Productivity Convergence across European Regions: the Effect of Structural and Cohesion Funds

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Abstract

In this paper we study the effects of the European Union regional policy on growth and convergence of productivity. We constructed a large database on Structural and Cohesion funds by gathering information on three programming periods: 1975-1988, 1989-1993, 1994-1999. On average, EU funding had a positive, but concave, effect on productivity growth. 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 effect, while funds devoted to Objectives 2, 3, 4 and 5 had a non significant or negative effect. These results indicate that funding became effective when it reached a critical level, and that the funds allocated to Objectives different from Objective 1 and Cohesion Funds may hinder the efficient reallocation of resources across sectors in European regions.

Keywords: convergence, Structural and Cohesion Funds, structural change, European regions.

JEL: *C14; C21; L7; L8; L9; O11; O14; O40*

Contents

1 Introduction

The European Union utilizes a relevant part of its budget (about 35% for the period 2007-2013) to favor social and economic cohesion among its different regions. The main instrument is represented by the Structural Funds, which are essentially, but not exclusively, allocated on regional basis. The Structural Funds are directed towards different goals: physical and human capital accumulation, development of tranport infrastructures, aid to the unemployed, support to declinging sectors, etc.

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

At present, the issue appears controversial: on the one hand, there exists agreement that the process of convergence among European regions, started from the end of World War II, has slowed down or even stopped from the eighties (see, e.g. De la Fuente and Vives (1995), p. 19). Such empirical evidence is considered as indirect evidence of the ineffectiveness of the funds, given that the intervention of the European Union has been particularly vigorous from the eighties, in particular after the reform of the Structural Funds in 1988 that strongly increased their amount, also proving a redefinition of the rule for the implementation of the programs aiming at improving their coordination (see also Boldrin and Canova (2001)). Fiaschi and Lavezzi (2005), in this respect, find that the funds seem to have had a positive effect in the period after the reform, but not for the regions with particularly unfavourable initial conditions.

On the other hand, there are contributions aiming at directly assessing the effectiveness of the funds, by the inclusion of a variable on the amount of funds in regressions explaining the growth rates of per capita GDP, or productivity. Examples are Cappelen *et al.* (2003), Rodriguez-Pose and Fratesi (2004), and Beugelsdijk and Eijffinger (2005) for Europe, and De la Fuente and Vives (1995) for Spain. Also in this case, however, results are not unanimous. While De la Fuente and Vives (1995), Cappelen *et al.* (2003) and Beugelsdijk and Eijffinger (2005) find positive effects of the funds, Rodriguez-Pose and Fratesi (2004) and Ederveen *et al.* (2006) conclude on the negative. The latter works offer further insights. 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 quality above a certain level (but their analysis is carried out at the level of states and not regions).

One of the main reasons of such discrepancies resides in the differences among the various studies with respect to the period analysed, the sample, 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 European Regional Development Fund (ERDF), which is the largest structural fund, on Spanish regions for the period 1986-90. In all cases, moreover, data are actually elaborated by the different authors on the basis of various publications of the European Union, resorting to a series of hypotheses to make the amounts of funds homogeneous across periods, to impute them to the individual regions or to different investment typologies.[1]

In this paper we aim at evaluating the effects of European regional policies on convergence in labour productivity across European regions. Specifically, we will consider both Structural and Cohesion Funds in the programming periods 1975-1988, 1989-1993 and 1994-1999. We propose a growth model which aims at capturing the main aspects of funding, i.e. its size and composition; then the empirical implications of the model are tested on a large database that we built by gathering data from different sources. The main findings of the paper are three: i) structural and cohesion funds increase the growth rate of productivity of the regions in the sample, but the effect appears subject to diminishing returns; since the distribution of funds across the regions mainly privileged poor regions, overall, this favoured convergence across regions'productivities; ii) the size of funds affects their effectiveness; the limited size of funds in the first period makes not statistical significant their impact on the growth of regions' productivities, while the impact is highly statistically significant in the last two periods (the size of funds was equal to 0.28 % and 0.5 % per year of total GVA of the sample repsectively in the second and third periods against 0.06 % in the first period); and, finally, iii) the composition of funds matters, being the Objective 1 and Cohesion Funds the most effective, while Objective 3, 4 and 5 funds show a non significant or small negative impact on regions' productivity; our guess is that the latter funds impede the resource riallocation from less to more productive sectors.

The paper is organized as follows. In Section 2 we summarize the main features of the European regional policies, and describe our database; in Section 3 we propose a neoclassical growth model incorporating the main features of the European regional policy; in Section 4 we present the results of the empirical analysis; Section 6 concludes.

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

2 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.[2]

- 1975-1988. The European Regional Development Fund (ERDF) was established to finance infrastructure projects and productive investment in less-favoured regions;
- 1989-1993. To ensure these funds are rationalized and well defined, regulations were adopted in 1988 and the Structural Funds were concentrated on the areas or social groups in the greatest difficulty according to socio-economic criteria which led to the assignment of five priority objectives to the Structural Funds:
  - Objective 1: promoting the development and structural adjustment of regions whose development is lagging behind, that is regions with a per capita GDP less than 75% of Community average;
  - Objective 2: converting regions seriously affected by industrial decline; 7
  - Objective 3: combating long-term unemployment;
  - Objective 4: facilitating the occupational integration of young people;
  - Objective 5: speeding up the adjustment of agricultural and fishing sectors.

  Community Initiative Programmes (CIP) were added to these objectives, by utilizing a limited proportion of the Structural Funds on more targeted topics.
- 1994-1999. Second generation of Structural Funds, where:
  - 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 a sixth Objective, in favour of the regions with very low population densities;
  - CIP were slightly redefined;
  - a Cohesion Fund of over 15 billions ecus was also introduced to help the Member States whose development was lagging further behind (that is 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, that is:

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

- ERDF (European Regional Development Fund). Established in 1975 and directed to less favoured regions, it mainly focuses on productive investment, infrastructure, SME's development, research and development projects. It should generate growth in capital stock, infrastructures, education, Small and Medium Enterprise (SME) firms and expansion of Research & Development (R&D) activity.

- ESF (European Social Fund). Created with the Treaty of Rome in 1986 and designed to vocational training, improvements in the education systems and employment aids. This fund covers much of Objectives 2, 3 and 4, and a portion of Objective 1. It should generate mobility of labour, raise employment of young people and women, growth in educational attainments, and increase in R&D.

- EAGGF (European Agricultural Guidance and Guarantee Fund). Introduced in 1962 as part of CAP (Common Agricultural Policy), it promotes the adjustment of 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 directed to 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, Cohesion Funds is allocated to member states (as opposed to regions), and, in particular, only to countries in line with the program of convergence in the monetary union are eligible.

We stress that the criteria for the allocation of funds are not unambiguously directed towards an increase in productivity of regions lagging behind. Support to the agricultural sector, for example, may actually slow down a possible process of productivity catching-up, as long as structural change based on the reduction of this sector is a key to obtaining productivity gains in the aggregate.[3] These types of support, along with for example support to the fishing industry, may be considered more income support than stimuli to productivity growth.[4]

In order to understand how the Structural Funds can affect the regional productivity of the European regions it would be useful to break these funds, taking into account sepa-

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

[4]See, e.g., European Commission (2007).

rately the programmes listed above. Unfortunately, this is not possible because a regional breakdown of committed funds is available for total Structural Funds only.

2.1 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:

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

Data represent the total Commitments that European Commission allocated for the entire programming period. Data on total Payments, that is data on money actually transferred to the 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 different regions, the fund is reallocated to the NUTS 2 regions in an amount inversely proportional to their per capita GDP in the initial year of the programming period to which to fund refers;[5]
- if the fund is allocated to a country, and is referred to a particular objective (for example Objective 1) for which it is possible to exactly know the eligible regions, then it is reallocated to all the objective (e.g. Objective 1) regions in an amount inversely proportional to their per capita GDP in the initial year of the programming period to which to fund refers;
- if the fund is allocated at national level, but it is referred to an objective (e.g. Cohesion Funds) for which it is not possible to know exactly the eligible regions, then it is reallocated to all the NUTS 2 regions belonging to the country in an amount inversely proportional to their per capita GDP in the initial year of the programming period to which to fund refers.

[5] We also tried to equally reallocate funds across regions without any significant difference in results.

2.2 Descriptive Statistics on Structural and Cohesion Funds

In this paper we will consider the effects of both Structural and Cohesion Funds (labeled *SCF* in the following) on convergence in productivity across European Regions . Table 1 shows that the total amount of these funds is increasing over time, raising from 0.06% of total European GVA in the first programming period to 0.5% in the third programming period.[6]

Programming Period	SCF/Total GVA
Period I (1975-1988)	0.06
Period II (1989-1993)	0.28
Period III (1994-1999)	0.50

Table 1: Share of Structural and Cohesion Funds on European total GVA (annual averages)

The increase in the amount of funds is accompanied by a change in the allocation of resources across the different programs. Table 2 illustrates such changes. In particular, even if the Objective 1 attracts the largest amount of funds, between the second and the third period funds devoted to the Cohesion Policy show a large increase.[7]

[6] Data on regional GVA and employment come 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	-
5a Agr.	-	5.37	2.88
5a Fish.	-	0.88	0.40
5b	-	3.30	3.57
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: Commitments of funds according to Objectives, as percentage of *SCF*. "NL": New Länder in Germany in Period II; "PIM": regional program in Period II for regions outside Objective I; "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 allocation of *SCF* across recipient countries. We also report two variables that should drive the allocation of these funds: the relative per worker GVA (with respect to the sample average), and the country share of workers (with respect to total employment of countries in the sample). The consideration of the former variable depends on the general criteria that poorer regions should receive more funds, the latter controls for the possible presence of a scale effect in the allocation of the funds: we expect that, for two similarly poor regions, the larger region receives more funds. We use the share of workers as a measure of economic size of regions.[8]

Table 3 captures possible differences among countries and across programming periods. As for individual countries, Table 3 shows that while UK faces a strong reduction in the relative share of funds received, Spain and Germany experienced a huge increase.[9] Some

[8]Moreover, we consider per worker GVA instead of per capita GVA because we will use information on the structure of regional economies, where labour allocated to different sectors matters.

[9]Let us recall that Spain (and Portugal) joined the European Union in 1986 and Germany, after the reunifi-

countries like Ireland and Portugal experienced an increase of funding in the second period and a reduction in the third, even if their economic performances during this period are different, with Portugal receiving a lower relative share in the third period despite of a deterioration of its level of relative productivity.

Another interesting point is how funds are allocated according to country's relative GVA *and* employment share. In general, the less productive regions tend to receive more funds and, indeed, across regions with similar levels of productivity, those with larger employment shares receive more funds. However, there are some exceptions: comparing Ireland and the United Kingdom, we note that the former had a higher relative GVA and a much lower employment share in all periods, but in the second period it received almost as much funding as the latter (and not much less in the third period).

