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Productivity Dynamics across European Regions: the Impact of Structural and Cohesion Funds

Abstract

This paper analyzes the impact of the European Union regional policy of the three programming periods 1975-1988, 1989-1993 and 1994-1999 on the dynamics of productivity of European regions. On average, funding had a positive, but concave, effect on productivity growth. In particular, a share of funds on GVA of 10% GVA is estimated to raise the regional growth rate of about 0.9% per year. However, by separately considering the three programming periods and the composition of the funds according to the objectives defined by the EU, we find that: i) only the funds allocated in the second and third programming periods, when they remarkably increased, had a significant impact; and ii) only Objective 1 and Cohesion funds played a significantly positive impact, while funds devoted to Objectives 2, 3, 4 and 5 had a negative or non significant impact. The results are robust to potential endogeneity of funds and spatial dependence.

Classificazione JEL: C21; E62; R11; O52

Keywords: European regional policy, structural change, convergence, European regions.

Contents

I. Introduction

The European Union utilizes a relevant part of its budget (about 35% for the period 2007-2013) to promote social and economic cohesion among the regions of its member states. The main instrument is represented by the Structural Funds, which are essentially allocated on regional basis. The Structural Funds are directed towards different aims: physical and human capital accumulation, development of transport infrastructures, aid to the unemployed, support to declining sectors, etc. The overall goal can in general be intended as promoting the competitiveness of European regions (Articles 130(f)-130(p), Single European Act, 1987) and, at the same time: "at reducing disparities between the levels of development of various regions, and the backwardness of the less-favoured regions" (Article 130(a), Single European Act, 1987).

The debate among economists on the effectiveness of EU funds has been mostly carried out through analyses of convergence across European Regions, where convergence is defined in terms of the neoclassical model of Solow (1956), or is evaluated through the dynamics of the cross-region income (or productivity) distribution (see, e.g., Boldrin and Canova (2001)).

At present, the issue appears controversial. For example, as indirect evidence of the ineffectiveness of the funds, some authors point to the recent slowing down of convergence among European regions in a period characterized by a particularly vigorous increase in funding (see, e.g., Boldrin and Canova (2001)). However, contributions aiming at directly assessing the effectiveness of the funds by including funds in growth regressions, do not provide unanimous results. De la Fuente and Vives (1995), Cappelen *et al.* (2003) and Beugelsdijk and Eijffinger (2005) find positive effects of the funds, while in other contributions the results are more articulated. In particular, Rodriguez-Pose and Fratesi (2004) argue that the part of the funds devoted to creating or consolidating human capital had a positive effect on growth of backward regions, differently from the funds devoted to the development of infrastructures. Ederveen *et al.* (2006), instead, find that the funds are effective if the institutions of the recipient economy have a sufficient institutional quality (but their analysis is carried out at country level). Estimating an augmented specification of the Verdoorn's law, Dall'erba *et al.* (2007) find that the impact of funds is negative, although very small. Moreover, when they disaggregate funds by "Objectives" (see below), Objective 1 funds turn out to have a negative effect, while the effect of Objective 2 funds is not significant. Differently, Checherita *et al.* (2009) find evidence that the overall spending of Structural and Cohesion Funds has a positive impact on growth, coming in particular from the Structural Funds devoted to the development of social and human resources, while funds devoted to agriculture have a negative impact on growth. However, the effect of funds on growth disappears when country dummies are introduced in the regressions.

It is likely that such discrepancies depend on the differences among the various studies with respect to the period analyzed, the sample of regions, the type of funds examined, and the econometric techniques adopted. For example, Rodriguez-Pose and Fratesi (2004) study the effect of the whole structural funds for the period 1989-99 on the regions identified by the so-called Objective 1 (that is regions with a per-capita GDP lower than 75% of European average, see European Commission (2001)), while De la Fuente and Vives (1995) focus on the effect of the largest Structural Fund, i.e. the European Regional Development Fund (ERDF), on Spanish regions for the period 1986-90. Moreover, in all cases data are elaborated by the authors on the basis of various publications of the European Union, which forced the researchers to resort to a series of hypotheses to make the amounts of funds homogeneous across periods, and to impute them to the individual regions or to different investment typologies.[1]

This paper aims at evaluating the impact of European Regional Policy on the dynamics of labour productivity across European regions, by proposing a broader analysis than those so far provided. Specifically, we will consider *both* Structural and Cohesion Funds in *three* programming periods: 1975-1988, 1989-1993 and 1994-1999. We analyze labour productivity because it appears better suited than per capita income to evaluate the goal of European Regional Policy, i.e. increasing competitiveness of European regions. We propose a simple growth model to capture the main aspects of funding, i.e. the size and composition of the funds, and then we test its empirical implications on a large database that we built by gathering data from different sources (see Section II.A. for more details).

The main findings of the paper are three. Firstly, structural and cohesion funds increase the growth rate of productivity of the regions in the sample, but the impact appears subject to diminishing returns. In particular, a value of 10% of the ratio funds/regional GVA is estimated to raise on average the regional growth rate of about 0.9% per year. Moreover, this impact is likely to be underestimated given that we use *commitments* instead of *payments* of funds. Regions of Greece, Ireland, Portugal, Spain, Southern Italy and Northern UK appear the have benefitted the most from the European Regional Policy.[2] Overall, since the most benefitted regions were relatively poor, European Regional Policy favoured convergence across European regions' productivities. These results are robust to the potential endogeneity of funds and to the presence of spatial dependence.

Secondly, the size of funds affects their effectiveness. Specifically, the limited size of the funds in the first programming period (1975-1988) is associated to a non significant impact on growth, while the impact is highly significant in the subsequent two programming periods, in which the amount of funding remarkably increased (the share of funds on total GVA of the regions in the sample was equal to 0.28% and 0.5% per year, respectively in the second and third periods, against 0.06% in the first period).

Finally, the composition of funds matters, being the Objective 1 and Cohesion Funds the most effective, while funds allocated to fulfill Objectives 2, 3, 4 and 5 show a negative or non

[1] See, e.g., the appendix in Rodriguez-Pose and Fratesi (2004).

[2] In a companion paper, Fiaschi *et al.* (2009) explore more deeply the impact of European Regional Policy on the *distribution* of productivity across European regions.

significant impact on regions' productivity. Our guess is that the latter funds interfere with an efficient reallocation of resources, in particular from less to more productive sectors.

The paper is organized as follows. Section II. summarizes the main features of European Regional Policy and describes our database; Section III. proposes a neoclassical growth model incorporating the main features of the European Regional Policy; Section IV. presents the results of the empirical analysis, while Section V. contains the robustness checks for endogeneity and spatial dependence; Section VI. concludes.

II. The European Regional Policy: an Overview

Below we summarize the different instruments used by the European Commission in three programming periods: 1975-1988, 1989-1993 and 1994-1999.[3]

- 1975-1988. The European Regional Development Fund (ERDF) was established to finance infrastructure projects and productive investment in less-favoured regions.
- 1989-1993. Regulations were adopted in 1988 to ensure these funds are rationalized and well defined. Structural Funds were concentrated on the areas or social groups in the greatest difficulty according to socio-economic criteria. This led to the definition of five objectives to be reached by the use of the funds:
  - Objective 1: promoting the development and structural adjustment of backward regions, that is regions with a per capita GDP lower than 75% of EU average;
  - Objective 2: revitalising areas facing structural difficulties;
  - Objective 3: combating long-term unemployment;
  - Objective 4: facilitating the occupational integration of young people;
  - Objective 5: speeding up the adjustment of the agricultural and fishing sectors.

  Community Initiative Programmes (CIP) were added to these objectives, by utilizing a limited portion of the Structural Funds on more specific topics.
- 1994-1999. The second generation of Structural Funds is launched. In particular:
  - Objectives 1, 2 and 5 remained unchanged, Objectives 3 and 4 were slightly redefined and the entry of Austria, Finland and Sweden in the European Union led to the creation of Objective 6, to favour regions with very low population densities;

[3] See `http://ec.europa.eu/regional_policy/policy/history/` for more details.

– CIP were slightly redefined;

– a Cohesion Fund of over 15 billions ecus was introduced to help less-developed Member *States*, i.e. states with a per capita GDP below 90% of EU average, to attain the convergence criteria that were defined for the introduction of the economic and monetary union.

Since the reform of 1988 the generic label "Structural Funds" covers a variety of programmes. The main funds are:

- ERDF (European Regional Development Fund). Established in 1975 and directed to less favoured regions, it mainly focuses on productive investment, infrastructures, SME's development, research and development projects. It should generate growth in capital stock, infrastructures, education, and expansion of R&D activities.
- ESF (European Social Fund). Created by the Treaty of Rome in 1986, it is targeted to vocational training, education and employment aid. This fund covers much of Objectives 2, 3 and 4, and a portion of Objective 1. It should favour mobility of labour, raise employment of young people and women, increase educational attainments and R&D.
- EAGGF (European Agricultural Guidance and Guarantee Fund). Introduced in 1962 as part of the Common Agricultural Policy (CAP), it promotes the adjustment of the agricultural sector and rural development. It should generate growth in farming employment, productivity and income, and employment of young people in the agricultural sector.
- FIFG (Financial Instrument for Fisheries Guidance). Established in 1994 and specifically targeted to the fishing industry. It should generate growth in fishing employment, productivity, infrastructure and income.

The purpose of the Cohesion Fund, instead, is to provide financial support for environmental investment projects and for transport infrastructure projects within the Trans-European Transport Network (both public and private). While the former projects should generate water treatment, transportation and environmental improvements, the latter should generate roads and railways. Moreover, the Cohesion Fund is allocated to member *states* (not regions) and, in particular, only countries in line with the program of convergence in the monetary union are eligible.

