REGIONAL CONVERGENCE AND THE IMPACT OF EUROPEAN STRUCTURAL FUNDS OVER 1989-1999: A SPATIAL ECONOMETRIC ANALYSIS [+]

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Abstract

This paper estimates the impact of structural funds on the convergence process between 145 European regions over 1989-1999. Since the majority of these funds finance transportation infrastructures, they induce spillover effects, industry relocation and do not necessarily succeed in reducing regional inequalities. To estimate their impact, including spillover effects, we first apply spatial econometrics on a conditional b-convergence model; second, we simulate their impact on the targeted region and then on all the other regions. The results show that structural funds have positively benefited to the targeted regions' growth, but that spillover effects are very small in peripheral regions.

Keywords : European structural funds, b-convergence, spatial econometrics, geographic spillovers

JEL Classification: C14, O52, R11, R15

1 Introduction

The phenomenon of persistent income and GDP disparities among European regions has been widely studied in the literature, using convergence models most of the time based on neo-classical specifications. The results of empirical estimations reveal greater cohesion among European regions (Barro and Sala-I-Martin, 1991; Amstrong, 1995), but at a slow rate (Martin, 2001) and also increasing disparities among regions within countries (Esteban, 1994). Instead of a catching-up of all the poorest regions, European integration seems to have benefited mainly to the richest regions in the poorest countries.

In order to decrease disparities, the European regional development policy (which amounted for 247 billion Ecus over 1989-1999, i.e. one-third of the Community budget) has implemented various instruments of which structural funds are the most important. The allocation of these funds induces strong spatial externalities since they mainly finance public infrastructures. For instance, when they finance transportation infrastructures leading to a decrease in transportation costs, they may also affect the process of industry relocation in the rich regions. As a result, structural funds do not systematically benefit to the long-run growth of the region where they are implemented (Venables and Gasiorek, 1999; Vickerman *et al.*, 1999; Dall'erba, 2004a). The existence of these externalities makes the impact of regional funds harder to estimate. Transportation infrastructures are not the only type of public investments financed by regional funds. However, in the absence of details on the sectoral allocation of structural funds for each region, this paper considers structural funds as public capital acting directly on the regional growth rate and assesses their impact using two complementary methods depicted in the two last sections of the paper.

This paper proceeds as follows: section 2 gives an overview of recent theoretical and empirical studies on the impact of regional assistance on uneven development. Section 3 provides some insights into the b-convergence model and spatial effects. Indeed, the majority of empirical tests of regional income convergence are based on the same assumptions as the ones underlying for international income convergence: regions are considered as isolated entities, as if their geographical location and potential interregional linkages did not matter. Only recently, the role of spatial effects has been considered in empirical studies using the formal tools of spatial statistics and econometrics[1]. The underlying idea is that forces driving to relocation/agglomeration process and hence to even/uneven regional development such as productivity (Lopez-Bazo *et al.*, 1999), transportation infrastructures (Krugman and Venables, 1995, 1996), technology and knowledge spillovers (Martin and Ottaviano, 1999), factor mobility (Krugman, 1991a, 1991b; Puga, 1999), have explicit geographic components. Section 4 presents the data and the weight matrix upon which the definition of space relies. In Section 5, exploratory spatial data analysis (ESDA) is used to detect spatial autocorrelation and spatial heterogeneity among European regional GDP. These two spatial effects and the structural funds are then included in the estimation of the appropriate b-convergence model. Simulation experiments, relying on the property of spatial correlation in the residuals, are carried out in section 6 to estimate the impact of the funds, first on the targeted region itself and second on all the regions of the sample. Le Gallo *et al.* (2003) have already simulated the spatial diffusion of a shock on neighboring regions. They find that the strength of diffusion depends on the economic dynamism and on the spatial location of the targeted region. In this paper, we simulate these spillover effects as well, but we extend the analysis to 1999, and include the real values of structural funds over 1989-1999. Section 7 concludes and provides some comments on the allocation of the European structural funds.

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[1] For the European regions, papers in this area include, among others, Fingleton (1999, 2001, 2003a and b), Maurseth (2001), Bivand and Brunstad (2003) or Le Gallo *et al.* (2003).

2 Impact of regional assistance on uneven development

The European Commission considers large regional imbalances unacceptable on distributional and political grounds. The successive enlargements of the European Community to the peripheral and less developed countries have made disparities in infrastructure endowments and per capita incomes so obvious (see figure 1[2]) that 68% of structural funds are devoted to the least developed regions[3]. Financed infrastructures mainly concern the transportation sector, in order to facilitate the development of the Single Market, and to a lower extent education, energy and telecommunication. Structural funds are the most important instruments of the European regional development policy with 247 billion Ecus over 1989-1999. In addition, the four least developed countries (Spain, Portugal, Ireland and Greece, which had a per capita GNP below 90% of the EU average) benefited from almost 17 billion Ecus allocated as cohesion funds over 1989-1999. Figure 2 displays the distribution of structural funds as a ratio of GDP during the 1989-1999 period. As expected, the poor and peripheral regions are the ones that benefited at most from Community support.

<< Insert figures 1 and 2 here>>

Four input-output models are used by the European Commission to assess the impact of structural funds on the four least developed countries (European Commission, 1999). Their results conclude that structural funds have had a significant effect in reducing disparities in economic performance across the Union and succeeded in narrowing the gap in GDP per head between the four Cohesion countries and the rest of the Union. Several empirical studies confirm the catching-up of cohesion countries in terms of per capita GNP (Esteban, 1994; Neven and Gouyette, 1995; and more recently Martin, 1999; Dall'erba and Hewings, 2003).

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[2] All figures have been realized using Arcview GIS 3.2 (Esri).

[3] Objective 1 regions having a per capita GDP below 75% of the European average.

However, these studies also reveal increasing regional disparities within these countries (but Greece). Therefore, a reconsideration of the impact of these funds on regional development is necessary.

From a theoretical perspective, two strands of literature provide insights into the effects of public assistance and infrastructures on regional growth and location of economic activity: growth models and economic geography models.

In a neoclassical Solow growth model, regional funds finance a greater level of physical capital, which corresponds to a higher steady state income. However, due to the decreasing marginal product of capital, the rate of investment declines towards the steady state income, where the stock of capital per person is constant. The investment rate is then equal to effective capital depreciation. Therefore, a higher investment rate in poorer regions may increase the convergence speed to rich regions, but is only transitional and does not raise the long run growth rate. Conversely, endogenous growth theory grants public policies an important role in the determination of growth rates in the long run. For instance, Aschauer (1989) and Barro (1990) predict that if public infrastructures are an input in the production function, then policies financing new public infrastructures increase the marginal product of private capital, hence fostering capital accumulation and growth.

When such investments finance transportation infrastructures that yield to a decrease in transportation costs, it may affect the process of industry location and favor agglomeration in the rich region. For example, Boarnet (1998) shows that highway projects in California counties benefit to the investing counties at the expense of the other counties within the state. Kelejian and Robinson (1997) make similar arguments concerning externalities at the state level. However, the economic geography literature shows that transportation infrastructures do not systematically benefit the region where they are implemented, more especially when they are used as regional development instruments (Vickerman, 1996; Martin and Rogers, 1995; Martin, 2000). In particular, with respectively 30% and 60% of structural and cohesion funds devoted to transportation infrastructures, their impact on regional development has to be seen in the light of characteristics of the transportation sector. The empirical study of Vickerman *et al.* (1999) points out that new transportation infrastructures tend to be built within or between rich regions, where the demand in this sector is the highest. Moreover, Puga and Venables (1997) show that in a transportation network based on hub-and-spoke interconnections, firms located in the hub face lower transaction costs in trading with firms in spoke locations than a firm in any spoke location trading with a firm in another spoke. As a consequence, this type of network promotes gains in accessibility in the hub location first (Puga, 2001; Venables and Gasiorek, 1999). The relationship between gain in accessibility and economic development in peripheral regions still requires considerable empirical investigation especially given the variations in transportation demands by sector. It is stated however that gains in accessibility due to interregional transport infrastructures will always be relatively higher in the central location than in the peripheral one (Vickerman *et al.*, 1999). Therefore, transportation infrastructures cannot always be seen as an efficient instrument to reduce interregional disparities.

