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Fostering the development of European regions: a spatial dynamic panel data analysis of the impact of Cohesion Policy

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Abstract

In this paper, we use a conditional-convergence econometric model to investigate whether the Cohesion Policy affect the European economies. The main contribution of our study is to consider both spatial and temporal dynamics in assessing the impact of European cohesion policy. Econometric estimations rely on a dataset of 143 EU14-NUTS1/NUTS2 regions from 1980 to 2005. Our results suggest that Objective 1 programmes have a direct effect on regional GDP p.c. growth rates, whereas total structural funds do not. Moreover, consideration of the spatial dimension of the panel brings to light a still significant, but less important, impact of structural funds.

Keywords: Dynamic panels, GMM, Regional Convergence, Spatial Dependence, Structural Funds

JEL: C21, C23, R11, R15

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Introduction

European Cohesion Policy investments aim at improving the competitive position of regional policies by encouraging regions to provide public goods, such as networks of transport and energy, environmental quality, investments in education and research-development. In other words, the Cohesion Policy fosters regional development by various means, like competitiveness enhancement, infrastructure improvement, active labour market facilities, innovation enhancement or sustainable development. The public goods provided result from public and private expenditure. The policy seeks to add value beyond simple investments, with a multi-levels governance framework to involve local and regional actors in the design and delivery of the policy. This governance framework enables regions to activate the most appropriate drivers to foster their development, and to design projects in a bottom-up approach.

The Cohesion Policy has relied on the same principles since 1988. The policy targets funds towards a limited number of aims (convergence, competitiveness and cooperation), with a focus on the least developed regions; funding is based on multi-annual programming with ongoing analysis and evaluation; the design and implementation of the programmes involve regional, national and EU actors, and additionality ensures that EU expenditure is not substituted for national investment. The focus on the least developed regions concentrates funding on the Objective 1 regions, that represent about 25% of the European population, and benefit from 64% of the allocated funds (for the last programme).

The policy was renewed for seven years in 2007. A debate has just been launched with a view to continuous improvement of the policy, based on a public consultation about the budget review and the territorial cohesion strategy (European Commission, 2008). At this stage, it is important to evaluate the impact of past Structural Funds (SF) expenditure to assess whether structural policies are effectively leading to a narrowing of disparities of wealth between EU regions. This paper focuses on that evaluation for the 1980-2005 period.

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A broad examination of the empirical evidence on the role of policies on growth convergence across the EU suggests that a conclusive answer can hardly be given. Though the literature on this topic has been growing recently, the results have been ambiguous. The large number of different model specifications, data and econometric methods offered in this literature may explain this[1]. More precisely, while some authors do find evidence of a positive impact of structural funds on economic growth, others find little to no impact at all. In some cases findings are conditioned by other development drivers than investment or population growth: for instance, institutional quality of member states (Ederveen *et al.*, 2006) or choice in expenditure target (Rodriguez-Pose and Fratesi, 2004).

On the whole, cross-section studies tend to overestimate the impact of the cohesion policy. In these studies, ignoring spatial effects leads to unreliable results (Abreu *et al.*, 2005). Furthermore, cross-section approaches do not capture unobserved heterogeneity among regions. The first shortcoming is handled by studies in spatial cross-section, which suggest lower impact of the policy, while unobserved heterogeneity can be controlled by using panel data. In this kind of context, dynamic panel-data specifications are increasingly adopted (Esposti and Bussoletti, 2008; Mohl and Hagen, 2010).

To determine if the SF foster the development of EU regions, we should observe the result of a region where there was political intervention and potential outcomes of the same region, without political intervention. This issue, notable with non-experimental data, is of importance to our study because SF allocation is highly correlated with regional income per capita (European Commission, 2004). Moreover, we could expect severe misspecification when the spatial spillover effects are not included in the analysis. If the Cohesion Policy affects the growth process of a particular region, this change may also affect the growth rate of neighbouring regions. Indeed, the omission of the spatial spillover effects can produce biased estimates of Cohesion Policy impact.

The main contribution of our study is to asses the impact of European cohesion policy in a spatially extended Solow model, considering both spatial and temporal dynamics. In this context, we use an original econometric approach based on the study of a Spatial Dynamic Panel Data model (SDPD). We can estimate this model by

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using a Generalized Method-of-Moments (GMM) estimator (Bouayad-Agha and Védrine, 2010). In line with several studies using panel data in other contexts, this specification provides more information and data variability, thereby controlling for both unobserved heterogeneity and reducing problems with collinearity among our variables (SF allocation and other explanatory variables).

We find empirical evidence that the Cohesion Policy fosters the endogenous development of Objective 1 regions in Europe. We interpret this result as an added-value of Objective 1 programmes, compared to total structural funds. Finally, our approach suggests that taking spatial dependence into account reduces the measured effect of the Cohesion Policy.

The remainder of the paper is organised as follows. The first section develops some theoretical and empirical considerations on the impact analysis of structural funds on convergence. Section 2 presents the econometric issues with regard to the spatial dynamic panel model. Section 3 describes the data used for assessing the parameters. Section 4 presents the results and Section 5 concludes.

1. Theoretical and empirical considerations: impact analysis of structural funds on convergence

The aim of this section is to provide the theoretical and the empirical background for the econometric analysis that is described in section 2.

1.1. Theoretical considerations

From a theoretical perspective, three strands of literature provide insights into the effects of Cohesion Policy on European regional growth and convergence. Firstly, the neoclassical growth model is the most often cited in this context. Secondly, endogenous growth models focus on the mechanisms that allow public policies to influence long-run growth. Last, the economic geography literature sheds light on the importance of spatial interdependencies and the effects of geographical location.

To a large extent, the analyses of the impact of structural funds on regional growth are rooted on the neoclassical Solow growth model (Solow, 1956; Swan, 1956). Roughly speaking, this model predicts a convergence of income among regions having a similar economic structure. An economy converges towards a steady state as a result of decreasing marginal capital product. When capital is scarce, it is very productive, so it receives a high return, inducing economic agents to save more. Because of decreasing marginal capital product, the capital growth rate depends on the distance between its initial stock and its steady state value. In this steady state, the regional income continues to grow, but this growth is determined by exogenous factors (technological change, demographic growth rate, depreciation rate…) mentioned below as structural characteristics. Indeed, regions with the same structural characteristics necessarily converge towards similar steady states.

The Cohesion Policy, that finances physical capital, has two effects: it affects the convergence of an economy towards its steady state and it induces structural changes which modify the steady state income value of less developed areas. Hence, the growth of capital-scarce regions is temporarily stimulated above the region's usual steady-state growth level, when SF finances physical capital. However, the way Cohesion Policy can induce this structural change is not endogenous in the Solow model. Hence, this model explains the development path for a given technology only. Despite the extended Solow model proposed by Bajo-Rubio (2000), public intervention plays no part in the dynamics described by the model.

Romer (1986), Barro (1990) and Lucas (1988) among others have proposed a new model to capture the main role of the technological path and the way public policies can affect this path. Analysing the Cohesion Policy framework with this model would suggest that the funds affect regional long-term growth rates by promoting labour force training (model based on human capital development; Lucas, 1988), increasing Research and Development (Romer, 1986) or, more generally, public infrastructure investment (Barro, 1990). Thereby, public policies can be directly considered as inputs in the production process or as factors to improve the "quality of other inputs" (such as technology or human capital).

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The two approaches above can be considered as being non-spatial, because the development of a given economy is considered separately from the other ones. The New Economic Geography (NEG) and Krugman's core-periphery models (Krugman, 1991) add a critical piece to the regional governance puzzle by explaining the concentration of economic activities and the productive advantages of spatial closeness. In this framework, two opposite directional spatial processes may be at work. On one hand, centripetal forces (like economies of scale, local innovation processes, transport costs or presence of demand for goods, among other drivers) tend to promote geographical concentration of economic activities. On the other hand, congestion costs (among others, real estate costs, wages and labour market costs, transport costs) tend to counteract concentration of economic activities. We can note the major role of transport costs which affect these two forces. In light of NEG theories, Cohesion Policy has an ambiguous impact on regional income convergence. As described by Martin (1998, 1999), transport infrastructure investments (between regions) can lead to an increase of spatial concentration by reducing these transport costs. However, public policies that facilitate technological diffusion spillover can be beneficial for less developed regions. Moreover, Fuest and Huber (2006) show in a two-regions model, that a subsidy on investment in the poorer region unambiguously increases welfare if the labour markets are competitive. If there is unemployment in both regions, the effect of regional subsidies is weaker.

To sum up each of these theoretical approaches sheds light on interesting aspects of the effects of Cohesion Policy on European regional growth. However they are difficult to compare. More precisely, the assumption of decreasing marginal capital p.c. returns is not compatible with the return to scale of the endogenous growth and NEG theories. Thus, we have to choose a basic framework to rely on it. Almost all econometric studies investigating the impact of the Cohesion Policy are based on the neo-classical growth framework. We rely on this framework that presents the main advantage of capturing temporal dynamics. We introduce in this framework the economic spillovers (Ertur and Koch, 2007; Lopez-Bazo *et al.,* 2004).

1.2. Empirical framework

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Firstly, we use the neo-classical framework as a benchmark, using a dynamic panel specification. Then we introduce spatial spillovers. In the last step, we extend the model towards the impact evaluation of the policy.

1.2.1. Modelling β-convergence for spatial dynamic panel data

Following the specification of Barro and Sala-I-Martin (1992), several empirical studies rely on a β-convergence model where the GDP per capita (hereafter GDP p.c.) growth depends not only on the initial GDP level, but also on other conditioning variables (proxying the structural characteristics of the steady state). Regions do not have the same structural characteristics and thus converge towards different steady state income levels. The further a region finds itself far from its steady state, the faster its growth rate will be. In this case, convergence is conditional: economies converge towards the same growth rate, and a gap may persist in income level. This can be explained through the transitional dynamics of the GDP p.c. ($\ln y_{i,t}$):

$$\ln y_{i,t} - \ln y_{i,t-1} = -\ln y_{i,t-1}(1-e^{-\lambda t}) + \ln y_i^*(1-e^{-\lambda t})$$

where $\ln y_{i,t-1}$ is the initial GDP p.c. for region *i*, $\ln y_i^*$ is the steady state and λ is the rate of convergence. This model implies conditional convergence: for a given steady state, the growth rate is higher for regions with low income at the previous period ($\ln y_{i,t-1}$).