We submit that the criteria for the allocation of funds do not unambiguously appear directed towards an increase in productivity of regions. In fact, only Objective 1 funds and Cohesion Funds are explicitly targeted to the poorest regions in order to favour productivity catching-up. On the contrary, Objective 2 funds and the support to the agricultural and fishing sectors provided by Objective 5 may actually slow down the productivity growth as long as such funding interferes with the ongoing structural change, in which mature sectors are gradually replaced by more innovative sectors, the size of the agricultural and fishing sectors are shrinking and workers are reallocated to more productive sectors.[4] These types of fundings should be therefore considered more income support than stimuli to productivity growth.[5] In the same respect, Objectives 4, 6 and other types of funds of limited amount appear to be mainly income support.

The discussion would suggest that a breakdown of funds on the basis of the programmes listed above would be very useful for a better understanding of the impact of the Structural Funds on European regional productivity. Unfortunately, this is not possible because a regional breakdown of committed funds is only available for *total* Structural Funds.

II.A. Our Structural and Cohesion Funds Dataset

Data on Structural Funds used in this paper come from different publications of the European Commission. Data cover the first three programming periods, in particular:

- data for 1975-1988 are from European Commission (1989);
- data for 1989-1993 are from European Commission (1995) and European Commission (1997);
- data for 1994-1999 are from European Commission (1997) and European Commission (2000).

These data represent the total Commitments that the European Commission allocated for the entire programming period. Data on total Payments, that is data on funds actually transferred to regions, are available for the last programming period only. All data are transformed in 1995 constant prices.

In this paper we consider European regions at the NUTS 2 level but, since not all funds are allocated directly to individual regions, we adopted the following criteria:

- if the fund is jointly allocated to a group of regions, we reassign it to individual NUTS 2 regions in an amount inversely proportional to their per capita GDP in the initial year of the programming period;
- if the fund is allocated to a country, and is referred to a particular objective for which it is possible to identify the eligible regions (for example Objective 1), then it is reassigned to all the objective regions (e.g. Objective 1) in an amount inversely proportional to their per capita GDP in the initial year of the programming period;

[4]See, e.g., Temple (2001) for a discussion on structural change in Europe and the results of Section IV..
[5]See, e.g., European Commission (2007).

- if the fund is allocated at country level, but it is referred to an objective for which it is not possible to exactly identify the eligible regions (e.g. Cohesion Funds), then we reassign it to all the NUTS 2 regions of the country in an amount inversely proportional to their per capita GDP in the initial year of the programming periods.

We chose to reallocate funds proportionally to per capita GDP since this is the main criterium used in the allocation of most of the funds (e.g. Objective 1 and Cohesion Funds). We also checked that equal reassignment of these funds to regions does not affect our results.

II.B. Descriptive Statistics on Structural and Cohesion Funds

The aim of the paper is to study the impact of both Structural and Cohesion Funds on the dynamics of productivity across European Regions. Our main indicator will be the ratio of funds on regional GVA, labeled *SCF* in the following.[6] Table 1 shows that: i) the total amount of these funds increased over time, raising from 0.06% of total European GVA in the first programming period to 0.5% in the third; ii) the average value of *SCF* slightly decreased; iii) the funds have been distributed more equally over time.

Programming Period	*SCF*/Total GVA	Mean *SCF*	St. Dev. of *SCF*
Period I (1975-1988)	0.06	0.0054	0.0103
Period II (1989-1993)	0.28	0.0054	0.0082
Period III (1994-1999)	0.50	0.0049	0.0065

Table 1: Descriptive statistics on Structural and Cohesion Funds in three programming periods

The increase in the amount of funds is accompanied by a change in the allocation to the different objectives. Table 2 illustrates such changes. In particular, even though Objective 1 attracts the largest amount of funds, between the second and the third period funds devoted to the Cohesion Policy have remarkably increased.[7] Objective 2 funds have a relevant size in the last two periods, and increased their relative weight in the third.

[6]Data on regional GVA and employment are from Cambridge Econometrics (2004).

[7]Given that the Objectives were not defined in the first programming period, we label the whole allocation "Objective 0".

Objective	Period I (1975-1988)	Period II (1989-1993)	Period III (1994-1999)
0	100	-	-
1	-	63.23	61.67
2	-	8.94	9.05
3	-	-	6.68
4	-	-	1.22
3 & 4	-	10.10	-
5	-	9.55	6.85
6	-	-	0.38
NL	-	4.66	-
PIM	-	1.02	-
2 In.	-	-	3.07
Other In.	-	-	1.68
Cohesion	-	2.50	9.39
Tot.	100	100	100

Table 2: Shares of commitments of funds according to Objectives. "NL": New Länder in Germany in Period II; "PIM": regional program in Period II for regions outside Objective 1; "2 In.": regional initiatives similar to Objective 2 for period III (*Adapt*, *Employment*, *Rechard*, *Resider*, *Retex*, *Konver*, *SMEs*), "Other In.": other initiatives in Period III (*Leader*, *Regis*, *Urban*, *Pesca*, *Peace*)

Table 3 reports the share of *SCF* allocated to regions with a per worker GVA lower than the 75% of the sample mean (i.e. the least productive regions). Looking at the total funds, only $35-55\%$ of total Structural and Cohesion Funds appears to be allocated to the least productive regions. The share is higher for Objectives 1 and Cohesion Funds given the fact that they are allocated according to the per capita GDP of the regions.[8] On the contrary, funds devoted to Objectives 2-5 seem to be mainly allocated to more productive regions, especially in the third programming period (almost 30%).

[8]The correlation between the per capita GDP and the per worker GVA of regions in the three programming periods is very high and, respectively, equal to 0.87, 0.83 and 0.86.

	Period I (1975-1988)	Period II (1989-1993)	Period III (1994-1999)
All.Obj	54.03	47.13	35.15
Ob. 1	-	66.18	43.61
Ob. 2	-	11.70	4.68
Ob. 3 & 4	-	18.81	8.36
Ob. 5	-	8.00	3.51
Ob. NL & PIM & 6	-	0	0
Ob. 2 In. & Other In.	-	-	28.01
Cohesion	-	63.22	61.50

Table 3: Percentage of *SCF* given to regions with per worker GVA below 75% of sample mean

II.C. Commitments vs Payments

So far the analysis has focused on the commitments of funds. However, the amount of funds actually spent by the regions is likely to be what effectively matters to measure the impact of funds on regions' productivity. Table 4 reports the ratio between Commitments and Payments for each country of the sample. The generalized reduction of this ratio from the first to the third period might be explained by the regulation adopted in 1988 and, in particular, by the adoption of the *additionality principle*.[9] Some countries, like Spain and Ireland, have however maintained high ratios of payments on commitments over the three periods, while other countries, like United Kingdom, Netherlands and Italy, had very low ratios (especially in the third programming period).

[9]According to the *additionality principle*, the Structural Funds are not intended to be utilized as a substitute for national funding, but rather to provide additional assistance. The Member States were thus under the obligation to maintain their public expenditure at the level of the beginning of the programming period.

Country	Period I (1975-1988)	Period II (1989-1993)	Period III (1994-1999)
AT	-	-	0.59
BE	0.95	0.81	0.70
DE	0.95	0.82	0.71
DK	0.96	0.78	0.76
ES	0.76	0.84	0.80
FI	-	-	0.63
FR	1.10	0.82	0.70
GR	1.08	0.83	0.72
IE	0.92	0.93	0.86
IT	0.88	0.70	0.60
LU	0.47	0.58	0.67
NL	0.99	0.76	0.60
PT	0.98	0.89	0.88
SE	-	-	0.70
UK	0.93	0.80	0.64

Table 4: Ratio of Payments on Commitments in the three periods at country level

Overall, the heterogeneity in the ratio of payments on commitments across countries in the sample suggests to control also for payments in order to have a more precise estimate of the actual impact of *SCF* on productivity.

To sum up, we have documented that: i) the resources devoted by the European Union to the Regional Policy have increased over the three programming periods; ii) the largest amount of Structural Funds is allocated to reach Objective 1; iii) the share allocated as Cohesion Funds is relatively large, and has remarkably increased over the last programming period; iii) Objective 2 funding is also substantial, relatively to the other objectives different from 1.

In the next section we propose a growth model incorporating the main aspects of EU funding, and derive its empirical implications in terms of productivity growth and convergence.

III. A Neoclassical Model of Growth and Regional Convergence

In this section we present a simple neoclassical model of economic growth with regional policy based on Solow (1956) and Barro (1990).[10]

[10]Current discussion on convergence and regional policies in Europe also focuses on spatial aspects, i.e. on possible spillovers across neighbour regions, agglomeration effects, etc. (see, e.g., Puga (2002)). In our model we abstract from these aspects and from possible patterns of regional specialization, although we will include them as controls in the empirical analysis of Section IV..

Output of region i, Y_i, is defined as:

$$Y_i = \Phi\left(SCF_i\right) F\left(K_i, AL_i\right), \tag{1}$$

where SCF_i indicates the funds allocated to region i (with respect to the level of output), K_i and L_i are its capital stock and number of workers, and A measures the exogenous level of technology.[11] Function $F\left(\cdot\right)$ has the standard properties of a neoclassical production function, i.e. it is increasing and concave in both arguments (i.e. $\partial F/\partial K_i$ and $\partial F/\partial AL_i > 0$, $\partial^2 F/\partial K_i^2$ and $\partial^2 F/\partial AL_i^2 < 0$) and is homogeneous of degree 1.

Function $\Phi(\cdot)$ captures the impact of structural funds on the output of region i. We assume that $\Phi(\cdot)$ is increasing in its argument(s), i.e. $\Phi'(\cdot) > 0$, and that $\Phi(0) = 1$, i.e. the availability of structural funds is not essential to carry out production.