The role of the above discussion is to highlight the obvious creation of spatial externalities due to the implementation of regional funds and therefore the need to formally include spatial dependencies in our model. Of course, we clearly do not claim that all the regions have financed transportation infrastructures through regional funds (actually the sectoral allocation of these funds for each region is unknown) nor that they are the only type of public investments financed. Regional policy instruments are also devoted to improve either the regional competitiveness as a whole or the incentives to locate at the level of each firm. Human capital formation or the improvement of infrastructures (in the transportation, telecommunication, energy or education sectors) belong to the first category whilst support to private capital investment through capital grants or tax breaks belong to the latter one.

Many recent empirical studies have investigated the impact of regional funds on development. De la Fuente and Vives (1995) show that promoting education has significantly contributed to the reduction of per capita income inequalities among 17 regions of Spain between 1980 and 1991. Boldrin and Canova (2001) conclude that regional and structural policies mostly serve a redistributional purpose, but have little relationship with fostering economic growth. Rodriguez-Pose and Fratesi (2004) focus on different expenditure axes. They find no significant impact of funds devoted to infrastructures or to business support. Only investment in education and human capital has medium-term positive effects, whilst support to agriculture has short-term positive effects on growth. Large agricultural sector and lack of R&D are the two main reasons that hamper growth and regional development efforts in the poor regions according to Cappelen *et al*. (2003). Finally, Midelfart-Knarvik and Overman (2003) find that European Structural Funds expenditure has an effect on the location of industry, notably by encouraging the industries that are intensive in R&D to locate in countries and regions that have low endowments in skilled labor. As a result, these incentives have mostly been acting counter to states' comparative advantage and have not allowed poor regions to catch-up to the EU average.

More studies could be cited but this is not the topic of this paper, which, as noted earlier, pays special attention to the presence of spatial externalities induced by the implementation of regional funds, which is not the case of the papers cited above. In that purpose, we take spatial effects into account in the estimation of the impact of structural funds on the regional growth rate. These spatial effects are described the next section.

3 b-convergence models and spatial effects

Since the publication of the seminal articles of Barro and Sala-i-Martin (1991, 1995), numerous studies have examined b-convergence between different countries and regions[4]. This concept is linked to the neoclassical growth model, which predicts that the growth rate of a region is positively related to the distance that separates it from its steady-state. Empirical evidence for b-convergence has usually been investigated by regressing growth rates of GDP on initial levels. Two cases are usually considered in the literature: (i) if all economies are structurally identical and have access to the same technology, they are characterized by the same steady state, and differ only by their initial conditions. This is the hypothesis of *absolute* b-convergence, (ii) the concept of *conditional* b-convergence is used when the assumption of similar steady-states is relaxed. Note that if economies have very different steady states, this concept is compatible with a persistent high degree of inequality among economies.

Both b-convergence concepts have been heavily criticized both on theoretical and methodological grounds. For example, Friedman (1992) and Quah (1993) show that b-convergence tests may be plagued by Galton's fallacy of regression toward the mean. Furthermore, they face several methodological problems such as heterogeneity, endogeneity, and measurement problems (Durlauf and Quah, 1999; Temple, 1999). In this paper, we want to point out the fact that most empirical studies do not take into account the spatial dimension of data. In the absence of interregional input/output tables in Europe, our empirical

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[4] See Durlauf and Quah (1999) for a review of this extensive literature.

estimations are based on the presence of spatial effects detected and modeled through the formal tools of spatial econometrics. Moreover, spatial effects in the form of backward and forward linkages are not the only type of externalities we intend to consider. Technology spillovers (see, for instance, Coe and Helpman, 1995; Keller, 2002) and migration effects (Grant and Vanderkamp, 1980; Van Dijk *et al.*, 1989) on neighboring locations' growth are also included in spatial effects.

More specifically, two different spatial effects are considered: spatial autocorrelation and spatial heterogeneity. Spatial autocorrelation refers to the coincidence of attribute similarity and locational similarity (Anselin and Bera, 1996). In our case, spatial autocorrelation means that rich regions tend to be geographically clustered as well as poor regions. In other words, economic activity is unevenly distributed, this fact being the most striking in contemporary economies (Henderson *et al.*, 2001). Europe is no exception and spatial concentration of economic activities in European regions has already been documented (Lopez-Bazo *et al.*, 1999, Le Gallo and Ertur, 2003; Dall'erba, 2004b) and some b-convergence studies have recently taken into account spatial interdependence between regions[5].

Integrating spatial autocorrelation into b-convergence models is useful for three reasons. First, from an econometric point of view, the underlying hypothesis in OLS estimations is based on the independence of the error terms, which may be very restrictive and should be tested since, if it is rejected, all statistical inference based on it is not reliable. Second, it allows capturing geographic spillover effects between European region using different spatial econometric models: the spatial lag model, the spatial error model or the spatial cross-regressive model (Rey and Montouri, 1999; Le Gallo *et al.*, 2003). Third, spatial

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[5] See for example the following papers: Armstrong (1995), Moreno and Trehan (1997), Fingleton (1999, 2001), Rey and Montouri (1999). See also Rey and Janikas (2003) for a recent literature review on the subject.

autocorrelation allows accounting for variations in the dependent variable arising from latent or unobservable variables. Indeed, in the case of b-convergence models, the appropriate choice of these explanatory variables may be problematic because it is not possible to be sure conceptually that all the variables differentiating steady states are included[6]. Furthermore, data on some of these explanatory variables may not be easily accessible and/or reliable. Spatial autocorrelation may therefore act as a proxy to all these omitted variables and catch their effects. This is particularly useful in the case of European data, where explanatory variables are scarce (Fingleton 1999).

Spatial heterogeneity means that economic behaviors are not stable over space. In a regression model, spatial heterogeneity can be reflected by varying coefficients, i.e. structural instability, or by varying error variances across observations, i.e. groupwise heteroskedasticity. These variations follow for example specific geographical patterns such as East and West, or North and South.

Spatial heterogeneity can be linked to the concept of convergence clubs, characterized by the possibility of multiple, locally stable, steady state equilibria (Durlauf and Johnson, 1995). A convergence club is a group of economies whose initial conditions are near enough to converge toward the same long-term equilibrium. When convergence clubs exist, one convergence equation should be estimated per club. To determine those clubs, some authors select *a priori* criteria, like the belonging to a geographic zone (Baumol, 1986) or some GDP per capita cut-offs (Durlauf and Johnson, 1995). Others prefer to use endogenous methods, as for example, polynomial functions (Chatterji, 1992) or regression trees (Durlauf and Johnson, 1995). In the context of regional economies characterized by strong geographic patterns, like the core-periphery pattern, convergence clubs can be detected using exploratory spatial data analysis which relies on geographic criteria (Baumont *et al*., 2003).

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[6] More than 90 of such variables have been included in cross-country regressions using international datasets (Durlauf and Quah, 1999).

Before going further in the spatial econometric estimation of European regional convergence, section 3 introduces data and the spatial weight matrix since all the following analysis relies on the definition of space through the weight matrix.

4 Data and spatial weight matrix

The regional per capita GDP series come from the most recent version of the NewCronos Regio database by Eurostat. This is the official database used by the European Commission for its evaluation of regional convergence[7]. We first use the logarithms of the per capita GDP of each region over the 1989-1999 period. Our sample is composed of 145 regions at NUTS II level (Nomenclature of Territorial Units for Statistics) over 12 EU countries: Belgium (11 regions), Denmark (1 region), Germany (30 regions, Berlin and the nine former East German regions are excluded due to historical reasons), Greece (13 regions), Spain (16 regions, as we exclude the remote islands: Canary Islands and Ceuta y Mellila), France (22 regions), Ireland (2 regions), Italy (20 regions), Netherlands (12 regions), Portugal (5 regions, the Azores and Madeira are excluded because of their geographical distance), Luxembourg (1 region), United Kingdom (12 regions, we use regions at the NUTS I level, because NUTS II regions are not used as governmental units, they are merely statistical inventions of the EU Commission and the UK government).

Austria, Finland and Sweden are not included in the study, as we want to focus on the impact of structural assistance over 1989-1999. These three countries joined the EU in 1995, meaning that they did not have access to any regional fund prior to membership. The data on structural funds come from the publications of the Commission. The period under study covers the two first programming periods: the data over 1989-1993 are from "*Community*

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[7] See the data appendix for further details.

structural interventions", *Statistical report n°3 and 4,* (July and Dec. 1992)[8] and for 1994-1999, from *The 11th annual report on the structural funds*. These last data are the total payments over the 1994-1999 period plus the commitments taken during this period, but that have not yet been paid. The inexistence of more recent data leads us to assume that structural funds commitments and expenditures are strongly correlated. We are aware that this may create some problems, as considerable lags between the commitments and actual expenditure often take place.