	Period I (1975-1988)			Period II (1989-1993)			Period III (1994-1999)		
Country	SCF	REL.GVA	EMP.SH	SCF	REL.GVA	EMP.SH	SCF	REL.GVA	EMP.SH
AT	-	-	-	-	-	-	0.87	1.27	2.33
BE	0.98	1.37	2.82	1.22	1.35	2.76	1.09	1.34	2.43
DE	5.22	1.38	21.44	9.49	1.31	21.4	19.19	1.19	24.6
DK	0.78	1.35	1.96	0.65	1.27	2.03	0.42	1.26	1.72
ES	9	0.81	9.64	20.95	0.82	10.09	28.06	0.8	8.9
FI	-	-	-	-	-	-	0.81	1.13	1.31
FR	9.77	1.22	17.02	7.88	1.27	16.34	8.66	1.23	14.46
GR	13.04	0.62	2.7	13.8	0.61	2.73	8.45	0.59	2.5
IE	6.91	0.72	0.89	7.77	0.87	0.82	2.87	0.9	0.81
IT	27.46	0.91	16.64	15.4	0.88	17	13.58	0.89	14.54
LU	0.22	1.25	0.12	0.1	1.47	0.13	0.05	1.77	0.14
NL	1.13	1.33	4.48	1.16	1.25	4.54	1.18	1.15	4.36
PT	7.07	0.38	2.95	14.46	0.5	2.74	9.26	0.42	2.93
SE	-	-	-	-	-	-	0.65	1.11	2.66
UK	18.42	0.74	19.35	7.11	0.78	19.42	4.88	0.79	16.32
Tot.	100		100	100		100	100		100

Table 3: Allocation of SCF across countries, average relative GVA per worker at country level (with respect to sample average) and country shares of workers on total number of workers of the sample.

Table 4 reports the mean and standard deviation of the regional shares of SCF in the three periods, where the amount of funds is divided by regional GVA.

cation of 1989, incorporated the poorer regions of former East Germany.

	Mean SCFshare	St. Dev. of SCF/GVA
Period I (1975-1988)	0.0054	0.0103
Period II (1989-1993)	0.0054	0.0082
Period III (1994-1999)	0.0049	0.0065

Table 4: Mean and standard deviation of regional shares of SCF in the three periods

The amount of the shares are not particularly large with respect to regional GVA, being equal on average to 0.5%, and are relatively constant across the programming periods (see Table 4). On the contrary, the dispersion tends to decrease, indicating a better balance in the distribution of funds.

2.3 On the Determinants of Funds' Allocation

Table 5 reports the estimated elasticities between the shares of SCF and regional shares of employment and relative per worker GVA (relative to the sample average).

	Intercept	log(EMP.SH)	log(REL.GVA)
Period I (1975-1988)	−6.46***	0.56**	−3.61***
Period II (1989-1993)	−5.96***	0.09	−1.98***
Period III (1994-1999)	−5.89***	0.12**	−1.98***

Table 5: Estimated elasticities between the shares of SCF and region shares of employment and relative per worker GVA (relative to the sample average). Dependent variable: SCF share. Statistical significance: '***' 0.01, '**' 0.05, '*' 0.1.

As expected, commitments are negatively correlated with relative per worker GVA (the less productive a region is relative to the European average, the more it receives), and positively correlated with the employment share (the higher the employment share, the more the region receives).[10] However, relative GVA seems to be more important in the allocation of funds with respect to the employment share (although the absolute value of the elasticity is decreasing in time): the employment share coefficient is not statistically significant in the second programming period, and its coefficients are much lower than those of relative productivity.

[10]We also have estimated the elasticities nonparametrically, obtaining very similar results. This implies that the linear specification that adopted in the following agrees with the evidence provided by the data.

Moreover, the fraction of funds allocated to regions independently both of the share of employment and relative GVA, increased between the first and the last period. The constant in the regression is, in fact, statistically significant and approximately equal to about 0.15%, 0.24%, 0.26% in the first, second and third period respectively ($0.15\% \approx exp(-6.46)$).[11]

If we focus on regions eligible for Objective 1 funds, the relevant variable that accounts for the allocation of funds is relative GVA. Indeed, Tables 6 shows that the only statistically significant variable is relative GVA per worker for period 1989-1993 even if also the size of the region turns out to be relevant in the last programming period.

	Intercept	log(EMP.SH)	log(REL.GVA)
Period II (1989-1993)	−14.19***	−0.48	−9.45***
Period III (1994-1999)	−14.11***	−0.62**	−8.89***

Table 6: Estimated elasticities between the shares of Objective I funds and region shares of employment and relative per worker GVA (relative to the sample average). Dependent variable: Objective I SCF share. Statistical significance: '***' 0.01, '**' 0.05, '*' 0.1.

Finally, considering regions that *actually* received Objective 1 funds, which include *phasing out* regions,[12] the relative amount of funds received by these regions is remarkably higher with respect to their GVA per worker (see Table 7). Table 8 shows that the employment share is a significant variable driving the allocation of funds in both periods and, after the reform of 1993, also relative GVA becomes a significant explanatory variable with the expected sign. Among these regions, the fraction of funds independently allocated decreased from about 2.8% in the second programming period to 1.9% in the third period (compare Table 5 with Table 7).

	Mean SCFshare	St. Dev. of SCF/GVA
Period II (1989-1993)	0.0238	0.0176
Period III (1994-1999)	0.0170	0.0104

Table 7: Mean and standard deviation of shares of Objective I funds for only regions which received Objective I funds

[11] Vanhove and Klaassen (1980) provide information on the background of European Regional Policy; they also shed light on the political factors affecting the allocation of funds.

[12] "Phasing out" regions are regions having no longer a GDP lower than the 75% (or less than 90%) of the European average, but still receiving Objective 1 (Cohesion) funds.

	Intercept	log(EMP.SH)	log(REL.GVA)
Period II (1989-1993)	−3.91***	0.33***	−0.12
Period III (1994-1999)	−4.49***	0.34***	−0.79**

Table 8: Estimated elasticities between the shares of Objective I funds (only positive values) and region shares of employment and relative per worker GVA (relative to the sample average). Dependent variable: Objective I SCF share (only positive). Statistical significance: '***' 0.01, '**' 0.05, '*' 0.1.

Table 9 reports the share of *SCF* allocated to regions with a per capita GDP lower than the 75% of the sample mean. Structural and Cohesion Funds are mainly directed to promote growth-enhancing conditions and sustain the factors leading to convergence for the poorer regions. Looking at the total funds, only 60%-70% of total Structural and Cohesion Funds are allocated to poorer regions. This is because objectives different from Objective 1 and Cohesion are not actually based on GDP criteria. Cohesion and Objective 1 funds result not completely allocated to regions with a per capita GDP lower than the 75% of the sample mean because: i) our sample mean is different from the one considered by the Commission for the eligibility; and ii) the presence of "phasing out" regions.

	Period I (1975-1988)	Period II (1989-1993)	Period III (1994-1999)
All.Obj	66.68	70.39	57.44
Ob. 1	-	98.62	72.98
Ob. 2	-	22.03	5.05
Ob. 3 & 4	-	23.32	15.20
Ob. 5a Agr.	-	14.44	7.37
Ob. 5a Fish.	-	24.20	18.17
Ob. 5b	-	11.98	6.88
Ob. NL & PIM & 6	-	0	0
Ob. 2 In. & Other In.	-	-	45.09
Cohesion	-	92.83	90.84

Table 9: Percentage of SCF given to regions with per capita GDP below 75% of sample mean

Table 9 provides further evidence on the fact that the funds only benefit the poorest, or least productive, regions. In particular, only a small share of funds relative to objectives different from Objective 1, benefit the poorer regions.

2.4 Commitments vs Payments

So far we considered the commitments of funds; however, it is likely that the amount of funds actually spent by the region is what effectively matters to measure the impact of funds on regions' productivity. Table 10 reports the ratio between Commitments and Payments for each country.[13] The generalized reduction of this ratio from the first to the third period can be traced to the regulation adopted in 1988 and, in particular, to the adoption of the *additionality principle*[14]. Moreover, some countries, like Spain and Ireland, have maintained high ratios of payments on commitments over the three periods, while other countries, like United Kingdom, Netherlands and Italy, have had very low ratios (especially in the third programming period).

[13]Budgetary Commitments relating to the *operational programmes* are presented annually, specified for each fund and each objective. The Member States and the Commission sign a financial contract whereby the Commission undertakes to pay *annual commitment appropriations* on the basis of the adopted programming documents. Each Member State then appoints a payment authority for each programme to act as intermediary between the final beneficiaries and the Commission. The payment authority, in collaboration with the managing authority, monitors the expenditure of the final beneficiaries and ensures that the Community rules are observed. The physical movement of funds (*payment appropriations*) from the Union to the Member States actually occurs when the Commission reimburses the actual expenditure of the final beneficiaries, approved and certified by the payment authorities.

[14]According to the *additionality principle*, the Structural Funds are not intended to be used 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 10: Ratio of Payments on Commitments in the three periods at country level

Overall, the heterogeneity in the ratio of Payments on Commitments across the countries in the sample suggests to check also for payments in the estimate of the effective impact on productivity of SCF.

To sum up, in this section we have documented that: i) the resources devoted by the European Union to the regional policy have increased over the three programming periods considered; 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 two programming periods; iii) the allocation of funds is largely determined by relative backwardness, but the size of the regions (measured by its relative share of workers) seems to matter, and a nonnegligible amount of funds appear to be allocated for other reasons.

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

3 A Neoclassical Model of Growth and Regional Convergence

In this section we present a theoretical framework based on Solow (1956) and Barro (1990) with regional policy, modelled following the criteria for the allocation of funds analyzed in Section 2.[15]

The economy is composed by I regions; we assume that there is no labour mobility across regions, while capital mobility is limited and driven by the differences in the returns on capital across the different regions.[16]

The production function of region i is given by:

$$Q_i = K_i^{\alpha} L_i^{1-\alpha} \left(\frac{\beta_i SCF_i}{Q_i} \right)^{\gamma}, \tag{1}$$

where K_i is the stock of physical capital in region i, L_i is employment in region i, SCF_i is the amount of Structural and Cohesion Funds (*SCF*) received by region i, and β_i is the share of *SCF* devoted to productive expenditures.[17] We assume α and $\gamma \in (0,1)$. In particular, the impact of the *SCF* allocated to productive expenditures is assumed proportional to the amount of *SCF* per unit of output of the region. The latter assumption intends to capture the idea that, for a given amount of funds, we expect it to be more effective the smaller the output of the region.[18]

Eq. (1) can thus be rewritten as:

$$Q_i = K_i^{\frac{\alpha}{1+\gamma}} L_i^{\frac{1-\alpha}{1+\gamma}} \left(\beta_i SCF_i \right)^{\frac{\gamma}{1+\gamma}}, \tag{2}$$

which shows how *SCF* affects the marginal productivity of private inputs. Hence, private capital and the funds are not perfect substitutes, as discussed in the previous section.

The income of region i is the sum of its output and of the share of *SCF* allocated as redistributive expenditures:

$$Y_i = K_i^{\frac{\alpha}{1+\gamma}} L_i^{\frac{1-\alpha}{1+\gamma}} \left(\beta_i SCF_i \right)^{\frac{\gamma}{1+\gamma}} + (1-\beta_i) SCF_i. \tag{3}$$

[15] 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 these aspects and possible patterns of regional specialization are not considered, although we will include them as controls in the empirical analysis of Section 4.

[16] This hypothesis takes into account the evidence on the very low mobility of labour in Europe. See, e.g. Puga (2002), pp. 385-387, and the references therein.