Accordingly, we use the following general specification, in line with the empirical growth literature (Durlauf *et al.*, 2006):

$$(1) \quad \ln\left(\frac{Y_{i,t}}{pop_{i,t}}\right) = (1+\beta_1)\ln\left(\frac{Y_{i,t-1}}{pop_{i,t-1}}\right) + \beta_2 \ln\left(\frac{I_{i,t}}{pop_{i,t}}\right) + \beta_3 \ln\left(\frac{pop_{i,t}}{pop_{i,t-1}}\right) + \alpha_i + \mu_t + \varepsilon_{i,t}$$

where $\frac{Y_{i,t}}{pop_{i,t}}$, $\frac{I_{i,t}}{pop_{i,t}}$ are respectively the gross domestic product and the investment per capita and $\ln\left(\frac{pop_{i,t}}{pop_{i,t-1}}\right)$ is the demographic growth rate. These last two variables partly determine the growth rate in the steady state.

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Using panel data improves the determination of $\ln y_i^*$ growth rate by controlling for unobserved heterogeneity across regions (Islam, 1995) through the introduction of individual effects and time effects (respectively α_i and μ_t). Therefore, β_1 measures the GDP convergence conditional on investment per capita and population growth rate.

In the underlying neoclassical growth model, economies are assumed to be independent. However, several recent studies have emphasized that the closed economy assumption might not be valid and that we need to take into account the possible interdependence between countries or regions, which can be explained by spatial externalities. Moreover, empirical evidence suggests that the productivity of technological spillovers declines as the geographical distance between regions increases (Keller, 2002). Several recent papers provide an empirical analysis of spatial effects, spatial autocorrelation and heterogeneity of the growth process to account for spatial dependence often detected in cross-country growth regressions (e.g. Dall'erba and Le Gallo, 2008). In these spatial econometric specifications, the spatial lag is a "methodological" means of introducing the dissemination of technological knowledge. Recent papers have developed a spatially-augmented Solow model which explicitly takes into account technological interdependence between countries using spatial externalities on total productivity (Ertur and Koch, 2007; Lopez-Bazo *et al.,* 2004) and physical capital accumulation (Ertur and Koch, 2007). Their models integrate spatial externalities with regard to both physical capital and the spread of knowledge, implying spatial heterogeneity in the parameters of the production function leading to a steady-state value for region i with spatial externalities and global technological interdependence. Our aim is to provide an average SF effect on regional development. We follow Lopez-Bazo *et al.* (2004) and Elhorst *et al*. (2010) and consider that the speed of convergence is the same for all regions:

$$\ln\left(\frac{Y_{i,t}}{pop_{i,t}}\right) = (1+\beta_1)\ln\left(\frac{Y_{i,t-1}}{pop_{i,t-1}}\right) + \rho\sum_{j\neq i} w_{ij}.\ln\left(\frac{Y_{j,t}}{pop_{j,t}}\right) + \beta_2\ln\left(\frac{I_{i,t}}{pop_{i,t}}\right) + \beta_3\ln\left(\frac{pop_{i,t}}{pop_{i,t-1}}\right) + \alpha_i + \mu_t + \varepsilon_{i,t} \quad (2)$$

where $\sum_{j \neq i} w_{ij} . \ln\left(\frac{Y_{j,t}}{pop_{j,t}}\right)$ is a first order spatial lag[2] and ρ represents the intensity of a contemporaneous spatial effect.

1.2.2. Impact of Cohesion Policy on European convergence

The previous specification is now extended towards impact evaluation of the policy, including structural funds, to assess the policy impact on regional growth.

i. Direct effect on regional development

Empirical literature on the effectiveness of Cohesion Policy is most often based on the neo-classical growth framework. Firstly, the work of Aschauer (1989), Gramlich (1994), tends to provide empirical evidence of effectiveness of public investment concentrated on infrastructure improvement as a direct input of the production process.

Hence, we can assume that structural funds directly affect regional growth rates[3] and as Mohl and Hagen (2010) we introduce the variable SF in equation (2):

$$\ln\left(\frac{Y_{i,t}}{pop_{i,t}}\right) = (1+\beta_1)\ln\left(\frac{Y_{i,t-1}}{pop_{i,t-1}}\right) + \rho\sum_{j \neq i} w_{ij} . \ln\left(\frac{Y_{j,t}}{pop_{j,t}}\right) + \beta_2 \ln\left(\frac{I_{i,t}}{pop_{i,t}}\right) + \beta_3 \ln\left(\frac{pop_{i,t}}{pop_{i,t-1}}\right) + \beta_4 \ln\left(\frac{SF_{i,t}}{pop_{i,t}}\right) + \alpha_i + \mu_t + \varepsilon_{i,t} \quad (3)$$

where $\ln\left(\frac{SF_{i,t}}{pop_{i,t}}\right)$ is structural funds commitments in region *i* for the current period *t*.

Structural funds can also induce indirect effects on investment in beneficiary regions. In fact, regional distribution of public investment policy may increase the return of public investment in receiving regions. Public infrastructure produced with the support of structural funds may also affect industrial location and enhance regional attractiveness. Structural funds may generate positive benefit in a region by increasing both public and private investment per capita ($\ln\left(\frac{I_{i,t}}{pop_{i,t}}\right)$) and by leading to a higher steady-state income value.

ii. Is there an "added-value" Objective 1 programmes?

Furthermore, we distinguish Objective 1 programmes from the others mainly because this programme concentrates most available funds on a few (less developed) regions. As recently shown by Becker *et al.* (2010) using a quasi-randomized experimental method, Objective 1 program has a positive effect on the growth rate of the regions benefiting from this programme. Here, we shall focus on assessing whether Objective 1 group membership enables valorising projects dynamics that can result in higher income levels (OECD, 2006). Initially, we introduce a Dummy variable (Obj1) in the previous equations specifying eligibility for Objective 1 program. Then, we introduce a distinction between total structural funds (whichever programme) and funds allocated for the Objective 1 programmes.

The equation (3) can be rewritten as:

$$\ln\left(\frac{Y_{i,t}}{pop_{i,t}}\right) = (1+\beta_1)\ln\left(\frac{Y_{i,t-1}}{pop_{i,t-1}}\right) + \rho\sum_{j\neq i} w_{ij}.\ln\left(\frac{Y_{j,t}}{pop_{j,t}}\right) + \beta_2\ln\left(\frac{I_{i,t}}{pop_{i,t}}\right) + \beta_3\ln\left(\frac{pop_{i,t}}{pop_{i,t-1}}\right) + \beta_4\ln\left(\frac{SF_{i,t}}{pop_{i,t}}\right) + \beta_5 Obj1 + \beta_6 Obj1.\ln\left(\frac{SF_{i,t}}{pop_{i,t}}\right) + \alpha_i + \mu_t + \varepsilon_{i,t} \quad (4)$$

β_5 captures the selection effect and β_6 is the added-value of the SF for O1 regions.

2. Econometric issues

As stated in the introduction, structural funds commitments are strongly correlated with past GDP levels. As mentioned by Bouvet and Dall'erba (2010), this correlation comes from the redistributive concerns of the cohesion policy. Furthermore, section 1 describes how the past GDP affects the economic development of European regions. Moreover, we can assume that the existence of spatial interactions affects both the SF allocation and the regional growth processes. These considerations are therefore crucial for the evaluation of the policy. This is another reason why it is essential to take into account both spatial and temporal dynamics in assessing the impact of structural funds. Section 2.1 presents some reasons why it is so important to include both temporal and spatial dynamics in the estimation of the cohesion policy impact. More precisely, we present some variables that affect both potential outcomes of the cohesion policy (economic development) and the allocation process of structural funds allocation.

2.1. Endogeneity of the SF allocation

Equity reasons lead to correlation between past GDP and current structural funds commitments, especially since the 1988 reform. Past GDP also directly affect current development. Thus, this variable can be a confounding factor of the cohesion policy impact. Moreover, as mentioned by Angrist and Pischke (2009), the introduction of the autoregressive term in our estimations allows subsuming time-varying confounders. In the case of structural funds allocation, the past GDP is a good proxy of the others socio-economic factors of structural funds allocation (Crescenzi, 2009). Beyond factors related to Objective 1 eligibility and socio-economic criteria affecting the allocation of structural funds, other factors (as politico-economic factors) are taken into account in the analysis (Bouvet and Dall'erba, 2010). In this way, Kemmerling and Bodestein (2006) shows that some of these confounding factors may have a spatial pattern. Thus, Crescenzi (2009) highlights spatial autocorrelation in the allocation of funds using a Moran's statistic. This spatial autocorrelation is analyzed by Védrine (2011) which highlights the importance of the level of GDP of the neighboring regions in the level of funds received by a region. From those analyzes, the allocation of structural funds can be specified as:

$$\ln\left(\frac{SF_{i,t}}{pop_{i,t}}\right) = \pi_1 \sum_{j\neq i} w_{ij}.\ln\left(\frac{Y_{j,t}}{pop_{j,t}}\right) + \pi_2 \ln\left(\frac{Y_{i,t-1}}{pop_{i,t-1}}\right) + e_{i,t}$$

where the spatial lagged GDP $\sum_{j\neq i} w_{ij}.\ln\left(\frac{Y_{j,t}}{pop_{j,t}}\right)$ is a synthetic way to include spatial determinants of the allocation of structural funds. All these factors may cause confusion to the extent of the impact of cohesion policy as they affect the dynamics of regional development regardless to the effect of politics. Indeed, the omission of these two variables would lead to biases that would grow with any increase in their respective covariance with the amount of funds (*cf.* appendix B for a more technical presentation of the omission bias of each autoregressive term). For this reason, we suggest that a spatial dynamic panel data model is a suitable specification for measuring the impact of cohesion policy. However, estimation methods for spatial dynamic panel data must deal with three main and potentially concurrent problems : i) serial dependence between the

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observations of each spatial unit over time, ii) spatial dependence at each point in time and iii) unobservable effects specific to space and time periods.