We now present the spatial weight matrix, on which all the following analyses rely. In the European context, the existence of islands doesn't allow the use of simple contiguity matrices; otherwise the weight matrix would include rows and columns with only zeros for the islands. Since unconnected observations are eliminated from the results of the global statistics, this would change the sample size and the interpretation of the statistical inference. Following the recommendations of Anselin (1996) and Anselin and Bera (1998), we choose to base them on pure geographical distance, as exogeneity of geographical distance is unambiguous. More precisely, we use the great circle distance between regional centroids. Distance-based weight matrices are defined as:

$$\begin{cases} w_{ij}^*(k) = 0 \text{ if } i = j, \forall k \\ w_{ij}^*(k) = 1/d_{ij}^2 \text{ if } d_{ij} \le D(k) \\ w_{ij}^*(k) = 0 \text{ if } d_{ij} > D(k) \end{cases} \quad \text{and} \quad w_{ij} = w_{ij}^* / \sum_j w_{ij}^* \quad \text{for } k = 1, \dots 3 \tag{1}$$

where w_{ij}^* is an element of the unstandardized weight matrix; w_{ij} is an element of the standardized weight matrix $\mathbf{W}$; d_{ij} is the great circle distance between centroids of region i and j; $D(1) = Q1$, $D(2) = Me$ and $D(3) = Q3$, $Q1$, Me and $Q3$ are respectively the lower

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[8] The authors would like to thank Jacky Fayolle and Anne Lecuyer for providing this dataset.

quartile, the median and the upper quartile of the great circle distance distribution. $D(k)$ is the cutoff parameter for $k = 1,...3$ above which interactions are assumed negligible. We use the inverse of the squared distance, in order to reflect a gravity function. Each matrix is row standardized so that it is relative and not absolute distance which matters[9].

5 The convergence process between European regions over 1989-1999

5.1 Detection of spatial regimes

Using the spatial weight matrices previously described, the first step of our analysis is to detect the existence of spatial heterogeneity in the distribution of regional per capita GDPs. In that purpose, we use the G-I* statistics developed by Ord and Getis (1995)[10]. These statistics are computed for each region and they allow detecting the presence of local spatial autocorrelation: a positive value of this statistic for region i indicates a spatial cluster of high values, whereas a negative value indicates a spatial clustering of low values around region i. Based on these statistics, we determine our spatial regimes, which can be interpreted as spatial convergence clubs, using the following rule: if the statistic for region i is positive, then this region belongs to the group of "rich" regions and if the statistic for region i is negative, then this region belongs to the group of "poor" regions.

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[9] The robustness of the results is also tested by using other weight matrices based on the k-nearest neighbors, with k=10, 15, 20, 25 neighbors. In the European context, the minimum number of nearest neighbors that guarantees international connections between regions is k=7, otherwise the Greek regions would not be linked to Italy. With k=10, Ireland is connected to the UK, which in turn is connected to the whole continent; and the islands of Sicilia, Sardegna, Corsica are connected to the continental French regions. Finally, three distance contiguity matrices are built according to the critical cut-off previously defined.

[10] All computations in this section are carried out using the SpaceStat 1.91 software (Anselin, 1999).

For all weight matrices described above two spatial regimes, representative of the well-known core-periphery framework (Krugman 1991a, 1991b; Fujita *et al.*, 1999), are persistent over the period and highlight some form of spatial heterogeneity:

- 100 regions belong to the spatial regime "Core":

Belgium, Germany, Denmark, France, Italy (but Molise, Campania, Puglia, Basilicata, Calabria, Sicilia), Luxembourg, the Netherlands, the United-Kingdom (except Northern-Ireland, Scotland and North West).

- 45 regions belong to the spatial regime "Periphery":

Spain, Greece, Ireland, Southern Italy (Molise, Campania, Puglia, Basilicata, Calabria, Sicilia), Portugal, the North of the United-Kingdom (Northern-Ireland, Scotland and North West).

This methodology differs from the one in Baumont *et al.* (2003) that use Moran scatterplots (Anselin, 1996) to determine the spatial clubs: Moran scatterplots imply that the "atypical"[11] regions must be dropped out of the sample (in their case, three regions are eliminated). However, in our study, this methodology would imply eliminating 9 regions. We therefore feel that the use of Getis-Ord statistics is more appropriate in order to be able to work with the entire sample.

5.2 Estimation results

The second step of our analysis consists in including both spatial effects in the estimation of the appropriate b-convergence model. Various tests aiming at detecting the presence of spatial effects have been described in Anselin (1988) and Anselin *et al.* (1996) and are applied here. Therefore, we shortly describe the various steps we followed to find the most appropriate model specifications in two cases: (i) b-convergence model without

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[11] Atypical regions in this context are regions located in the "HL" ("High-Low") or in the "LH" ("Low-High") quadrants of the Moran scatterplot.

structural funds and (ii) b-convergence model with structural funds (divided by GDP). In all cases, we start with the OLS estimation of the absolute b-conditional model. In order to identify the form of the spatial dependence (spatial error model or spatial lag), the Lagrange Multiplier tests (resp. LMERR and LMLAG) and their robust version (resp. R-LMERR and R-LMLAG) are performed. The decision rule suggested by Anselin and Florax (1995) is then used to decide the most appropriate specification as follows: if LMLAG (resp. LMERR) is more significant than LMERR (resp. LMLAG) and R-LMLAG (resp. R-LMERR) is significant whereas R-LMERR (resp. R-LMLAG) is not, then the most appropriate model is the spatial autoregressive model (resp. the spatial error model)[12].

b-convergence model without structural funds

In the case of the b-convergence model without structural funds, the application of the decision rule using the weight matrix $D(1)$[13] shows that the spatial error model is the best specification (table 1, column 1). In order to study whether spatial heterogeneity should also be included in the model, structural instability in the form of the two spatial regimes previously described is included in the spatial error model, which is estimated using Maximum Likelihood (ML). The estimation results are provided in column 2 of table 1. The individual and global stability tests on the coefficient always reject the null hypothesis, which confirms the existence of two spatial regimes. However, since the Breusch-Pagan test still reveals the presence of residual groupwise heteroskedasticity, the model is re-estimated including both structural instability and groupwise heteroskedasticity.

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[12] Rey and Montouri (1999) and Le Gallo *et al*. (2003) provide a detailed description of spatial models in the context of b-convergence.

[13] $D(1)$ is the distance-based matrix with cut-off set to the first quartile of the distance distribution. All results are robust to the choice of the weight matrix and are available upon request from the authors.

This final model can then be described as follows:

$$\mathbf{g_T} = a_C D_C + b_C D_C \mathbf{y_0} + a_P D_P + b_P D_P \mathbf{y_0} + \mathbf{e}$$
$$\text{with } \mathbf{e} = l\,\mathbf{We} + \mathbf{u} \text{ and } \mathbf{u} \sim N\left(0, \begin{bmatrix} s^2_{e,C}\mathbf{I_{100}} & 0 \\ 0 & s^2_{e,P}\mathbf{I_{45}} \end{bmatrix}\right) \qquad (2)$$

where $\mathbf{g_T}$ is the $(n \times 1)$ vector of average growth rates of per capita GDP between dates 0 and *T*; $\mathbf{y_0}$ is the vector of log per capita GDP levels at date 0; D_C and D_P are dummy variables corresponding respectively to the core and periphery regimes previously defined; a_C, a_P, b_C, b_P are unknown parameters to be estimated; l is a coefficient indicating the extent of spatial correlation between the residuals. The estimation results by ML and Generalized Method of Moments (GMM) estimation are respectively displayed in columns 3 and 4 of table 1.

<<Insert table 1 here>>

The results show that there is significant convergence among the regions belonging to the periphery regime (*p*-value of 0.000) leading to a convergence speed of 3.42% for both ML and GMM and a half-life of 23.5 years. On the contrary, $\hat{b}_C$ does not have the expected sign and is not significant (*p*-value greater than 0.5). The Chow test of overall stability strongly rejects the joint null hypothesis and both the individual coefficient stability tests reject the corresponding null hypotheses.

The convergence process seems therefore to be quite different across regimes: if there is a convergence process among European regions, it mainly concerns the peripheral regions but does not concern the core regions. In other words, the peripheral regions converge to a common steady-state, while the core regions do not converge. This result is consistent with the persistence of inequalities among regions. These last results confirm those found by

Beine and Jean-Pierre (2000) using a sample of 62 NUTS 1 regions over the 1980-1995 period with an endogenous determination of convergence clubs. It is also consistent with the results obtained by Baumont *et al.* (2003) for a sample of 138 NUTS 2 regions over the same period.