With this specification, the marginal product of private factors positively depends on *SCF*.[12] Eq. (1) appears a very flexible way of introducing the structural funds into the production function. Section III.C. discusses an extension to the case of different types of funds.

Following Solow (1956), we assume that the investment rate of region i is constant and equal to s_i. Thus, the equation describing capital accumulation in region i is:

$$\dot{K}_i = s_i Y_i - \delta K_i, \tag{2}$$

where δ is the depreciation rate of capital (assumed for simplicity equal for all regions). From Eqq. (1) and (2) we have:

$$\dot{K}_i = s_i \Phi\left(SCF_i\right) F\left(K_i, AL_i\right) - \delta K_i,$$

from which:

$$\frac{\dot{K}_i}{K_i} = \frac{s_i \Phi\left(SCF_i\right) F\left(K_i, AL_i\right)}{K_i} - \delta.$$

Assuming that A and L_i grow, respectively, at constant rates g and n_i, we have:

$$\frac{\dot{\hat{k}}_i}{\hat{k}_i} = \frac{s_i \Phi\left(SCF_i\right) f(\hat{k}_i)}{\hat{k}_i} - (\delta + n_i + g), \tag{3}$$

where $\hat{k}_i \equiv K_i/AL_i$ is the capital per worker measured in efficient units, and $f \equiv F\left(K_i/AL_i, 1\right)$, with $f(\cdot)' > 0$ and $f(\cdot)'' < 0$.

[11] For the sake of simplicity we omit the time subscripts.
[12] Public expenditure in Barro (1990) has the same impact on output as *SCF*.

III.A. Equilibrium

Eq. (3) implicitly defines the equilibrium level of $\hat{k}_i^*$, i.e.:

$$\frac{f(\hat{k}_i^*)}{\hat{k}_i^*} = \frac{\delta + n_i + g}{s_i \Phi\left(SCF_i\right)}. \tag{4}$$

Eq. (4) highlights that an increase in the level SCF_i leads to an increase in the equilibrium level of capital (as $f(\hat{k}_i^*)/\hat{k}_i^*$ is decreasing in $\hat{k}_i^*$). This is a general conclusion for an economy with a production function as in Eq. (1).[13]

From Eq. (4) (or Eq. (5)) it is straightforward to show that the effect of funds on the equilibrium level of capital is positive but decreasing, i.e. $d\hat{k}_i^*/dSCF_i$ is decreasing in SCF_i, when $\partial^2\Phi/\partial SCF_i^2 < 0$.

III.B. Transitional Dynamics to Equilibrium

The presence of structural funds also affects the transitional dynamics to equilibrium and the relative speed of convergence. Assume that $F(\cdot)$ is Cobb-Douglas, i.e.:

$$F\left(K_i, AL_i\right) = K_i^\alpha \left(AL_i\right)^{1-\alpha}, 0 < \alpha < 1,$$

from which:

$$f(\hat{k}_i) = \hat{k}_i^\alpha.$$

From Eq. (4) we have that:

$$\hat{k}_i^* = \left[\frac{s_i \Phi\left(SCF_i\right)}{\delta + n_i + g}\right]^{\frac{1}{1-\alpha}} \quad \text{and} \quad \hat{y}_i^* = \left[\frac{s_i \Phi\left(SCF_i\right)}{\delta + n_i + g}\right]^{\frac{\alpha}{1-\alpha}} \tag{6}$$

The log-linearization around the equilibrium level of output leads to:

$$\log \hat{y}_{i,t} = \left(1 - e^{-\lambda_i t}\right) \log \hat{y}_i^* + e^{-\lambda_i t} \log y_{i,0}, \tag{7}$$

where λ_i measures the speed of convergence, $\hat{y}_{i,t}$ and $\hat{y}_{i,0}$ are, respectively, output in efficiency units at period t and period 0. Considering that the values of $\hat{y}_i$ are unobservable, and de-

[13] Assuming a standard intertemporal optimization framework with agents having an intertemporal elasticity of substitution equal to $1/\sigma$ (e.g. with instantaneous utility given by $c^{1-\sigma}/\left(1-\sigma\right)$), and with a discount rate given by ρ, the equilibrium level of capital in efficient units is implicitly defined by:

$$\left.\frac{\partial f(\hat{k}_i)}{\partial \hat{k}_i}\right|_{\hat{k}_i = \hat{k}_i^*} = \frac{\rho + \delta + \sigma g}{\Phi\left(SCF_i\right)}. \tag{5}$$

Again, $\hat{k}_i^*$ is a positive function of SCF_i.

noting labour productivity in region i as $y_i = Y_i/L_i = \hat{y}_i/A$, some manipulations lead to the approximate (around the equilibrium) transitional dynamics of output:[14]

$$\gamma_i = \frac{\log y_{i,t} - \log y_{i,0}}{t} = g + \beta \log \hat{y}_0 - \beta \log \hat{y}_i^* - \beta log A_{i,0}, \tag{8}$$

where γ_i is the average growth rate of productivity between period 0 and period t, and $\beta = (1 - e^{-\lambda t})/t$ (assuming that $\lambda_i = \lambda, \forall i$).

By introducing the expression for $\hat{y}_i^*$ in Eq. (8), we obtain:

$$\gamma_i = g - \beta log A_{i,0} + \beta \log y_{i,0} - \frac{\alpha\beta}{1-\alpha} \log s_i + \frac{\alpha\beta}{1-\alpha} \log(\delta + n_i + g) - \frac{\alpha\beta}{1-\alpha} \log \Phi(SCF_i). \tag{9}$$

Eq. (9) represents the basis of our empirical analysis. Basically, it tests the empirical predictions of the Solow model modified by the introduction of funds. If the estimated value of β is negative, investments have a positive impact on growth, labour force growth has a negative impact, as the initial level of output. The latter effect would imply *β-conditional convergence*. Structural funds are instead expected to have a positive impact, i.e. $\partial\gamma_i/\partial SCF_i = -(\alpha\beta/1-\alpha)(\Phi'(SCF_i)/\Phi(SCF_i)) > 0$. Therefore, cœteris paribus, regions receiving more funding should grow faster. Finally, the marginal impact of SCF_i on γ_i, i.e. $\partial\gamma_i/\partial SCF_i$, is increasing or decreasing with respect to SCF_i depending on the sign of $\Phi''(\cdot)$. According to the law of decreasing marginal returns, we expect that the marginal effect of funds is decreasing as the total amount of funds increases, that is $\Phi''(\cdot) < 0$, and, therefore, $\partial^2\gamma_i/\partial {SCF_i}^2$ should be negative.

III.C. Extensions and Caveats

Possible extensions to the baseline model can address two relevant issues. The first is the actual impact of structural funds on the output of region i. In Section II. we have described many types of funds and have argued that some funds appear explicitly aiming at improving productivity in the poorest regions (e.g. Objective 1 funds and Cohesion Funds), while others appear more targeted to subsidize the income of, e.g., workers employed in certain sectors (e.g. Objectives 2 and 5 funds). Therefore Eq. (1) could be rewritten as:

$$Y_i = \Phi\left(SCF_i^{OB_1}, SCF_i^{OB_2}, ...\right) F\left(K_i, AL_i\right),$$

where $SCF_i^{OB_1}$ are structural funds for Objective 1, $SCF_i^{OB_2}$ are structural funds for Objective 2, etc. From the very definitions of the objectives, therefore, it is possible to conjecture that different types of funds may have a different impact on the output of region i. In extreme cases,

[14] See Durlauf *et al.* (2005), pp. 577-579.

when the fund interferes with the reallocation of labour from a less productive sector to a more productive one (e.g. from the agricultural sector to industrial sectors), cœteris paribus, it could negatively affect regional productivity. In short, it is possible that for some Objective J:

$$\frac{\partial Y_i}{\partial SCF_i^{OB_J}} \leq 0. \tag{10}$$

In the empirical analysis we will show that such case is indeed possible (in particular for Objective 2 funds).

The second aspect is that Eq. (3) neglects any inflow and outflow of capital and labour. For European regions these assumptions appears to be very restrictive given the high mobility of both factors, at least within national borders.[15] Taking into account these features should increase the speed of convergence across the regions, reducing the importance of the saving rates of the individual regions with respect to their investment rates.

Finally, we remark that the model does not consider how *SCF* are financed i.e., differently from Barro (1990), we do not consider a budget constraint of the EU. This prevents us to consider the funds' allocation that could maximize the aggregate growth of the European economy.

IV. Empirical Analysis

This section evaluates the empirical implications of the model of Section III.. Our baseline specification is based on Eq. (9). In particular, it adds to the regressors identified in Eq. (9) a vector $\mathbf{Z}$ of controls which should capture other possible regional growth determinants which, in the original specification of Mankiw *et al.* (1992) should be captured by the initial level of technology $A_{i,0}$, and a region-specific shock υ_i. Moreover, we specify $\Phi(\cdot)$ as:

$$\Phi(SCF_i) = e^{\eta_1 SCF_i + \eta_2 SCF_i^2}, \tag{11}$$

which respects our assumptions, i.e., $\Phi(0) = 1$ and $\Phi'(\cdot) > 0$, and allows for the presence of nonlinearities in the effects of the funds, i.e. it allows to test whether $\partial^2\gamma_i/\partial SCF_i{}^2$ is negative by the estimated value of η_2.

Hence, assuming no constraints on the coefficients, we have:

$$\gamma_i = intercept + \beta_{y_0}\log y_{i,0} - \beta_s \log s_i + \beta_n \log(\delta + n_i + g) + \beta_{SCF} SCF_i + \beta_{SCF^2} SCF_i^2 + \boldsymbol{\beta}\mathbf{Z} + \upsilon_i, \tag{12}$$

where $\beta_{SCF} = -(\beta\alpha\eta_1)/(1-\alpha)$, $\beta_{SCF^2} = -(\beta\alpha\eta_2)/(1-\alpha)$, and $\boldsymbol{\beta}$ is the vector collecting the coefficients of the control variables $\mathbf{Z}$.

