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ASSESSING COHESION POLICY EFFECTIVENESS ON EUROPEAN NUTS 2: COUNTERFACTUAL EVALUATION ON TRANSPORT ACCESSIBILITY AND RESEARCH AND INNOVATION USING A REGRESSION DISCONTINUITY DESIGN APPROACH

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ABSTRACT

Traditionally, European Cohesion Policy effectiveness has been evaluated in the economic literature in terms of its impacts on the per-capita growth rate of GDP. However, no unanimous results have been reached so far. In this paper, the effect of European Regional Policy are evaluated at the EU 15 NUTS 2 level by considering, alongside GDP growth, two specific fields of intervention, namely “Research, Technological Development and Innovation” (RTDI), and “Transport Infrastructure” (TI). Our aim is to assess whether Objective 1 regions experienced greater growth than non-Objective 1 regions, by considering improvement in the potential road accessibility and in research and innovation activities (patent applications). Our econometric approach involves the use of a non-parametric Regression Discontinuity Design technique to a uniquely-disaggregated Cohesion Policy dataset broken down according to the specific objectives of each stream of funding. The analysis considers different time intervals and different regional sub-samples. The results point to significant growth effects in these indicators for Objective 1 regions above those displayed by non-Objective 1 regions. Indeed, the difference is sufficiently large that when observed in terms of levels effects, the two types of regions become largely indistinguishable in terms of these particular features, exactly as intended by the policy.

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1. Introduction[2]

The aim of this paper is to assess the effectiveness of European Cohesion Policy during the programming period 2000-2006[3] in improving both research and innovation activities and transport accessibility, alongside its impact on the growth rate of per-capita GDP.
Previous contributions to the assessment of EU Cohesion Policy were focused mainly on the growth rate of the Gross Domestic Product (Becker 2010, 2012; Hagen and Mohl 2009; Manzella and Mendez 2009, Pellegrini et al. 2013), leaving its impact on other specific fields of intervention unexplored. In recent years, however, a number of studies has stressed the importance of considering the multidimensional nature of both social progress and economic development, broadening the scope of analysis to more than just the production sphere (Acemoglu et al. 2005; CMEPSP 2009; Fitoussi 2013; Sen 1999, 2006; Stiglitz et al. 2009; Tabellini 2010; UNDP 2013). This strand of research is in line with the European Union Treaty statement that: "in order to promote its overall harmonious development, the Union shall develop and pursue its actions leading to the strengthening of its economic, social and territorial cohesion" (art. 174 of the Treaty on the functioning of the European Union, ex art. 158 TEC).

2. Theoretical Framework

The effectiveness of EU Regional Policy was especially evaluated in terms of convergence in per capita growth rate of GDP amongst regions. The use of GDP as a synthetic indicator of regional performance and of policy effectiveness has the advantage of being a standard measure available for all countries, thus facilitating spatial and temporal comparisons of the results. However, GDP does not account for dimensions of social and economic progress that are not strictly related to the production activity (Fleurbaey 2009, Bleys 2012).
The Report of the Stiglitz, Sen, Fitoussi Commission (2009) emphasises the necessity of going "beyond GDP" for "measuring economic performance and social progress". Following this point of view, our work takes a multidimensional approach to the evaluation of the effects of the EU Regional Policy in the NUTS 2 regions of the European Union, looking at specific outcome variables concerning a wider range of progress dimensions than that of production.
Several studies have investigated the impact of Cohesion Policy on economic growth. However, the heterogeneity of the data, the variety of methodological approaches used and the low quality of regional data on Structural Funds have not allowed to reach unanimous results, leaving open the debate on the effectiveness of Regional Policy (Hagen and Mohl 2008). In terms of the impacts of the policy, there are now more than fifty studies analysing the effects of European regional policy on EU regions, of which between approximately two thirds and three quarters of these papers find either positive effects or positive but mixed effects on the recipient regions while the remaining quarter find either negligible or even negative effects (McCann 2015). For a summary of the main findings, see Table 1.
Following Ederveen et al. (2002), we classify these studies into three groups based on the type of evaluative approach adopted: case studies, model simulations and econometric models. We further expand the survey with a number of more recent contributions and a more detailed clustering of the econometric studies.

2.1 Case studies

The case studies literature evaluates single policy projects, with varying emphasis on the way in which the funds are actually spent, on their impact on local authority practices, or on their macroeconomic implications (Ederveen et al. 2002). A number of case studies assesses the impact of Cohesion Policy on the growth of gross per-capita regional production and employment. In most of the cases, they find some kind of limitation to the effectiveness of Cohesion Policy, though they do not present quantitative estimates of the policy's impact. The great majority of these studies in fact contains a detailed description of the socio-economic situation in the regions analysed as well as of the projects to be financed by Cohesion support, but the evaluation itself boils down an enumeration of the project's

[2] I wish to thank: Prof. Philip McCann for his helpful comments, Prof. G. Pellegrini for the methodological suggestions, Prof. D. Stelder and Dr. Flavia Terribile for providing part of the datasets.

[3] More precisely, the programming period 2000-2006 is the focus of the analysis, but we aim to account also for the time-delayed effects of the policy; thus we consider a longer time interval for the outcome variables. Moreover, in order to have a greater stability of the sample, we consider the eligibility status of the regions for both programming periods (1994-1999 and 2000-2006).

output (kilometres of roads constructed, number of jobs created and so on). Some studies adopt this approach focusing on single programmes and single areas. Among these, the most cited are Huggings (1998) on the Objective 2 programmes in industrial South Wales, Daucé (1998), who focused on the most depressed rural area in Burgundy, and Lolos (1998) who analysed the macroeconomic and structural policies in Greece and Portugal.

Further, many researchers argue that considering only the numeric impact of the policies is insufficient and have tried to include single projects in regional economic models in order to capture also the spillover effects (European Commission, 1999). Others have tried to get an idea of the impact of Cohesion Funds from reviewing various case studies of different projects referring to specific areas (Das Neves 1994). Bachtler and Taylor (1996) consider the evaluation of projects and the EU official surveys, though they do not estimate a quantitative impact. The practical experiences of Cohesion support are brought together in the work of Bachtler and Turok (1997) with case studies on the United Kingdom, Germany, The Netherlands, Austria, Finland and Sweden. These studies highlight the difficulty in achieving coherence in these big *ad hoc*-defined projects, even in the presence of reforms aiming to define regional plans and a common EU framework; they also stress the difficulties in evaluating policy effects which are considered by the majority of these studies presumably modest.

2.2 Model simulations

Model simulations complement the traditional case studies in three main ways. First, they evaluate the contribution of Cohesion Policy on a macroeconomic ground, considering the results in terms of regional productivity or employment levels. Second, they model the general equilibrium consequences of Cohesion Policy and sometimes investigate the occurrence of externalities. Third, they provide the counterfactual, analysing how regions would have fared without the Cohesion support.