The presence of spatial autocorrelation is confirmed by a highly significant and positive l coefficient ($\hat{l} = 0.713$). This specification thus implies the existence of spatial spillover effects between the regions that will be further investigated in section 6.

b - ***convergence model with structural funds***

Table 2 presents the estimation results of a conditional b-convergence model to which we have added structural funds (as a ratio of GDP) as an explanatory variable. The results of the Lagrange Multiplier tests and their robust versions (column 1) show that the spatial lag model is more appropriate than the spatial error model (81.963 for LMLAG is greater than 76.072 for LMERR and R-LMLAG is significant, whereas R-LMERR is not at 5%). The same results hold for the model estimated by OLS with structural instability of the coefficients (column 2). As in the preceding case, various tests aimed at detecting the presence of spatial heterogeneity have been performed and lead to the conclusion that the most appropriate model is the spatial lag model with structural instability defined by the two spatial regimes and groupwise heteroskedasticity:

$$\begin{aligned}&\mathbf{g_T} = r\,\mathbf{W}\mathbf{g_T} + a_C D_C + b_C D_C \mathbf{y_0} + d_{1C} D_C \mathbf{F} + a_P D_P + b_P D_P \mathbf{y_0} + d_{1P} D_P \mathbf{F} + \mathbf{e} \\ &\text{with } \mathbf{e} \sim N\left(0, \begin{bmatrix} s^2_{e,C}\mathbf{I_{100}} & 0 \\ 0 & s^2_{e,P}\mathbf{I_{45}} \end{bmatrix}\right)\end{aligned} \qquad (3)$$

with the same notations as above; **F** is the $(n \times 1)$ vector of structural funds divided by GDP; d_{1C} and d_{1P} are the corresponding unknown parameters to be estimated for the core and periphery regimes and r is a coefficient indicating the extent of spatial correlation in the dependent variable.

<<Insert table 2 here>>

The ML estimation results displayed in column 3 of table 2 show that there is significant convergence among the regions belonging to the periphery regime (*p*-value of 0.037) leading to a convergence speed of 1.62% for ML and a half-life of 46 years. The convergence is therefore a bit slower than in the model without structural funds. Again, the coefficient in the core regime does not give any evidence of convergence ($\hat{b}_C$ = -0.001 and is not significant). The spatial lag ($\hat{r}$ = 0.728) is strongly significant (*p*-value of 0.000) indicating that in this model specification, the growth rate of a region is significantly influenced by the growth rate of its surrounding regions. On the contrary, the impact of the funds is not significant in any regime. The Chow test of overall stability does not reject the joint null hypothesis on the equality of the regimes' coefficients; whereas the individual coefficient stability tests reject the corresponding null hypotheses at 10% (except the coefficient on structural funds with a *p*-value of 0.804). The LR test confirms the presence of two significantly different variances across regimes. Therefore, the steady states of the regions do not seem to be significantly affected by the amount of structural funds they have received.

Finally, when structural funds and their spatial lags are also included in the b-convergence model, none of the coefficients is significant. Therefore, these results are not displayed due to space limitation. One possible explanation may be due to the delayed effect of structural funds on the convergence process, so that their impact does not appear in our short time period.

The results of the previous estimations do not conclude that the impact of structural funds on regional convergence is significant[14]. The next section will therefore assess the impact of structural funds using simulation experiments based on the diffusion properties of the spatial error model (2).

6 Spatial diffusion effects in European regions

Rather than introducing structural funds as explanatory variables in a conditional b-convergence equation, this section considers as a point of departure the spatial error b-convergence model without structural funds estimated in section 5 and investigates in detail its spatial diffusion properties by considering the impact of shocks affecting growth in the targeted region itself and in all the other regions of the sample. The steady-state of each region is not assumed to be significantly affected by the shocks, which is consistent with the results found in the previous section. The shocks are set proportional to the amounts of structural funds. The interpretation of this choice is explained below.

Formally, since $\mathbf{e} = l\mathbf{W}\mathbf{e} + \mathbf{u} \Rightarrow \mathbf{e} = (\mathbf{I} - l\mathbf{W})^{-1}\mathbf{u}$, model (2) can be written in the following form:

$$\mathbf{g_T} = a_C D_C + a_P D_P + b_C D_C \mathbf{y_0} + b_P D_P \mathbf{y_0} + (I - l\mathbf{W})^{-1}\mathbf{u} \qquad (4)$$

In this specification, spatial spillovers are supposed to be global and a shock affecting one region propagates to all the other regions of the sample through the spatial transformation

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[14] Since the results of the Lagrange multiplier tests do not lead to clear-cut results for the choice between a spatial error and a spatial lag model, we also estimated a spatial lag model without structural funds and spatial error models with structural funds and their lags. The conclusions on the impact of structural funds drawn from these models are very similar to those presented in the paper. They are available upon request from the authors.

$(\mathbf{I}-l\,\mathbf{W})^{-1}$ (Anselin, 2003). We use this property to conduct a simulation experiment aimed at analyzing the way shocks in the regions of the sample propagate to all the other regions.

In that purpose, let a_i be the amount of the shock affecting region i and $\mathbf{\hat{u}^i}$ be the $(n\times 1)$ vector containing the estimated error of model (4) after a shock on error i: $\mathbf{\hat{u}^{i'}} = \left(\hat{u}_1 \quad \dots \quad \hat{u}_i + a_i \quad \dots \quad \hat{u}_n\right)'$. Therefore, the $(n\times 1)$ vector $\mathbf{y^{i*}}$ containing the observations on the simulated average growth rates of per capita GDP after a shock in region i can be computed in the following way:

$$\mathbf{y^{i*}} = \mathbf{X?} + (\mathbf{I} - \hat{l}\,\mathbf{W})^{-1}\mathbf{\hat{u}^i} \tag{5}$$

where $\mathbf{X} = \left[D_C \quad D_P \quad D_C\mathbf{y_0} \quad D_P\mathbf{y_0}\right]$; $\hat{g} = [\hat{a}_C \quad \hat{a}_P \quad \hat{b}_C \quad \hat{b}_P]'$; $\hat{a}_C$, $\hat{a}_P$, $\hat{b}_C$, $\hat{b}_P$ and $\hat{l}$ are the ML estimations of a_C, a_P, b_C, b_P and l in the spatial error model (2). Let $\mathbf{Y^*}$ be the matrix of dimension $(n\times n)$ containing the observations on the simulated average growth rates of per capita GDP after a shock in each region:

$$\mathbf{Y^*} = \left[\mathbf{y^{1*}} \quad \dots \quad \mathbf{y^{n*}}\right] = [\mathbf{X?} \quad \dots \quad \mathbf{X?}] + \mathbf{A}^{-1}\left[\mathbf{\hat{u}^1} \quad \dots \quad \mathbf{\hat{u}^n}\right] \tag{6}$$

with $\mathbf{A} = \mathbf{I} - \hat{l}\,\mathbf{W}$. Equation (6) can also be rewritten in a more compact way:

$$\mathbf{Y^*} = \mathbf{S'} \otimes \mathbf{X?} + \mathbf{A^{-1}\hat{U}} \tag{7}$$

where $\otimes$ is the Kronecker product; $\mathbf{S}$ is the $(n\times 1)$ sum vector; $\mathbf{\hat{U}}$ is the matrix of dimension $(n\times n)$ defined as: $\mathbf{\hat{U}} = \left[\mathbf{\hat{u}^1} \quad \dots \quad \mathbf{\hat{u}^n}\right]$.