2.2. Estimation in spatial dynamic panel: a general review

In line with recent literature (Beck *et al.*, 2006, Blonigen *et al.*, 2007) a spatial autoregressive specification seems to be appropriate to quantify how the growth rate of a region is affected by the growth rate in the surrounding regions.[4]

According to Anselin (2001) and Abreu *et al.* (2005), the addition of a spatially lagged dependent variable causes simultaneity and endogeneity problems and thus a candidate consistent estimator should lie between the OLS and Within estimates. There is a relatively recent development in the literature on spatial dynamic panel data (SDPD). Elhorst (2005) suggests an unconditional maximum likelihood estimator for an SDPD model with either a spatial lag or a spatial error structure under a restrictive assumption of no additional explanatory variables. Yu *et al.*, (2008) and Lee and Yu (2010a) provide the asymptotic properties of a quasi-maximum likelihood for an SDPD model with exogenous explanatory variables. More recently, Korniotis (2010) proposed a solution based on Hahn and Kuersteiner's Corrected Bias Least Square Dummy Variable (2002) and instrumental methods (Anderson and Hsiao, 1982) extended to allow for the spatial effect. Moreover these various estimators may be complementary, depending on which specification is considered. For instance, Korniotis (2009) focuses on a "time-space recursive" model whereas Yu and Lee (2009) work on a "time-space dynamic" specification.

2.3. Extended moment conditions for spatial dynamic panel data

We consider that GMM estimators present several important advantages. First, GMM enables each special case of the general specification to be estimated with only a few modifications to moment restrictions. Furthermore, GMM allows the possible serial correlation of additional variables to be considered by introducing different moment restrictions on the explanatory variables.

Let us consider the general "time-space simultaneous" specification of equation (2) and (3)[5]:

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$$y_{it} = \alpha y_{i,t-1} + \rho \sum_{j \neq i} w_{ij} . y_{i,t} + x_{i,t}\beta + (\eta_i + \nu_{i,t})$$

We restrict our attention to the stable case, i.e. with $|\alpha| < 1$, $|\rho| < 1$ and $|\alpha + \rho| < 1$.

We consider moment restrictions involving no correlation between first-differenced errors and earlier lagged levels of $y_{i,t-1}$ (as described in section 2.1):

(i) $E(y_{i,s} \Delta\varepsilon_{i,t}) = 0$ for $s=1,...,T-2$ and $t=3,...,T$.

Let $x_{i,t}$ be defined as a vector of current and lagged values of additional explanatory variables. Depending on what is assumed about the correlation between $x_{i,t}$ and the two components of the error term, we can design different moment conditions (Bond, 2002):

- If $x_{i,t}$ is strictly exogenous

(ii) $E(x_{i,s} \Delta\varepsilon_{i,t}) = 0$ for $s=1,...,T$ and $t=3,...,T$.

- If $x_{i,t}$ is weakly endogenous,

(iii) $E(x_{i,s} \Delta\varepsilon_{i,t}) = 0$ for $s=1,...,T-1$ and $t=3,...,T$.

- If $x_{i,t}$ is strictly endogenous,

(iv) $E(x_{i,s} \Delta\varepsilon_{i,t}) = 0$ for $s=1,...,T-2$ and $t=3,...,T$.

As mentioned in the previous section, structural funds commitments are strongly correlated with initial GDP, which implies an obvious endogeneity problem for this variable. Hence, we consider this variable as endogenous, whatever the specification and the selected moment condition sets.

The choice of moment restrictions on other explanatory variables (investment per capita and demographic growth rate) is less clear. Thus, our choice will be more pragmatic (see section 4). As suggested by Bond (2002), we use a Hansen-diff test to discriminate between different moment restriction sets on these additional variables.

As the spatial lag is strictly endogenous, the moment restrictions described above are not sufficient to provide an unbiased and consistent estimation. An obvious solution is to estimate equation (2) and (3) with further moment restrictions considering $\sum_{j \neq i} w_{ij} y_{i,t}$ as an endogenous variable. These additional moment restrictions are written in the same way as (i):

(v) $$E\left(\sum_{j \neq i} w_{ij} y_{i,s} \Delta\varepsilon_{i,t}\right) = 0 \text{ for } s=1,\dots,T-2 \text{ and } t=3,\dots,T.$$

Spatially-weighted explanatory variables $\sum_{j \neq i} w_{ij} x_{i,t}$ can be used to instrument the spatial lag term. The exogenous part of the spatial lag variability is identified using a "spatially-weighted model". The validity of this procedure requires the following moment restrictions (with $\sum_{j \neq i} w_{ij} x_{i,t}$ exogenous):

(vi) $$E\left(\sum_{j \neq i} w_{ij} x_{i,t} \Delta\varepsilon_{i,t}\right) = 0 \text{ for } t=3, \dots,T$$

3. EU structural funds and O1 regions

3.1. Data description

The analysed dataset has been designed according to econometric issues described in Section 2. We use a panel dataset of 143 regions in 14 member states of EU-15 (see Appendix A which describes the sets of regions included and excluded in the sample). Owing to missing data, a small number of regions are excluded, among which several are eligible on Objective 1 programmes (New German Lander, French overseas etc...). We use NUTS2 data level for the main part of our sample, except for Germany and the United Kingdom for which data on structural funds regional allocation are available at NUTS1 level[6].

Finally, our dataset represents 90% of overall EU-15 regions and 80 % of Objective1 regions. The 143 regions are observed over a period to 25 years (1980-2005).

Data variables related to equations (1) to (4) come from the Cambridge Econometrics database[7]. The gross domestic product (GDP) and investment (provided by Cambridge Econometrics in 1995 constant euros) have been transformed into logarithms of per capita terms ($\ln\left(\frac{Y_{i,t}}{pop_{i,t}}\right)$, $\ln\left(\frac{I_{i,t}}{pop_{i,t}}\right)$) in order to consider the scale effect. The demographic growth rate is measured from the total population data dynamics ($\ln\left(\frac{pop_{i,t}}{pop_{i,t-1}}\right)$).

Mohl and Hagen (2010) focus their attention on the short-run growth effect of the structural funds using annual data on 1995-2005. We interested in the effect of structural funds on long term growth. Thus, for the estimation, we consider five aggregated time periods (1980-84, 1985-89, 1990-94, 1995-99 and 2000-2005) to avoid short-run variations in GDP growth rates due to business-cycle effects. The accurate number of years required to avoid short-run variations is still discussed in the literature[8]. Temple (1999) recommends 5 or 10 years long periods, but we preferred to follow the approach proposed by Badinger (2004) and chose quinquennial time periods to collect information from at least two periods before the beginning of the policy. The 1980-2005 period has been split into 5 periods (1980-84, 1985-89, 1990-94, 1995-99 and 2000-05) that include three different policy programs (1989-93, 1994-99 and 2000-06). Thereby, we have a panel on 572 observations of 143 regions during 5 periods. The dynamic panel specification restricts this panel to 4 periods because of the autoregressive term ($\ln\left(\frac{Y_{i,t-1}}{pop_{i,t-1}}\right)$). The variable measuring the structural funds commitments comes from the 11th annual report on the structural funds (1999). Data in this report are collected only in NUTS1 level for Germany and the United Kingdom. For data before 1989, we use ERDF allocation collected in the 14th annual report of the ERDF (1988). Finally, all variables are expressed in 1995 euros.

3.2. Spatial weight matrix specification

The spatial weight matrix is used to evaluate the covariance of characteristics across regional locations. While a variety of weighting matrices may be constructed, in order to allow spatial interaction, the empirical literature chooses weights based on arc distance or contiguity between regions (Abreu *et al.*, 2005).

Thus, we have chosen a geographical definition of neighbourhood based on arc distance between regions in order to define the W matrix. More precisely we have chosen a k-nearest neighbours weight specification, $w_{ij}(k)$ representing the element of W matrix in row i and column j:

$w^*_{ij}(k) = 0$ if $i = j$

$w^*_{ij}(k) = 1$ if $d_{ij} \leq d_i(k)$

$w^*_{ij}(k) = 0$ if $d_{ij} \geq d_i(k)$

d_{ij} is the distance between the centroids of regions i and j, and $d_i(k)$ is a cut-off distance based on the distance of k-nearest neighbour for region i. The interactions are assumed to be negligible above this distance. Although we have constructed W with k=10, the results are similar with k=5, 15 and 20.

So, the matrix is row-standardised $w_{ij}(k) = \frac{w^*_{ij}(k)}{\sum_j w^*_{ij}(k)}$ to provide easier interpretation (each weight may be interpreted as the region's share in the total spatial effect of the sample) and to make parameter estimates more comparable.

k-nearest neighbours seems the best weight matrix to represent spatial interaction in our sample: this specification leads to each region having the same number of neighbouring regions (k), including islands, in our sample, and to reducing the heterogeneity problem of regional superficies (Anselin, 2002).

3.3. Income dynamics in European regions

Table 1 Descriptive statistics

Table 1 depicts the dynamics of GDP p.c., investment per capita, demographic growth rate and spatially lagged GDP for Objective 1 (O1) regions and other regions in Europe. For every time period, O1 regions exhibit a GDP per capita far lower than the European average. The difference between O1 and non-O1 regions increases from the 1980-84 period to 1985-89 on, and then slowly decreases till today.