The first attempts at evaluating Cohesion support through model simulations used EU macroeconomic models, and in particular the HERMES model, developed to analyse supply side shocks in the 1970s and 1980s. This model reveal a positive impact of Cohesion Policies, however, it has only been applied to Ireland (Bradley 1992; Bradley, Fitz Gerald and Kearney 1992). The HERMIN model on the other hand (Bradley, O'Donnell, Sheridan, and Whelan 1995; Bradley, Modesto, and Sosvilla-Rivero 1995; Bradley 2000), has been applied to Ireland (Bradley, Whelan, and Wright 1995), Spain (Herce and Sosvilla-Rivero 1995) and Portugal (Modesto and Neves 1994; Modesto and Neves 1995). All these studies find a positive impact of Cohesion support with a significant role in the reduction of regional disparities, which would not have been the same in the absence of the Policy. Further, the European Commission (1999a, 1999b, 2001a) reports on the results of other simulations obtained using HERMIN as well as QUEST, a model that focuses on the demand side (Röger 1996).

Another strand of research refers to model simulations other than the European Commission models. Gaspar and Pereira (1992) develop a two-sector endogenous growth model of private, public and human capital accumulation for Portugal and they find that the current structural changes have a marked impact on economic growth as they contribute to generating a convergence process. A different modelling approach is used by Goybet and Bertoldi (1994), who consider models that range from a neo-Keynesian to a dynamic general equilibrium with endogenous growth; they conclude that Objective 1 regions on average grow faster than EU member states. Greece is the focus of analysis in the works of Lolos, Suwa-Eisenmann, and Zonzilos (1995) and Lolos and Zonzilos (1994), who use a general equilibrium model; their results are mixed in terms of both the sign and intensity of the Policy's impact. More recent studies by Pereira (1997, 1999), Gaspar and Pereira (1995) and Pereira and Gaspar (1999) use an endogenous growth model to assess the impact of the Cohesion support on the GDP growth of Greece, Ireland and Portugal for the period 1989-93. The results show a substantial impact on economic growth in these economies and a significant contribution to convergence. They also highlight the importance of continuing the transfer programme since the relative long-run position of these countries would still be far from EU standards.

The overall conclusion from the simulation exercises is that Cohesion support significantly contributes to regional growth and employment. The weakness of this approach is however, the indirect measurement of the Policy's effect, which is highly dependent on the hypotheses underlying the model used in the analysis.

In conclusion, model simulations illustrate the Policy's potential effects, which are found to be positive, but they fail to account for a number of important factors that may reduce the actual effectiveness of Cohesion support, such as crowding out effects, inefficient allocation and rent-seeking behaviour.

2.3 Econometric models

Among the contributions that adopt econometric methods, we can identify two different approaches: the classical regression framework, where growth equation models are estimated (Barro 1991, 1997; Barro and Sala-i-Martin 1992; Sala-i-Martin 1994), and the more recent literature based on the treatment effect technique. In both strands of research, however, no unambiguous results have been reached and it is possible to provide a further classification of these studies based on the effects they observe.

2.3.1 Classical regression framework

In the classical econometric regression approach, there is a controversial evidence of the policy effects. Based on the results obtained, we identify three groups of works: the first group gives an optimistic policy evaluation, finding a positive and statistically significant impact (de la Fuente *et al.* 1995; Cappellen *et al*. 2003; Rodriguez-Pose *et al.* 2004; Beugelsdijk and Eijffinger 2005; Falk and Sinabell 2008); the second group obtains mixed results, finding that policy effectiveness is dependent on the presence of specific conditions (Puigcerver-Penalver 2004; Antunes and Soukiazis 2005; Percoco 2005; Ederveen *et al*. 2006; Bäh, 2008; Esposti and Bussoletti 2008; Mohl and Hagen 2008, 2010; Bouvet 2010; Rodríguez-Pose and Novak 2013); finally, the third group includes works that have a pessimistic vision of the policy, showing either negative or redistributive effects (Fagerberg and Verspagen 1996; Boldrin and Canova 2001; Garcia-Milà and McGuire 2001; de Freitas *et al*. 2003; Dall'Erba and Le Gallo 2008; Aiello and Pupo 2012; Wostner and Šlander 2009).

Amongst the works highlighting the policy's success we find the research of de la Fuente et al. (1995), where a growth model that includes public capital and human capital is estimated. The authors show evidence that public investments in infrastructure and education have a significant impact on growth in the Spanish regions in the period 1980-1990. They thus conclude that adequate regional policies can encourage both growth and convergence. A positive and statistically significant impact of EU Regional Policy on the regional growth is found also in Cappellen et al. (2003). In addition, they show that the effects are stronger in more developed environments, calling for policy interventions to improve the competences of the receiving contexts (for example by facilitating structural changes, or by increasing the investment capacity in R&D in the poorer regions). In their empirical analysis, the authors validate the hypothesis that regional growth is the outcome of three groups of factors: the exploitation of knowledge developed elsewhere (diffusion of knowledge); the creation of new knowledge in the region (innovation) and the presence of "complementary factors" that affect the capacity for exploiting the potential of knowledge created elsewhere. This research design entails two main problems: the definition of an indicator of innovation, and the measurement of "complementary factors". As a proxy for innovation, they use the intensity of research and development (employees in R&D in firms as a percentage of the total employment); whereas among the complementary variables they consider: transport infrastructure, population density, industrial structure, long-term unemployment. The estimation results confirm that the impact of the contributions (public financing) is strictly dependent on the receptiveness of the receiving environment.

Rodriguez-Pose and Fratesi's (2004) evaluation of the effects of Regional Policies is also positive. They consider the impact of the Structural Funds on the Objective 1 regions. Their results confirm a key role of the development funds allocated to lagging regions in Europe: their positive impact on regional economies keeps regional disparities more stable, meaning that they avoid the expansion of regional gaps. However, transfers have failed to achieve their goal of reducing the gap between the European core and its periphery.

Beugelsdijk and Eijffinger (2005) deal with two main issues: first, they verify convergence across European member states over the period 1995-2001; secondly, they analyse the problems of moral hazard and substitution effect. As regards the first issue, they show that Structural Funds have a positive impact on convergence, as there is a trend of backward countries catching up with richer ones. In terms of the second issue, they consider two kinds of problems. The first one is the possibility that opportunistic behaviour may occur: since eligibility for the Funds is dependent on the presence of a certain GDP threshold, policy makers could decide to use the funds inefficiently in order to get more funds in the future (moral hazard). A crowding out effect (or substitution effect), on the other hand, might prevail if the transfers received are invested in projects for which the states have already allocated national resources: states, substitute the national resources with Structural Fund transfers with the consequence of no additional impact. To consider the moral hazard and substitution effect, the authors estimate two different convergence equations, one for "clean" countries and another one for "corrupt" countries[4]. The influence of

[4] A corruption index related to perceptions of the degree of corruption as seen by business people, risk analysts and the general public and ranging from 10 (highly clean) to 0 (highly corrupt), is included in the regression equations.

corruption on the funds' impact on economic growth is evaluated with an interaction term. Results do not show a weaker relationship of Structural Funds to growth for the more corrupt countries.
In the work of Falk and Sinabell (2008), a spatial econometric approach is used to investigate the growth effects of EU Structural Funds for Objective 1 regions at the NUTS 3 level. They estimate the regional growth of per-capita GDP as a function of (a) the initial level of per-capita GDP (in PPT), (b) the share for each sector (primary or secondary), (c) Objective 1 area eligibility and (d) population density. In addition, in order to investigate the sources of the growth differential between Objective 1 and other regions, they apply the Blinder-Oaxaca decomposition, finding that the growth differential between Objective 1 regions and other regions is solely due to differences in the characteristics and not to differences in the coefficients.

