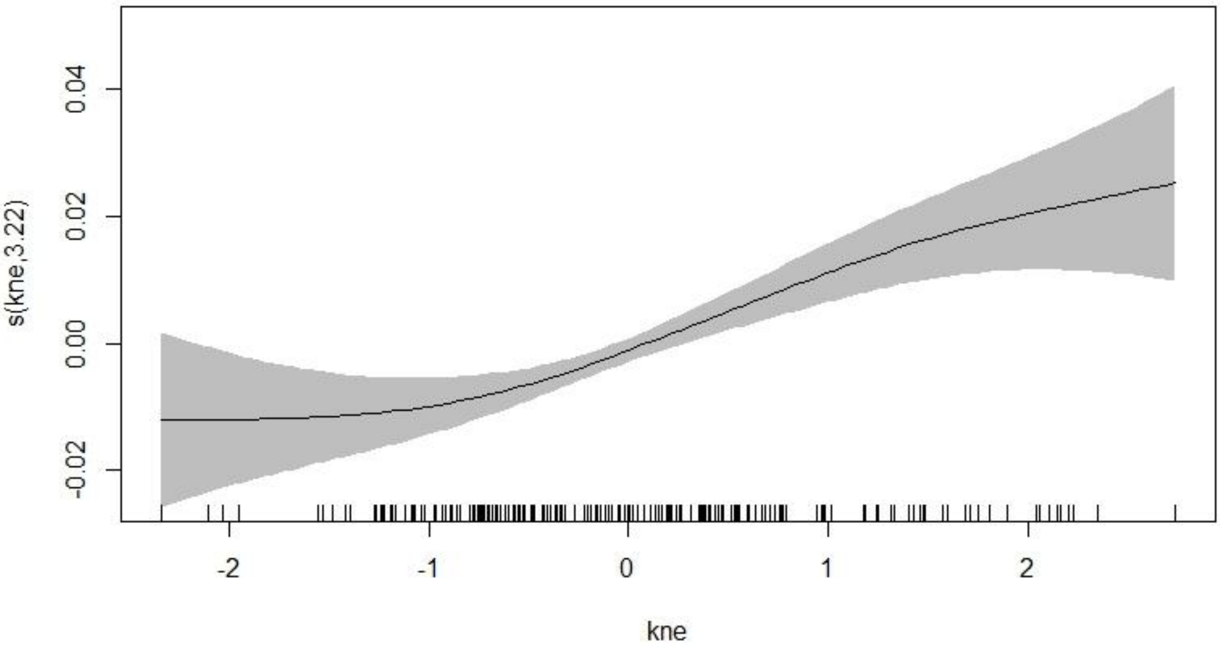


Figure 4

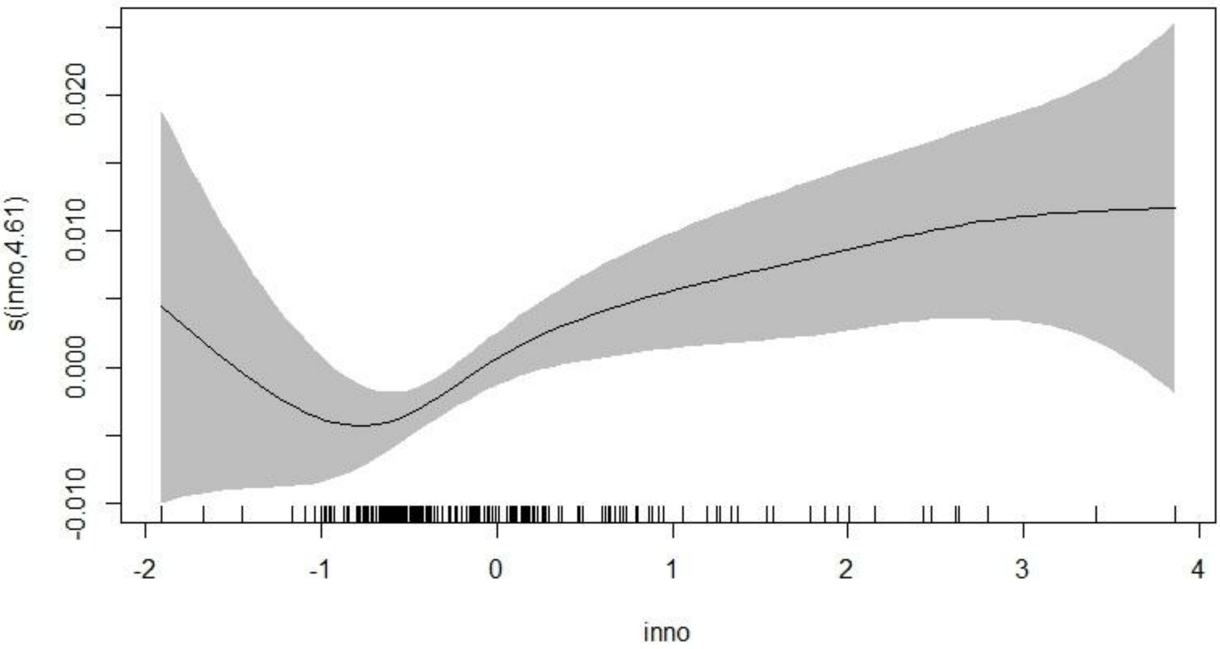
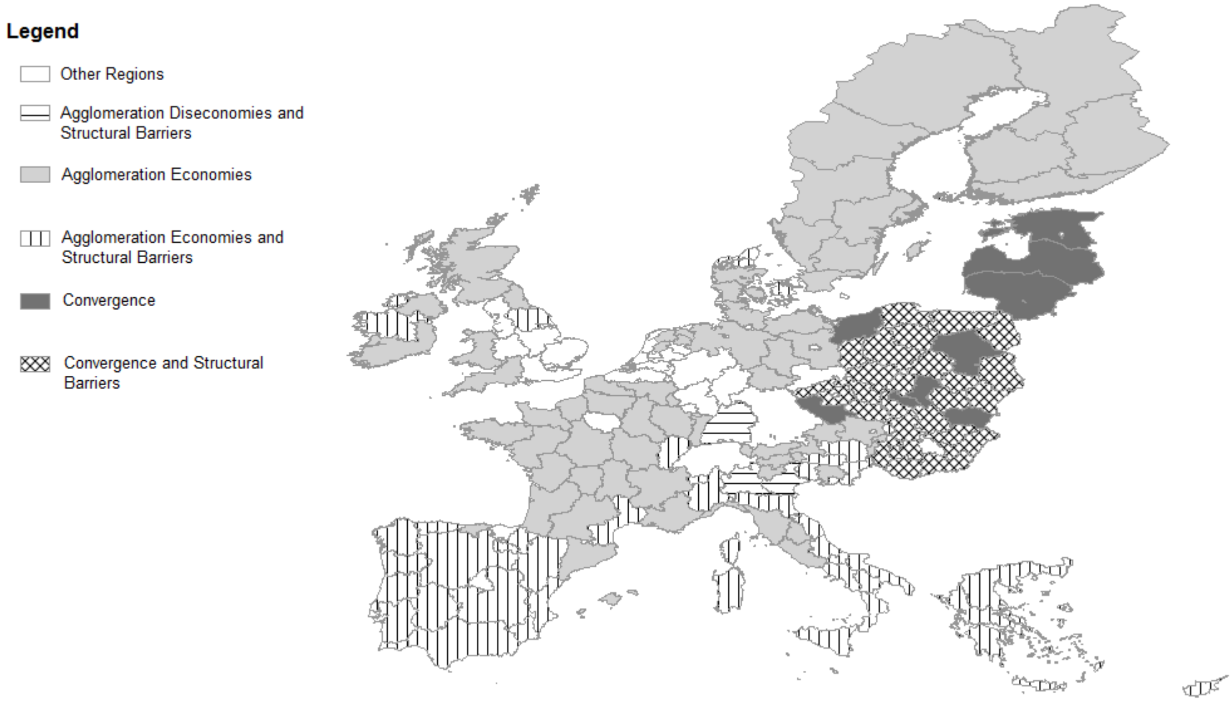


Figure 5


Legend
Other Regions
Agglomeration Diseconomies and Structural Barriers
Agglomeration Economies
Agglomeration Economies and Structural Barriers
Convergence
Convergence and Structural Barriers