[15]But see the remarks of Puga (1999) and Puga (2002) on the low mobility of labour in Europe.

IV.A. Results

We study the period 1980-2002, and consider regions at NUTS 2 level for 12 EU countries. In particular, we do not consider Austria, Finland and Sweden since they jointed in the EU only on 1 January 1995 and, consequently, they received funds only in the third programming period.[16] Our dependent variable is the annual average growth rate of per worker GVA of a region. For short, we will indicate this as labour productivity.

We will include as explanatory variables:[17] the share of funds on regional GVA with a three-year lag *SCF*;[18] the initial productivity level, normalized with respect to sample average (*PROD.REL1980*); some variables suggested by the standard Solow model and present in the model of Section III., such as the average annual investment rate (*INV.RATE*), and the average annual employment growth rate (*EMP.GR*). In addition, following Fiaschi and Lavezzi (2007), we add: the density of economic activity (*ECO.DEN*), measured by GVA per km^2, to control for the possible presence of agglomeration effects (see Ciccone and Hall (1996)); some variables that control for the structure of the regional economy, such as the initial value of the relative share of GVA in Manufacturing (*MAN1980*), Mining (*MINEG1980*), Construction (*COSTR1980*), Non Market Services (*NMS1980*), Financial Services (*FIN1980*), Hotels and Restaurants (*HOT1980*), Transportation (*TRANSP1980*), Wholesale and Retail (*WHR1980*), Other Services (*OS1980*). We separately consider the effect of the size of the agricultural sector, by utilizing the change between 1980 and 2002 of the agricultural share on GVA (*DELTA.SHARE.AGRI*). Furthermore, we consider a variable to control for the possible presence of spatial effects (*SPATIAL.IDX*), which are indicated as relevant by a large literature on regional convergence.[19] Finally, we introduce country dummies (excluding Germany) to capture the effects of variables like political institutions, regulation in labour and product markets, educational systems, etc., i.e. variables whose dimension is typically national, or for which we have not data at regional level.

The average growth rate of employment EMP.GR is augmented by the rate of depreciation of capital,[20] but not by the long-run trend of productivity, as the latter is already taken into

[16] Appendix A contains the list of regions.

[17] Appendix B contains the descriptive statistics of the variables.

[18] Specifically, for a given programming period, we consider the yearly average level of funds for the whole period divided by the level of GVA at the beginning of the period. For example, the growth rate of productivity over the period 1980-2000 is regressed on the yearly average of funds relative to the period 1977-1999 divided by the level of GVA in 1977. Results are robust to alternative lags (1-4 years). Moreover, results are similar when region ES63 (Ceuta and Melilla) is removed from the sample (the value of region ES63's GVA appears uncertain, given that the values reported in Cambridge Econometrics (2004) and in Eurostat-Regio datasets present a huge discrepancy for the most recent years).

[19] See Magrini (2004). Our variable is based on the Getis and Ord index and it is calculated on the basis of the geographical distance among regions. The index takes on a positive value when high productivity values are clustered together, while it takes negative values when low values are clustered together. See Fiaschi and Lavezzi (2007) for details. A further treatment of spatial dependence is presented in Section V..

[20] Given that we do not have data on capital at regional level, we use the value of 0.03 proposed by Mankiw *et al.* (1992).

account by considering relative productivity. The initial composition of output leads to a better definition of the initial level of productivity of a region and provides useful information on the role of different sectors; the change in the size of the agricultural sector should capture a relevant aspect of structural change of the regional economies, on the assumption that a reduction of the size of the agricultural sector should positively contribute to productivity, if workers are reallocated to more productive sectors (e.g. manufacturing).

Table 5 contains the results of our preferred OLS specification with and without the variable *SCF*.[21]

	without *SCF*	with *SCF*	with SCF^2
COUNTRY DUMMIES	YES	YES	YES
SECTORAL CONTROLS	YES	YES	YES
SPATIAL CONTROLS	YES	YES	YES
Intercept	-0.0034 (0.6439)	0.0007 (0.9341)	0.0037 (0.6811)
log(PROD.REL.1980)	-0.0174 (0.0000)	-0.0167 (0.0000)	-0.0158 (0.0000)
log(INV.RATE)	0.0034 (0.1596)	0.0040 (0.1426)	-
log(EMP.GR)	-0.0061 (0.032)	-0.0069 (0.0006)	-0.0047 (0.0299)
SCF	-	0.0466 (0.0056)	0.1855 (0.0093)
SCF^2	-	-	-0.8677 (0.0317)
Obs. 173	$\bar{R}^2 = 0.679$	$\bar{R}^2 = 0.739$	$\bar{R}^2 = 0.742$

Table 5: Best linear models with and without *SCF*. Dependent variable: annual average growth rate of GVA per worker. Estimation method: OLS; p-values in parenthesis, based on White-heteroskedasticity robust standard errors.

In the second column of Table 5 we see that the variable *SCF* is significant, and that it positively contributes to $\bar{R}^2$. In addition, when we introduce a quadratic term for *SCF* (see the third column), we obtain significant coefficients for *SCF* and SCF^2, and a modest further contribution to $\bar{R}^2$. This suggests that, on average, regional productivity benefited from the funds distributed in the three programming periods, but the estimated relationship between *SCF* and the productivity growth rate is concave.[22]

In addition, Table 5 reveals the presence of conditional convergence, as the coefficients on initial productivity are negative, statistically significant and quite stable across specifications, and shows that the growth rate of the labour force reduces growth, while the investment rate

[21] This is obtained by estimating first of all a regression with all the explanatory variables, and sequentially eliminating the least significant, in order to obtain the highest goodness of fit measured by the adjusted R^2. See Wooldridge (2003), pp. 192-296.

[22] In a regression not including sectoral controls and the quadratic term for *SCF*, the term for *SCF* is not significantly different from zero (its p-value is equal to 0.35).

has not a significant effect.[23]

Figure 1 reports the curve based on the estimated coefficients of *SCF* and SCF^2, which highlights the decreasing marginal impact of *SCF* on productivity growth.[24]

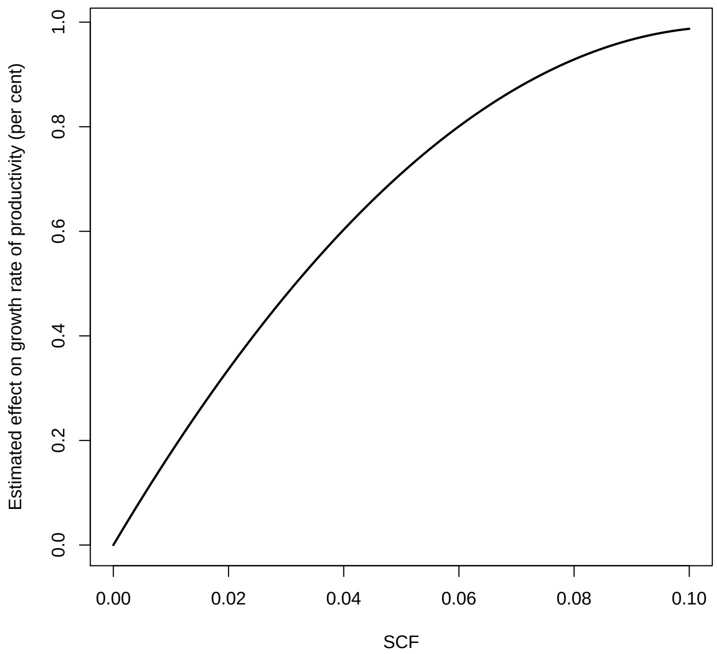

Figure 1: Estimated impact of *SCF* on the growth rate of productivity

The impact of *SCF* appears sizable: starting from zero, an increase of one standard deviation of *SCF* (equal to 0.02) produces an increase of approximately 0.3 points of the average annual productivity growth rate.

Table 6 contains the results of various robustness checks and extensions of the best linear model (all performed by applying OLS). In particular, we checked the stability of the estimated coefficients of funds in different periods, and separately considered the effects of different types of funds. We considered a quadratic term for the fund(s) in all the models presented.

In particular, Model I is based on a pooled regression with dummies on the different programming periods. Period II and Period III are jointly considered for their relative shortness (Period II lasts only five years while Period III just six years). Model II is based on a pooled regression with dummies on the different programming periods (again Period II and III are jointly considered) and on the coefficients of *SCF*. Model III and IV are cross-sections that consider only the most substantial funds, i.e. funds given for Objective 1, the Cohesion Funds

[23]In the first column, the investment rate is included in the best specification, albeit with a nonsignificant coefficient, while in the second and third columns the investment variable was dropped in the procedure to obtain the best specification.

[24]The curve is plotted for the range $(0-0.10)$ of *SCF*, which contains approximately 98% of observations.

as well as the ERDF, i.e. the only fund utilized in the first programming period when objectives were not defined. Models V, VI and VII introduce a breakdown of the funds according to the objectives and, therefore, are cross-sections which only cover the second and third programming periods. Models IX and X separately consider the effects of commitments and payments for the third programming period, being the only one for which we have data.

In Model I the effect of *SCF* appears nonlinear, although the quadratic term is not significant. With respect to results in Table 5, both coefficients of *SCF* are lower in magnitude and in statistical significance. This is likely due to two reasons: i) separating the funds allocated in each period implies that the funds of the first programming period, which were low in size and allocated to few regions, reduced the overall effect of *SCF* on growth; and ii) the consideration of funding in the different periods increases the variance of the regressor, and therefore reduces the estimated coefficient. The drop in significance can be explained by results in Model II.