Another group of studies finds evidence that the effectiveness of European Regional Policy is dependent on the specific context's features. Puigcerver-Penalver (2004) model the impact of the Objective 1 policy, adopting a "hybrid" growth model that links the growth rate of per-capita income to (a) its initial level, (b) the Structural Funds transfers, the catching-up variable and the initial level of Total Factors Productivity (TFP). The model is estimated by means of OLS using a panel data approach with fixed effects (only Objective 1 regions are considered). The results show a positive effect of the Structural Funds on the per-capita growth rate of income in Objective 1 regions. However, these results change when the two programming periods are considered separately: the impact is still positive during the first programming period but almost null in the second.
Antunes and Soukiazis (2005) aim to determine whether there are differences in the convergence process between the coastal and the inland regions of Portugal. They examine the relevance of Structural Funds as conditioning factors in the convergence process and to what extent they contribute to regional per-capita income growth. The analysis considers the NUTS 3 regions of Portugal by using a panel data approach. Results show that Structural Funds help regions to grow faster but their marginal impact is small. They have a significant positive effect only in the coastal area, helping its regions to grow faster.
Percoco's research (2005) focuses on six Italian Mezzogiorno regions and analyses the impact of the Structural Funds by means of a supply-side model, with a Cobb-Douglas function. He finds a high volatility in the level of growth rates induced by Structural Fund expenditure. The work of Endeerven et al. (2006) also belongs to this strand of research. They investigate the effectiveness of Structural Funds through a panel analysis for 13 EU countries. They demonstrate that, on average, the funds are only effective, in the countries with the "right" institutions[5]. In the conclusions, the authors stress the necessity of improving institutional quality as an essential step for triggering a catching-up process.
Bähr (2008) analyses EU Regional Policy effectiveness by focusing on the different federal structure of its member states (EU13) for seven five-year periods, from 1960-1965 to 1990-1995. A pooled cross-sectional regression econometric model is used for the estimation of the different degrees of sub-national autonomy (decentralisation) among member states on the effectiveness of Structural Funds expenditure. The results suggest that Structural Funds are more effective in promoting growth when decentralisation is higher.
Esposti and Bussoletti (2008) investigate the impact of Objective 1 Structural Funds expenditure using a database of 206 EU 15 regions in a time interval ranging from 1989 to 2000. They assume that structural payments condition the "natural" convergence process of the poorer European regions towards the richer ones. Therefore, they estimate an augmented conditional regional convergence model to assess whether growth convergence actually occurs. Considering they consist mainly of investment expenditure, Structural Funds are included in the regional growth convergence model as a variable, affecting the investment rate. A limited but positive impact of Objective 1 Funds was found for the EU as a whole; whereas a negligible or negative effect is registered in some specific cases.
Mohl and Hagen (2008, 2010) seek to evaluate the growth effects of EU Structural funds at both the NUTS 1 and NUTS 2 levels over the period 2000-2006. They use a panel estimation controlling for endogeneity, serial and spatial correlations and heteroskedasticity. They find that the total EU aid (including Objectives 2 and 3) has no statistically significant or even negative impact on regional growth; whereas Objective 1 payments have a positive and statistically significant impact on the regional GDP growth rate. Bouvet (2009) analyses the impact of the EU Regional Policy on inequalities, as the reduction of interregional income inequalities is a leading aim of EU cohesion policy. His findings confirm the persistence of within-country inequality, calling for a reform to existing

[5] The authors distinguish between three broad groups of institutional quality variables. First, they consider variables related to the outcome of government policy (inflation and government savings); second there are variables that synthesise social cohesion

EU Regional Policies. More specifically, he concludes that structural policies should be elaborated at the regional level and not at the national level and that funds should be further concentrated onto poorer regions.
An econometric model is adopted to evaluate the effect of Structural Fund expenditure on the growth of regional per-capita GDP in Rodriguez-Pose and Novak (2013). They refer to the last programming periods for which full sets of data are available (1994-1999 and 2000-2006), using factor endowments, institutional quality and initial conditions as conditioning variables. They also take into account the learning mechanism resulting from evaluation of the policy. The results reveal an increase in policy effectiveness in successive periods.
In the third group are those studies that observe no policy impact or redistributive effects. Fagerberg and Verspagen (1996) analyse growth in 70 regions (in six EU member states) in the post-war period. Their findings show no impact of the Funds on convergence in terms of per-capita GDP, but that Europe seems to grow with at least three different speeds for dynamism, productivity and unemployment. No evidence of convergence (or divergence) was also found in the work of Boldrin and Canova (2001) on the EU15 regions between 1980 and the mid '90s. Their results do not allow to definitively assert the effects of Structural Funds on growth; however, they show the redistributive function of Regional Policies to be a consequence of political equilibria inside the European Union.
A clear negative effect is instead observed by Garcia-Milà and McGuire (2001). They evaluate the impact of EU grants on the economic performance of the Spanish regions, using a difference-in-difference model. Results highlight that the policies have not been effective in stimulating private investment or improving the overall economies of the grant-recipient (and poorer) regions. De Freitas et al. (2003) link Objective 1 status to the speed of convergence among regions in the period 1990-2001, in order to account for the effects of the 1989 Structural Funds reform. They estimate Barro equations and control for the quality of national institutions. The authors explicitly investigate whether "Objective 1" status on average improves the rate of convergence. Their findings give evidence of conditional convergence among regions, but they show that Objective 1 eligibility does not have a statistically significant role in fostering convergence. On the contrary, it emerges that region specific factors are important in explaining regional disparities.
Dall'Erba and Le Gallo (2008) evaluate the impact of Structural Funds on convergence across 145 European regions in the period 1989-1999. They estimate a neoclassical model of growth (Barro and Sala-I-Martin, 1995), accounting for location externalities and for a possible endogeneity of the funds. Fund endogeneity might occur as Objective 1 eligibility is fixed with the 75 percent rule (the region must have a per-capita GDP lower than 75% of the European average in the three years previous to the start of the programme); as a consequence, regions receive an amount that is proportional to their development gap. Their estimation results show that significant convergence does occur, but funds have no role in determining it. Cohesion Policy effectiveness is also investigated in the work of Aiello and Pupo (2012) that evaluates the impact of Structural Funds on the growth of Italian regions from 1980 to 2007. For the period 1994-2007, they consider the amount of expenditure actually spent and not only committed; moreover, they consider some institutional aspects in the definition of the fund impact. They use a convergence equation (growth model) with panel data in which the Structural Funds are an explanatory variable. The results show that, although the distribution of the funds is coherent with greater resource allocation to the lagging regions, there are different performances in the management of the funds among the Italian regions. They conclude that Structural Funds have a mainly distributive effect and do not affect the pattern of growth of Italian regions in the long-run.
Wostner and Šlander (2009) demonstrate that the Cohesion Policy increases structural expenditure of the receiving countries, but their effectiveness is also related to other conditions, such as micro-efficiency in the management of the funds and their effects on private investments.