Figure 1: Annual versus Before/After intervention income and growth by treatment status (authors' calculation, Cambridge Econometrics database)

Figure 1 highlights the difference in GDP p.c. and growth rate between O1 regions and Non-treated regions before and after the reform of the Cohesion Policy which introduced Objective 1 programme eligibility. Although the GDP p. c. gap remains relatively stable before and after the 1988 Cohesion Policy reform, one can see that the growth rates are slightly different and much more important for treated regions just before the reform and at the end of the period considered, suggesting that the catch-up process is at work within a conditional convergence framework. From 1995 to 2005 the regions' growth rates vary too much to conclude that regions seem to converge towards country-specific steady state GDP levels, but the growth-rate gap is stable.

This process is liable to spread out first among the neighbouring regions and then disseminate over the whole European space. Observed spatial correlations highlight an obvious spatial dimension of regional convergence (see Figure 2). Figure 2 graphs the GDP-per-capita geographic pattern relative to the EU-14 average GDP level for the 5 periods. The regions are split into 6 classes, from below 50% of the European average to more than 150% of this average. For the first period, regions with income below 50% of the EU average can be found mainly in the southern periphery and most of them are in Greece or Portugal. A small number (7) of these regions had GDP p.c. below 50% of the EU average over the whole period. More precisely these are in Spain (1), Greece (3) and Portugal (3). Except these particular regions, the GDP p.c. spatial pattern between 1980-1984 and 2000-2005 is more dynamic in the periphery. Most regions in Spain, Greece, Ireland or Portugal

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experienced growth rates above the average EU-14 growth rate[9], while the most spectacular result is for Ireland, even if only two regions are concerned.

Figure 2: Geographic pattern of GDP per capita relative to the EU-14 average GDP level for the 5 periods (authors' calculation, Cambridge Econometrics database)

4. Estimation results: impact analysis of structural funds on regional convergence

The results are summarized in Tables 3 to 6. In keeping with the structure of Section 1.2, we present the results of specifications for which the variables are successively introduced. We start with the estimation of a neoclassical growth equation (Table 3) as a benchmark specification. Then, we introduce a spatial lag (Table 3) and the structural fund commitments directly in our estimations (Table 5), as previously carried out by Rodriguez-Pose and Fratesi (2004) in a static panel framework, and Dall'erba and Le Gallo (2008) in a spatial cross-section analysis.

Whatever the misspecification, when the spatial spillover effects are not considered in the analysis, it is of interest to analyse if consideration of the impact of structural funds slightly changes the results presented previously. For that comparative purpose, Table 4 reports some estimation results of the impact of structural funds in a simple dynamic panel data framework.

Structural funds may increase investment per capita leading to a higher steady-state income value. We investigate how robust are the estimated results when omitting the investment variable within a specification that includes the structural funds, and we check if the latest effect is stronger (Table 6).

As ignoring spatial dependencies in residuals leads to potentially misleading estimates and incorrect statistical inference, we will first analyse the spatial properties of the residuals before presenting the estimation results and validity tests. To the best of our knowledge, the spatial Lagrange multiplier (LM) tests have not yet been extended to SDPD; therefore the specifications previously presented cannot be tested directly. We check for spatial autocorrelation in the error term using the LM-test in static panel data developed by Baltagi *et al.*, (2003, 2007) and Baltagi and Liu (2008). The results are summarized in Table 2. The result of the LM joint test for no spatial autocorrelation and no random effects tends to confirm that at least one of these two components is present in the error term (1369.03) with a p-value of 1%. The presence of spatial correlation has been detected by a conditional LM test for spatial autocorrelation given the presence of random regional effects (15.50 with a p-value of less than 1%). The simple LM test for a missing spatially lagged dependent variable is significant (47.38).

Table 2 LM tests for spatial dependence, random effects and serial correlation

The consistency of the GMM estimator relies on the validity of the lagged values of the autoregressive and spatial autoregressive terms as instruments for the regression. Using an orthogonality condition between the first-differenced error terms and lagged values of the dependent variables, we have to ensure, with specification tests, that these assumptions are justified.

Firstly, the AR(2) test (Arellano and Bond, 1991) examines the absence of second order serial correlation properties of the residuals in levels (null hypothesis). Failure to reject this hypothesis could supply evidence to validate moment restriction for the autoregressive term. The p-values associated with this test (reported at the end of each table) lend further support to our estimates as they fail to reject absence of second order serial correlation.

Secondly, the overall validity of the moment conditions is checked by the Hansen test. However, too many instruments lead to inaccurate estimation of the optimal weight matrix, biased standard errors and, therefore, incorrect inference in these overidentification tests.

In order to check the sensitivity of our results to the number of instruments, we present alternative instrument sets. The first one uses the full set of instruments available for autoregressive terms and spatial autoregressive terms (full lag instruments). The second restricts it to the nearest lags which can be used for each variable (second lag instruments only). Finally the third collapses it (Roodman, 2009). Structural funds commitments are always treated as endogenous, whatever instrument sets are used. In order to have significant lags to estimate the effect of the first programming period, we introduce the regional ERDF allocation for the period 1980-89. Overall validity tests do not indicate problems with instrument validity and orthogonality conditions used by first-differenced GMM estimators for Table 4 and 5 (i.e. estimates with our key equation including structural funds effects on development)[10]. Table 3 reports weak identification problems for the traditional neo-classical convergence equation and its spatial extended version. Hence, the results of these estimations need to be interpreted carefully.

Table 3 Estimation of the neo-classical convergence equation and its spatially extended version (eq. (1) and (2))

The regression results (Table 3) of the neo-classical convergence equation are mostly consistent with the predictions obtained by previous studies (Caselli *et al.*, 1996; Esposti and Bussoletti, 2008). For the traditional convergence equation, the autoregressive term coefficient is around 0.71 for Least Square Dummy Variable (LSDV) and 0.88 when the Pooled Ordinary Least Square (POLS) estimator is used. As expected, the coefficient estimated by GMM lies close to 0.85 and falls between the theoretical bounds provided by LSDV and POLS (Caselli *et al.*, 1996). Investment per capita (demographic growth rate) has a significant and positive (negative) effect on regional development. These results are consistent with the Solow model predictions (expected coefficients sign).

The introduction of the spatial autoregressive term ($\sum_{j \neq i} w_{ij} . \ln\left(\frac{Y_{i,t}}{pop_{i,t}}\right)$) implies a fall of the ($1+\beta_1$) coefficient (from 0.8 to 0.5), while the coefficients associated with investment and demographic growth change very slightly (the last five columns of Table 3). Within the SDPD specification, we find empirical evidence of conditional convergence of European regions. Convergence (here net of spatial spillover) is faster when we consider the impact of neighbouring income on regional development. This process is strongly affected by spatial dependence. In fact, the spatial lag coefficient (0.4) suggests a strong significant impact of spatial spillover effects between European regions in their dynamics of development.

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The simple dynamic panel specification that takes into account the structural funds as an additional variable allows us to compare the results with previous studies (Table 4). The structural funds seem to directly affect regional development, but not with the expected sign (negative significant effect). However, the effect becomes positive for the structural funds allocated in Objective 1 programmes. The magnitude of the effect is comparatively important (0.05), in line with previous results (Mohl and Hagen, 2010; Bussoletti and Esposti, 2008) in a same simple dynamic panel specification (without spatial lag).

Table 4 Estimation of Structural Funds direct effect with a standard dynamic panel

Table 5 Estimation of SPDP with direct effect of structural funds (eq. (3) and (4))

The direct effect of structural funds on regional development is displayed in Table 5. First, the effect of total structural funds is not significant. Furthermore, that additional variable does not significantly affect the estimated parameter of the autoregressive term (the coefficient still remains around 0.5 within a very similar confidence interval) and neither spatial lag coefficient (around 0.37) nor other additional variables.

The Objective 1 dummy variable which captures programme eligibility effect is significant[11]. The effect of structural funds allocated in Objective 1 programmes is significantly positive (the last three columns in Table 5). These results are consistent with the evidence provided by Mohl and Hagen (2010) in a short-medium term evaluation (1995-2006) with annual data. The size of this coefficient is smaller than in the non-spatial case (0.02 instead of 0.05).

The estimates tell us about the significance and the sign of the effects of cohesion policy. From these estimates, we calculate the cumulative effects (long-term elasticity) and the direct effects (short-term elasticity) of structural funds on the long term economic growth of beneficiary regions (Table 6). The cumulative impact of Objective 1 funding is relatively high in the model without spatial effects (0.30). An increase of 10% of allocated funds would mean an increase of 3% of GDP level per capita for recipient regions. This value is close

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to the elasticity estimated by Aschauer (1989) (on U.S. data and for all public investments) and in the range of elasticities calculated by Esposti and Bussoletti (2008).

Moreover, it is worthwhile noting that the cumulative impact of non-O1 funds is negative but very low when estimated without spatial effects. But, the effect of these funds is not significantly different from 0 when we introduce the spatial effects. The cumulative impact of the O1 funds calculated from the spatial dynamic model is not negligible: an increase of 10% of O1 funds generates an average increase of 0.7% of GDP per capita level of recipient regions (which is lower than calculated with non-spatial estimates). We also note that the impact of subsidies on the O1 regional development grounds for two-thirds of its effect the short term (0.05 for the short term and 0.07 for the long term).

Table 6 Cumulative and direct impact of SF derived from estimates of tables 4 and 5

As mentioned in section 1.2, structural funds may generate a positive benefit in a region by increasing both public and private investment per capita and leading to a higher steady-state income value. We test the robustness of our results by estimating equation (4) without investment per capita (Table 6). This omission significantly affects the value of the autoregressive term which falls to around 0.25 and the value of the spatial lag coefficient which increases from 0.37 (Table 4) to around 0.8. However, beyond the change in value of these coefficients (due to the omission of a key variable, investment per capita), the main results with regard to the impact of structural funds are not affected. Total structural fund commitments don't significantly affect European regional growth, whereas funds allocated in Objective 1 programmes do. We can mention, however, that the coefficient associated with Objective 1 funds rises slightly following the omission of the investment per capita.