Model II shows that the effect of *SCF* on growth in the three programming periods (the last two are jointly considered) is remarkably different. It is not significant in Period I, while it is significantly positive in Period II & III. Hence, the magnitude and significance of the "average" coefficient of *SCF* in Model I and in Table 5 essentially depends on the effectiveness of the funds in the second and third programming periods. We take this result as evidence of a possible threshold effect on growth of the size of funding.

Models III and IV are cross-sections over the entire period and are focused on Objective 0, Objective 1 and Cohesion Funds. The estimates show that even separately funds have a positive, concave and highly significant effect on growth. A comparison of the coefficients reveals that the marginal effect is lower when the Cohesion Funds are added. This is likely caused by the measurement error induced by our reassignment of Cohesion Funds across NUTS2 regions (recall that Cohesion Funds are allocated at country level).

Models V, VI and VII focus on the last two programming periods (since we can not break down the funds by objectives in Period I). Model V shows that funds allocated to Objective 1 are the only ones with a positive and highly significant effect.[25] Funds devoted to Objective 2 instead have a negative and significant effect. Finally, funds devoted to Objectives 3-5 do not have a significant impact on productivity growth.[26] Estimates of Models V, VI and VII suggest that the effects of funds on growth differ across types of fund. Funds devoted to "poor" regions have the strongest effect: from our reading of the criteria adopted by the EU, these funds are those most likely to be directly targeted to productivity-enhancing uses. On the contrary, funds such as those allocated to fulfil Objectives 2-5, are likely to include a higher share devoted to distributive purposes. For example, Objective 2 funds, aiming at aiding areas affected by serious industrial crises, as long as they try to support these industries, can

[25] According to the model selection based on $\bar{R}^2$ the quadratic term relative to Objective 1 is retained even though not statistically significant at the usual levels of significance.

[26] The amounts of funds devoted to Objectives 3-5 are relatively small, and therefore have been aggregated in the regressions.

represent a support to inefficient activities and, therefore, interfere with an efficient allocation of resources. The same argument can apply to Objective 5 funds, when they explicitly aim at providing: “measures to support farm incomes and maintain activities in mountain, hill or less-favoured areas” (European Commission (2002)). The non statistically significance of the estimated coefficient for Objectives 3-5 and the negative coefficient estimated for Objective 2 indicate that the impact on productivity of these funds is indeed ambiguous.

Moreover, the estimates of Models VI and VII show that Objective 1 funds and Cohesion Funds distributed in second and in third programming periods had a significant positive, but linear, effect on productivity growth. However, the shorter period of observation seems to reduce the overall fit of the estimate, as shown by the decrease in $\bar{R}^2$ in models VI and VII.

Models VIII and IX show that the effect is highly significant for both the payments and the commitments in the third programming period (the only one for which we have data on commitments and payments). However, the estimated impact using the commitments seems to underestimate the true impact of the funds, which results using the payments in the regressions.

Figure 2 compares the estimated impact of SCF on the annual growth rate of productivity for Model VIII and IX, i.e. commitment versus payments.

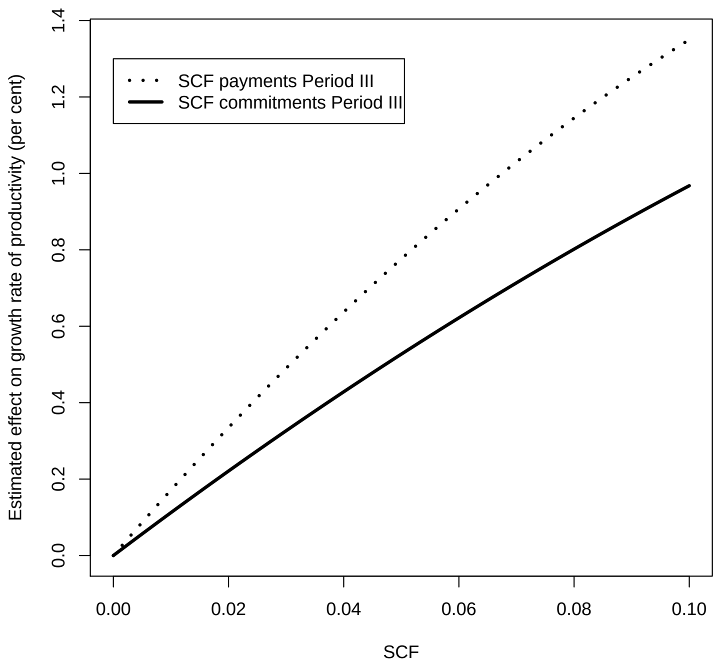

Figure 2: Estimated impact of SCF on the growth rate of productivity. Coefficients from Models VIII and IX in Table 6.

The difference between the marginal impacts of commitments and payments reveals that for high levels of SCF (about 0.1) the bias in the estimated impact may amount to about 0.3

	I	II	III	IV	V	VI	VII	VIII	IX
TIME DUMMIES	YES	YES	NO	NO	NO	NO	NO	NO	NO
Intercept	−0.0461 (0.0000)	−0.0447 (0.0000)	−0.0253 (0.0019)	−0.0250 (0.0022)	−0.1086 (0.0000)	−0.1016 (0.0009)	−0.1013 (0.0000)	−0.0615 (0.0000)	−0.0613 (0.0000)
log(PROD.1980)	−0.0204 (0.0000)	−0.0211 (0.0000)	−0.0153 (0.0000)	−0.0151 (0.0000)	−0.0129 (0.0126)	−0.0137 (0.0033)	−0.0137 (0.0033)	−0.0166 (0.0016)	−0.0164 (0.0015)
log(EMP.GR)	−0.0118 (0.0000)	−0.0121 (0.0000)	−0.0057 (0.0035)	−0.0056 (0.0044)	−0.0218 (0.0000)	−0.0203 (0.0000)	−0.0203 (0.0000)	−0.0221 (0.0000)	−0.0222 (0.0000)
SCF	0.0813 (0.0298)							0.1140 (0.0006)	
SCF^2	−0.1200 (0.3898)							−0.1723 (0.0460)	
Period I∗*SCF*		−0.0905 (0.7993)							
Period I∗SCF^2		15.0706 (0.1860)							
(Period II & III) ∗*SCF*		0.0409 (0.0454)							
(Period II & III)∗SCF^2		−0.1217 (0.3935)							
OB0.OB1			0.2355 (0.0028)						
$OB0.OB1^2$			−1.3731 (0.0158)						
OB0.OB1.CF				0.2178 (0.0020)					
$OB0.OB1.CF^2$				−1.1093 (0.0107)					
OB1					0.1208 (0.0113)	0.1208 (0.0112)			
$OB1^2$					−0.1644 (0.3636)	−0.1489 (0.3880)			
OB2					−1.6653 (0.0102)				
$OB2^2$					-				
OB3.OB4.OB5					0.2286 (0.3176)				
$OB3.OB4.OB5^2$					-				
OB1.CF							0.1087 (0.0091)		
$OB1.CF^2$							−0.1331 (0.3162)		
SCF.Payments									0.1755 (0.0006)
$SCF.Payments^2$									−0.4051 (0.0260)
R^2	0.558	0.558	0.745	0.747	0.692	0.675	0.673	0.799	0.798
Obs.	344	344	173	173	173	173	173	173	173

Table 6: Robustness checks. All regressions include country dummies, control for sectoral composition of GVA in the initial period, and for the presence of spatial (SPAT.IDX) and agglomeration (log(ECO.DEN)) effects; *SCF* with three-year lags; p-values in parenthesis, based on White-heteroskedasticity robust standard errors.

percentage points in terms of annual growth rate. Another point of view to look at Figure 2 is to consider a target increase in the annual growth rate of productivity of a region, say 0.8 percentage points: if all funds allocated to the region are indeed used, the funds needed to reach this goal are about 5% of GVA of that region instead of 8%.

Finally, all regressions show evidence of conditional convergence. The coefficient of the initial level of productivity appears to be highly significant and slightly lower for the second and third period. However, for well-know reasons (see, e.g., Durlauf *et al.* (2005)) a negative coefficient on initial income in cross-section analyses may provide misleading information on convergence. A more exhaustive discussion of the issue of conditional convergence requires the adoption of the distribution dynamics approach (see Fiaschi *et al.* (2009)).

IV.B. The Estimated Impact of *SCF* on Individual Regions

Figure 3 shows the estimated impact of *SCF* on the annual productivity growth rate of regions according to the estimate of the best model reported in Table 5. The regions with the highest impact (more than an annual growth rate of 0.25%) are located in the periphery of the Europe, that is in Portugal, Spain, Ireland, North of United Kingdom, South of Italy and Greece. On the contrary, regions of the core of Europe, i.e. of Belgium, Germany, France and Denmark, show a very low impact, with the exception of some regions of France and United Kingdom (between 0.05% and 0.10% in terms of annual growth rate).

Figure 4 shows that the impact of *SCF* on the annual productivity growth rate for the funds given in Periods II and III only appears very similar to the estimate for the three periods.

Figure 5 reports the impact of Objective 1 funds according to the estimate of Model V in Table 5. Regions with the highest impact appear concentrated in Ireland, Spain and Greece.

Finally, Figure 6 shows that the negative impact of Objective 2 funds according to the estimate of Model V reported in Table 5 appears more serious in Northern Spain and Northern England.