2.3.2 Treatment effect framework

Over the past few years, several studies have evaluated public policies with counterfactual methods. These studies adopt non-experimental methodologies based on the idea that eligibility for a specific policy Objective can be considered as a treatment (like the treatments received by patients in medicine). It is thus possible to identify two different groups of regions with comparable characteristics - "treated" and "untreated" regions - and evaluate the causal effect of the treatment. As mentioned before, no unanimous results have been achieved. Policy success is confirmed in Becker *et al.* (2010, 2012) and Pellegrini *et al.* (2013); whereas Becker et al. (2013) and Gagliardi and Percoco (2013) observe a conditional effect. Conversely, a positive but not strongly significant effect is highlighted in Hagen and Mohl (2008) and a negative effect is observed in Accetturo *et al.* (2014).

(trust, norms of civic cooperation, the degree of ethnolinguistic fractionalisation); third, a group of indicators that measure institutional quality directly (corruption perception index or institutional quality index).

The analysis of Becker et al. (2010) seeks to evaluate the causal effect between the Objective 1 status and the growth rate of per-capita GDP for the treated regions, using a fuzzy Regression Discontinuity Design (RDD) approach for the evaluation of the programmes. The results point to a positive effect of the funds on the per-capita GDP growth rate. However, the result is less optimistic if the employment rate is considered; this might be related to the fact that the creation of new jobs requires a longer period of time than the duration of a programming period (5-7 years). As a robustness check, they repeat the analysis at different territorial levels (NUTS 2 and 3), for three sub-periods, taking into account the possible presence of location externalities. In Becker *et al.* (2012), the analysis considers only the NUTS 3 regions in the programming periods 1994-1999 and 2000-2006 by means of a Generalised Propensity Score estimation. The authors aim to understand whether the transferred funds foster growth in the Objective 1 regions. A dose-response function is estimated; it connects the annual average per-capita GDP growth rate with the intensity of the treatment received, in order to find the optimal dose of the treatment. The results show that EU transfers sustain a more rapid growth, but in 36 percent of the regions considered the intensity of the transfers is higher than the optimal level and their reduction would not produce any loss in terms of growth. In a recent work by Pellegrini *et al.* (2013), the effects of regional policy are evaluated through a *sharp* RDD approach, using an original dataset for the period 1994-2006. The results show the presence of a weak positive impact of the European regional policy on regional growth. The robustness of the results is investigated by applying both a parametric and a non-parametric approach with different kernels.

In Becker *et al.* (2013), attention is focused on the heterogeneity between units. They consider Structural Funds transfers to Objective 1 NUTS 2 regions in three programming periods (1989-93, 1994-99 and 2000-06) and use a RDD approach with heterogeneous treatment (HLATE). Heterogeneity in the reaction to the treatment is modelled through the consideration of a different absorptive capacity of the regions, expressed as a function of the endowment of human capital (percentage of workers with at least secondary education) and/or the quality of regional government (by means of a composite indicator which synthesises public services, education, health services and respect for the laws). The results confirm that EU transfers produce a positive effect on the growth rate of per-capita GDP and on the growth rate of investments only for regions with a sufficient endowment of human capital and "good enough" institutions, that is to say, higher absorptive capacity.

Gagliardi and Percoco (2013) assess the effectiveness of EU Cohesion Policy on Objective 1 regions performance by adopting a Regression Discontinuity Design (RDD) in the context of a Local Average Treatment Effect (LATE) regression. Differing from the previous literature, they introduce spatial heterogeneity amongst the units of analysis. The results show that EU Cohesion Policy has been effective in fostering development in lagging areas in Europe. However, its effectiveness remains controversial: policy impact is strongly heterogeneous within each NUTS 2 region. Rural areas close to the main urban agglomerates are those that benefited the most; further, they have driven the positive results observed for the full sample.

In order to avoid the problem of misspecification of the functional form, Hagen and Mohl (2008) carry out an analysis using the Generalised Propensity Score (GPS). They estimate a dose-response function (Hirano and Imbens 2004) over a sample of 122 regions belonging to the NUTS 1 and 2 levels of the EU 15 in the period 1995-2005. The main assumption for the application of this method is the Stable Unit Treatment Value Assumption (SUTVA) that considers the distribution of output for each region as independent from the potential state of the treatment in another region, conditional to the observed covariates. Though this is a very strong assumption, it avoids the presence of spatial correlation. The authors cannot investigate the presence of externalities, but they adopt the "weak unconfoundedness" hypothesis, which posits a treatment for each region as independent from the potential outcome. The results show a positive but not statistically significant impact of Structural Funds transfers on the average growth rate of the regions. Therefore, the dose of payment received is not important for the determination of the policy's effects on growth.

Accetturo *et al.* (2014) look at the impact of the transfers on local social capital endowments by using a regression discontinuity design for EU Objective 1 Structural Funds. They find evidence that transfers reduce local endowments of trust and cooperation and they conclude that it is necessary to focus more deeply on the pre-requisites for receiving the aid. In particular, the authors argue that effectiveness of local public goods has a crucial role in the right use of the transfers.

A new regression discontinuity technique has been developed recently in other fields of geographically-related research dealing with the issue of education (Black 1999), labour markets (Dell 2010), real estate markets (Dachis *et al.* 2011), firm size (Giacomelli and Menon 2012) and firm incentives (Einio and Overman 2012). These approaches are commonly known as 'spatial Regression Discontinuity Design' or 'spatial RDD', and they consider the

geographical location as the key forcing variable. In these cases, the discontinuity which is to be exploited by the econometric technique is given by the administrative or geographical boundaries and the sub-samples to be examined are the spatial units on either side of the geographical boundary. In the case of EU Regional Policy evaluation, in some countries the regions falling into the Objective 1 and in the non-Objective 1 groups, respectively, can be simply identified by looking at the geographical boundaries. However, this is not true for all countries, with the consequence that the effect of the policy for the treated regions that have a good performance but are located far from the geographical boundaries may be rather underestimated.

Following this view of analysis, in this study we use an original dataset with comparable information at the European regional level to investigate a wider range of impacts of European Regional Policy than those considered in the literature so far.