Given the definition of each element $\hat{\mathbf{u}}^{\mathbf{i}}$, this matrix $\hat{\mathbf{U}}$ can also be written as:

$$\hat{\mathbf{U}} = \begin{pmatrix} \hat{u}_1 + a_1 & \hat{u}_1 & \cdots & \hat{u}_1 \\ \hat{u}_2 & \hat{u}_2 + a_2 & \cdots & \hat{u}_2 \\ \vdots & \vdots & \ddots & \vdots \\ \hat{u}_n & \hat{u}_n & \cdots & \hat{u}_n + a_n \end{pmatrix} \Rightarrow \hat{\mathbf{U}} = \mathbf{S}' \otimes \hat{\mathbf{u}} + \mathrm{diag}(a_i) \qquad (8)$$

Combining (7) and (8), we obtain:

$$\mathbf{Y}^* = \mathbf{S}' \otimes \mathbf{X?} + \mathbf{A}^{-1}(\mathbf{S}' \otimes \hat{\mathbf{u}} + \mathrm{diag}(a_i)) \qquad (9)$$

This expression yields a matrix of dimension $(n \times n)$ where the column i indicates the simulated average growth rates of per capita GDP for all regions in the sample after a shock in region *i*. The difference **D** between the matrix of simulated average growth rates $\mathbf{Y}^*$ (after the shock) and the matrix of actual average growth rates Y (without shock) is $\mathbf{D} = \mathbf{Y}^* - \mathbf{Y}$. Since $\mathbf{Y} = \mathbf{S}' \otimes \mathbf{y}$, with $\mathbf{y} = \mathbf{X?} + \mathbf{A}^{-1}\hat{\mathbf{u}}$, then:

$$\mathbf{D} = \mathbf{A}^{-1}\mathrm{diag}(a_i) \qquad \text{with } \mathbf{A} = \mathbf{I} - \hat{l}\,\mathbf{W} \qquad (10)$$

Finally, we consider the matrix **V**, containing the variation in percentage between the simulated and the actual average growth rates. **V** is obtained by dividing each term of the **D** matrix by each corresponding term of the **Y** matrix. On the one hand, the elements on the main diagonal represent the impact of a shock in a region on the region itself. On the other hand, the other elements in each column *i* of the matrix **V** indicates how the region *i* affects the other regions of the sample when there is a shock in this region.

This methodology extends the one developed in Le Gallo *et al.* (2003), where all shocks are set equal to twice the residual standard error of the estimated spatial error model. Using a sample of 138 regions over the 1980-1995 regions, they show that the strength of diffusion both depends on localization and economic dynamism: rich regions located in the core diffuse more than the poor regions in the periphery. In this paper, rather than considering equal random shocks, we include the real values of average structural funds as a ratio of GDP over 1989-1999. Note that the simulation is carried out on the 1989-1999 growth rates that already include the effects of structural funds. Therefore, in that context, we do not directly analyze the impact of structural funds themselves but rather we study whether allowing for differentiated shocks can offset the effects of poor economic dynamism and unfavorable relative localization of peripheral regions.

We consider two different cases[15]. In the first one, each region experiences a similar shock proportional to average amount of structural funds distributed during the 1989-1999 period. In the second one, each region experiences a different shock proportional to the real amount of structural funds it has received during the period[16].

<<Insert figures 3 and 4 here>>

Figures 3 and 4 display the main diagonal of V that represents the impacts of the shocks on the region itself. In the case of equal shocks, the extent of the impact is not necessarily greater in periphery, with the exception of Mezzogiorno. In the case of differentiated shocks, the extent of the impact on the peripheral regions increases a lot since they receive the largest amounts of structural funds. The three regions which are the most affected by the differentiated shock are Alentejo (Portugal), Voreio Aigaio and Sterea Ellada (Greece). Border (Ireland) is the the seventh most impacted region in figure 4, whereas it is the second main beneficiary of structural funds. However, regional funds are not the only element at the origin of the unprecedented development of Ireland over the last two decades.

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[15] The codes used to carry out the simulations in this section have been developed using Python 2.2 (http://www.python.org).

[16] The factor of proportionality is set to twice the average of residual standard errors of each regime in the estimated spatial error model (4).

Indeed, the country benefited from huge foreign investments, mostly American and Japanese, and narrow trade relationships with the UK.

<<Insert figures 5 and 6 here>>

To capture the extent of spillover effects, we analyze the diffusion properties of a shock in each single region to all the other regions. It corresponds to the computed median for each column of V, excluding the main diagonal. As in Le Gallo *et al.* (2003) when the shocks are equal (figure 5), it appears that the most influential regions are rich northern European regions mainly belonging to Belgium, Germany, Netherlands, Luxembourg and the Northern and Eastern part of France. All these regions belong to the core of Europe. On the contrary, all the regions belonging to the periphery are the less influential. When the shocks are differentiated (figure 6), the overall picture is not really modified: the most influential regions are still located in the core even though they are less numerous than in the previous case. The extent of the diffusion decreases in figure 6 because core regions received less assistance than the average amount of structural funds (used in figure 5). The diffusion properties of the peripheral regions have not increased, with the exception of Corsica, but to a very low extent (0.003%). This result that can imply that the nature and the extent of diffusion properties does not depend on the amount of structural funds received, but rather on the characteristics of peripheral regions. They are relatively bigger than core regions (for instance, Castilla-y-Leon is 585 times greater than Brussels, whereas both are considered as NUTS 2 regions) and thus have fewer neighbors within the critical cut-off we used for the weight matrix[17]. Because these regions are peripheral, and thus lined by the Mediterranean Sea, the spillover effect does not spread in every direction. On the contrary, core regions are centrally located and are much smaller regions, which facilitates interregional dependences as

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[17] However, all the results presented in this section are confirmed using a 10 nearest neighbors matrix, where each region has exactly the same number of neighbors.

well. They are also more connected with each other in terms of accessibility via transportation network. Indeed, the empirical study of Vickerman *et al.* (1999) points out that transportation infrastructures are more developed between core regions, because the demand in this sector is the highest. Finally, as the economic structure of core regions becomes more homogeneous and as trade among them becomes more concentrated, these regions tend to move in phase rather than according to different set of rhythms[18]. This result suggests also that the small extent of spillover effects in peripheral regions could be a relevant explanation of their backwardness, and that even greater targeted funds would not favor spillovers in periphery. Note that the reverse may also be true: the lack of skilled labor and investments in human capital within poor regions hinder the diffusion of knowledge externalities from neighboring locations (Mankiw *et al.*, 1992).

Finally, we perform a more qualitative analysis and rank the regions according to their diffusion properties displayed in figures 5 and 6 in order to identify the regions that win or loose when the shock is differentiated compared to the case of an equal shock. The results are displayed in figure 7.

<<Insert figure 7 here>>

The standard deviation of the change in rankings between these two cases is about 22. It appears that 41 regions shifted by more than one standard deviation. Among these 41 regions, almost all the 23 regions that shifted downward belong to the core, like Zuid-Holland, Nord-Holland, Ile-de-France. Conversely, all the 18 regions that shifted upward are located in the periphery: Extremadura, Cantabria, Molise, among others. The smallest changes (rank variation below 10) concern three regions in Greece and two in Portugal.

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[18] These results are confirmed by non-parametric tests on the equality of the medians between core regions and peripheral regions. In both cases of equal and differentiated shocks, the Kruskall-Wallis, U Mann-Whitney and Wald-Wolfowitz tests all reject the null hypothesis. Furthermore, these results are similar when considering the first or the third quartiles of each row of matrix *V*.

These last findings show that the most peripheral regions seem to never improve their diffusion properties, whatever the amount of structural funds allocated.

7 Conclusion

The aim of this paper has been to highlight the impact of structural funds on the convergence process of 145 European regions over the 1989-1999 period. If these funds are mainly devoted to the least developed regions, the persistence of regional inequalities over the period leads to a real reconsideration of their efficiency. Since the majority of these funds finance transportation infrastructures, which induce industry relocation effects, their impact on regional development is not clear yet but surely needs to be seen in the light of spillover effects their spatial allocation implies. In other words, estimating the impact of structural funds on regional growth without including the presence of significant spatial effects would lead to unreliable results.

In order to include spatial effects in the determination of the most appropriate b-convergence model, we start by using the Getis-Ord statistics. The results display the presence of significant local spatial autocorrelation in the form of two regimes representative of the well-known core-periphery pattern over the whole period (Krugman, 1991a, 19991b; Fujita *et al.*, 1999). Various tests aimed at including the significant presence of spatial effects in our model lead to a spatial error model (in the case of no structural funds) or to a spatial lag model (in the case of structural funds) with groupwise heteroskedasticity and structural instability in the form of the two regimes detected using the Getis-Ord statistics. Estimation results display significant convergence in the peripheral regime only, a significant, positive and very small impact of the lag of the funds as well, but a non significant impact of the funds themselves. Therefore, we use another approach to estimate the impact of a shock proportional to structural funds on the growth rate of the targeted region first, and then on the growth rate of all the other regions of our sample. Based on the spatial diffusion properties of the spatial error model, simulation experiments are performed in two cases: first with shocks proportional to the average amount of structural funds distributed during the period for all the regions (equal shock), and second with shocks proportional to the real value of structural funds as a ratio of GDP for each region (differentiated shock). The results show that in the case of an equal shock, the extent of the impact on the targeted region's growth does not vary much from one region to another. In the case of differentiated shocks, the extent of the impact on most peripheral regions increases since they are the main beneficiaries of these funds. However, the extent of the impact does not increase in some Greek and Portuguese regions, which implies that greater regional development efforts are not necessarily useful within these regions, at least in its current form. It does not mean that regional support to Greece and Portugal should vanish. Indeed, it could also be argued that in the absence of these policies the regional divide could be even worsened because of the circular and cumulative causation effects that lead to industry agglomeration in the core. When it comes to measuring spillover effects through the impact of the shocks targeted in one region on the growth rate of all the other regions, the results detect the presence of a growth diffusion process only from the core regions, whatever the extent of the shock is (either equal or differentiated). This may reflect that core regions are generally smaller and more connected with each other, through trade and transport network, than peripheral regions. This result also suggests that the small extent of spillover effects in peripheral regions could be an explanation of their backwardness. Finally, it should be noted that the empirical findings, while supporting the expectations advanced by the theory, may in part result from the particular nature of the modeling formulations we used. In this regard, further works examining the consistency of the nature and the extent of spillover effects would need to be undertaken.