Table 7 Estimation of equation (4) without investment p.c.

Finally, we check the sensitivity of our results to the presence of structural funds spillover effect (Table 7). We exclude other spatial lag variables because they can not be confounded with the effect of the Structural Funds (these spatial lags would be orthogonal to the allocation of structural funds). We can note that the introduction of this variable does not radically affect the interpretation of our results: the effect of funds for other programs remains insignificant, while the funds still positively affect O1 regions with the same magnitude as in the previous estimation (Table 5). The level of funds received by a region seems to be correlated positively with the development of the regions surrounding it, which allows us to suggest positive spillover effects of structural funds on regional growth.

Table 8 Estimation of equation (4) with SF spillovers effect

5. Conclusion

The aim of this paper is to empirically investigate the impact of Cohesion Policy on European regional convergence. Using a dynamic panel dataset of 143 regions over the period 1980-2005, we consider in the same framework the spatial dependencies and the impact analysis.

Within the framework of a spatial dynamic panel specification, we find empirical evidence that the Cohesion Policy fosters the endogenous development of Objective1 regions in Europe. Moreover, our results confirm that the Cohesion Policy, which aims at counterbalancing the effects of GDP concentration over the richest regions, attains this objective. Our results suggest that Objective 1 programmes have a direct effect on regional GDP p.c. growth rates, whereas total structural funds do not. We interpret this result as an Objective 1 programmes added-value, compared to total structural funds. This finding could be extended to the estimation of indirect effects on non-Objective 1 regions (e.g. through a technology diffusion effect) but they do not allow additional growth specifically in these regions, when we consider the spatial dependences. This framework could be extended to take into account the potential diffusion effects implied by a structural change induced by structural funds expenditure in the more advanced regions.

Analysing the spatial dimension of the panel data, we find that regional spillovers do have an impact on regional development. The Cohesion Policy counterbalances the negative effect on regional development that occurs when the richest regions concentrate income and activities on themselves. It is however our opinion that improving regional spillovers can contribute to foster the endogenous development of regional clusters, as has been demonstrated with Interregional Cooperation Programmes (Interreg). Ultimately, the Cohesion Policy is implemented along with other EU policies (like agricultural policies, industrial regulations) that can favour or hamper the effects of this policy. Extending our analysis towards national redistributive effects, national pensioning strategies and regional clustering can help to design more efficient policies toward regional development. Moreover, it would be interesting to use this type of model (SDPD) to simulate the diffusion effects due to structural policy in Europe. This study may be considered a first step in estimating the equation that determines steady state income and in simulating the effect of an increase of this steady state (as a shock due to structural funds expenditure) on neighbouring outcomes. However, this proposition requires taking into account the impact of this shock on regional and national behaviour respectively (e.g. in public investment) in order to not rely on too restrictive assumptions (such as the assumption that the shocks are proportional to the amount of funds allocated to regions).

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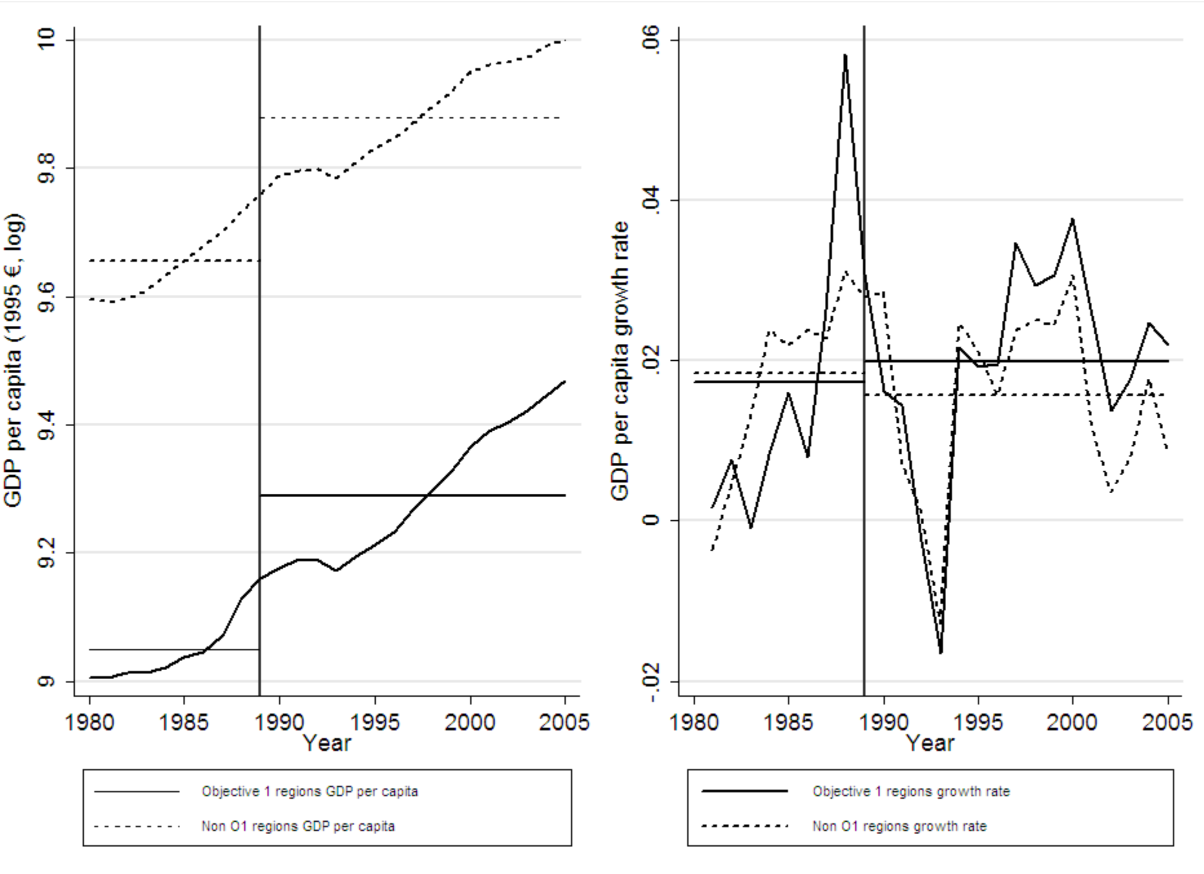

Figure 1: Annual versus Before/After intervention income and growth by treatment status (authors' calculation, Cambridge Econometrics database)

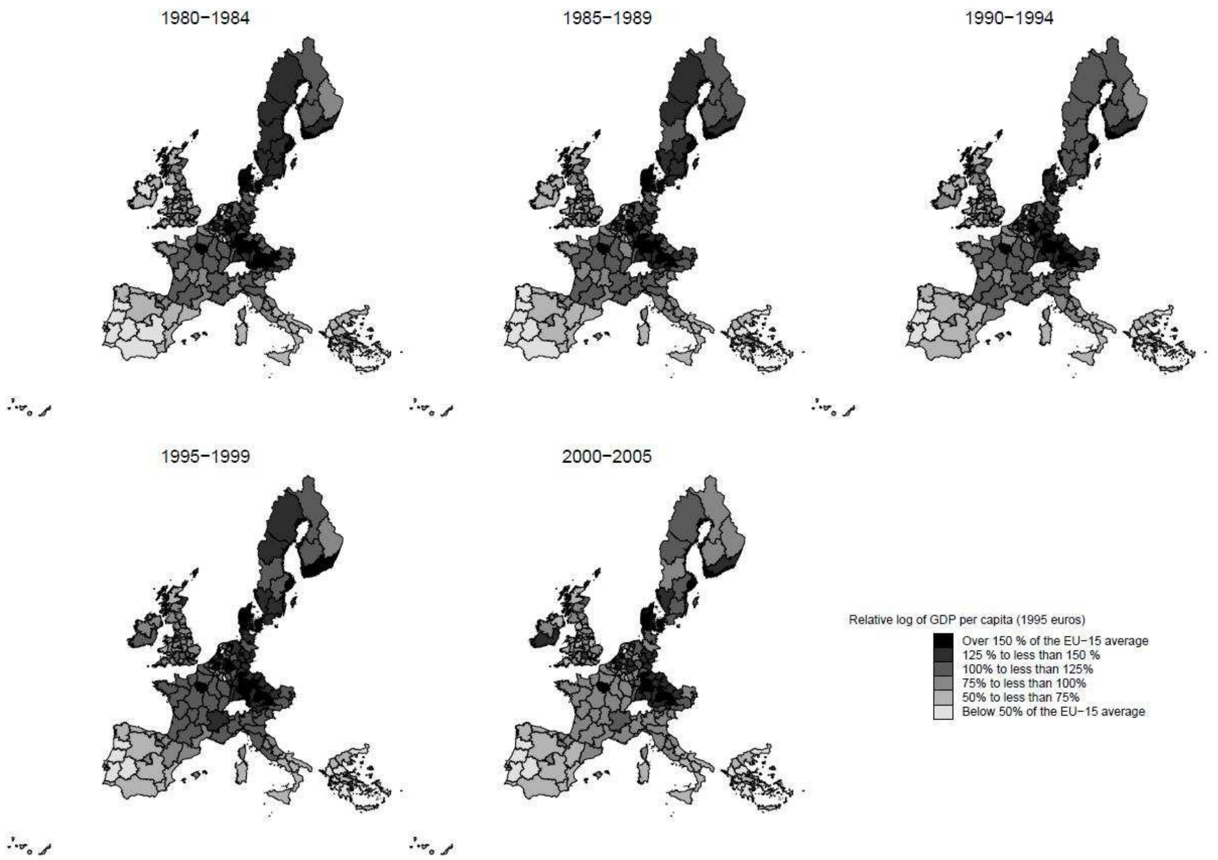

Figure 2: Geographic pattern of the GDP per capita relative to the EU-14 average GDP level for the 5 periods (authors' calculation, Cambridge Econometrics database)