With this aim in mind, we apply a Regression Discontinuity Design, a non-experimental method for comparing the performance of different groups of observations. The article is structured as follows. Section 2 presents a survey of previous studies on the effects of EU Regional Policies. Section 3 illustrates the study's methodology and Section 4 presents the results of the analysis by comparing trends in the regions affected by the EU Regional Policy with trends in other regions. Section 5 discusses the conclusions. Finally, an appendix describes the construction of the dataset and the outcome variables employed.

3. Methodology

The empirical literature on the evaluation of Regional Policies relies on different methodologies and data, and no consensus has yet been reached (see section 2). In this paper, the effects of EU Regional Policy are observed by means of a technique that can isolate it from other factors that may affect the analysis' results: the Regression Discontinuity Design (Thistelthwaite and Campbell 1960; Hahn *et al.* 2001) in the *sharp* version. This methodology considers a discontinuity in the treatment related to some observations, to obtain an estimation of the Local Average Treatment Effect (LATE), by comparing units eligible for the treatment (Objective 1 regions) with non-eligible ones (non-Objective 1 regions). The effect of the treatment estimated is located in the point of discontinuity. For the application of RDD, four basic assumption need to be respected (Lee *et al.* 2009):

- the treatment is not randomly assigned, but there is at least one observable variable (assignment variable or forcing variable);
- the assignment variable presents a discontinuity in correspondence of a threshold;
- the assignment variable cannot be manipulated (agents cannot modify it in order to move from one side to the other of the threshold);
- the other variables are regular functions (without discontinuity in correspondence of the cut-off point): the only reason that produces a jump at the threshold is discontinuity in the treatment.

The fundamental hypothesis of this method is that the units just above (or below) the threshold that do not receive the treatment, represent a good term of comparison with those just below (or above) the threshold that receive the treatment. Therefore, any discontinuity in the conditioned expected value of the outcome, in proximity of the cut-off point, may be interpreted as evidence of the causal effect of the treatment.

In our analysis, the statistical units are the NUTS 2 regions of the European Union with 15 member states (EU15)[6]. Our aim is to assess whether Objective 1 regions experienced greater growth than non-Objective 1 regions, by considering improvement in the potential road accessibility (Stelder 2014) and in research and innovation activities (patent applications). However, we will assess the presence of a discontinuity also by looking at the growth rate of per-capita GDP. Objective 1 eligibility is defined by the "75 percent rule"; as a consequence, regions with a per-capita GDP lower than 75 percent the community average are considered Objective 1. The forcing variable is the regional per-capita GDP and the cut-off point is the 75 percent threshold; the treatment is eligibility to the Objective 1 Fund. This situation is a good framework for the application of the RDD: consider a NUTS 2 (A) with a per-capita GDP equal to 74.99 percent the EU average and a NUTS 2 (B) with a per-capita GDP equal to 75.01 percent, the first one will be eligible for Objective 1, whereas the second will not receive the treatment. We can assume that the two regions have similar characteristic except for the treatment, therefore they are more comparable than others that are more distant from the cut-off threshold (Becker *et al.* 2010).

Considering c as the cut-off point and Xi as the forcing variable, following the work of Pellegrini *et al.* (2013), we adopt a *sharp* version of the RDD, since treatment assignment is assumed to depend only on the 75 percent rule (to

[6] EU15 includes: Germany, France, Italy, the Netherlands, Belgium, Luxembourg (founding countries), Denmark, Ireland and the United Kingdom (1973), Greece (1981), Spain and Portugal (1986), Austria, Finland and Sweden (1995).

support this assumption we exclude from the sample regions that receive aid for other reasons). We denote the potential outcomes of the region *i* with *Yi(0)* and *Yi(1)*, where *Yi(1)* is the outcome obtained in presence of the treatment (Objective 1 regions) and *Yi(0)* is the outcome obtained by the non-treated regions (non-Objective 1). In correspondence with the discontinuity point, the conditioned expectancy of the outcome, given the covariates, underlines the causal effect of the treatment (Imbens and Lemieux, 2008):

$$\lim_{x \downarrow c} E[Y_i | X_i = x] - \lim_{x \uparrow c} E[Y_i | X_i = x] \quad (1)$$

If the average causal effect of the treatment is taken into consideration the above relation becomes:

$$\tau_{SRD} = E[Y_i(1) - Y_i(0) | X_i = c] \quad (2)$$

In order to increase result robustness, estimation will use both a parametric and non-parametric approach and the results will be verified for different samples specifications, kernels and confidence intervals. The aim is to avoid problems related to the limited number of observations in proximity with the cut-off point, which can reduce the accuracy of the estimations. Moreover, the effects of Regional Policy may be affected by other factors that enhance or prevent growth (e.g.: geographical location and externalities).

In the parametric regressions, the Ordinary Least Square (OLS) estimation with robust standard errors is applied. For the non-parametric estimation, we use the local linear regression method with standard errors obtained with bootstrap (Nichols 2001).

The equation for a generic polynomial model of *m* order is[7]:

$$Y = \alpha + \tau D + \sum_{i=1}^{m} \beta_i X^i + \sum_{i=1}^{m} \delta_i D X^i + \varepsilon$$

Y is the annual average growth rate of the outcome variable considered, D is a binary variable identifying the Objective 1 regions, τ is the coefficient of the estimated discontinuity and X is the forcing variable.

When a parametric approach is used, the choice of bandwidth is equivalent to the definition of the polynomial order of the regressions (Lee and Lemieux 2009). Different specifications are considered in order to analyse how the polynomial degree affects the results. The best polynomial order is chosen by looking at the Alkaike Information Criterion (AIC): the best model is the one with the lowest AIC[8].

Following Lee and Lemieux (2009), Imbens and Lemieux (2008) and Pellegrini *et al.* (2013), two additional robustness checks are added: we verify whether in the density function of *X*, for *X*=*c*, there are other discontinuities (that may show an alteration in the control variable) and we investigate the presence of other discontinuities in the outcome variable. In order to exclude any gerrymandering (Menon 2012) type of manipulation in the proximity of the threshold with respect to the continuity of the density function of the forcing variable, the McCrary test is used (McCrary 2008). In our case, the assignment to the treatment (i.e. eligibility for Objective 1 status) cannot be easily predicted. We might think that countries may behave opportunistically by maintaining their per-capita GDP below the threshold in order to attract funds; actually, this cannot happen, because the threshold is fixed at 75 percent of per-capita GDP community average, the value of which can be known only after publication of all regional data. Moreover, Eurostat applies strict controls on the procedures for estimation of regional accounts. McCrary (2008) suggests that a jump in the conditional density of the forcing variable can be considered as a test of its manipulability: when regions are sorted around the threshold, the RDD approach is not applicable.

The McCrary test (2008) estimates the density function of per-capita GDP for a confidence interval of 95 percent. In the RDD approach, the choice of the kernel is of fundamental importance: some authors consider the Epanechnikov kernel, whereas other scholars prefer the Triangle; we opt for more than one kernel specification: Epanechnikov, Gaussian, Rectangular and Triangle.