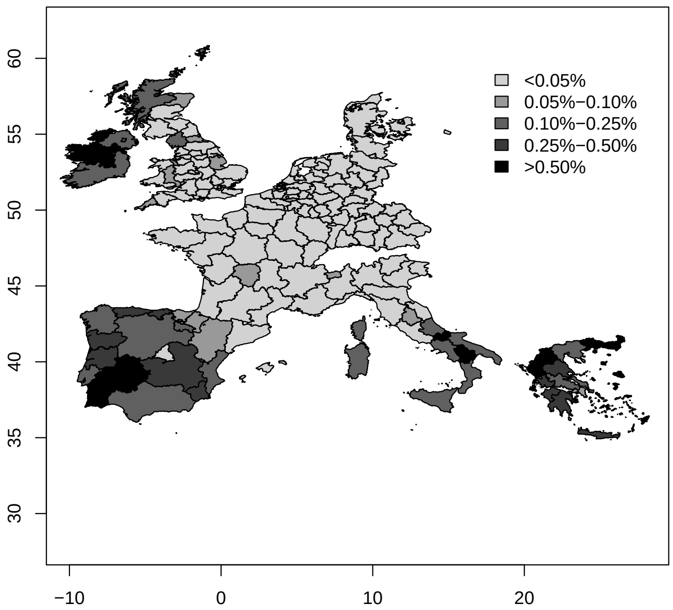

Figure 3: Estimated impact of *SCF* on annual growth rate of productivity of individual regions (for a better visualization Açores, Canarias and Madeira are not reported in the figure)

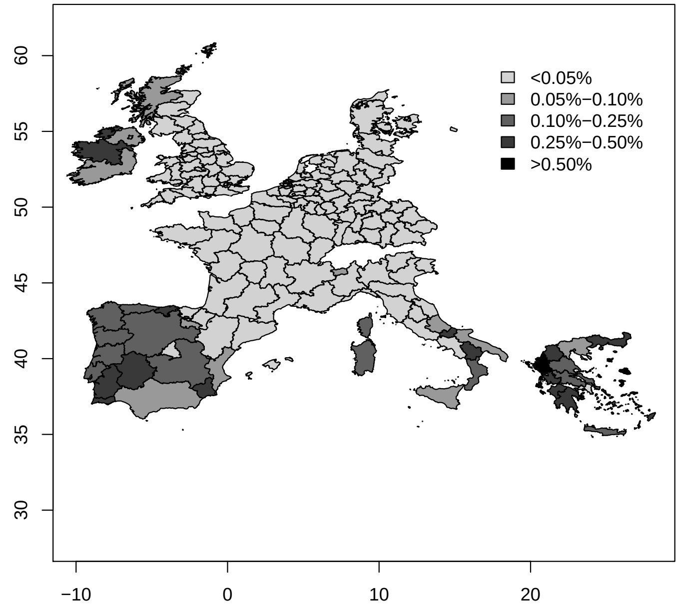

Figure 4: Estimated impact of *SCF* on annual growth rate of productivity of individual regions (Period II and III only)

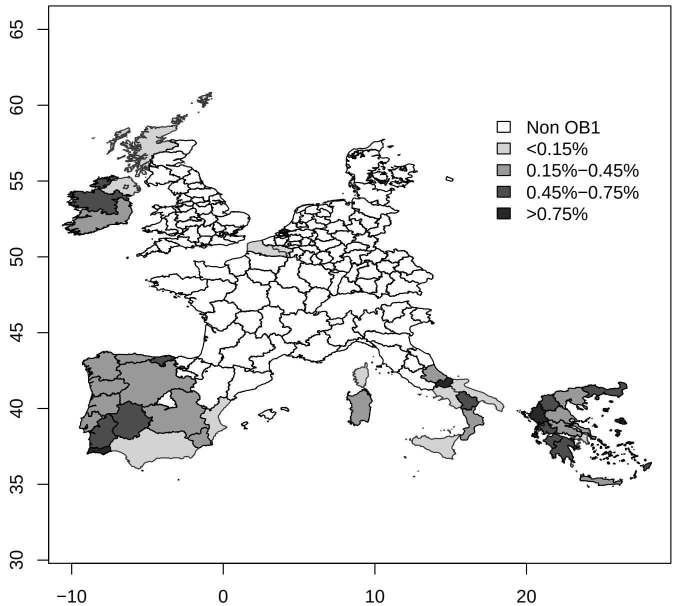

Figure 5: Estimated impact of Objective 1 funds on annual growth rate of productivity of individual regions

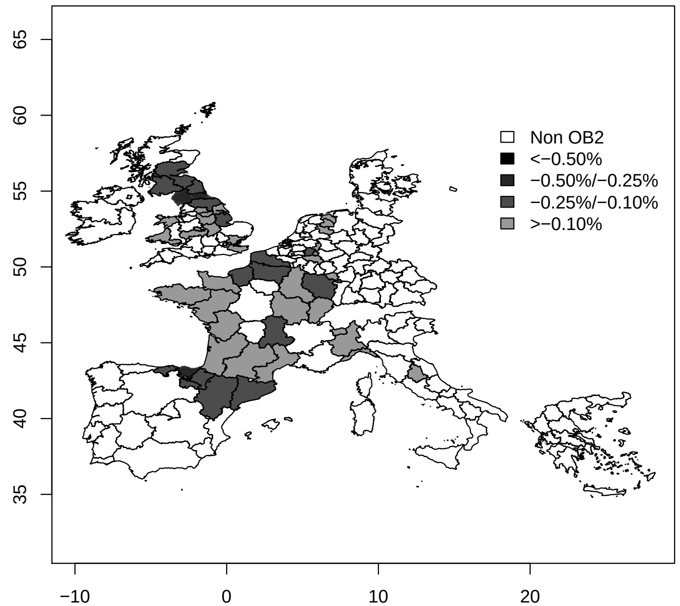

Figure 6: Estimated impact of Objective 2 funds on annual growth rate of productivity of individual regions

V. *Robustness of results*

In the following we discuss the robustness of results to the possible presence of endogeneity and spatial dependence.

V.A. Endogeneity of Structural and Cohesion Fund

The variable *SCF* is potentially endogenous. Funds are indeed not allocated randomly, but they are in principle conditional on per capita GDP, implying potential reverse causality of productivity growth on per capita *SCF* (on the assumption that an increase in productivity implies an increase in per capita GDP which, consequently, affects the *SCF* allocation). Moreover, in our analysis the endogeneity of *SCF* could also arise by the measurement error induced both by the use of commitments instead of payments and by our reassignment of some funds to NUTS2 regions. In order to test for the exogeneity of *SCF* (and its square), the Durbin-Wu-Hausman test is performed in its regression-based form on the subperiod 1989-1999, using as instruments all the exogenous explanatory variables of the model and some additional instruments.[27]

We define four instruments for *SCF*. The first instrument, denoted *INSTR.3G*, is derived by the three-group method described in Kennedy (1992), in which the instrumental variable takes values -1, 0 or 1 if the potentially endogenous variable is respectively in the top, middle or bottom third of its ranking. This instrument is usually utilized when variables are subject to measurement error. The second instrument is the lagged value of *SCF* (that is, the value of *SCF* in the first programming period, 1975-1988, denoted as *INSTR.SCF.1975_1988*). The latter should be a valid instrument since it is correlated with *SCF* of Period II and III, but it should not be correlated with the error term. Finally, the last two instruments are variables that, in separate analyses,[28] we find to be relevant determinants of funds'allocation, that is the regional share of population (*INSTR.POP.SH.1986_1988*), and relative per capita GDP (*INSTR.REL.GDP.1986_1988*), that we consider by three-year average values (1986-1988) . Accordingly, the instrument for SCF^2 derived by the three-group method, i.e. $INSTR.GR^2$, is calculated by SCF^2, while the other three instruments, i.e. $INSTR.SCF.1975\_1988^2$, $INSTR.POP.SH.1986\_1988^2$ and $INSTR.REL.GDP.1986\_1988^2$ are calculated taking the square of respective variables.[29]

Table 11 in Appendix C reports the results of first-stage and second-stage regressions of

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[27]For more details see Wooldridge (2002), pp. 118-122.

[28]Results are available upon request.

[29]Endogeneity tests assume that instruments used in the first-stage regressions are valid, i.e. they are assumed not to be correlated with the error term. However, this cannot be the case for the type of instrument like INSTR.3G as discussed by Fingleton and Le Gallo (2008). The Sargan test of overidentifying restrictions allows to check the hypothesis of validity of all instruments (for more details see Wooldridge (2002), pp. 122-124). The resulting statistics of the Sargan test of both *SCF* and SCF^2 is equal to 6.64 against a critical value of 122.69 while the statistics for *SCF* only is equal to 5.69 against a critical value of 126.31. We then conclude that all the instruments are valid.

Durbin-Wu-Hausman test. Results of the first-stage regression for *SCF* show that all the instruments are statistically significant at the usual significance level. In the first-stage regression for SCF^2 instead $INSTR.REL.GDP.1986\_1988^2$ is not significant and $INSTR.SCF.1977\_1988^2$ is significant only at 10% level. The null hypothesis that *SCF.1989-1999_RES* and $SCF.1989\text{-}1999\_RES^2$ (the residuals of the first-stage regressions) are jointly equal to zero cannot be rejected at high level of significance (i.e. with a p-value of 0.83). We then conclude that both *SCF* and SCF^2 are exogenous.

For the sake of completeness we also check for the exogeneity of *SCF* alone (in fact, in some of the estimated models the effect of *SCF* appeared linear). Table 12 in Appendix C reports the results of first-stage and second-stage regressions. All the instruments are statistically significant at the usual significance level. The null hypothesis that the coefficient of $SCF.1989\text{-}1999\_RES$ is equal to zero cannot be rejected at the usual significant level (p-value is equal to 0.47). We then conclude that *SCF* is exogenous.