Table 1 Descriptive statistics

Variable	1980-84	1985-89	1990-94	1995-99	2000-05
Initial GDP p.c.					
Total sample mean (std)	9.44(0.40)	9.54(0.39)	9.63(0.39)	9.71(0.38)	9.81(0.37)
O1 regions mean (std)	9.01(0.32)	9.09(0.31)	9.18(0.28)	9.27(0.29)	9.41(0.29)
Other regions mean (std)	9.60(0.29)	9.71(0.27)	9.80(0.27)	9.87(0.26)	9.96(0.26)
Investment p.c.					
Total sample mean (std)	7.82(0.47)	7.95(0.44)	7.99(0.41)	8.08(0.37)	8.21(0.34)
O1 regions mean (std)	7.44(0.36)	7.54(0.33)	7.62(0.30)	7.73(0.27)	7.93(0.28)
Other regions mean (std)	7.96(0.43)	8.11(0.36)	8.14(0.36)	8.21(0.30)	8.32(0.30)
Spatial lag of GDP p.c.					
Total sample mean (std)	9.46(0.34)	9.55(0.34)	9.64(0.34)	9.72(0.34)	9.84(0.32)
O1 regions mean (std)	9.10(0.33)	9.18(0.33)	9.26(0.31)	9.35(0.32)	9.48(0.30)
Other regions mean (std)	9.60(0.24)	9.70(0.22)	9.78(0.23)	9.86(0.21)	9.96(0.21)
Population growth					
Total sample mean (std)		2.84(1.39)	3.37(1.19)	3.28(1.24)	3.29(1.30)
O1 regions mean (std)		3.01(1.45)	2.73(1.26)	3.12(1.37)	3.42(1.34)
Other regions mean (std)		2.78(1.36)	3.55(1.11)	3.33(1.20)	3.26(1.29)
Structural funds p.c.					
Total sample mean (std)	3.34(1.59)	3.43(1.53)	4.87(1.05)	5.05(1.19)	5.29(1.35)
O1 regions mean (std)	5.07(0.87)	4.79(0.82)	6.16(0.64)	6.33(0.64)	6.83(0.49)
Other regions mean (std)	2.74(1.32)	2.69(1.29)	4.26(0.50)	4.55(0.95)	4.68(1.06)

Table 2 LM tests for spatial dependence, random effects and serial correlation

LM test description	Statistic	p. value
Baltagi et al. (2003)		
Joint test (H_0 : absence of spatial autocorrelation and/or random effects)	1369.03	0.01
Conditional test of spatial autocorrelation (H_0 : absence of spatial autocorrelation, assuming random effects are non null)	15.50	<0.01
Marginal test of spatial autocorrelation (H_0 : absence of spatial autocorrelation)	14.28	<0.01
Marginal test of random effects (H_0 : absence of random effects)	0.001	0.50
Baltagi et al. (2007)		
Two dimension marginal test (H_0 : absence of spatial autocorrelation and serial correlation)	563.90	<0.01
Baltagi and liu (2008)		
Marginal test of spatial lag (H_0 : absence of spatial lag)	47.38	<0.01

Table 3 Estimation of neo classical convergence equation and its spatially extended version (eq. (1) and (2))

	POLS	LSDV	GMM-DIFF			POLS	LSDV	S-GMM-DIFF		
			Full lag instruments	Second lag instruments only	Collapsed instruments			Full lag instruments	Second lag instruments only	Collapsed instruments
Initial GDP p.c.	0.881***	0.707***	0.842***	0.867***	0.866***	0.854***	0.409***	0.482***	0.495***	0.503***
	(0.01)	(0.02)	(0.07)	(0.08)	(0.08)	(0.01)	(0.03)	(0.13)	(0.13)	(0.13)
Spatial lag of GDP p.c.						0.041***	0.454***	0.408**	0.400**	0.393**
						(0.01)	(0.03)	(0.14)	(0.14)	(0.14)
Investment p.c.	0.112***	0.247***	0.178***	0.165***	0.166***	0.107***	0.148***	0.136***	0.134***	0.134***
	(0.01)	(0.02)	(0.04)	(0.04)	(0.04)	(0.01)	(0.01)	(0.03)	(0.03)	(0.03)
Population growth	-0.002	-0.006*	-0.007*	-0.007*	-0.007*	-0.001	-0.004	-0.004*	-0.005*	-0.005*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Constant	0.325***	0.908***				0.234***	0.160			
	(0.05)	(0.15)				(0.06)	(0.13)			
Observations nb.	572	572	429	429	429	572	572	429	429	429
r²	0.985	0.908						0.985	0.937	
AR(2)			-0.612	-0.644	-0.642			-1.174	-1.174	-1.176
(AR(2) p.value)			(0.542)	(0.520)	(0.521)			(0.240)	(0.241)	(0.240)
Hansen J			29.900	26.147	26.375			14.519	9.579	10.911
(Hansen J p.value)			(0.000)	(0.000)	(0.000)			(0.105)	(0.088)	(0.053)
Hansen-Diff			45.44	36.93	34.62			36.33	37.25	16.10
(Hansen-Diff p.v.)			(0.00)	(0.00)	(0.00)			(0.000)	(0.000)	(0.007)
Instruments nb.			5	4	4			13	9	9

Notes: POLS: Pooled Ordinary Least Squares; LSDV: Least Dummy Variable; S-GMM-DIFF: Generalized Method of Moments on forward orthogonal deviation equation. *, **, *** indicate significance at the 10 , 5 and 1 level. Robust standard errors are displayed in parentheses. Moment restrictions used in S-GMM-DIFF: *full lag instruments (for each time period)*: lag-2 and greater of the dependent variable and the spatial lag, lag-0 only of investment pc, demographic growth rate, spatially lagged investment and demographic growth rate. *Second lag instruments only (for each time period)*: lag-2 of the dependent variable and the spatial lag only, lag-0 only of investment pc, demographic growth rate, spatially lagged investment and demographic growth rate. *Collapsed instruments*: same description as full lag instruments but for all time periods. Similar results are obtained by considering investment pc and demographic growth rate as weakly endogenous.

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Table 4 Estimation of Structural Funds direct effect with a standard dynamic panel

	GMM-DIFF			GMM-DIFF		
	Full lag instruments	Second lag instruments only	Collapsed instruments	Full lag instruments	Second lag instruments only	Collapsed instruments
Initial GDP p.c.	0.789***	0.816***	0.815***	0.790***	0.820***	0.819***
	(0.11)	(0.11)	(0.11)	(0.10)	(0.10)	(0.10)
Investment p.c.	0.339***	0.318***	0.318***	0.277***	0.233***	0.233***
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)
Population growth	-0.000	-0.001	-0.001	-0.003	-0.004	-0.004
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)
SF p.c.	-0.026***	-0.025***	-0.025***	-0.019**	-0.016*	-0.016*
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Obj1 dummy	0.144***	0.136***	0.136***	-0.149	-0.213	-0.215
	(0.04)	(0.04)	(0.04)	(0.12)	(0.12)	(0.12)
Obj1×SF p.c.				0.046**	0.054**	0.054**
				(0.02)	(0.02)	(0.02)
Observations nb.	429	429	429	429	429	429
AR(2)	-1.796	-1.684	-1.685	-0.032	0.308	0.320
(AR(2) p.value)	(0.073)	(0.092)	(0.092)	(0.974)	(0.758)	(0.749)
Hansen J	5.649	3.417	3.530	4.470	0.143	0.157
(Hansen J p.value)	(0.059)	(0.065)	(0.060)	(0.107)	(0.705)	(0.692)
Hansen-Diff	35.32	42.93	20.14	35.95	41.80	36.09
(Hansen-Diff p.v.)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Instruments nb.	7	6	6	8	7	7

Notes: POLS: Pooled Ordinary Least Squares; LSDV: Least Dummy Variable; S-GMM-DIFF: Generalized Method of Moments on forward orthogonal deviation equation. *, **, *** indicate significance at the 10 , 5 and 1 level. Robust standard errors are displayed in parentheses. Same moment restrictions as table 5 without spatial lag and other spatially lagged additional variables.

Table 5 Estimation of SPDP with direct effect of structural funds (eq. (3) and (4))

	S-GMM-DIFF			S-GMM-DIFF		
	Full lag instruments	Second lag instruments only	Collapsed instruments	Full lag instruments	Second lag instruments only	Collapsed instruments
Initial GDP p.c.	0.473***	0.516***	0.530***	0.477***	0.512***	0.529***
	(0.14)	(0.13)	(0.14)	(0.13)	(0.13)	(0.14)
Spatial lag of GDP	0.411**	0.394**	0.384**	0.393**	0.373**	0.361**
p.c.	(0.15)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)
Investment p.c.	0.135***	0.129***	0.129***	0.129***	0.124***	0.122***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Population growth	-0.004**	-0.004**	0.004**	-0.004**	-0.005**	0.005**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
SF p.c.	-0.0001	-0.002	-0.002	0.0001	-0.001	-0.001
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Obj1 dummy	0.013	0.017*	0.018*	-0.080	-0.095*	-0.106*
	(0.01)	(0.01)	(0.01)	(0.05)	(0.06)	(0.06)
Obj1×SF p.c.				0.016*	0.019**	0.021**
				(0.01)	(0.01)	(0.01)
Observations nb.	429	429	429	429	429	429
AR(2)	-1.297	-1.303	-1.308	-0.727	-0.630	-0.584
(AR(2) p.value)	(0.195)	(0.193)	(0.191)	(0.467)	(0.528)	(0.560)
Hansen J	15.013	9.572	11.067	12.504	7.244	7.013
(Hansen J p.value)	(0.091)	(0.088)	(0.050)	(0.186)	(0.203)	(0.220)
Hansen-Diff	25.51	24.13	8.18	31.13	38.38	28.85
(Hansen-Diff p.v.)	(0.001)	(0.001)	(0.043)	(0.000)	(0.000)	(0.001)
Instruments nb.	15	11	11	16	12	12

Notes: S-GMM-DIFF: Generalized Method of Moments on forward orthogonal deviation equation. *, **, *** indicate significance at the 10%, 5% and 1% level. Robust standard errors are displayed in parentheses. Moment restrictions used in S-GMM-DIFF: *full lag instruments (for each time period)*: lag-2 and greater of the dependent variable, the spatial lag and the structural funds variable,lag-0 only of investment pc, demographic growth rate, spatially lagged investment, structural funds and demographic growth rate. *Second lag instruments only (for each time period)*: lag-2 of the dependent variable, the spatial lag only and the structural funds variable, lag-0 only of investment pc, demographic growth rate, spatially lagged investment and demographic growth rate. *Collapsed instruments*: same description as full lag instruments but for all time periods. Similar results are obtained by considering investment pc and demographic growth rate as weakly endogenous.