Another important element is the choice of bandwidth. There are many rules of thumb for the definition of the optimal bandwidth. Different bandwidths produce different estimations, so it is important to estimate more than one and at least three: the optimal bandwidth, its double and its half. The wider the bandwidth, the stronger the discontinuity will be, because the impact of possible erratic observations close to the threshold becomes smaller. For the choice of the optimal bandwidth, the index of Imbens and Kalyanaraman (2009) is calculated; this index determines the asymptotic optimal interval for the regression discontinuity.

It is also important to test that there are no jumps in the treatment and outcome levels and that, other covariates do not have discontinuity at the cut-off point. In order to verify the first point, the effect is estimated for different

[7] We consider *m*=3.

[8] The parametric estimation is applied only as a further robustness check of the results obtained with the non-parametric method, for this reason the usual issues related with this approach (heterogeneity, endogeneity and so on) are not considered here.

thresholds and with different kernels and bandwidths; for the second, we consider the population average, using a local linear regression with different kernels.

Our goal is to try to move attention away from the strictly economic-productive sphere towards some specific fields of policy intervention. The main challenge is the identification of possible outcome variables and the availability of data at the NUTS 2 level. With this aim in mind, we decided to take into account two different aspects of regional social and economic development in addition to per-capita GDP: transport infrastructure and research and innovation.

We use an exclusive dataset on the certified expenditure of European regions between 1999 and 2007. Thanks to this data, we know which regions received the transfers for specific fields of intervention (FOI). The importance of using this kind of data is stressed by Aiello *et al.* (2012), who argue that considering both regional-level and specific areas of intervention expenditure is one of the most critical points in the study of EU policy effectiveness.

De La Fuente (2003) points to the importance of considering the amounts effectively spent and not only those programmed or committed. Consideration of certified expenditure avoids all these inconveniences. For the evaluation of the effects of the policy, we refer to specific outcome variables for each area: for transport infrastructure, we consider potential accessibility to road networks (Stelder 2014); for research and innovation, we consider the patent applications per million inhabitants. The sample we refer to, for each of these outcome variables, is different because we analyse only regions with certified transfers in the specific FOI. To test the robustness of the results, the analysis is conducted with different specifications of the outcome variables (growth rate and difference in levels) [9]. The use of the Regression Discontinuity Design allows us to eliminate the problem of the choice of a specific functional form, which usually occurs in classical growth equations.

4. Results

In this section, we discuss the main results of our analysis[10]. First we investigate the presence of a discontinuity by considering the most widely used outcome variable: the growth rate of per-capita GDP, in order to compare this findings with those of the fields'specific outcomes.

After the exclusion of the outliers and colonial regions[11], the new sample consisted of 165 units: 44 Objective 1 and 121 non-Objective 1. Preliminary evidence of discontinuity can be obtained by considering a *naïve* estimation of the difference between the annual average growth rate of the treated and non-treated regions. The result is a negative and not statistically significant coefficient in all the three periods considered[12]. Representing per-capita GDP growth rate in function of the forcing variable, as Lee and Lemieux (2009) suggest, the information given by the *naïve* estimations was confirmed. The graphic analysis (Figures 1 a,b,c) does not reveal big differences in the growth rate of the outcome variable. However, for the period 1995-2010 (Figure 1a), the left side of the graph displays a higher growth of the outcome variable than the right side. A simple difference in growth rate is not enough for an evaluation of the Regional Policy. Consequently, we use a RDD approach with a local linear regression estimation with four different kernels (Triangle-tri, Rectangular-rect, Gaussian-gau and Epanechnikov-epa) and three bandwidths (optimal, half and double), standard errors estimated with bootstrap (500 replications). If we instead consider the local linear regression estimation, the results are quite different, there is no statistically significant discontinuity in favour of non-Objective 1 regions in the three periods analysed (Tables 2, 3 and 4); whereas an advantage (5.5) in the annual average per-capita GDP growth rate in favour of the treated regions persists when considering the whole period (Table 2), a triangle kernel and the optimal bandwidth. Nonetheless, this result is not confirmed with other kernels and using a parametric estimation (Table 5). In conclusion, we argue that European Regional Policy seems to have a positive impact on the annual average growth rate of per-capita GDP, but its effect is observed in the long-term and not confirmed in the short term.

Afterwards we move the attention to the expenditure in Research, Technological Development and Innovation, by considering the growth rate in patent applications as outcome variable. The analysis and its robustness check were carried out with reference to two main guidelines: the first is the time interval; the second is based on the sample composition. The decision to consider the time dimension was due to the nature of the investments that may require different time intervals for their effectiveness. For this reason, the outcome variable was considered for the whole

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[9] For more details on the construction of the dataset and the outcome variables used refer to the enclosed appendix.

[10] For the sake of brevity, we do not report here the results for all the samples considered, but they are available from author on request.

[11] Sachsen-Anhalt, Salzburg, Nord-Pas de Calais, Noord Holland, Essex, Inner London, Guadalupe, Martinique, Guyana, Reunion, Ceuta and Melilla, the Azores and Madeira - and Alentejo.

period (1999-2010) as well as for three sub-periods: the first (1999-2007) excludes the last three years (it considers just the years in which the transfers were devolved); the second (2002-2010) excludes the first three years, so it takes into account the possibility that some investments require time to be effective; finally, the third considers only the central years (2002-2007). Results robustness was verified also by considering the outcome variable equal to the simple difference between the first and the final year. As for GDP we show the results of the sample adjusted for the outliers[13]. The results were strongly robust to the sample restrictions and they also gained advantages in terms of stability, so we decided to refer to this last sample for the other common robustness checks.

First, we looked at the graphic impact of the discontinuity for different kernels and different bandwidths; then we estimated the polynomial regressions with OLS. Once we had looked at discontinuity at different thresholds, we controlled for the presence of discontinuity considering a different variable (the average population) that should not be affected by the treatment, as a robustness check.

The *naïve* estimation of the difference in the average growth rate of patent applications still emphasised the presence of a strong discontinuity for the Objective 1 regions. Their advantage was equal to 1.11 percentage points (standard error 0.18) if the whole period was considered. The advantage of the Objective 1 regions became 1.5 percentage points (standard error 0.22) when the last three years were excluded and decreased to 0.71 (standard error 0.15) in the period 2002-2007 and to 0.57 (standard error 0.16) in 2002-2010. The value was always significant at 1 percent. The graphic analysis in Figures 2-a (1999-2010), 2-b(1999-2007), 2-c (2002-2010) and 2-d (2002-2007), confirms these results: once again, the regions on the left exhibit a higher growth rate than the regions on the right. If we look at the local linear regression, we find that only the Gaussian and the Epanechnikov kernels are significant. When the whole period is considered (Table 6, 1999-2010) the discontinuity is about 1 percentage point with the optimal bandwidth (significant at 5 percent for Epanechnikov and at 10 percent for Gaussian) and it is equal to 1.1 percentage points with double bandwidth (significant at 5 percent). The period 2002-2010 (Table 8) exhibits feeble evidence of discontinuity with a value of 0.66 percentage points (significant at 10 percent) with optimal bandwidth and 0.6 (significant at 5 percent for the Epanechnikov kernel and at 10 percent for the Gaussian kernel) if the bandwidth is double.