[17] We abstract from the possible presence of labor augmenting exogenous technological progress. Alternatively, it is possible to consider the level of employment L_i as representing effective units of labor. Its inclusion, however, would not significantly affect the theoretical results in the following.

[18] In addition, this is the measure of funding typically used in empirical analyses of the effectiveness of funds, which will also be adopted in Section 4.

The share of funds devoted to redistributive expenditure represents a lump-sum subsidy to individuals in region i; in a multi-sectoral model this subsidy would affect the reallocation of labour across the different sectors, that is it would be a possible source of inefficiency.

The distinction between Q_i and Y_i clearly depends on the assumption that part of the funds can be considered more as direct income support than support to the productive activities. Obviously, setting $\beta_i = 1$ eliminates the difference between Q_i and Y_i.

Following Barro (1990), *SCF* are financed by a flat tax rate τ on the total income of the economy, Y. In addition, according to the findings of Section 2.3, we assume that the total amount of *SCF* is shared among the regions according to their size, measured by the L_i/L, where L the total number of workers of the economy, and to the ratio between capital per worker of region i, k_i, the average capital per worker k, which reflects the redistributive aspect of *SCF* and an idiosyncratic component.

Formally, we assume that *SCF* allocated to region i are given by:

$$SCF_i = \hat{\phi}_i \tau Y = \eta_i \phi_i \tau Y = \eta_i \psi_i \phi(\frac{k_i}{k}) \tau Y = \eta_i \psi_i \phi(\theta_i) \tau Y, \tag{4}$$

where $\hat{\phi}_i$ is the share of *SCF* assigned to region i, $\eta_i = L_i/L$, $\theta_i = k_i/k$ and ψ_i is an idiosyncratic component in the allocation of SCF.

Redistribution of resources among the regions is reflected by the negative sign of the first derivative of ϕ; in particular we assume that:

$$\phi' < 0 \; \forall \theta_i, \text{ and } \phi(1) = 1. \tag{5}$$

Condition (5) states that: i) the higher the capital per worker of a region, the lower the share of *SCF* received; ii) if a region has a level of capital per worker equal to the average capital per worker of the economy, it receives a share of *SCF* proportional to its share of workers on the total number of workers.

Given the definitions of the variables we have the following constraints:

$$\hat{\phi}_i, \eta_i, \theta_i \geq 0 \text{ for } i = 1, ..., I; \tag{6}$$

$$\sum_{i=1}^{I} \hat{\phi}_i = \sum_{i=1}^{I} \eta_i \psi_i \phi(\theta_i) = 1; \tag{7}$$

$$\sum_{i=1}^{I} \eta_i = 1 \text{ and} \tag{8}$$

$$\sum_{i=1}^{I} \eta_i \theta_i = 1. \tag{9}$$

Substituting Eq. (4) into Eq. (3) and aggregating, we obtain gross aggregate income Y:

$$Y = \tau^{\gamma} K^{\alpha} L^{1-\alpha} \Omega^{1+\gamma}, \tag{10}$$

and substituting Eq. (10) and Eq. (4) into Eq. (3) yields the income per worker of region i, y_i:

$$y_i = y\left[\frac{\theta_i^{\frac{\alpha}{1+\gamma}}\left(\phi_i\beta_i\right)^{\frac{\gamma}{1+\gamma}}}{\Omega} + \tau\left(1-\beta_i\right)\phi_i\right], \tag{11}$$

where:

$$\Omega = \frac{\sum_{i=1}^{I}\eta_i\theta_i^{\frac{\alpha}{1+\gamma}}\left(\beta_i\phi_i\right)^{\frac{\gamma}{1+\gamma}}}{1-\tau\left(1-\sum_{i=1}^{I}\beta_i\eta_i\phi_i\right)}, \tag{12}$$

and $y = Y/L$ is the average income per worker in the economy.

The term Ω defined in Eq. (12) includes different aspect of funding. A measure of the absolute size of the funds, τ; a measure of the share of the funds allocated to productive activities, β_i; the criteria for the allocation of funds, which are strictly related to the distribution of resources across the regions, i.e. $\eta_i\phi_i$.

3.1 Effects of Regional Policy

Eq. (11) highlights the redistributive effect of *SCF*, which depends both on a measure of the size of *SCF*, i.e. τ, and on the distribution in individual regions of *SCF* between productive and redistributive expenditure, i.e. β_i. In particular, an increase in ψ_i has the unambigous effect of increasing the income of region i with respect to the average (under the assumption that region i is "small", i.e. $\partial\Omega/\partial\psi_i = 0$), while an increase in β_i and τ has an ambiguous effect.[19]

Eqq. (10) and (12) highlight that the level of flat tax rate τ and the sharing of *SCF* between productive and redistributive expenditures β affects the net aggregate income $(1-\tau)Y$.

Indeed, if $\beta_i = 1\,\forall i$ then net income is maximized for:[20]

$$\tau^* = \frac{\gamma}{1+\gamma}. \tag{13}$$

This result is reminiscent of the one in Barro (1990), p. 109, where an increase in public expenditure (and taxation) has a positive effect on the growth rate if the government is small, that is if the initial level of taxation is low, and depends on the inverted U-shape relationship between τ and net income.

Moreover, if $\beta_i = \beta\,\forall i$ then net income is maximized for $\beta^* = \gamma\left(1-\tau\right)/\tau < 1$ if $\tau > \tau^*$ and $\beta^* = 1$ if $\tau \leq \tau^*$. The intuition is straightforward: if taxation is low then all *SCF* should be allocated to productive expenditures; otherwise, if taxation is high, a part of *SCF* should be allocated to redistributive expenditures, given that the alternative use of funds is not

[19] In terms of comparison the level of income per worker of region i without regional policy should be given by $y_i = y\left(\theta_i^\alpha / \sum_{i=1}^{I}\theta_i^\alpha\eta_i\right)$.

[20] If $\beta_i = \beta\,\forall i$, it can be shown that $\tau^* \in (0,1)$ and implicitly solves $\gamma\left(1-\tau\right) - \tau\beta - \gamma\tau\left(1-\beta\right)\left(1-\tau\right) = 0$.

efficient. Moreover, all other things equal, lower endowment of capital per worker in region i should imply lower level of β_i^* . In fact, under the hypothesis that $\partial y/\partial\beta_i = \partial\Omega/\partial\beta_i = 0$ (i.e. region i is "small") y_i is maximized when $\beta_i = \beta_i^*$, where:

$$\beta_i^* = \frac{\theta_i^\alpha}{\phi_i}\left[\frac{\gamma}{(1+\gamma)\tau\Omega}\right]^{1+\gamma}, \tag{14}$$

and consequently:

$$\frac{\partial\beta_i^*}{\partial\theta_i} = \left[\frac{\gamma}{(1+\gamma)\tau\Omega}\right]^{1+\gamma}\left[\frac{\alpha\theta_i^{\alpha-1}\phi_i - \theta_i^\alpha\phi_i'}{\phi_i^2}\right] > 0; \tag{15}$$

the result in Eq. (15) reflects the positive relationship between the marginal productivity of funds allocated to production and the level of capital per worker of region i.

3.2 Dynamics of Capital

The accumulation of physical capital of region i is given by:

$$\dot{K}_i = s_i\,(1-\tau)\,Y_i + \mu\,(r_i - r)\,K_i - \delta K_i, \tag{16}$$

where $r_i \equiv \partial Q_i/\partial K_i$ and $r \equiv \partial Y/\partial K$. Therefore, the accumulation of capital depends on: i) the saved resources within the region, i.e. $s_i\,(1-\tau)\,Y_i$, where s_i is the investment rate in region i; ii) the net inflows of capital from the other regions, i.e. $\mu\,(r_i - r)\,K_i$; iii) the depreciation rate of capital, i.e. δK_i.

We assume that capital mobility is *not perfect*, that is the (net) return on capital, can be different across regions; but a positive difference between the (net) capital return of region i, i.e. r_i, and the average (net) capital returns, i.e. r, causes a positive net inflow of capital into region i,[21] that is:

$$\mu' > 0 \text{ and } \mu(0) = 0. \tag{17}$$

The sum of net inflows of capital must be zero, i.e.:

$$\sum_{i=1}^{I}\mu\,(r_i - r)\,K_i = 0. \tag{18}$$

Finally, assume that employment of region i is growing at a constant rate equal to l_i , that is:

$$L_i\,(t) = L_i\,(0)\exp\,(l_i t)\ \text{ for } i = 1, ..., I \text{ and } \forall t. \tag{19}$$

From Eqq. (10), (11), (16) and (18) the accumulation of aggregate capital follows:

$$\dot{K} = (1-\tau)\tau^\gamma K^\alpha L^{1-\alpha}\Omega^\gamma\sum_{i=1}^{I}s_i\eta_i\left[\theta_i^{\frac{\alpha}{1+\gamma}}\,(\phi_i\beta_i)^{\frac{\gamma}{1+\gamma}} + \tau\,(1-\beta_i)\,\phi_i\Omega\right] - \delta K, \tag{20}$$

[21]For sake of simplicity we ignore taxation on capital income because it would affect symmetrically r_i and r.

from which the growth rate of the average capital per worker:

$$\frac{\dot{k}}{k} = (1-\tau)\tau^{\gamma} k^{\alpha-1}\Omega^{\gamma}\sum_{i=1}^{I} s_i\eta_i \left[\theta_i^{\frac{\alpha}{1+\gamma}}\left(\phi_i\beta_i\right)^{\frac{\gamma}{1+\gamma}} + \tau\left(1-\beta_i\right)\phi_i\Omega\right] - (\delta + l), \quad (21)$$

where $l = \Sigma_{i=1}^{I}\eta_i l_i$ is the growth rate of L.

From Eqq. (11) and (16) capital per worker of region i, $k_i = K_i/L_i$, is growing at the following rate:

$$\frac{\dot{k}_i}{k_i} = (1-\tau)\tau^{\gamma} s_i k^{\alpha-1}\Omega^{\gamma}\left[\theta_i^{\frac{\alpha-1-\gamma}{1+\gamma}}\left(\phi_i\beta_i\right)^{\frac{\gamma}{1+\gamma}} + \tau\left(1-\beta_i\right)\phi_i\theta_i^{-1}\Omega\right] + \mu(r_i - r) - (\delta + l_i). \quad (22)$$

3.3 The Steady State

Proposition 1 characterizes the steady-state level of capital per worker in region i.

Proposition 1 *The steady-state level of capital per worker of region i, k_i^{EQ}, is implicitly given by:*

$$(1-\tau)\tau^{\gamma} s_i \left(k^{EQ}\right)^{\alpha-1}\left(\Omega^{EQ}\right)^{\gamma}\left[\left(\theta_i^{EQ}\right)^{\frac{\alpha-1-\gamma}{1+\gamma}}\left(\phi_i^{EQ}\beta_i\right)^{\frac{\gamma}{1+\gamma}} + \tau\left(1-\beta_i\right)\phi_i^{EQ}\left(\theta_i^{EQ}\right)^{-1}\Omega^{EQ}\right] =$$
$$= (\delta + l_i) - \mu(r_i^{EQ} - r^{EQ}), \quad (23)$$

where Ω^{EQ} is the steady-state level of Ω, $\phi_i^{EQ} = \psi_i\phi\left(\theta_i^{EQ}\right)$, $\theta_i^{EQ} = k_i^{EQ}/k^{EQ}$, r_i^{EQ} and r^{EQ} are, respectively, the return on capital of region i and at aggregate level in the steady state.