Table 6 Cumulative and direct impact of SF derived from estimates of tables 5 and 6

	Without spatial effects		With spatial effects	
	Objective 1	Non O1	Objective 1	Non O1
Cumulative impact of SF (long-run elasticity)	0.30***	-0.09***	0.07***	-0.004
Direct impact of SF (short-run elasticity	0.21***	-0.06***	0.05***	-0.001

Notes: *, **, *** indicate significance at the 10 , 5 and 1 level.

Table 7 Estimation of equation (4) without investment p.c.

	S-GMM-DIFF		
	Full lag instruments	Second lag instruments only	Collapsed instruments
Initial GDP p.c.	0.156	0.249**	0.265*
	(0.11)	(0.13)	(0.15)
Spatial lag of GDP p.c.	0.840***	0.759***	0.739***
	(0.10)	(0.10)	(0.12)
Population growth	-0.002	-0.003	-0.003
	(0.00)	(0.00)	(0.00)
SF p.c.	-0.001	-0.001	-0.001
	(0.00)	(0.00)	(0.00)
Obj1 dummy	-0.145*	-0.153*	-0.168**
	(0.01)	(0.01)	(0.01)
Obj1×SF p.c.	0.027*	0.029**	0.032**
	(0.01)	(0.01)	(0.01)
Observations nb.	429	429	429
AR(2)	0.444	0.244	0.206
(AR(2) p.value)	(0.657)	(0.808)	(0.837)
Hansen J	7.015	4.330	3.385
(Hansen J p.value)	(0.535)	(0.363)	(0.496)
Hansen-Diff	12.05	14.15	5.65
(Hansen-Diff p.v.)	(0.210)	(0.117)	(0.227)
Instruments nb.	14	10	10

Notes: S-GMM-DIFF: Generalized Method of Moments on forward orthogonal deviation equation. *, **, *** indicate significance at the 10 , 5 and 1 level. Robust standard errors are displayed in parentheses. Same moment restrictions as table 5 without investment pc and spatially lagged investment pc.

Table 8 Estimation of equation (4) with SF spillovers effect.

	S-GMM-DIFF		
	Full lag instruments	Second lag instruments only	Collapsed instruments
Initial GDP p.c.	0.483***	0.497***	0.498***
	(0.13)	(0.13)	(0.13)
Spatial lag of GDP p.c.	0.388***	0.366***	0.369***
	(0.14)	(0.14)	(0.14)
Investment p.c.	0.129***	0.124***	0.122***
	(0.03)	(0.03)	(0.03)
Population growth	-0.004*	-0.004*	-0.004*
	(0.002)	(0.002)	(0.002)
SF p.c.	-0.003	-0.003	-0.003
	(0.01)	(0.01)	(0.01)
Obj1 dummy	-0.07*	-0.11**	-0.10*
	(0.05)	(0.05)	(0.05)
Obj1×SF p.c.	0.019**	0.027**	0.026**
	(0.01)	(0.01)	(0.01)
Spatial lag of SF p.c.	0.007**	0.007**	0.007**
	(0.003)	(0.003)	(0.003)
Observations nb.	429	429	429
AR(2)	0.444	0.244	0.206
(AR(2) p.value)	(0.657)	(0.808)	(0.837)
Hansen J	7.015	4.330	3.385
(Hansen J p.value)	(0.535)	(0.363)	(0.496)
Hansen-Diff	12.05	14.15	5.65
(Hansen-Diff p.v.)	(0.210)	(0.117)	(0.227)
Instruments nb.	14	10	10

Notes: S-GMM-DIFF: Generalized Method of Moments on forward orthogonal deviation equation. *, **, *** indicate significance at the 10 , 5 and 1 level. Robust standard errors are displayed in parentheses. Same moment restrictions as table 5 without the two first lags of spatially lagged SF pc.

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Appendix A: Sample region with Objective 1 eligibility periods

CODE	NAME	O1	CODE	NAME	O1	CODE	NAME	O1
AT11	Burgenland	1995-2006	FI13	Itä-Suomi		ITE2	Umbria	
AT12	Niederösterreich		FI18	Etelä-Suomi		ITE3	Marche	
AT13	Wien		FI19	Länsi-Suomi		ITE4	Lazio	
AT21	Kärnten		FI1A	Pohjois-Suomi	1995-2006	ITF1	Abruzzo	1989-96
AT22	Steiermark		FR10	Île de France		ITF2	Molise	1989-2006
AT31	Oberösterreich		FR21	Champagne-Ardenne		ITF3	Campania	1989-2006
AT32	Salzburg		FR22	Picardie		ITF4	Puglia	1989-2006
AT33	Tirol		FR23	Haute-Normandie		ITF5	Basilicata	1989-2006
AT34	Vorarlberg		FR24	Centre		ITF6	Calabria	1989-2006
BE10	Région de Bruxelles-Capitale		FR25	Basse-Normandie		ITG1	Sicilia	1989-2006
BE21	Prov. Antwerpen		FR26	Bourgogne		ITG2	Sardegna	1989-2006
BE22	Prov. Limburg (B)		FR30	Nord - Pas-de-Calais	1994-2004	NL11	Groningen	
BE23	Prov. Oost-Vlaanderen		FR41	Lorraine		NL12	Friesland	
BE24	Prov. Vlaams Brabant		FR42	Alsace		NL13	Drenthe	
BE25	Prov. West-Vlaanderen		FR43	Franche-Comté		NL21	Overijssel	
BE31	Prov. Brabant Wallon		FR51	Pays de la Loire		NL22	Gelderland	
BE32	Prov. Hainaut	1989-2006	FR52	Bretagne		NL31	Utrecht	
BE33	Prov. Liège		FR53	Poitou-Charentes		NL32	Noord-Holland	
BE34	Prov. Luxembourg (B)		FR61	Aquitaine		NL33	Zuid-Holland	
BE35	Prov. Namur		FR62	Midi-Pyrénées		NL34	Zeeland	
DE1	Baden-Württemberg		FR63	Limousin		NL41	Noord-Brabant	
DE2	Bayern		FR71	Rhône-Alpes		NL42	Limburg (NL)	
DE5	Bremen		FR72	Auvergne		PT11	Norte	1989-2006
DE6	Hamburg		FR81	Languedoc-Roussillon		PT15	Algarve	1989-2006
DE7	Hessen		FR82	Provence-Alpes-Côte d'Azur		PT16	Centro (PT)	1989-2006
DE9	Niedersachsen		FR83	Corse	1989-2004	PT17	Lisboa	1989-2004
DEA	Nordrhein-Westfalen		GR11	Anatoliki Makedonia, Thraki	1989-2006	PT18	Alentejo	1989-2006
DEB	Rheinland-Pfalz		GR12	Kentriki Makedonia	1989-2006	SE01	Stockholm	
DEC	Saarland		GR13	Dytiki Makedonia	1989-2006	SE02	Östra Mellansverige	
DEF	Schleswig-Holstein		GR14	Thessalia	1989-2006	SE04	Sydsverige	
DK00	DENMARK		GR21	Ipeiros	1989-2006	SE06	Norra Mellansverige	
ES11	Galicia		GR22	Ionia Nisia	1989-2006	SE07	Mellersta Norrland	1995-2006
ES12	Principado de Asturias	1989-2006	GR23	Dytiki Ellada	1989-2006	SE08	Övre Norrland	1995-2006
ES13	Cantabria	1989-2006	GR24	Sterea Ellada	1989-2006	SE09	Småland med öarna	
ES21	Pais Vasco		GR25	Peloponnisos	1989-2006	SE0A	Västsverige	
ES22	Comunidad Foral de Navarra		GR30	Attiki	1989-2006	UKC	North East	
ES23	La Rioja		GR41	Voreio Aigaio	1989-2006	UKD	North West	1994-2006
ES24	Aragón		GR42	Notio Aigaio	1989-2006	UKE	Yorkshire and The Humber	2000-06
ES30	Comunidad de Madrid		GR43	Kriti	1989-2006	UKF	East Midlands	
ES41	Castilla y León	1989-2006	IE	Ireland	1989-2006	UKG	West Midlands	
ES42	Castilla-la Mancha	1989-2006	ITC1	Piemonte		UKH	Eastern	
ES43	Extremadura	1989-2006	ITC2	Valle d'Aosta/Vallée d'Aoste		UKI	London	
ES51	Cataluña		ITC3	Liguria		UKJ	South East	
ES52	Comunidad Valenciana	1989-2006	ITC4	Lombardia		UKK	South West	2000-06
ES53	Illes Balears		ITD3	Veneto		UKL	Wales	2000-06
ES61	Andalucia	1989-2006	ITD4	Friuli-Venezia Giulia		UKM	Scotland	1994-2006
ES62	Región de Murcia	1989-2006	ITD5	Emilia-Romagna		UKN	Northern Ireland	1989-2006
ES70	Canarias (ES)	1989-2006	ITE1	Toscana				

Appendix B

1**. Omission bias of the spatial autoregressive term (** $\sum_{j \neq i} w_{ij}.\ln\left(\frac{Y_{j,t}}{pop_{j,t}}\right)$ **)**

The outcome equation is given by (3) and the equation for the allocation of structural funds can be written as:

$$\ln\left(\frac{SF_{i,t}}{pop_{i,t}}\right) = \pi_1 \sum_{j \neq i} w_{ij}.\ln\left(\frac{Y_{j,t}}{pop_{j,t}}\right) + \pi_2 \ln\left(\frac{Y_{i,t-1}}{pop_{i,t-1}}\right) + e_{i,t}$$

where the GDP level in neighbouring regions affects both the amount of funds received by a region (π_1) and its economic development (ρ).