When the central years are considered (Table 9, 2002-2007), a lower variability in the estimation of the discontinuity in relation to bandwidth dimension emerged. The discontinuity varied from 0.7 (half bandwidth) to 0.83 (optimal and double bandwidth) and it was significant at 5 percent.

The discontinuity trend related to bandwidth dimensions can be analysed by looking at Figure 3 (a, b, c) for the Epanechnikov kernel and figure 4 (a, b, c) for the Gaussian kernel. Figure 5 shows the estimation of the McCrary density function for the forcing variable.

Table 10 shows the parametric estimations (OLS with robust standard errors). Model 5 was chosen as the best model using the AIC. The effect of the Regional Policy was positive and statistically significant at 5 percent and equal to 3.6 annual percentage points. The selected model presents one linear term and one quadratic term. The most similar results to the non-parametric model was the estimation number 4, in which the effect was of 1.15 percentage points.

Another robustness test is to verify whether there are no jumps in the level of the outcome when the threshold is not identified. The model was tested for a null effect for different values of the forcing variable. In Table 11 the effect is estimated with different kernels (Epanechnikov and Gaussian) and the optimal bandwidth (4.8) for different thresholds (50, 60, 70, 90). The results confirm that there are no significant discontinuities.

Finally, we verified that there is no discontinuity at the cut-off point for another covariate that could not be affected by the treatment: we considered the average population. The estimations were carried out with a non-parametric local linear regression with three kernels (Gaussian, Epanechnikov and Rectangular) with the optimal bandwidth and standard errors computed with bootstrap. Table 12 shows the results and confirms that no significant discontinuity was found.

From our analysis on the investigation of discontinuity in the growth rate of patent applications, we can see that Objective 1 regions who received RTDI transfers experienced a higher growth rate in patent applications than non-Objective 1 regions. Furthermore, these results are not due to the presence of outliers and, in particular, to the presence of regions who exhibited a worse initial situation, because the results are robust to different sample compositions. Although there is some evidence to suggest a greater effect in earlier years, these results are robust to

[12] Coefficients are equal to -.0188 in the whole period, -.03656 in 1995-2003, and - .0007 in 2003-2010.

[13] We exclude Martinique, Guyana, the Autonomous Region of the Azores, the Autonomous City of Melilla, the Autonomous City of Ceuta and Alentejo.

the time period and to the samples being considered[14]. The results obtained were strongly confirmed also in a polynomial parametric regression and were robust to the presence of other cut-off points and to the presence of discontinuity in other covariates, not influenced by the funds. No discontinuity was found if the outcome variable is expressed as a difference in levels. This means that the lagging regions experienced a higher growth rate and had the same variation in levels as the more developed units.

Analysis of the transport infrastructure field of intervention is quite different and less structured than the one of patents applications. The reason for this lies in the nature of the data. As regards potential road accessibility data, there were no complete time series available, just some specific years, so it was not possible to consider different sub-periods. We refer to the period 2000-2012. We decided to exclude the Reunion from the sample, given its location far outside of Europe. The *naïve* estimation of the annual difference in the average growth rate showed an advantage of about 1.14 percentage points (standard error 0.22) in favour of the Objective 1 regions, statistically significant at 1 percent. The value increased by 0.14 percentage points compared with the previous case. Figure 6-a confirms the existence of two opposite trends in the treated group. The results of the non-parametric estimation with the local polynomial regression are presented in Table 13 (the standard errors are still estimated via bootstrap with 1000 replications).

As we did for the patents, we considered the outcome variable expressed as difference in levels. The results are shown in Table 14 and in Figure 6-b: no significant discontinuity was found. In the graph, the two opposite trends in the treated group are less defined. Discontinuity in the growth rate was not very strong but it was still significant. In the following part, we look into its robustness. Figure 7 (*a*, *b*, *c*) shows the discontinuity trend with the Epanechnikov kernel in relation to bandwidth size. It appears in sections *b* and *c* of the graph. Figure 8 displays the discontinuity in relation to bandwidth size when the Gaussian kernel is considered. In this case, the jump in proximity with the cut-off point is visible also with the half bandwidth, but the high variability of the treated regions does not allow for any significant estimation[15]. As a robustness check, we also ran the parametric estimation with a different polynomial order (table 15). The results show a problem of strong multicollinearity; indeed, from model 3 onwards, the Variance Inflation Factor (VIF) assumes a value higher than 20 and blows up in models 5 and 6.

We can conclude, on the basis of the results obtained, that for the transport infrastructure the discontinuity observed is less robust than the results obtained for the patent applications. The position of the dots in the scatter plot implies that this finding is due to the heterogeneous composition of the treated group. This is likely linked to the outcome variable used, that considers only the road accessibility and thus improvements in road infrastructures. The regions of the sample received transfers for all kinds of transport projects, so part of the funds may have been devoted to accessibility improvement of other transport networks. For this reason, the result obtained is significant in the identification of the impact of EU Regional Policy transfers to the Objective 1 NUTS 2 regions.

5. Conclusions

This paper investigates the effectiveness of EU Regional Policy transfers in two fields of intervention: Research, Technological Development and Innovation, and Transport Infrastructure, through the proxies of patent applications and potential road accessibility respectively, alongside analysis of per-capita GDP. The *sharp* Regression Discontinuity Design was used.

The sample refers to the NUTS 2 regions of the EU with 15 member states. We estimated the effects both with a non-parametric (local linear regression) and parametric (polynomial regression estimated with OLS) approach. The results obtained were tested with the usual robustness checks put forward in the literature. Standard errors were estimated with the bootstrap method (with 500 replications for patents and GDP and 1000 replications for transport[16]), whereas in the parametric regressions, standard errors were robust to heteroskedasticity. The analysis was conducted separately for the two fields of intervention and for per-capita GDP.

First, we assessed the presence of discontinuity by looking at the most widely used outcome variable: the annual average growth rate of per-capita GDP. We considered the Eurostat database on regional accounts and we referred to a fifteen year period (1995-2010) and two sub-periods (1995-2003 and 2003-2010). We took into account several

[14] The analysis was also conducted by considering the number of people employed in technology and knowledge-intensive sectors as outcome variable and looking to the field of expenditure on human resources but not significant results have been obtained; in particular, for the latter there were not enough units in proximity of the threshold.