Proof. From Eq. (23) we have that $k_i = k_i^{EQ}$ implies that $\dot{k}_i = 0$. QED ■

With respect to the standard Solow model with conditional convergence driven by decreasing returns to capital per worker, in the present model convergence across regions is increased by three factors: i) the allocation of *SCF* which favors poor regions, i.e. differences in ϕ_i^{EQ}, ii) the capital mobility, i.e. the presence of $\mu(.)$; and iii) the allocation of *SCF* which increases the returns on capital in poor regions, i.e. r_i^{EQ} is increasing in ϕ_i^{EQ}. Moreover, differences in the allocation of *SCF*, i.e. β_i and ψ_i, are a source of further heterogeneity across regions other than s_i and l_i. In fact, taken two regions i and j, where $s_i = s_j$ and $l_i = l_j$, but $\beta_i \neq \beta_j$ and/or $\psi_i \neq \psi_j$, Eq. (23) states $k_i^{EQ} \neq k_j^{EQ}$, i.e. the steady-state levels of capital of regions i and j are different.

Proposition 2 reports the steady-state level of average capital per worker.

Proposition 2 *In the steady state the average level of the capital per worker is implicitly given by:*

$$k^{EQ} = \left[\frac{(1-\tau)\,\tau^{\gamma}\left(\Omega^{EQ}\right)^{\gamma}\sum_{i=1}^{I} s_i\eta_i\left[\left(\theta_i^{EQ}\right)^{\frac{\alpha}{1+\gamma}}\left(\phi_i^{EQ}\beta_i\right)^{\frac{\gamma}{1+\gamma}} + \tau\left(1-\beta_i\right)\phi_i^{EQ}\Omega^{EQ}\right]}{\delta + l}\right]^{\frac{1}{1-\alpha}}. \quad (24)$$

Proof. Directly from Eq. (21) for $\dot{k} = 0$. QED ■

Here we have three novelties with respect to the standard Solow model: i) an increase in the level of taxation can increase the steady-state level of capital per worker; ii) the allocation between productive and redistributive expenditure within each region affects the level of capital per worker and, iii) the allocation of capital and employment across regions affects capital per worker. When $s_i = s$, $l_i = l$, $\beta_i = \beta$ and $\psi_i = \psi$ for each region, then we will end up with a symmetric equilibrium in which the steady-state level of per capita output of each region is the same and it is exactly equal to the average level of the capita per worker.

3.3.1 Comparative Statics Analysis

In the following we analyse the relationships between the steady-state level of capital per worker of region i, k_i^{EQ}, and some of the most interesting variables of the model. In particular, Remarks 3 and 4 analyse the impact of the investment rate and the growth rate of employment on the steady-state level of capital per worker and on the growth rate of capital in the transitional dynamics, while Remarks 5-7 focus on the effects of parameters reflecting regional policy, i.e. changes in the level of SCF_i through ψ_i; in the overall size of SCF, measured by τ; and in the allocation of SCF_i to productive uses, measured by β_i.

Remark 3 shows that the level of the investment rate in region i, s_i, positively affects the steady-state level of capital per worker of the region and the growth rate of capital in the transitional dynamics.

Remark 3 *Assume that region i is "small", i.e. $\partial\Omega^{EQ}/\partial s_i = \partial k^{EQ}/\partial s_i = \partial\Omega^{EQ}/\partial k_i = \partial k^{EQ}/\partial k_i = 0$; then an increase in the investment rate of region i leads to an increase in k_i^{EQ}, i.e.:*

$$\frac{dk_i^{EQ}}{ds_i} > 0. \tag{25}$$

Proof. See Appendix B ■

Remark 4 shows that the level of growth rate of employment of region i, l_i, negatively affects the steady-state level of capital per worker of the region and the growth rate of capital in the transitional dynamics.

Remark 4 *Assume region i is "small", i.e. $\partial\Omega^{EQ}/\partial l_i = \partial k^{EQ}/\partial l_i = \partial\Omega^{EQ}/\partial k_i = \partial k^{EQ}/\partial k_i = 0$; then an increase in the growth rate of employment of region i leads to a decrease in k_i^{EQ}, i.e.:*

$$\frac{dk_i^{EQ}}{dl_i} < 0. \tag{26}$$

Proof. See Appendix B ■

Remark 5 shows that there exists a positive but concave relationship between the idiosyncratic component of SCF_i, measured by ψ_i, and the steady-state level of capital per worker of the region i (and on the growth rate of capital in the transitional dynamics).

Remark 5 *Assume that region i is small, i.e. $\partial\Omega^{EQ}/\partial\psi_i = \partial k^{EQ}/\partial\psi_i = \partial\Omega^{EQ}/\partial k_i = \partial k^{EQ}/\partial k_i = 0$; then an increase in the idiosyncratic component of SCF_i, ψ_i, leads to an increase in k_i^{EQ}, i.e.:*

$$\frac{dk_i^{EQ}}{d\psi_i} > 0, \tag{27}$$

and $dk_i^{EQ}/d\psi_i$ is decreasing in ψ_i.

Proof. See Appendix B ■

This result is driven by the positive impact of higher level of funds on income of region i; but its marginal effect is decreasing because of the decreasing marginal effect of funds on the level of output.

Remark 6 shows that the size of SCF, measured by τ, can have a non-monotonic effect on the steady-state level of capital per worker of the region i.

Remark 6 *Assume that region i is "small", i.e. $\partial\Omega^{EQ}/\partial k_i = \partial k^{EQ}/\partial k_i = 0$, that taxation is neutral on net capital inflows, i.e. $\partial\mu/\partial\tau = 0$, and that $\beta_i = 1\ \forall i$; the there is an inverted U-shape relationship between τ and the steady-state level of capital per worker k_i^{EQ}, i.e.:*

$$\begin{aligned} &\frac{dk_i^{EQ}}{d\tau} > 0 \qquad \text{for } \tau < \tau^* \text{ and} \\ &\frac{dk_i^{EQ}}{d\tau} < 0 \qquad \text{for } \tau > \tau^*, \end{aligned} \tag{28}$$

where τ^* is defined in Eq. (13).

Proof. See Appendix B ■

This result is driven by the nonlinear relationship between the level of net income and the level of taxation (see the discussion of Eq. (13)).[22]

Finally, Remark 7 says that the composition of SCF, measured by β_i, can have a non-monotonic effect on the steady-state level of capital per worker of the region i.

Remark 7 *Assume that region i is "small", i.e. $\partial\Omega^{EQ}/\partial\beta_i = \partial k^{EQ}/\partial\beta_i = \partial\Omega^{EQ}/\partial k_i = \partial k^{EQ}/\partial k_i = 0$, that $\partial\mu/\partial\beta_i = 0$, i.e. the effect of β_i on net capital inflows in region i is negligible, and that $\tau = \tau^* = \gamma/(1+\gamma)$; then if $y_i < \underline{y}$, where $\underline{y} = y^{EQ}\left[(1+\gamma)/\gamma\right]^2 \phi^{EQ}/s_i$, there is a inverted U-shaped relationship between the share of SCF devoted by region i to productive expenditure, β_i, and the steady-state regional capital per worker k_i^{EQ}, i.e.:*

$$\begin{aligned} &\frac{dk_i^{EQ}}{d\beta_i} > 0 \qquad \text{for } \beta_i < (1+\gamma)\frac{y_i}{\underline{y}} - \gamma \text{ and} \\ &\frac{dk_i^{EQ}}{d\beta_i} < 0 \qquad \text{for } \beta_i > (1+\gamma)\frac{y_i}{\underline{y}} - \gamma. \end{aligned} \tag{29}$$

[22] The finding of a nonlinear relationship between τ and k^{EQ} could be generalized to β_i different from 1 and $\partial\mu/\partial\tau$ different from zero, but we would not gain any further insight on this point.

If $y_i \geq \underline{y}$ *then*

$$\frac{dk_i^{EQ}}{d\beta_i} > 0 \; \forall \beta_i. \tag{30}$$

Proof. See Appendix B ■

Remark 7 confirms the intuition that in poor regions, i.e. regions with income per worker lower than $\underline{y}$, the allocation of funds to redistribution (i.e. a reduction in β_i) may increase the steady-state level of capital per worker and the growth rate of capital in the transitional dynamics. This depends on the low productivity of funds allocated to production (i.e. the ratio between funds and private factors is high). In other words the opportunity cost of allocation of funds to productive uses (equal to 1) is higher than the marginal return of funds allocated to production. On the contrary, "rich" regions always gain from allocating funds to productive expenditure. In this respect, the assumption that $\tau = \tau^*$ aims to rule out that the results on the optimal share of funds depends on the availability of "too many" funds, being τ^* the intuitive optimal level of taxation (see Remark 6).[23]

3.3.2 Speed of convergence

Assume that every region is converging to its long-run equilibrium; then *SCF* also affect the speed of convergence to equilibrium. Proposition 8 reports the approximate speed of convergence to equilibrium of region i.[24]

Proposition 8 *Assume that every region is small, i.e.* $\partial \dot{k}/\partial k_i = \partial \Omega/\partial k_i = 0$, *and is converging to its steady state. Then the approximate speed of convergence around the steady state of region* i *is given by:*

$$\begin{aligned}
\left.\frac{\partial \dot{k}_i}{\partial k_i}\right|_{k_i=k_i^{EQ}} \approx & \left(\frac{\alpha-(1+\gamma)}{1+\gamma}\right)(1-\tau)\tau^{\gamma} s_i \left(k^{EQ}\right)^{\frac{\alpha\gamma}{1+\gamma}} \left(\Omega^{EQ}\right)^{\gamma} \left(k_i^{EQ}\right)^{\frac{\alpha-(1+\gamma)}{1+\gamma}} \left(\phi_i^{EQ}\beta_i\right)^{\frac{\gamma}{1+\gamma}} + \\
& - (1-\tau)\tau^{1+\gamma} s_i \left(k^{EQ}\right)^{\frac{\alpha\gamma}{1+\gamma}} \left(\Omega^{EQ}\right)^{1+\gamma} (1-\beta_i)\,\phi_i^{EQ} \left(k_i^{EQ}\right)^{-1} + \\
& + (1-\tau)\tau^{\gamma} s_i \left(k^{EQ}\right)^{\alpha} \left(\Omega^{EQ}\right)^{\gamma} \left[\left(\frac{\gamma}{1+\gamma}\right)\left(k^{EQ}\right)^{-\frac{\alpha}{1+\gamma}} \left(k_i^{EQ}\right)^{\frac{\alpha}{1+\gamma}} \left(\phi_i^{EQ}\right)^{-\frac{1}{1+\gamma}} \beta_i^{\frac{\gamma}{1+\gamma}} + \right. \\
& \left. + \tau(1-\beta_i)\,\Omega^{EQ} \left.\frac{\partial \phi_i}{\partial k_i}\right|_{k_i=k_i^{EQ}}\right] + \\
& + k_i^{EQ}\mu'(r_i^{EQ}-r) \left.\frac{\partial r_i}{\partial k_i}\right|_{k_i=k_i^{EQ}}.
\end{aligned} \tag{31}$$

[23] If $\partial\mu/\partial\beta_i \neq 0$ the main results remain, but the threshold income level $\underline{y}$ should be higher.