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Data Appendix

The data are based on the most recent version of the NewCronos Regio database (2002) created by Eurostat. We use both datasets e2gdp79 and e2gdp95, which provide the per capita GDP at the NUTS 2 level in Ecus (Nomenclature of Territorial Units Statistics). This dataset is the official dataset used by the European Commission for evaluating regional income in Europe. Over 1989-1996, our data come from e2gdp79. We have added some modifications to this dataset since some data of our interest were missing. For instance, the data on the per capita income in Ireland are given only at the national level. We therefore used the dataset from Cambridge Econometrics (2001) which provides the Gross Value Added (GVA) at the NUTS 2 level for Ireland as well. Two NUTS 2 regions compose Ireland: Border and Dublin. The annual share of each region in the total GVA was calculated from this dataset and applied on e2gdp79 to estimate the annual per capita GDP of each region. For the United-Kingdom, the data are used at the NUTS 1 level, since NUTS 2 regions are not used as governmental units (they are merely statistical inventions of the EU Commission and the UK government). Luxembourg and Denmark are considered as NUTS 2 regions by Eurostat. The per capita GDP of Groningen (Netherlands) was exceptionally high in 1980 because all the North Sea oil revenues were attributed to this region until 1985. We therefore use the mean growth rate over 1980-1985 to calculate the data over 1980-1988, this last date being the first year were none oil income was systematically attributed to Groningen.

Table 1: Estimation results of the b-convergence model without structural funds and weight matrix $D(1)$

	Model without structural funds						
	1	2		3		4	
	OLS-White	ML-ERR with regime		ML-ERR with regime and heteroskedasticity		GMM-ERR with regime and heteroskedasticity	
		Core	Periph.	Core	Periph.	Core	Periph.
$\hat{a}_r$	0.211 (0.000)	0.019 (0.641)	0.309 (0.000)	0.020 (0.547)	0.308 (0.000)	0.023 (0.505)	0.313 (0.000)
$\hat{b}_r$	-0.018 (0.000)	0.002 (0.612)	-0.029 (0.000)	0.002 (0.566)	-0.029 (0.000)	0.002 (0.617)	-0.029 (0.000)
$\hat{l}$	-	0.769 (0.000)		0.759 (0.000)		0.713 (0.000)	
$s^2_{e,P}$	-	-	-	-	$1.03.10^{-4}$ (0.000)	-	$1.06.10^{-4}$ (0.000)
$s^2_{e,C}$	-	-	-	$4.38.10^{-5}$ (0.000)	-	$4.46.10^{-5}$ (0.000)	-
Convergence speed	1.98%	-	3.42%	-	3.42%	-	3.42%
Half-life	38.16	-	23.55	-	23.55	-	23.55
Sq. Corr.	-	0.342		0.342		0.344	
LIK	450.965	488.598		502.467		-	
AIC	-897.930	-969.196		-996.933		-	
SC	-891.976	-957.289		-985.026		-	
Moran's I	10.531 (0.000)	-		-		-	
LMERR	93.415 (0.000)	-		-		-	
R-LMERR	6.470 (0.010)	-		-		-	
LMLAG	92.587 (0.000)	-		-		-	
R-LMLAG	5.643 (0.017)	-		-		-	
Chow-Wald	-	17.341 (0.000)		14.016 (0.000)		14.872 (0.001)	
Ind. stab. test on $\hat{a}_r$	-	16.378 (0.000)		12.059 (0.000)		12.621 (0.000)	
Ind. stab. on $\hat{b}_r$	-	15.505 (0.000)		11.132 (0.000)		11.743 (0.000)	
BP-test on groupwise heteroskedasticity	-	13.900 (0.000)		-		-	
LR test on groupwise heteroskedasticity	-	-		27.737 (0.000)		-	

Notes: p-values are in brackets. *OLS-White* indicates the use of heteroskedasticity consistent covariance matrix estimator. *ML* indicates maximum likelihood estimation. *GMM* indicates iterated generalized moments estimation (Kelejian and Prucha, 1999). *Sq. Corr.* is the squared correlation between predicted values and actual values. *LIK* is value of the maximum likelihood function. *AIC* is the Akaike information criterion. *SC* is the Schwarz information criterion. *LMERR* stands for the Lagrange Multiplier test for residual spatial autocorrelation and *R-LMERR* for its robust version. *LMLAG* stands for the Lagrange Multiplier test for spatially lagged endogenous variable and *R-LMLAG* for its robust version (Anselin *et al*., 1996). The individual coefficient stability tests are based on a spatially adjusted asymptotic Wald statistics, distributed as c^2 with 1 degree of freedom. The Chow – Wald test of overall stability is also based on a spatially adjusted asymptotic Wald statistic, distributed as c^2 with 2 degrees of freedom (Anselin, 1988). *BP* is the Breusch-Pagan test for groupwise heteroskedasticity. *LR* is the likelihood ratio test for groupwise heteroskedasticity.

Table 2: Estimation results of the *b*-convergence model model with structural funds and weight matrix *D*(1)

	Model with structural funds				
	1	2		3	
	OLS-White	OLS-White with structural instability		ML-LAG with structural instability and groupwise heteroskedasticity	
		Core	Periph.	Core	Periph.
$\hat{a}_r$	0.142 (0.003)	0.135 (0.037)	0.262 (0.008)	0.018 (0.622)	0.147 (0.028)
$\hat{b}_r$	-0.011 (0.033)	-0.009 (0.151)	-0.024 (0.026)	-0.001 (0.841)	-0.015 (0.037)
$\hat{l}$	-	-		0.728 (0.000)	
$\hat{d}_{1r}$	0.002 (0.044)	-0.007 (0.273)	0.001 (0.380)	-0.001 (0.661)	8.831.10^{-5} (0.577)
$s^2_{e,P}$	-	-	-	-	1.09.10^{-4} (0.000)
$s^2_{e,C}$	-	-	-	4.47.10^{-5} (0.000)	-
Convergence speed	1.12%	-	2.73%	-	1.62%
Half-life	65.27	-	28.66	-	46.07
Sq. Corr.	-	-		0.612	
LIK	454.206	459.435		494.054	
AIC	-902.412	-906.871		-974.107	
SC	-893.482	-889.010		-953.270	
Moran's *I*	9.623 (0.000)	10.060 (0.000)		-	
LMERR	76.072 (0.000)	75.973 (0.000)		-	
R-LMERR	3.337 (0.068)	1.299 (0.254)		-	
LMLAG	81.963 (0.000)	84.108 (0.000)		-	
R-LMLAG	9.228 (0.002)	9.433 (0.002)		-	
Chow-Wald	-	3.465 (0.018)		4.735 (0.192)	
Ind. stab. test on $\hat{a}_r$	-	2.276 (0.134)		2.885 (0.089)	
Ind. stab. test on $\hat{b}_r$	-	2.540 (0.113)		3.019 (0.082)	
Ind. stab. test on $\hat{d}_{1r}$	-	3.040 (0.083)		0.196 (0.658)	
LR test on groupwise heteroskedasticity	-	-		13.341 (0.000)	

Notes: see table 1.