Assume that we resume the previous outcome equation omitting the spatial lag[1]:

$$\ln\left(\frac{Y_{i,t}}{pop_{i,t}}\right) = (1+\beta_1)\ln\left(\frac{Y_{i,t-1}}{pop_{i,t-1}}\right) + \beta_2 \ln\left(\frac{I_{i,t}}{pop_{i,t}}\right) + \beta_3 \ln\left(\frac{pop_{i,t}}{pop_{i,t-1}}\right) + \beta_4 \ln\left(\frac{SF_{i,t}}{pop_{i,t}}\right) + \alpha_i + \mu_t$$
$$+ \underbrace{\left[\rho \sum_{j \neq i} w_{ij}.\ln\left(\frac{Y_{j,t}}{pop_{j,t}}\right) + u_{i,t}\right]}_{\varepsilon_{i,t}}$$

By focusing on the influence of this omission on measuring the impact of structural funds, we can write (with $X_{i,t}$ for control variables, and β_4 the real impact of cohesion policy):

$$E\left[\ln\left(\frac{Y_{i,t}}{pop_{i,t}}\right) \middle| \ln\left(\frac{Y_{i,t-1}}{pop_{i,t-1}}\right), X_{i,t}, \ln\left(\frac{SF_{i,t}}{pop_{i,t}}\right)\right] = \beta_4 \ln\left(\frac{Y_{i,t}}{pop_{i,t}}\right) + \rho \mathrm{E}\left[\sum_{j \neq i} w_{ij}.\ln\left(\frac{Y_{j,t}}{pop_{j,t}}\right) \middle| \ln\left(\frac{SF_{i,t}}{pop_{i,t}}\right)\right]$$

with $\pi_1 = \dfrac{\mathrm{cov}\left(\ln\left(\frac{SF_{i,t}}{pop_{i,t}}\right), \sum_{j \neq i} w_{ij}.\ln\left(\frac{Y_{j,t}}{pop_{j,t}}\right)\right)}{\mathrm{var}\left(\sum_{j \neq i} w_{ij}.\ln\left(\frac{Y_{j,t}}{pop_{j,t}}\right)\right)}$ when the error term are normally distributed, the previous equation can be written as:

$$E\left[\ln\left(\frac{Y_{i,t}}{pop_{i,t}}\right) \middle| \ln\left(\frac{Y_{i,t-1}}{pop_{i,t-1}}\right), X_{i,t}, \ln\left(\frac{SF_{i,t}}{pop_{i,t}}\right)\right] = \left(\beta_4 + \rho\left(\frac{\pi_1}{\mathrm{var}\left(\ln\left(\frac{SF_{i,t}}{pop_{i,t}}\right)\right)}\right)\right)\left(\ln\left(\frac{SF_{i,t}}{pop_{i,t}}\right)\right)$$

[1] This is equivalent to a simple dynamic specification (Esposti and Bussoletti, 2008; Mohl and Hagen, 2010).

The magnitude of this bias $\rho\left(\frac{\pi_1}{\operatorname{var}\left(\ln\left(\frac{SF_{i,t}}{pop_{i,t}}\right)\right)}\right)$ is even more important that the covariance between $\ln\left(\frac{SF_{i,t}}{pop_{i,t}}\right)$ and $\sum_{j\neq i} w_{ij}.\ln\left(\frac{Y_{j,t}}{pop_{j,t}}\right)$ is strong, than the direct effect of the value of the spatial lag is large, and that the variance of the allocation of funds is low.

The direction of bias will depend both on the covariance between the amount of funds received by a region and the GDP level of its neighbors, and of the covariance between the level of development of this region and those of its neighbors.

2. **Omission bias of the autoregressive term (** $\ln\left(\frac{Y_{i,t-1}}{pop_{i,t-1}}\right)$ **)**

Past levels of development are also important to consider: they affect both eligibility and the amount of funds received by a region (Crescenzi, 2009). Studies on cross section (including spatial ones) and static panel (fixed effects and spatial fixed effects estimator) neglect this aspect of the allocation of funds.

Using the previous notations:

$$\ln\left(\frac{Y_{i,t}}{pop_{i,t}}\right) = \rho\sum_{j\neq i} w_{ij}.\ln\left(\frac{Y_{j,t}}{pop_{j,t}}\right) + \beta_2 \ln\left(\frac{I_{i,t}}{pop_{i,t}}\right) + \beta_3 \ln\left(\frac{pop_{i,t}}{pop_{i,t-1}}\right) + \beta_4 \ln\left(\frac{SF_{i,t}}{pop_{i,t}}\right) + \alpha_i + \mu_t$$
$$+ \underbrace{\left[(1+\beta_1)\ln\left(\frac{Y_{i,t-1}}{pop_{i,t-1}}\right) + u_{i,t}\right]}_{\varepsilon_{i,t}}$$

The Omitted-variable bias on the estimated impact of the cohesion policy is written:

$$E\left[\ln\left(\frac{Y_{i,t}}{pop_{i,t}}\right) \middle| \ln\left(\frac{Y_{i,t-1}}{pop_{i,t-1}}\right), X_{i,t}, \ln\left(\frac{SF_{i,t}}{pop_{i,t}}\right)\right] = \left(\beta_4 + (1+\beta_1)\left(\frac{\pi_2}{\operatorname{var}\left(\ln\left(\frac{SF_{i,t}}{pop_{i,t}}\right)\right)}\right)\right)\left(\ln\left(\frac{SF_{i,t}}{pop_{i,t}}\right)\right)$$

We know that $0 < (1+\beta_1) < 1$ (convergence of GDP p.c.) and $\pi_2 < 0$ (redistributive concerns of the cohesion policy). Therefore, the omission of the autoregressive term in the equation (3) leads to underestimate the impact of the policy (downward bias).

Appendix C: Variables description

Variable	Name	Description	Source
$\ln\left(\frac{Y_{i,t}}{pop_{i,t}}\right)$	Initial GDP p.c.	The logarithm of Gross Domestic Product per capita in 1995 euros. For each regions, we scale GDP by dividing its value by the total regional population	Cambridge Econometrics Database (2007)
$\ln\left(\frac{I_{i,t}}{pop_{i,t}}\right)$	Investment p.c.	The logarithm of total Investment per capita in 1995 euros. For each regions, we scale Investment by dividing its value by the total regional population	Cambridge Econometrics Database (2007)
$\ln\left(\frac{pop_{i,t}}{pop_{i,t-1}}\right)$	Population growth	The logarithm of demographic growth rate. This variable depicts the dynamic of total regional population	Cambridge Econometrics Database (2007)
$\ln\left(\frac{SF_{i,t}}{pop_{i,t}}\right)$	SF p.c.	The logarithm of Structural funds commitments per capita expressed in 1995 euros (using GDP deflator)	SF commitments: 14th annual report of the ERDF (1988), 11th annual report of SF (1999, including 2000-06 commitments) GDP deflator: OECD statistics Total regional population: Cambridge Econometrics Database (2007)
$\sum_{j\neq i} w_{ij}.\ln\left(\frac{Y_{j,t}}{pop_{j,t}}\right)$	Spatial lag of GDP p.c.	Spatial autoregressive GDP per capita in 1995 euros	Cambridge Econometrics Database (2007)

[1] In their recent contribution Hagen and Mohl (2009) provides a fundamental review of the econometric evaluation of EU Cohesion Policy in order to shed light on the reasons for the diverging results.

[2] We define this term without distinction of meaning through spatial lag, spatial autoregressive term or spatial spillover.

[3] As in Rodriguez-Pose and Fratesi (2004) among others.

[4] Jacobs *et al.* (2009) allow both processes to be present simultaneously. They argue that spatial error dependence may exist above and beyond the theoretically motivated lag structure;

[5] This specification is similar to that suggested in Mohl-Hagen (2010), but they are using a different estimation method. Specifically, Mohl and Hagen (2010) estimate a simple dynamic model using GMM. They estimate then the spatial dynamic specification using maximum likelihood as it usual for a static spatial panel specification, without taking into account the endogeneity of the autoregressive term and the potential endogeneity of the structural fund allocation. Hence, our estimation strategy seems more adequate to consider both these two sources of endogeneity with the spatial autoregressive term.

[6] Nomenclature of Territorial Unit Statistics (NUTS) provides homogenisation of sub-national boundaries into the European Union. Although the level of decision reference for Cohesion Policy is the NUTS2 level, some Member States use statistical NUTS 1 level for the simple reason that it corresponds to a real administrative level in their own territorial organisation (*e.g.* Lander in Germany).

[7] The Cambridge Econometrics database is available at http://www.camecon.com

[8] See Temple (1999) for an analysis.

[9] Looking at some descriptive statistics (not presented here) one can note that for regions in Spain, Greece and Portugal the GDP p.c. average in 2000-2005 is still below the EU-14 1980-1984 average

[10] We did not use system-GMM because the additional instruments of the level equation are not valid.

[11] This effect is also significant in a specification without the variable measuring the structural funds allocated for Objective 1 program.