[24] In the standard Solow model the speed of convergence is measured by $-\partial\left(\dot{k}_i/k\right)/\partial \log k_i = -\partial\left(d\log k_i/dt\right)/\partial \log k_i$ (see Barro and Sala-i-Martin (2004), p. 56).

Proof. The approximate slope of the linearised differential equation of capital per workers around the steady-state gives the approximate speed of convergence to equilibrium of region i. First derivative of Eq. (22) with respect to k_i evaluated in $k_i = k_i^{EQ}$ under the assumption that $\partial k/\partial k_i = \partial\Omega/\partial k_i = 0$ yields Eq. (31). QED ■

All four terms in Eq. (31) are negative as expected. The first term represents the standard effect of the decreasing marginal productivity of capital (i.e. $\alpha < 1$). The second and third terms represent the direct effect of *SCF*: the second term is the effect of redistributive expenditures, while the third of the decrease of the share of *SCF* as k_i increases (indeed $\phi' < 0$, see Eq. (5)). Finally, the fourth term represents the effect of net inflows of capital caused by the changes of interest rate. An increase in k_i decreases the net inflows of capital by decreasing the interest rate of region i. Indeed $\mu' > 0$ (see Eq. (17)) and $\partial r_i/\partial k_i < 0$ since:

$$\frac{\partial r_i}{\partial k_i} = r_i \left[\left(\frac{\alpha - 1 - \gamma}{1+\gamma} \right) k_i^{-1} + \left(\frac{\gamma}{1+\gamma} \right) \phi_i^{-1} \frac{\partial \phi_i}{\partial k_i} \right], \tag{32}$$

where $r_i = \alpha k_i^{\frac{\alpha-1-\gamma}{1+\gamma}} \left(\beta_i \eta_i \phi_i Y\right)^{\frac{\gamma}{1+\gamma}} / \left(1+\gamma\right)$. We stress that when capital per worker increases two forces push downward r_i: i) the decreasing marginal productivity of capital (represented by the first term in the square brackets in Eq. (32)) and the drop in ϕ_i as k_i increases (represented by the second term in the square brackets in Eq. (32)). Hence *SCF* directly increase the speed of convergence by the second and third terms and indirectly by the fourth term affecting the return on capital r_i.

Summing up: from the model we presented we expect the following effects on growth and convergence:

- investment rate of region i increases the productivity level of region i (see Remark 3);
- the growth rate of employment of region i decreases the productivity level of region i (see Remark 4);
- there exists a positive, but concave, relationship between the amount of SCF_i via ψ_i and the productivity level of region i (see Remark 5);
- the size of Structural and Cohesion Funds have a nonlinear impact on productivity level of regions and, in particular, the impact of an increasing size is positive if size is low (see Remark 6);
- an increase in the share of funds devoted to productive activities increases the the productivity level of region i, unless the income of region is low and the share is high (see Remark 7);
- the speed of convergence should be affected by the Structural and Cohesion Funds (see Proposition 8).

4 Empirical Analysis

In this section we evaluate the effects ot the funds, and the empirical implications of the theoretical model in the framework of β-conditional convergence, which is based on parametric regression equations.[25]

4.1 Conditional Convergence

We study the period 1980-2002, and consider regions at NUTS 2 level.[26] Our dependent variable is the annual average growth rate of per worker GVA of a region. That is, with respect to the theoretical model, we focus on income per unit of labour, y, as Gross Value Added refers to what is distributed to the factors of production, including transfers which, in the present contest, may depend on the amount of *SCF* not directly allocated to productive activities. For short, we will indicate this as labour productivity.

We will include in the explanatory variables:[27] the share of funds on regional GVA with three-year lag (which, with a slight abuse of notation, will be indicated as SCF);[28] 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 3, 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 some additional control variables that reflect the possible presence of agglomeration effects, such as the density of economic activity (ECO.DEN), measured by GVA per km^2 (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). In addition, we add a variable to control for the possible presence of spatial effects (SPATIAL.IDX), which are indicated as relevant by a large liter-

[25]In a companion paper we repeat the analyses of this paper with nonparametric techniques. See Fiaschi *et al.* (2008).

[26]Appendix A contains Regions' list.

[27]Appendix C contains the descriptive statistics of the variables.

[28]Specifically, we consider the yearly average level of *SCF* in the whole period, or in each programming period, divided by the level of GVA at the beginning of the period. Results are robust to alternative time lags (1-4 years). Moreover, results are similar when region ES63 (Ceuta and Melilla) is removed from the sample (region ES63's GVA presents some level of uncertainty, given that the values reported in Cambridge and Regio datasets present a huge discrepancy for the last years).

ature on regional convergence.[29] Finally, we introduce country dummies (excluding Germany) to capture the effects of variables whose dimension is typically national, like political institutions, labour markets, educational systems, etc, for which we do not have data at regional level.

The average growth rate of employment EMP.GR is augmented by the rate of depreciation of capital,[30] but not by the long run trend of productivity, as the latter is already taken into account by considering relative productivity. The 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 and the change in agricultural sector should capture the structural change of the regional economies, on the assumption that a reduction of the agricultural sector should positively contribute to productivity, if workers are reallocated to more productive sectors (e.g. manufacturing).

Table 11 contains the results of our preferred OLS specification[31] with and without the variable *SCF*.

[29] See Magrini (2004). Our variable is based on the Getis and Ord index. When the index takes a positive value it means that high values are clustered together, while if the value is negative it means that low values are clustered together. See Fiaschi and Lavezzi (2007) for further details.

[30] 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).

[31] 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.

	without SCF	with SCF	with SCF^2
COUNTRY DUMMIES	YES	YES	YES
SECTORAL CONTROLS	YES	YES	YES
SPATIAL CONTROLS	YES	YES	YES
(Intercept)	0.0088 (0.2754)	0.0071 (0.3241)	−0.0138 (0.0892)
log(PROD.REL.1980)	−0.0196 (0.0000)	−0.0198 (0.0000)	−0.0175 (0.0000)
log(INV.RATE)	0.0043 (0.1319)	-	-
log(EMP.GR)	−0.0050 (0.0181)	−0.0043 (0.0285)	−0.0041 (0.0423)
SCF	-	0.0457 (0.0935)	0.2301 (0.0010)
SCF^2	-	-	−1.2763 (0.0024)
Obs. 195	$\bar{R}^2 = 0.688$	$\bar{R}^2 = 0.694$	$\bar{R}^2 = 0.710$

Table 11: Best linear models with and without SCF (SCF with three-year lags). Dependent variable: annual average growth rate of GVA per worker. Estimation method: OLS; p-values in parenthesis, based on White-heteroschedasticity robust standard errors.

Table 11 reveals the presence of conditional convergence, as the coefficient on initial productivity is negative and statistically significant. In addition, we find that the growth rate of the labour force reduces growth, while the investment rate does not have a significant effect.[32] In column two, the variable *SCF* is marginally significant (p-value: 9.52%), and provides a modest contribution to $\bar{R}^2$. However, when we introduce a quadratic term for *SCF* in column three, we obtain significant coefficients and a nonnegligible contribution to $\bar{R}^2$. This suggests that, on average, regional productivity benefited from the funds given for the first three programming periods.[33]

However, the estimated relationship between SCF and the growth rate of productivity is concave. Figure 1 reports the curve based on the estimated coefficients of *SCF* and SCF^2, which highlights the marginal impact of a change in SCF on growth.[34] This impact appears important: in particular, starting from zero, an increase of one standard deviation of *SCF* (equal to 0.02) produces an increase of approximately 0.4 points of the average annual

[32] In the first two columns, the investment rate resulted included in the best specification, albeit with a nonsignificant coefficient, while in the third column the investment variable was dropped in the procedure to reach the best specification.

[33] 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 0.51). Moreover, including the quadratic term makes both terms for *SCF* strongly statistically significant (their p-values are both below 1%).

[34] This curve is plotted on the range $(0 - 0.10)$ of *SCF* which contains approximately 98% of the observations.

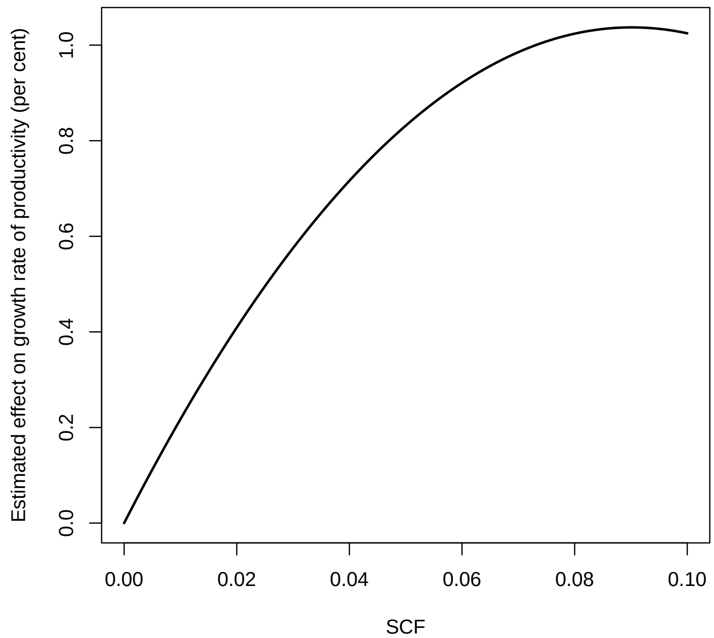

Figure 1: Estimated impact of SCF on the growth rate of productivity

growth rate of productivity.

Table 12 contains the results of various robustness checks and extensions of the best linear model (all performed by applying OLS). In particular, we considered the issue of the stability of the coefficient of the funds in different periods, and for different types of funds. In all cases we considered a quadratic term for the fund(s).[35] Model I is based on a pooled regression with dummies on the different programming periods. Period II and Period III are jointly considered due to the shortness of the two programming periods (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, IV and V are cross-sections that introduces a breakdown of the funds according to the Objectives for all three periods. Models VI and VII are, instead, cross-sections which only consider the second and third programming periods. In Models IX and X we separately consider the effects of commitments and payments for third programming period, being the only one for which we have data. The use of commitments may actually imperfectly measure the funds, while the payments should be more informative on the funds which have been actually spent.

[35]In the regressions presented in Table 12 we entered all the funds with a quadratic term. However, we only report the significant values.

In Model I the effect of *SCF* appears nonlinear, although the quadratic term is not significant. With respect to results in Table 11, both coefficients of *SCF* are lower in magnitude and in statistical significance. This is likely due to two reasons: i) to separately considered 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 increase 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 the 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 11 essentially depends on the effectiveness of the funds in the second and third programming periods. We take this result as further evidence in favour of the hypothesis of a threshold effect of the size of funding on growth.

In Models III, IV, V we consider only Period II & III. Model III shows that funds allocated to Objective 1 and Cohesion funds are the only ones with a positive, concave and highly significant effect. Funds devoted to Objective 2 have a negative, but marginally significant effect, while funds allocated to Objectives 3-5 have not a significant effect.

The results in Models III, IV and V suggest that the effects of funds on growth differs across funds. 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 productive 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 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 not statistically significance of the estimated coefficient for Objectives 3-5 indicates that the effect of these funds is indeed ambiguous.