V.B. Spatial dependence

Spatial dependence across regions can be caused by a variety of factors among which the arbitrary delineation of spatial units of observations, spatial aggregation and, most importantly, the presence of spatial externalities and spillover effects. As pointed out by Boldrin and Canova (2001) perhaps the regions obtained by the NUTS aggregation introduced by the European Commission are not the appropriate units of observation, since they refer to administrative units which do not necessarily reflect homogeneous economic characteristics. Moreover, a large part of the empirical literature already showed the typical core-periphery structure of Europe in terms of per worker GDP and its growth rate (see, e.g., Fiaschi and Lavezzi (2007)), suggesting the possible presence of spatial effects.

Spatial dependence can be present in two ways: i) *spatial lag dependence*, i.e. spatial correlation in the dependent variable and, ii) *spatial error dependence*, i.e. spatial correlation in the error term (see, e.g., Anselin (1988) for more details).

Spatial lag models assume that the outcome in a given area (e.g. a region) is dependent on the outcome of its neighbours. In spatial error models, instead, the spatial autocorrelation affects the covariance structure of the random disturbance terms. The standard explanation for this type of spatial dependence is that unmodeled effects may spill over across units of observation resulting in spatially correlated errors.

In order to detect the possible presence of spatial dependence, a set of maximum likelihood tests has been performed. In particular: (i) the *LMerr* test, which is a Lagrange Multiplier test with a null hypothesis of no spatial dependence and has as alternative hypothesis the spatial error model; (ii) the *LMlag* test, which has the same null hypothesis and has as alternative hypothesis the spatial lag model (for more details see Anselin (2001)). A robust version of these two tests is provided by Bera and Yoon (1993) and Anselin et al. (1996), respectively denoted as *RLMerr* and *RLMlag* tests. Finally, the *SARMA* test has the same null hypothesis of the other tests, but has as alternative hypothesis a model with either spatial error dependence or spatial lag dependence.

The tests of spatial dependence have been performed considering three different spatial weight matrices, where weights are given by the inverse distance between neighbours and are defined according to three different distance cut-offs: i) 660.8km (the same considered for the construction of the spatial index $SPATIAL.IDX$ used in the previous regressions), ii) 368.5km (corresponding to the second quantile of the distance distribution); and iii) 1022.8km (corresponding to the fourth quantile).[30] Results of tests are reported in Table 7.

	Best Model with SCF^2				
$\bar{d}$	LMerr	LMlag	RLMerr	RLMlag	SARMA
660.8km	2.0349 (0.1537)	1.6443 (0.1997)	0.9677 (0.3253)	0.577 (0.4475)	2.6119 (0.2709)
368.5km	2.3098 (0.1286)	1.5979 (0.2062)	1.0716 (0.3006)	0.3597 (0.5487)	2.6696 (0.2632)
1022.8km	0.1943 (0.6594)	0.0105 (0.9184)	0.2688 (0.6041)	0.085 (0.7706)	0.2793 (0.8697)

Table 7: Spatial tests for the best model. P-values in parenthesis.

All tests cannot reject the null hypothesis of no spatial dependence in the best model at the usual significance levels. Therefore, we conclude that our OLS regressions are not biased by spatial dependence.

VI. Concluding Remarks

This paper estimates the effect of European Union Regional Policy on productivity growth and convergence. We find that the funds have on average a positive and a quite remarkable impact. However, some qualifications of this general claim are needed. Firstly, the impact appears nonlinear and funds seems to be subject to diminishing returns. In addition, not all funds are favourable to productivity growth and convergence. A large positive effect seems to be played by Objective 1 and Cohesion funds; on the contrary, the allocation of funds to other objectives, in particular Objective 2, appears to hinder the efficient reallocation of resources across sectors in European regions.

Moreover, funding in the second and third programming period that we examined seems to have exerted the most significant effect. This finding points to the presence of a nonlinear impact of the size of funds, in the sense that the funds started to be effective when their amount reached a threshold level.

[30]For the test of spatial dependence we only use a geographical distance-based matrix instead of other possible measure of spatial proximity (e.g. transport costs, trade flows, etc.) due to the lack of data.

The analysis can be extended in many respects. Firstly, the impact of funds could be evaluated by conditioning on the output composition of regions. A particular output composition could indeed affect the effectiveness of funds. For example, Objective 1 funds could be more effective in regions whose output composition is more concentrated in industrial sectors, while the opposite could hold for Objective 2. The latter conditioning, along with a control for the institutional quality at regional level,[31] could provide additional information for a more efficient allocation of funds. Secondly, the hypothesis of whether the Regional Policy crowded out or, on the contrary, had complementarities with investments, could be examined. This piece of information is crucial to evaluate the long-run impact of *SCF* on regions' productivities. Thirdly, further information on the long-run impact of *SCF* could also be obtained from the analysis of the dynamics of regions which received funds in the past, but are no longer receiving them.

The availability of a dataset covering the fourth programming period 2000-2006 should allow to carry out these extensions, with the further possibility to include in the analysis the regions of the new EU accession countries, as well as to evaluate the impact of funds allocated to specific expenditure categories.

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[31] Tabellini (2008) analyzes the effect of cultural traits on recent regional economic growth, and clarifies their relation with past regional institutional quality.

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A List of NUTS2 Regions in the Sample

AT11	Burgenland	DEA1	Düsseldorf	FR26	Bourgogne	IT52	Umbria	UKD1	Cumbria
AT12	Niederösterreich	DEA2	Köln	FR3	Nord - Pas-de-Calais	IT53	Marche	UKD2	Cheshire
AT13	Wien	DEA3	Münster	FR41	Lorraine	IT6	Lazio	UKD3	Greater Manchester
AT21	Kärnten	DEA4	Detmold	FR42	Alsace	IT71	Abruzzo	UKD4	Lancashire
AT22	Steiermark	DEA5	Arnsberg	FR43	Franche-Comté	IT72	Molise	UKD5	Merseyside
AT31	Oberösterreich	DEB1	Koblenz	FR51	Pays de la Loire	IT8	Campania	UKE1	East Riding, North Lincol.
AT32	Salzburg	DEB2	Trier	FR52	Bretagne	IT91	Puglia	UKE2	North Yorkshire
AT33	Tirol	DEB3	Rheinhessen-Pfalz	FR53	Poitou-Charentes	IT92	Basilicata	UKE3	South Yorkshire
AT34	Vorarlberg	DEC	Saarland	FR61	Aquitaine	IT93	Calabria	UKE4	West Yorkshire
BE1	Rég. Bruxelles	DEF	Schleswig-Holstein	FR62	Midi-Pyrénées	ITA	Sicilia	UKF1	Derbyshire, Nottingh.
BE21	Antwerpen	DK	Danmark	FR63	Limousin	ITB	Sardegna	UKF2	Leicestershire, Rutland
BE22	Limburg (B)	ES11	Galicia	FR71	Rhône-Alpes	LU	Luxembourg		and Northamptonshire
BE23	Oost-Vlaanderen	ES12	Principado de Asturias	FR72	Auvergne	NL11	Groningen	UKF3	Lincolnshire
BE24	Vlaams Brabant	ES13	Cantabria	FR81	Languedoc-Roussillon	NL12	Friesland	UKG1	Herefordshire, Worcest.
BE25	West-Vlaanderen	ES21	Pais Vasco	FR82	Prov.-Alpes-Côte d'Azur	NL13	Drenthe		and Warwickshire
BE31	Brabant Wallon	ES22	Comunidad de Navarra	FR83	Corse	NL21	Overijssel	UKG2	Shropshire and Staffordshire
BE32	Hainaut	ES23	La Rioja	GR11	Anatoliki Mak., Thraki	NL22	Gelderland	UKG3	West Midlands
BE33	Liège	ES24	Aragón	GR12	Kentriki Makedonia	NL31	Utrecht	UKH1	East Anglia
BE34	Luxembourg (B)	ES3	Comunidad de Madrid	GR13	Dytiki Makedonia	NL32	Noord-Holland	UKH2	Bedfordshire, Hertford.
BE35	Namur	ES41	Castilla y León	GR14	Thessalia	NL33	Zuid-Holland	UKH3	Essex
DE11	Stuttgart	ES42	Castilla-la Mancha	GR21	Ipeiros	NL34	Zeeland	UKI1	Inner London
DE12	Karlsruhe	ES43	Extremadura	GR22	Ionia Nisia	NL41	Noord-Brabant	UKI2	Outer London
DE13	Freiburg	ES51	Catalua	GR23	Dytiki Ellada	NL42	Limburg (NL)	UKJ1	Berkshire, Buckinghamshire
DE14	Tübingen	ES52	Comunidad Valenciana	GR24	Sterea Ellada	PT11	Norte		and Oxfordshire
DE21	Oberbayern	ES53	Islas Baleares	GR25	Peloponnisos	PT12	Centro (P)	UKJ2	Surrey, East, West Sussex
DE22	Niederbayern	ES61	Andalucia	GR3	Attiki	PT13	Lisboa, Vale do Tejo	UKJ3	Hampshire, Isle of Wight
DE23	Oberpfalz	ES62	Región de Murcia	GR41	Voreio Aigaio	PT14	Alentejo	UKJ4	Kent
DE24	Oberfranken	ES63	Ceuta y Melilla	GR42	Notio Aigaio	PT15	Algarve	UKK1	Gloucestershire, Wiltshire
DE25	Mittelfranken	ES7	Canarias	GR43	Kriti	PT2	Açores		and North Somerset
DE26	Unterfranken	FI13	Itä-Suomi	IE01	Border, Mid., Western	PT3	Madeira	UKK2	Dorset, Somerset
DE27	Schwaben	FI18	Etelä-Suomi	IE02	Southern and Eastern	SE01	Stockholm	UKK3	Cornwall, Isles of Scilly
DE5	Bremen	FI19	Länsi-Suomi	IT11	Piemonte	SE02	Östra Mellansverige	UKK4	Devon
DE6	Hamburg	FI1A	Pohjois-Suomi	IT12	Valle d'Aosta	SE04	Sydsverige	UKL1	West Wales, The Valleys
DE71	Darmstadt	FI2	land	IT13	Liguria	SE06	Norra Mellansverige	UKL2	East Wales
DE72	Gießen	FR1	Île de France	IT2	Lombardia	SE07	Mellersta Norrland	UKM1	North Eastern Scotland
DE73	Kassel	FR21	Champagne-Ardenne	IT31	Trentino-Alto Adige	SE08	Övre Norrland	UKM2	Eastern Scotland
DE91	Braunschweig	FR22	Picardie	IT32	Veneto	SE09	Småland med öarna	UKM3	South Western Scotland
DE92	Hannover	FR23	Haute-Normandie	IT33	Friuli-Venezia Giulia	SE0A	Västsverige	UKM4	Highlands and Islands
DE93	Lüneburg	FR24	Centre	IT4	Emilia-Romagna	UKC1	Tees Valley	UKN	Northern Ireland
DE94	Weser-Ems	FR25	Basse-Normandie	IT51	Toscana	UKC2	Northumberland		