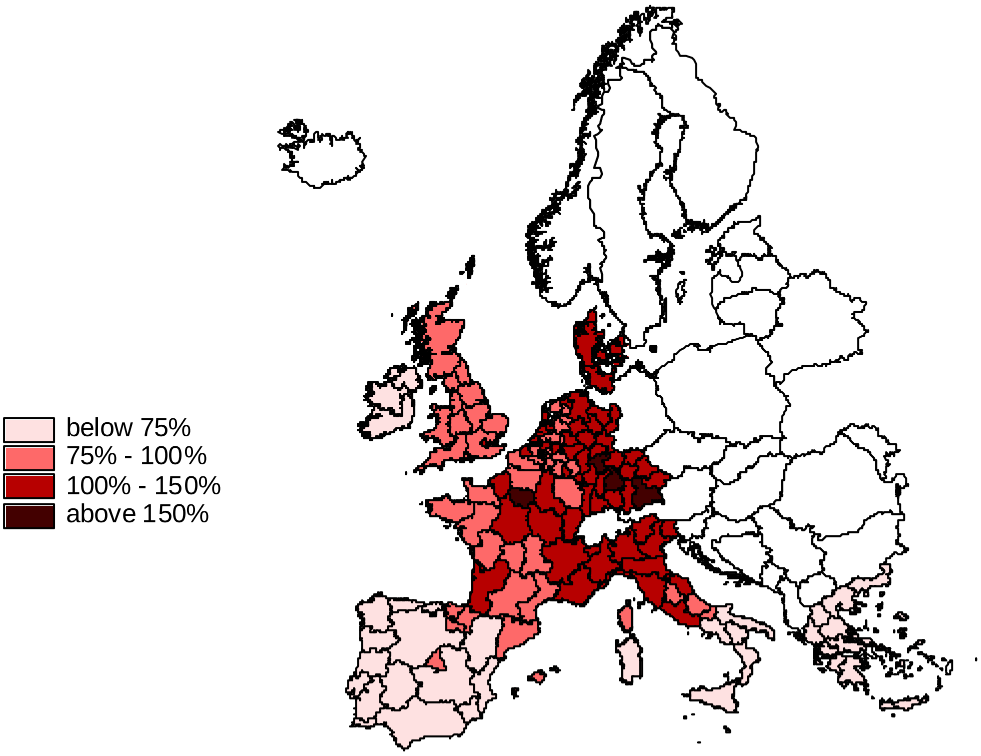

Figure 1: GDP per capita relative to the European average in 1989

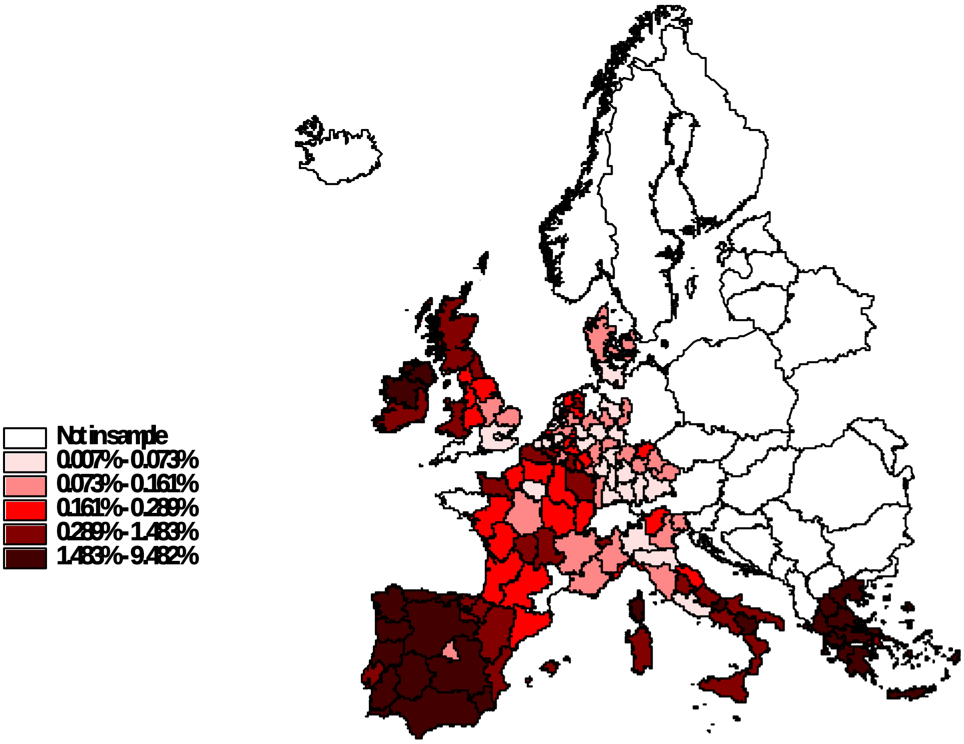

Figure 2: Spatial distribution of regional funds as a ratio of GDP during 1989-1999