Model IV and V focus on Objective 1 and Cohesion funds only, and show that even separately they 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 to Objective 1 funds. This is likely caused by the measurement error in the allocation of Cohesion Funds between NUTS2 regions (our dataset on Cohesion Funds is at country level).

In Models VI and VII we focus on the last two programming periods. These models show that Objective 1 funds and Cohesion Funds distributed both 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 have notably reduced the overall fit of the estimate, as shown by the decrease in $\bar{R}^2$.

Models VIII and IX show that the concave relation is highly significant for both the payments and the commitments in the third period. However, the value we estimated using the commitments is quite different from the one obtained using the payments; indeed, the coefficients on commitments underestimate the true effect of the funds.

	I	II	III	IV	V	VI	VII	VIII	IX
TIME DUMMIES	YES	YES	NO	NO	NO	NO	NO	NO	NO
Intercept	−0.0426 (0.0000)	−0.0476 (0.0000)	−0.0165 (0.0382)	−0.0157 (0.0433)	−0.0154 (0.0488)	−0.0518 (0.0008)	−0.0531 (0.0006)	−0.0540 (0.0000)	−0.0540 (0.0000)
log(PROD.1980)	−0.0220 (0.0000)	−0.0216 (0.0000)	−0.0170 (0.0000)	−0.0171 (0.0000)	−0.0169 (0.0000)	−0.0172 (0.0000)	−0.0169 (0.0000)	−0.0182 (0.0001)	−0.0181 (0.0001)
log(EMP.GR)	−0.0111 (0.0000)	−0.0115 (0.0000)	−0.0045 (0.0283)	−0.0042 (0.0337)	−0.0041 (0.0396)	−0.0156 (0.0000)	−0.0157 (0.0000)	−0.0187 (0..0000)	−0.0187 (0.0000)
SCF	0.0966 (0.0128)							0.0963 (0.0055)	
SCF^2	−0.1850 (0.1791)							−0.1473 (0.0847)	
Period I∗SCF		−0.0842 (0.8232)							
Period I∗SCF^2		16.1867 (0.1446)							
(Period II & III) ∗SCF		0.0916 (0.0303)							
(Period II & III)∗SCF^2		−0.1537 (0.2928)							
OB0.OB1				0.2635 (0.0005)					
OB0.$OB1^2$				−1.7431 (0.0019)					
OB0.OB1.CF			0.2162 (0.0022)		0.2420 (0.0004)				
OB0.OB1.CF^2			−1.2116 (0.0082)		−1.3813 (0.0013)				
OB2			−2.0464 (0.1448)						
$OB2^2$			479.3551 (0.2868)						
OB3.OB4.OB5			0.0496 (0.9592)						
OB3.OB4.$OB5^2$			−25.1239 (0.8891)						
(Period II & III)∗OB1						0.1150 (0.0286)			
(Period II & III)∗$OB1^2$						−0.1450 (0.4730)			
(Period II & III)∗OB1.CF							0.1045 (0.0230)		
(Period II & III)∗OB1.CF^2							−0.1353 (0.3874)		
SCF.Payments									0.1502 (0.0035)
$SCF.Payments^2$									−0.3478 (0.0518)
$\bar{R}^2$	0.537	0.540	0.711	0.712	0.713	0.625	0.624	0.701	0.701
Obs.	366	366	195	195	195	195	195	195	195

Table 12: 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-heteroschedasticity robust standard errors.

Figure 2 compare the estimated effect of SCF on the growth rate of productivity for different regressions.

The estimated effect of SCF in the third period appears less subject to diminishing return than the average effect over the three programming periods (the coefficient of square

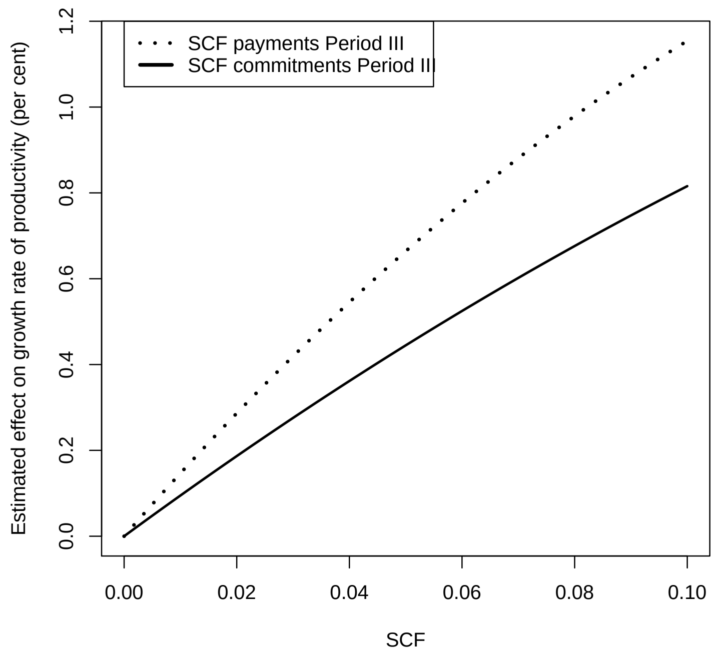

Figure 2: Estimated impact of SCF on the growth rate of productivity. Coefficients from from model with SCF^2 in Table 11 and from Models VIII and IX in Table 12.

terms are lower). Moreover, Figure 2 shows that the effect of the funds by the commitments underestimates the true effect on growth: comparing the difference in the marginal effect of commitment and payments reveals that for high levels of SCF (about 0.1) the bias may amount to about 0.3 percentage points.

Finally, all regressions show evidence of conditional convergence. The coefficient on the initial level of productivity appears to be stable in time (except for the pooled regression in Model I and II), but we remark that cross-section estimates may lead to misleading results. A more exhaustive discussion of the issue of conditional convergence requires the adoption of the distribution dynamics approach (see, Fiaschi *et al.* (2008)).

5 Robustness of results

5.1 Endogeneity of Structural and Cohesion Fund

In light of these results, it is relevant to examine the possibility that the *SCF* can be endogenous since their are not allocated randomly but their are conditional on GDP, implying a reverse causality of productivity growth on *SCF*. In order to test for the exogeneity of *SCF* and its square the Durbin-Wu-Hausman test is performed in its regression-based form (see

Wooldridge, 2002, 118-122) on the sub-sample 1989-1999 using as instruments all the exogenous explanatory variables of model and some additional instruments. With regard to the choice of the instruments for *SCF*, the first one is derived from the three-group method described in Jonhston 1984 and Kennedy 1992, in which the instrumental variable takes values -1, 0 or 1 if the endogenous variable is in the top, middle or bottom third of its ranking. This method that is usually described in the context of variables subject to measurement error, and it is used here with the intent of eliminate the correlation between the instrument and the error term. In fact, by averaging the data in this way the measurement error is also averaged reducing its impact. This approach allows the creation of instruments that do not require extra variables or information beyond the one already available. Moreover, in our case the potentially endogeneity of *SCF* regressor could also be due to measurement error induced both by the use of commitments instead of payments and our reallocation of funds to NUTS2 regions.

As additional instruments we use the lagged value of *SCF* (that is, the *SCF* relative to the first programming period 1975-1988) which is potentially a valid instrument since it is correlated with the original potentially endogenous independent variable and it is not contemporaneously correlated with the disturbance. Moreover we also include the variable which previously identified as determinants of funds' allocation, that is the three-years mean (from 1986 to 1988) regional share of employment and the three-years mean (from 1986 to 1988) of the relative per worker GVA (relative to sample average). SCF^2 is instead instrumenting using an instrument derived from the three-group method for SCF^2 and the square of the lagged value of *SCF*, three-years mean (from 1986 to 1988) regional share of employment and the three-years mean (from 1986 to 1988) of the relative per worker GVA (relative to sample average). According to the Durbin-Wu-Hausman test in the first step, each endogenous variable is regressed on all the exogenous variables and the its instruments and the parameters are estimated by OLS. In the second step, the residuals derived from the first-stage regressions of each endogenous are added into the original regression which is then estimated by OLS. Therefore, a test of the exogeneity of *SCF* and SCF^2 is simply performed by testing the hypothesis that the coefficients relative to the first-stage residuals are jointly not statistically significant (using the usual OLS F statistic).

Results of firs-stage and second-stage regressions are reported in Table 13.

	Estimate First Stage		Estimate Second Stage
Dep. Var.	*commOnGVA.1989-1999*	$commOnGVA.1989-1999^2$	*GR.PROD.1992-2002*
Country Dummies	YES	YES	YES
Intercept	0.1335 (0.0491)	0.0601 (0.0125)	−0.1007 (0.0000)
log(PROD.REL.INIT.1992)	0.0006 (0.6947)	0.0006 (0.9166)	−0.0160 (0.0005)
log(EMP.GR.1992_2002)	−0.0131 (0.3456)	0.0009 (0.8348)	−0.0188 (0.0000)
log(ECO.DEN.1992_2002)	0.0205 (0.0003)	0.0062 (0.0010)	−0.0012 (0.0701)
MANU.1992	−0.2463 (0.0001)	−0.0632 (0.0006)	0.0459 (0.0000)
MIN.1992	−0.2642 (0.0008)	−0.0687 (0.0180)	0.0380 (0.0387)
FIN.1992	−0.5352 (0.0012)	−0.1337 (0.0071)	0.0859 (0.0177)
HOT.1992	−0.3523 (0.0059)	−0.1238 (0.0021)	0.0454 (0.0034)
WHOLE.1992	−0.0684 (0.6512)	0.0251 (0.6969)	0.1002 (0.0005)
OTHER.1992	−0.3518 (0.0031)	−0.1465 (0.0012)	0.1134 (0.0000)
commOnGVA.1977_1988	2.5328 (0.0008)		
Instr.ThreeGroup	−0.0193 (0.0001)		
log(REL.GVA.1986_1988)	−0.0103 (0.7782)		
log(EMP.SH.1986_1988)	−0.0257 (0.0001)		
$commOnGVA.1977\_1988^2$		8.4579 (0.3455)	
Instr.ThreeGroup2		−0.0042 (0.0026)	
$log(REL.GVA.1986\_1988)^2$		−0.0034 (0.6811)	
$log(EMP.SH.1986\_1988)^2$		0.0032 (0.0005)	
commOnGVA.1989_1999			0.1081 (0.0450)
$commOnGVA.1989\_1999^2$			−0.1086 (0.4871)
commOnGVA.1989-1999_res			−0.0265 (0.4632)
$commOnGVA.1989-1999\_res^2$			0.0405 (0.7404)
Obs. 173	$\bar{R}^2 = 0.77$	$\bar{R}^2 = 0.67$	$\bar{R}^2 = 0.67$
F-Test H0: resComm = resCommSquared = 0 F= 0.2111, Pr(>F)=0.8099			

Table 13: Exogeneity test of both *SCF* and SCF^2

Results of the first-stage regression for *SCF* show that all the instruments are statistically significant at the usual level of significance but the $log(REL.GVA.1986\_1988)$. In the first-stage regression for SCF^2 also the instrument derived from the three-group method is not

significant. Moreover, on the period 1989-1999 *SCF* turns out to be positively correlated with *SCF* of the first programming period, but negatively correlated with $log(EMP.SH.1986\_1988)$ and the instrument constructed using the three-group method. From the *F* statistic on the residuals' parameters of $commOnGVA.1989-1999\_res$ and $commOnGVA.1989-1999\_res^2$ the null hypothesis of coefficients jointly equal to zero cannot be rejected. This implies that both the *SCF* and SCF^2 variables are exogenous and, consequently, that OLS estimates of the nonlinear models are consistent.
Since the exogeneity test performed above controls for no exogeneity contemporaneously *SCF* and SCF^2, we also perform an exogeneity test in order to see if the only *SCF* is exogenous (in fact in many models the effect *SCF* results to be linear). Results of firs-stage and second-stage regressions are reported in Table 14.