B Descriptive Statistics of Variables

	GR.PROD	PROD.REL	INV.RATE	EMP.GR	ECO.DEN	SPAT.INDEX
Mean	0.02	1.00	0.20	0.04	7.47	0.51
St.Dev.	0.01	0.35	0.06	0.01	25.85	3.04

	AGRI	MANU	MIN	CONS	NOMARKS	FIN
Mean	0.06	0.22	0.03	0.08	0.23	0.05
St.Dev.	0.07	0.09	0.05	0.03	0.06	0.02

	HOT	TRAN	WHOL	OTH	*SCF*	PAY
Mean	0.04	0.06	0.11	0.14	0.01	0.01
St.Dev.	0.04	0.02	0.03	0.04	0.02	0.04

Table 8: Mean and standard deviation of variables used in regressions.

	PROD.REL	INV.RATE	EMP.GR	ECO.DEN	SPAT.INDEX	AGRI
PROD.REL	1	0.16	0.11	0.53	0.08	−0.55
INV.RATE	0.16	1	0.19	−0.24	0.16	0.22
EMP.GR	0.11	0.19	1	0.11	−0.10	−0.33
ECO.DEN	0.53	−0.24	0.11	1	−0.01	−0.64
SPAT.INDEX	0.83	0.28	0.07	0.32	1	−0.48
AGRI	−0.55	0.22	−0.33	−0.64	0.12	1
MANU	0.22	−0.20	−0.11	0.21	−0.01	−0.35
MIN	0.09	−0.04	−0.02	−0.03	0.00	0.04
CONS	0.04	0.49	0.14	−0.28	0.13	0.07
NONMARKS	0.29	−0.06	0.21	0.27	−0.04	−0.45
FIN	0.40	0.12	0.07	0.49	−0.07	−0.37
HOT	−0.43	0.04	0.15	−0.33	−0.06	0.27
TRAN	0.01	0.03	0.20	0.18	−0.10	−0.25
WHOL	−0.28	0.03	−0.01	0.00	−0.26	0.23
OTH	0.30	−0.30	0.14	0.45	0.13	−0.48
SCF	−0.50	0.26	0.01	−0.29	0.07	0.45
PAY	−0.46	0.26	0.09	−0.22	0.06	0.30

Table 9: Correlations between variables used in regressions

	MANU	MIN	CONS	NONMARKS	FIN	HOT
PROD.REL	0.22	0.09	0.04	0.29	0.40	−0.43
INV.RATE	−0.20	−0.04	0.49	−0.06	0.12	0.04
EMP.GR	−0.11	−0.02	0.14	0.21	0.07	0.15
ECO.DEN	0.21	−0.03	−0.28	0.27	0.49	−0.33
SPAT.INDEX	−0.01	0.00	0.13	−0.04	−0.07	−0.06
AGRI	−0.35	0.05	0.07	−0.45	−0.37	0.27
MANU	1	−0.16	−0.11	−0.34	−0.11	−0.31
MIN	−0.16	1	−0.16	−0.01	−0.21	−0.08
CONS	−0.11	−0.16	1	0.06	−0.03	−0.14
NONMARKS	−0.34	−0.01	0.06	1	0.18	−0.36
FIN	-0.11	−0.21	−0.03	0.18	1	−0.16
HOT	−0.31	−0.08	−0.14	−0.36	−0.16	1
TRAN	−0.23	−0.18	−0.12	0.06	0.32	0.09
WHOL	−0.42	−0.20	−0.17	−0.11	0.06	0.27
OTH	−0.05	−0.27	−0.18	0.28	0.27	−0.13
SCF	−0.40	0.01	0.27	−0.16	−0.19	0.25
PAY	−0.37	0.00	0.31	−0.09	−0.11	0.21

	TRAN	WHOL	OTH	*SCF*	PAY
PROD.REL	0.01	−0.28	0.30	−0.50	−0.46
INV.RATE	0.03	0.03	−0.30	0.26	0.26
EMP.GR	0.20	−0.01	0.14	0.01	0.09
ECO.DEN	0.18	0.00	0.45	−0.29	−0.22
SPAT.INDEX	−0.10	−0.26	0.13	0.07	0.06
AGRI	−0.25	0.23	−0.48	0.45	0.30
MANU	−0.23	−0.42	−0.05	−0.40	−0.37
MIN	−0.18	−0.20	−0.27	0.01	0.00
CONS	−0.12	−0.17	−0.18	0.27	0.31
NONMARKS	0.06	−0.11	0.28	−0.16	−0.09
FIN	0.32	0.06	0.27	−0.19	−0.11
HOT	0.09	0.27	−0.13	0.25	0.21
TRAN	1	0.25	0.14	0.16	0.23
WHOL	0.25	1	−0.11	0.25	0.20
OTH	0.14	−0.11	1	−0.30	−0.23
SCF	0.16	0.25	−0.30	1	0.96
PAY	0.23	0.20	−0.23	0.96	1

Table 10: Continued: Correlations between variables used in regressions

C Test of Endogeneity of SCF

Dependent Variable	First Stage Estimation: *SCF* (1989-1999)	First Stage Estimation: SCF^2 (1989-1999)	Second Stage Estimation: γ (1992-2002)
COUNTRY DUMMIES	YES	YES	YES
SECTORAL CONTROLS	YES	YES	YES
SPATIAL CONTROLS	YES	YES	YES
Intercept	0.1262 (0.0611)	0.0653 (0.0080)	−0.1000 (0.0000)
log(PROD.1992)	0.0341 (0.1078)	0.0046 (0.4282)	−0.0158 (0.0007)
log(EMP.GR.1992_2002)	0.0003 (0.9522)	0.0009 (0.8348)	−0.0188 (0.0000)
log(ECO.DEN.1992_2002)	0.0206 (0.0004)	0.0064 (0.0029)	−0.0012 (0.0879)
INSTR.SCF.1977_1988	2.5030 (0.0009)		
INSTR.3G	−0.0193 (0.0000)		
INSTR.REL.GDP.1986_1988	−0.0305 (0.0448)		
INSTR.POP.SH.1986_1988	−0.0255 (0.000)		
$\mathrm{INSTR.SCF.1977\_1988}^2$		13.0679 (0.0973)	
$\mathrm{INSTR.3G}^2$		−0.0041 (0.0022)	
$\mathrm{INSTR.REL.GDP.1986\_1988}^2$		−0.0037 (0.4831)	
$\mathrm{INSTR.POP.SH.1986\_1988}^2$		0.0032 (0.0019)	
SCF.1989_1999			0.1082 (0.0316)
$\mathrm{SCF.1989\_1999}^2$			−0.1169 (0.4393)
SCF.1989-1999_RES			−0.0264 (0.4847)
$\mathrm{SCF.1989\text{-}1999\_RES}^2$			0.0508 (0.6733)
Obs. 173	$\bar{R}^2 = 0.77$	$\bar{R}^2 = 0.64$	$\bar{R}^2 = 0.67$
F-Test			H0: *SCF*.1989-1999_RES = $\mathrm{SCF.1989\text{-}1999\_RES}^2$=0 F= 0.1916, Pr(>F)=0.83

Table 11: Exogeneity test of *SCF* and SCF^2. P-values in parenthesis. *SCF.1989-1999_RES* and $SCF.1989-1999\_RES^2$ are respectively the residuals of first-stage regressions.

Dependent Variable	First Stage Estimation *SCF* (1989-1999)	Second Stage Estimation γ (1992-2002)
COUNTRY DUMMIES	YES	YES
SECTORAL CONTROLS	YES	YES
SPATIAL CONTROLS	YES	YES
Intercept	0.1409 (0.0545)	-0.1061 (0.0000)
log(PROD.1992)	0.0383 (0.0712)	-0.0158 (0.0007)
log(EMP.GR.1992_2002)	-0.0159 (0.2662)	-0.0211 (0.0000)
log(ECO.DEN.1992_2002)	0.0205 (0.0003)	-0.0013 (0.0478)
INSTR.SCF.1977_1988	2.2800 (0.0001)	
INSTR.3G	-0.0191 (0.0000)	
INSTR.REL.GDP.1986_1988	-0.0325 (0.0400)	
INSTR.POP.SH.1986_1988	-0.0252 (0.0000)	
SCF.1989_1999		0.0763 (0.0008)
SCF.1989-1999_RES		-0.0200 (0.4703)
Obs. 173	$\bar{R}^2 = 0.77$	$\bar{R}^2 = 0.68$

Table 12: Exogeneity test of *SCF*. P-values in parenthesis.