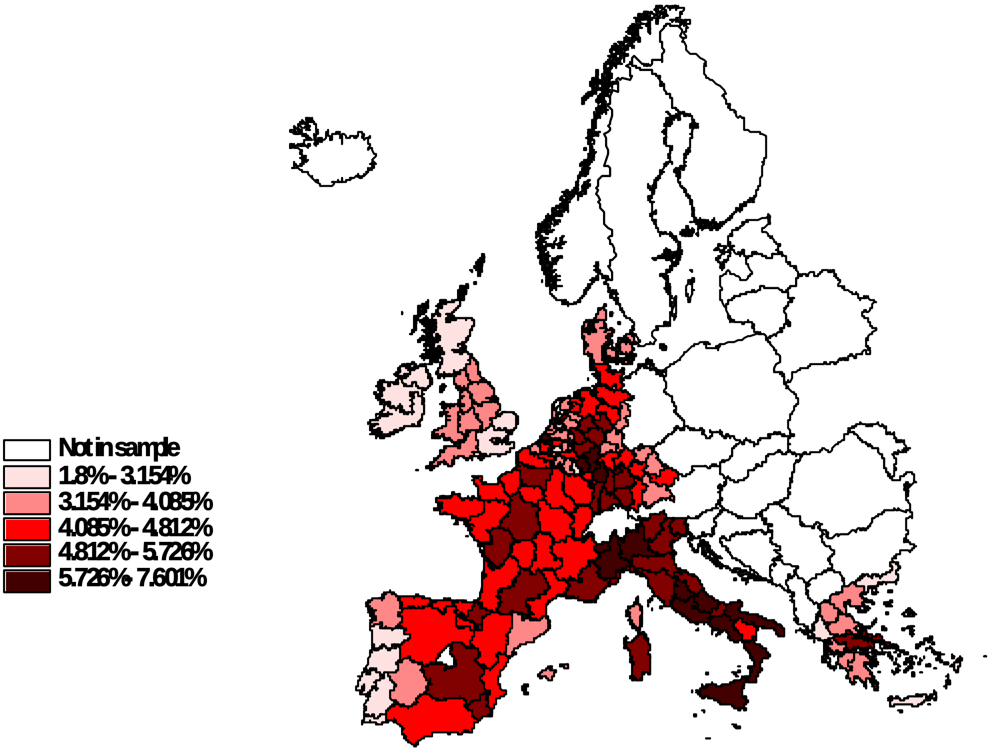

Figure 3: Impact of equal shocks on each region’s growth

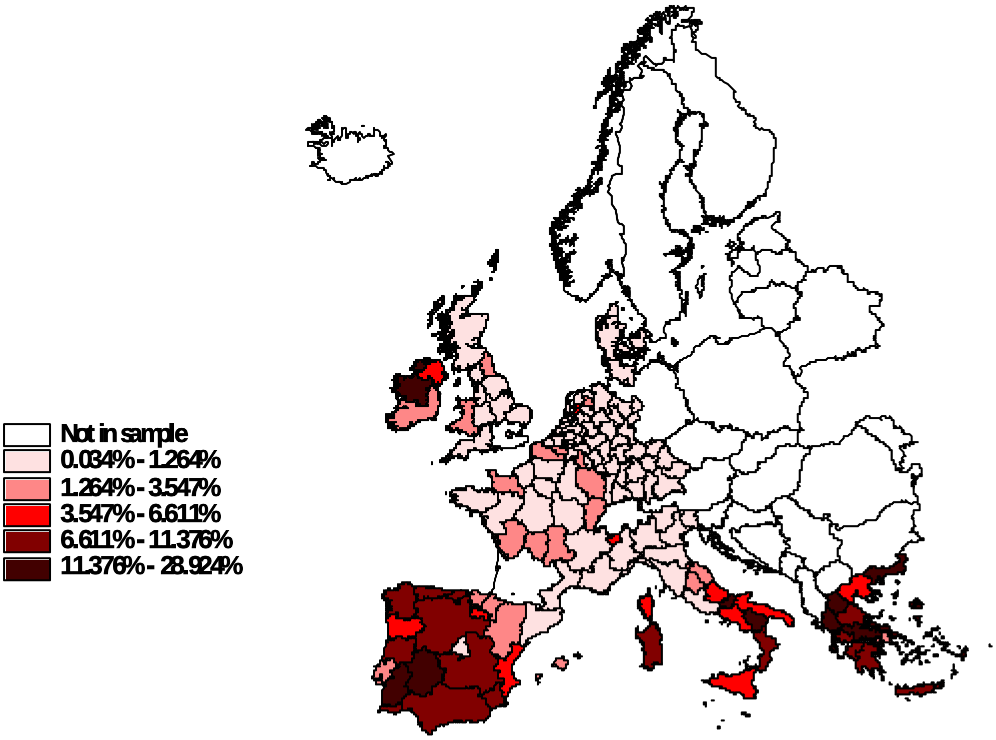

Figure 4: Impact of differentiated shocks on each region’s growth

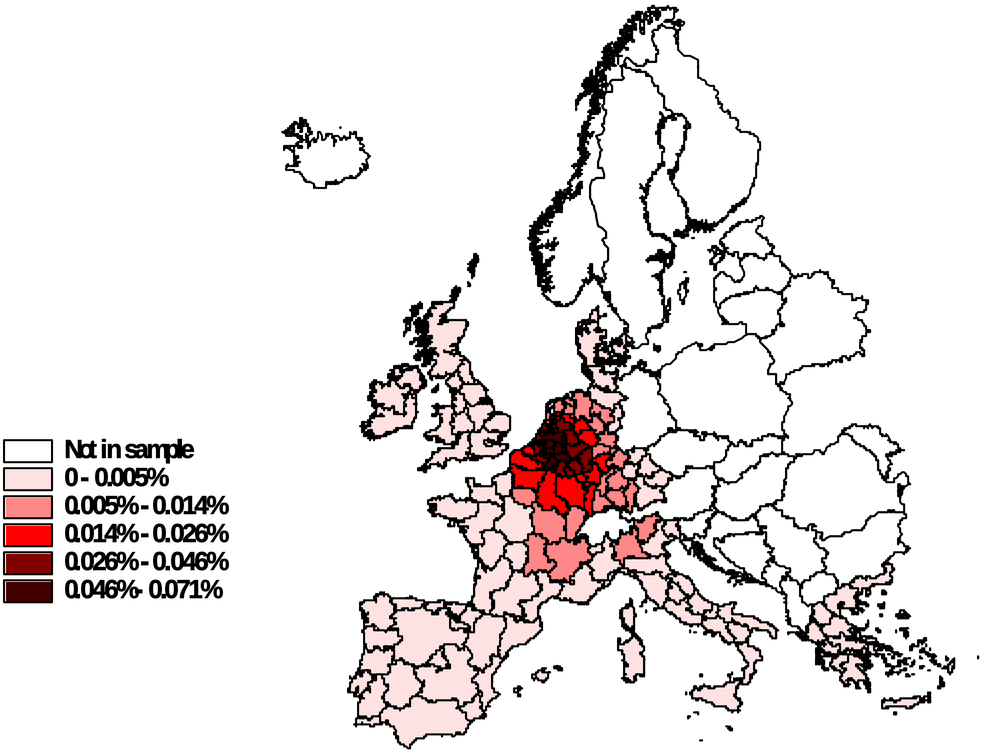

Figure 5: Distribution of regions according to the extent of diffusion effects they produce with an equal shock

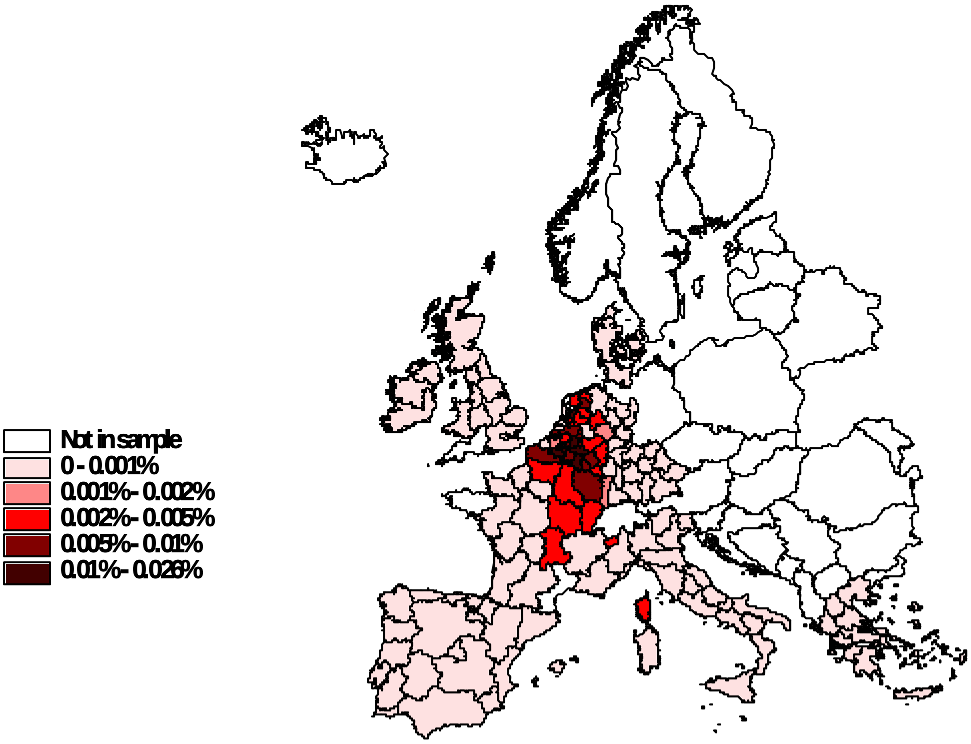

Figure 6: Distribution of regions according to the extent of diffusion effects they produce with differentiated shocks

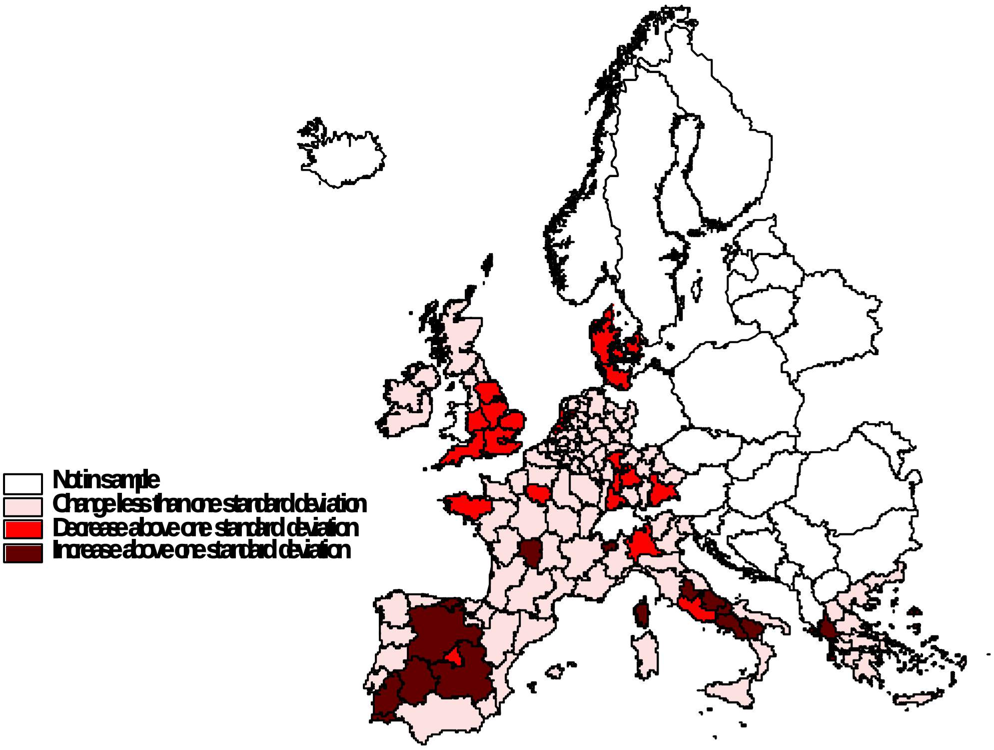

Figure 7: Variations in regions' rankings between equal shocks and differentiated shocks