Dep. Var.	Estimate First Stage *commOnGVA.1989-1999*	Estimate Second Stage *GR.PROD.1992-2002*
Country Dummies	YES	YES
Intercept	-0.2444 (0.0000)	-0.0544 (0.0002)
log(PROD.REL.INIT.1992)	0.0722 (0.0863)	-0.0165 (0.0001)
log(EMP.GR.1992_2002)	-0.0307 (0.0193)	-0.0184 (0.0000)
NON.MARKET.SER.1992	0.3875 (0.0000)	-0.0550 (0.0003)
FIN.1992	-0.0898 (0.4894)	0.0250 (0.4079)
WHOLE.1992	0.4281 (0.0002)	0.0374 (0.1704)
OTHER.1992	-0.0588 (0.4169)	0.0709 (0.0000)
commOnGVA.1977_1988	2.3232 (0.0004)	
Instr.ThreeGroup	-0.0224 (0.0000)	
log(REL.GVA.1986_1988)	-0.0530 (0.1367)	
log(EMP.SH.1986_1988)	-0.0187 (0.0000)	
commOnGVA.1989_1999		0.0809 (0.0053)
commOnGVA.1989-1999_res		0.0355 (0.2603)
Obs. 173	$\bar{R}^2 = 0.69$	$\bar{R}^2 = 0.67$

Table 14: Exogeneity test of *SCF*

Results of the first-stage regression show that all the instruments are statistically significant at the usual level of significance but the $log(REL.GVA.1986\_1988)$ (whose p-value is equal to 0.14). From the *t* statistic relative to the coefficient of $commOnGVA.1989-1999\_res$ the null hypothesis of coefficient equal to zero cannot be rejected. This implies that the *SCF* variable results to be exogenous and, consequently, that OLS estimates of the linear models are consistent.

It is important to point out that the endogeneity test we carried out requires the validity of the instruments used in the first-stage regression. The instrument built using the three-group method is usually called a "quasi-instrument" because by construction this instrument is correlated with the endogenous variable but Fingleton and Le Gallo (2008) show that is not completely uncorrelated with the error terms. In order to test the hypothesis of exogeneity of the instruments a Sargan test of overidentifying restrictions is carried out.

According to the Sargan test, firstly the regression coefficients must be estimated with the IV technique. Then, the residuals derived from the IV regression are regressed on a constant, the exogenous regressors and the instruments (excluding endogenous regressors). From the latter regression we obtain the R^2 in order to calculate the Sargan statistics (which is equal to $(n-k)*R^2$, where n is the number of observations and k the number of coefficients in the original regression) which, under the null, is asymptotically distributed as a $\chi^2_{(n-k)}$.

The statistic for the Sargan test in our case takes the value of 5.342 against a critical value of 180.68, suggesting that there is no correlation between the instruments and the error term, even though the instruments built with the three-group method is a transformation of a potentially endogenous regressor.

5.2 Check for the presence of spatial effects

Spatial dependence can be caused by a variety of measurement problems due to 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) maybe the NUTS aggregations specified by the European Commission are not of appropriate size given the corresponding theories. Moreover, a large part of the empirical literature already showed the typical core-periphery structure of the Europe in terms of per capita GDP and its growth rate.

Spatial dependence refers both to spatial lag dependence (i.e., spatial correlation in the dependent variable), and spatial error dependence (i.e., spatial correlation in the error term. See Anselin, 1988). Spatial lag models assume that the outcome in a given place (e.g. region) is dependent on the outcome in its neighbours (e.g. in case of reaction functions, disease transmission and other sorts of spatial diffusion). In spatial error models instead, the spatial autocorrelation affects the covariance structure of the random disturbance terms. The typical motivation for this is that unmodeled effects spill over across units of observation

resulting in spatially correlated errors.
Ignoring spatial autocorrelation when it is in fact present has different consequences, depending on whether the correct model is a spatial lag or a spatial error specification. Ignoring a spatially lagged dependent variable is equivalent to an omitted variable error, thus yielding OLS estimates for the model coefficients to be bias and inconsistent. On the other hand, ignoring spatially correlated errors is mostly a problem of efficiency, in the sense that OLS coefficients are still unbiased but their standard errors are instead biased.
In order to take into account the possible presence of spatial dependence in the relation, a set of maximum likelihood based test has been performed. In particular, the Lagrange Multiplier (LM) tests only require the estimation of the model under the null hypothesis of no spatial dependence and they are "focused"tests in the sense that they have a clear alternative hypothesis, suggesting the researcher in which direction to search for a proper re-specification. Specifically, *LMerr* is the test having as alternative hypothesis the spatially autoregressive error model, while *LMlag* is the test for an erroneously omitted spatially lagged dependent variable. Moreover, since the spatial lag model can be rewritten as $y = (I - \rho W)^{-1}(X\beta + \epsilon)$, showing that it is equivalent to a model with both spatially lagged exogenous variables and spatially autoregressive errors, the respective LM tests for spatial error and spatial lag model exhibit power against both alternatives (Anselin 2001). A solution for this problem is pointed out by Bera and Yoon (1992) and Anselin (1996), that derive misspecification tests for the error and the lag model robust to local misspecification. The robust unidirectional test for a spatial error process in the presence of a spatial dependent variable is given by *RLMerr* test, while the robust unidirectional test for a spatial dependent variable in the presence of a spatial error process is given by *RLMlag*. Finally, the *SARMA* test considers as alternative hypothesis a spatial autoregressive moving average model.
All these tests have been performing considering different spatial weigth matrices. In particular, we use three matrices in which weights are given by the inverse distance between neighbours defined according to three different distance cut-offs: i) 660.8km, the one we use in the construction of the spatial index used in our regression, ii) a lower distance equals to 368.5km, corresponding to the sencond quantile of the distance distribution; and iii) a greater distance equals to 1022.8km, corresponding to the fourth quantile. Results are reported in Table 15.

All the LM tests cannot reject the null hypothesis of no spatial dependence in the best-nonlinear model at 5% level of significance. In particular, some tests are significant at 10% level but only in their non robust version. That is, at 10% level of significance both *LMerr* and *LMlag* tests can reject the null hypothesis of no spatial dependence, respectively against a spatial error and a spatial lag model. In order to decided which model to choose, we have to look at the robust version of the tests which turn to be not significantly differnt from zero even at 10% level of significance. Also the *SARMA* model that consider a mixed model with

H

	Best Model with SCF^2				
	LMerr	LMlag	RLMerr	RLMlag	SARMA
660.8km	2.8244 (0.09284)	3.4071 (0.06492)	0.7987 (0.3715)	1.3814 (0.2399)	4.2058 (0.1221)
368.5km	2.7783 (0.09555)	1.4944 (0.2215)	1.4414 (0.2299)	0.1575 (0.6915)	2.9358 (0.2304)
1022.8km	1.1139 (0.2912)	0.6001 (0.4385)	0.6362 (0.4251)	0.1224 (0.7264)	1.2363 (0.5389)

Table 15: Spatial test for best nonlinear model

both spatial lag and spatial error dependence, cannot reject the null of no spatial dependece at 5% and 10% level of significance. Therefore we can conclude that our model is consistently and efficiently estimated.
The same tests have been performed also for a "restricted" model, i.e. a model where *SCF* enter only linear and where there are no control for the sectoral composition of the regions. The results of the tests show that when we consider a cut-off distance equal to 660.8km, we can reject the null of no spatial dependence in favour of the hypothesis of a spatial error model (i.e. $LMerr = 4.912$ is statistically significant at 5% level). This implies that the presence of spatial dependence can be due to omitted variable and misspecification problems instead of the presence of spatial effects. When we control for sectoral composition and allow for *SCF* to enter nonlinearly in the specification we find no evidence of spatial dependence between productivity growth of European regions.

6 Concluding Remarks

This paper represents an attempt at estimating the effect of European Union regional policy on productivity growth and convergence. We find that the effect appears in general positive and of a quite remarkable size. However, the results show that some qualifications of this general claim are needed. Firstly, the effect appears nonlinear, and the allocation of 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; while, the allocation of funds to other objectives appears to hinger the efficient reallocation of resources across sectors in European regions.

Moreover, it appears that it is the funding of the third programming period that exerted the most significant effect. This finding points to the presence of a nonlinear effect of the size of funds, in the sense that the funds started to be effective when their amount has reached a threshold level.

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A List of NUTS2 Regions in the Sample

B Proof of Remarks

B.1 Proof of Remark 3

Rewrite Eq. (23) as:

$$f_1(\theta_i^{EQ}, s_i, \tau, \psi_i, \beta_i, \Omega^{EQ}, k^{EQ}) = f_2(l_i, \theta_i^{EQ}, \tau, \psi_i, \beta_i, \Omega^{EQ}, k^{EQ}), \tag{33}$$

AT11	Burgenland	DEA1	Dsseldorf	FR26	Bourgogne	IT52	Umbria	UKD1	Cumbria
AT12	Niedersterreich	DEA2	Kln	FR3	Nord - Pas-de-Calais	IT53	Marche	UKD2	Cheshire
AT13	Wien	DEA3	Mnster	FR41	Lorraine	IT6	Lazio	UKD3	Greater Manchester
AT21	Krnten	DEA4	Detmold	FR42	Alsace	IT71	Abruzzo	UKD4	Lancashire
AT22	Steiermark	DEA5	Arnsberg	FR43	Franche-Comt	IT72	Molise	UKD5	Merseyside
AT31	Obersterreich	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	Rg. Bruxelles	DEF	Schleswig-Holstein	FR62	Midi-Pyrnes	ITA	Sicilia	UKF1	Derbyshire, Nottingh.
BE21	Antwerpen	DK	Danmark	FR63	Limousin	ITB	Sardegna	UKF2	Leicestershire, Rutland
BE22	Limburg (B)	ES11	Galicia	FR71	Rhne-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-Cte 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	Lige	ES24	Aragn	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 Len	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	Tbingen	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	Regin 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	Aores		and North Somerset
DE26	Unterfranken	FI13	It-Suomi	IE01	Border, Mid., Western	PT3	Madeira	UKK2	Dorset, Somerset
DE27	Schwaben	FI18	Etel-Suomi	IE02	Southern and Eastern	SE01	Stockholm	UKK3	Cornwall, Isles of Scilly
DE5	Bremen	FI19	Lnsi-Suomi	IT11	Piemonte	SE02	stra 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	Gieen	FR1	le de France	IT2	Lombardia	SE07	Mellersta Norrland	UKM1	North Eastern Scotland
DE73	Kassel	FR21	Champagne-Ardenne	IT31	Trentino-Alto Adige	SE08	vre Norrland	UKM2	Eastern Scotland
DE91	Braunschweig	FR22	Picardie	IT32	Veneto	SE09	Smland med arna	UKM3	South Western Scotland
DE92	Hannover	FR23	Haute-Normandie	IT33	Friuli-Venezia Giulia	SE0A	Vstsverige	UKM4	Highlands and Islands
DE93	Lneburg	FR24	Centre	IT4	Emilia-Romagna	UKC1	Tees Valley	UKN	Northern Ireland
DE94	Weser-Ems	FR25	Basse-Normandie	IT51	Toscana	UKC2	Northumberland		

where f_1 is the left hand side of Eq. (23) and f_2 is the right hand side. According to the implicit function theorem:

$$\frac{\partial f_1}{\partial \theta_i^{EQ}} d\theta_i^{EQ} + \frac{\partial f_1}{\partial s_i} ds_i = \frac{\partial f_2}{\partial \theta_i^{EQ}} d\theta_i^{EQ} \tag{34}$$

and consequently:

$$\frac{d\theta_i^{EQ}}{ds_i} = \frac{\partial f_1 / \partial s_i}{\partial f_2 / \partial \theta_i^{EQ} - \partial f_1 / \partial \theta_i^{EQ}}. \tag{35}$$

Since $\partial \Omega^{EQ} / \partial k_i = \partial k^{EQ} / \partial k_i = 0$ then $\partial f_1 / \partial \theta_i^{EQ} < 0$ and $\partial f_2 / \partial \theta_i^{EQ} > 0$ (r_i is decreasing in θ_i); therefore the denominator of Eq. (35) is positive. Hence the sign of the derivative $d\theta_i^{EQ} / ds_i$ depends on the sign of $\partial f_1 / \partial s_i$, which results positive under assumption $\partial k^{EQ} / \partial s_i = \partial \Omega^{EQ} / \partial s_i = 0$. The positive derivative of θ_i with respect to k_i concludes the proof. QED

B.2 Proof of Remark 4

As in the proof of Remark 3 by implicit function theorem:

$$\frac{d\theta_i^{EQ}}{dl_i} = -\frac{\partial f_2 / \partial l_i}{\partial f_2 / \partial \theta_i^{EQ} - \partial f_1 / \partial \theta_i^{EQ}}. \tag{36}$$

Since $\partial k^{EQ} / \partial l_i = \partial \Omega^{EQ} / \partial l_i = \partial \Omega^{EQ} / \partial k_i = \partial k^{EQ} / \partial k_i = 0$ the denominator of Eq. (36) is positive and $\partial f_2 / \partial l_i = 1 > 0$; therefore $d\theta_i^{EQ} / dl_i < 0$. The positive derivative of θ_i with respect to k_i concludes the proof. QED

B.3 Proof of Remark 5

As in the proof of Remark 3:

$$\frac{d\theta_i^{EQ}}{d\psi_i} = \frac{\partial f_1 / \partial \psi_i - \partial f_2 / \partial \psi_i}{\partial f_2 / \partial \theta_i^{EQ} - \partial f_1 / \partial \theta_i^{EQ}} \tag{37}$$

Since $\partial k^{EQ} / \partial \psi_i = \partial \Omega^{EQ} / \partial \psi_i = \partial \Omega^{EQ} / \partial k_i = \partial k^{EQ} / \partial k_i = 0$ then the denominator of Eq. (36) is positive; moreover, $\partial f_1 / \partial \psi_i - \partial f_2 / \partial \psi_i > 0$ (r_i is increasing in ψ_i); therefore $d\theta_i^{EQ} / d\psi_i > 0$. The positive derivative of θ_i with respect to k_i concludes the first part of the proof. The numerator in Eq. (37) is decreasing in ψ_i while the denominator is increasing; therefore $d\theta_i^{EQ} / d\psi_i$ is decreasing in ψ_i. QED

B.4 Proof of Remark 6

As in the proof of Remark 3:

$$\frac{d\theta_i^{EQ}}{d\tau} = \frac{\partial f_1/\partial \tau - \partial f_2/\partial \tau}{\partial f_2/\partial \theta_i^{EQ} - \partial f_1/\partial \theta_i^{EQ}} \tag{38}$$

Since $\partial \mu/\partial \tau = 0$ then $\partial f_2/\partial \tau = 0$ and under assumptions $\partial \Omega^{EQ}/\partial k_i = \partial k^{EQ}/\partial k_i = 0$ and $\beta_i = 1 \ \forall i \ \partial f_1/\partial \tau > 0$ for $\tau < \tau^*$ while $\partial f_1/\partial \tau < 0$ for $\tau > \tau^*$, where τ^* is defined Eq. (13). This implies that $d\theta_i^{EQ}/d\tau > 0$ for $\tau < \tau^*$ and $d\theta_i^{EQ}/d\tau < 0$ for $\tau > \tau^*$. The positive derivative of θ_i with respect to k_i concludes the proof. QED

B.5 Proof of Remark 7

As in the proof of Remark 3:

$$\frac{d\theta_i^{EQ}}{d\beta_i} = \frac{\partial f_1/\partial \beta_i - \partial f_2/\partial \beta_i}{\partial f_2/\partial \theta_i^{EQ} - \partial f_1/\partial \theta_i^{EQ}}. \tag{39}$$

First note that since $\partial \mu/\partial \beta_i = 0$ then $\partial f_2/\partial \beta_i = 0$. Moreover, since $\partial \Omega^{EQ}/\partial k_i = \partial k^{EQ}/\partial \beta_i = \partial \Omega^{EQ}/\partial \beta_i = \partial k^{EQ}/\partial k_i = 0$ and $\tau = \tau^* = \gamma/(1+\gamma)$, the sign of $d\theta_i^{EQ}/d\beta_i$ depends on the sign of $\partial f_1/\partial \beta_i$ (the denominator is positive). In particular, if

$$y_i < y^{EQ} \left(\frac{1+\gamma}{\gamma}\right)^2 \left(\frac{\phi^{EQ}}{s_i}\right) = \underline{y},$$

then $\partial f_1/\partial \beta_i > 0$ for

$$\beta_i < \frac{\gamma^2}{(1+\gamma)} \frac{s_i}{\phi^{EQ}} \frac{y_i}{y^{EQ}} - \gamma = (1+\gamma) \frac{y_i}{\underline{y}} - \gamma,$$

while $\partial f_1/\partial \beta_i < 0$ for

$$\beta_i > (1+\gamma) \frac{y_i}{\underline{y}} - \gamma.$$

Otherwise, if $y_i > \underline{y}$ then $\partial f_1/\partial \beta_i > 0 \ \forall \beta_i$. The positive derivative of θ_i with respect to k_i concludes the proof. QED

C Descriptive statistics of variables

	PROD	PROD.REL	INV.RATE	EMP.GR	ECO.DEN	SPAT.INDEX
Mean	0.02	1.00	0.20	0.03	7.28	0.68
St.Dev.	0.01	0.33	0.06	0.01	25.39	2.91
	AGRI	MANU	MIN	CONS	NOMARKS	FIN
Mean	0.05	0.21	0.04	0.08	0.23	0.05
St.Dev.	0.07	0.09	0.04	0.03	0.06	0.02
	HOT	TRAN	WHOL	OTH	SCF	PAY
Mean	0.04	0.07	0.11	0.14	0.01	0.66
St.Dev.	0.04	0.03	0.03	0.04	0.03	0.07

Table 16: 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	0.1	0.4	0.83	−0.53
INV.RATE	0.16	1	0.17	−0.25	0.28	0.22
EMP.GR	0.1	0.17	1	0.18	0.07	−0.34
ECO.DEN	0.4	−0.25	0.18	1	0.32	−0.59
SPAT.INDEX	0.83	0.28	0.07	0.32	1	−0.48
AGRI	−0.53	0.22	−0.34	−0.59	−0.48	1
MANU	0.16	−0.25	−0.11	0.22	0.19	−0.31
MIN	0.14	−0.01	−0.02	−0.06	−0.01	0.03
CONS	0.05	0.49	0.13	−0.22	0.17	0.06
NONMARKS	0.28	−0.01	0.19	0.24	0.36	−0.45
FIN	0.4	0.12	0.11	0.42	0.37	−0.41
HOT	−0.39	0.07	0.18	−0.25	−0.42	0.23
TRAN	0.04	0	0.19	0.08	−0.03	−0.18
WHOL	−0.26	0.05	0	0.07	−0.29	0.18
OTH	0.21	−0.33	0.08	0.26	0.16	−0.4
SCF	−0.48	0.26	0.03	−0.23	−0.4	0.42
PAY	0.2	−0.05	0.08	0.07	0.28	−0.29

Table 17: Correlations between variables used in regressions

	MANU	MIN	CONS	NONMARKS	FIN	HOT
PROD.REL	0.16	0.14	0.05	0.28	0.4	−0.39
INV.RATE	−0.25	−0.01	0.49	−0.01	0.12	0.07
EMP.GR	−0.11	−0.02	0.13	0.19	0.11	0.18
ECO.DEN	0.22	−0.06	−0.22	0.24	0.42	−0.25
SPAT.INDEX	0.19	−0.01	0.17	0.36	0.37	−0.42
AGRI	−0.31	0.03	0.06	−0.45	−0.41	0.23
MANU	1	−0.12	−0.17	−0.35	−0.14	−0.26
MIN	−0.12	1	−0.11	−0.04	−0.23	−0.08
CONS	−0.17	−0.11	1	0.11	−0.02	−0.09
NONMARKS	−0.35	−0.04	0.11	1	0.23	−0.35
FIN	-0.14	−0.23	−0.02	0.23	1	−0.18
HOT	−0.26	−0.08	−0.09	−0.35	−0.18	1
TRAN	−0.27	−0.13	−0.09	−0.02	0.22	0.06
WHOL	−0.37	−0.24	−0.13	−0.09	0.15	0.24
OTH	−0.06	−0.27	−0.27	0.16	0.25	−0.13
SCF	−0.37	−0.02	0.26	−0.16	−0.2	0.23
PAY	0.06	−0.14	0.03	0.25	0.13	−0.22
0.25						

	TRAN	WHOL	OTH	SCF	PAY
PROD.REL	0.04	−0.26	0.21	−0.48	0.2
INV.RATE	0	0.05	−0.33	0.26	−0.05
EMP.GR	0.19	0	0.08	0.03	0.08
ECO.DEN	0.08	0.07	0.26	−0.23	0.07
SPAT.INDEX	−0.03	−0.29	0.16	−0.4	0.28
AGRI	−0.18	0.18	−0.4	0.42	−0.29
MANU	−0.27	−0.37	−0.06	−0.37	0.06
MIN	−0.13	−0.24	−0.27	−0.02	−0.14
CONS	−0.09	−0.13	−0.27	0.26	0.03
NONMARKS	−0.02	−0.09	0.16	−0.16	0.25
FIN	0.22	0.15	0.25	−0.2	0.13
HOT	0.06	0.24	−0.13	0.23	−0.22
TRAN	1	0.11	0.13	0.2	0
WHOL	0.11	1	−0.09	0.22	−0.26
OTH	0.13	−0.09	1	−0.24	0.39
SCF	0.2	0.22	−0.24	1	−0.09
PAY	0	−0.26	0.39	−0.09	1

Table 18: Continued: Correlations between variables used in regressions