[15] The graphics of the estimation of the density function of the forcing variable (McCrary, 2008) and of the others robustness checks are similar to figure 5 and tables 11 and 12 and are not reported again for the sake of brevity.

sample compositions in order to exclude the effects of possible outliers. The results obtained did not highlight a clear effect, as statistical significant discontinuity in favour of the treated regions emerged only when the whole period and a Rectangular kernel were considered. However, in most cases the results were not statistically significant. After these considerations, we can conclude that the effects of European Cohesion Policy on the growth rate of per-capita GDP are not clearly defined, particularly in the short term.

The second part of our analysis assessed the impact of the policy focusing on specific fields of intervention and using specific outcome variables for each one. We then considered the impact of transfers in RTDI and Technical Assistance on the growth rate of patent applications per million inhabitants (fractional count; by inventor and priority year). The results demonstrate that Objective 1 regions exhibit a higher (by at least one percentage point) growth rate in patent applications than non-Objective 1. The analysis was structured along two guidelines; one relative to the time intervals and the other one to the composition of the sample. The results appeared robust to both different periods of analysis and sample compositions. The entire period of analysis for the outcome variable was 1999-2010, but we looked also at three sub-periods: 1999-2007, 2002-2010 and 2002-2007. The results show that the first three years give an important contribution to the discontinuity in the outcome variable, whilst in the last three years it appears weaker. The significant discontinuity found is not due to the presence of outliers and, in particular, to having included in the sample those regions who had a worse initial situation, because the results are also robust to different sample compositions. Our findings are strongly confirmed also in a polynomial parametric regression and they are robust to the presence of other cut-off points and to a discontinuity in other covariates not influenced by the funds. As an additional check, we considered the outcome variable expressed as difference in levels and no significant discontinuity was found. This means that the backward regions experienced a higher growth rate and the same variation in levels as the more developed regions, and this can be considered as evidence of convergence.

In the second part of the analysis, we looked for the presence of discontinuity in the growth rate of potential road accessibility, as an outcome of expenditure in transport infrastructure. In this case, the results were less strong than those on patent applications and the analysis could not be structured into different time intervals, because of a lack of appropriate data. Data was provided by Stelder (2014) in the context of a European project of construction of a historical archive on road accessibility in Europe. The results show the presence of a feeble discontinuity in favour of the treated regions of 0.9 percentage points, statistically significant only for the double bandwidth. Another important aspect stemming from the analysis is the presence in the treated group of two opposite trends in the growth rate of potential road accessibility: on one side, there are the Spanish and Portuguese regions that experienced greater growth and on the other side, there are the Italian, German and Greek regions. The high variability within the groups contributes to weakening the results on discontinuity. Another element of weakness is that the outcome variable does not account for other transport networks, that might be the object of more improvements in their accessibility, especially in recent years.

The results point to significant growth effects in these indicators for Objective 1 regions above those displayed by non-Objective 1 regions. Indeed, the difference is sufficiently large that when observed in terms of levels effects, the two types of regions become largely indistinguishable in terms of these particular features, exactly as intended by the policy. The innovation-relate results were stronger than those obtained for transport-accessibility, although the patterns of policy-outcomes are remarkably very similar between the two cases.

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[16] In the case of transport, we considered a greater number of replications because the sample appeared more unstable.

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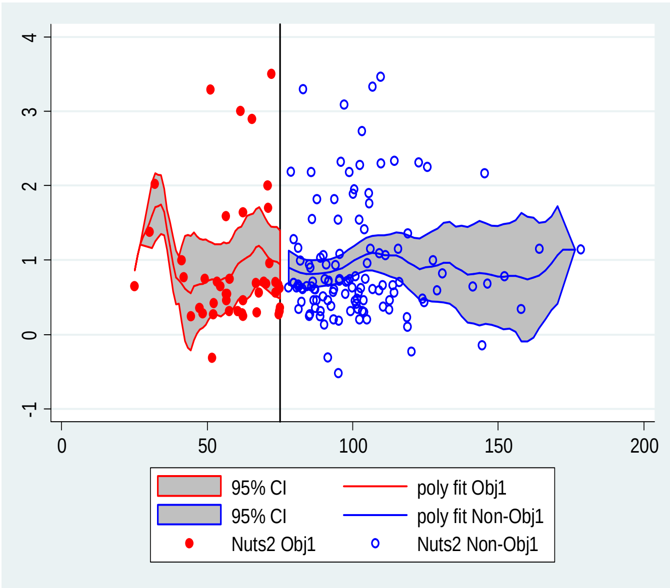
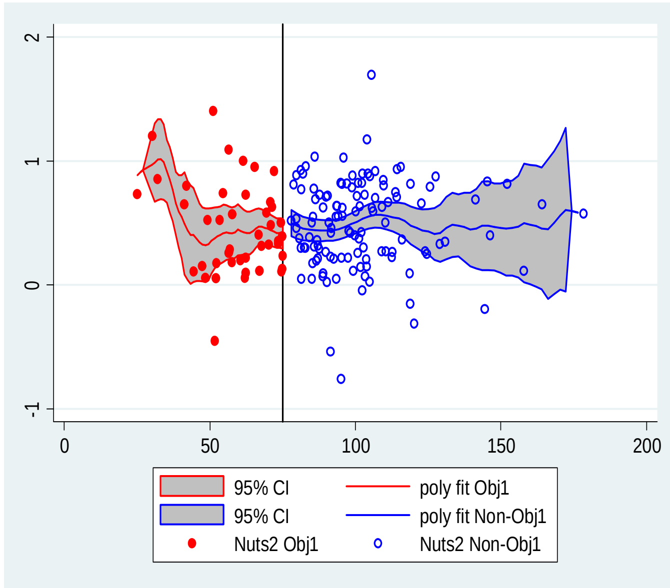
FIGURES

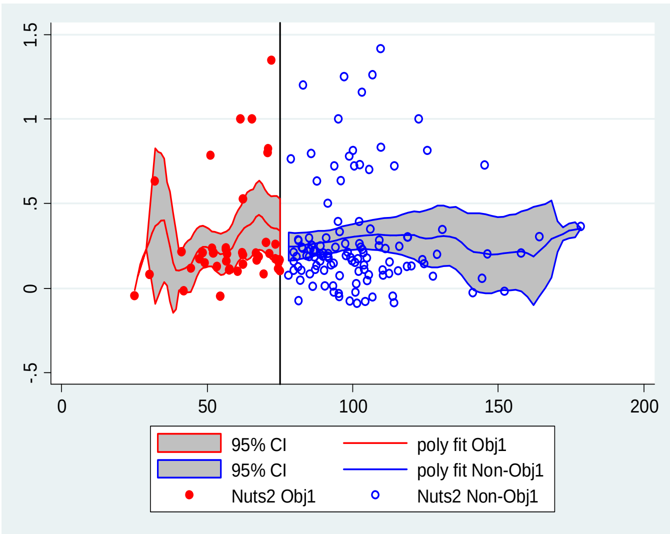
Figure 1- Comparison of the annual average growth rate of per-capita GDP between the Objective 1 and non-Objective 1 regions



a) 1995-2010



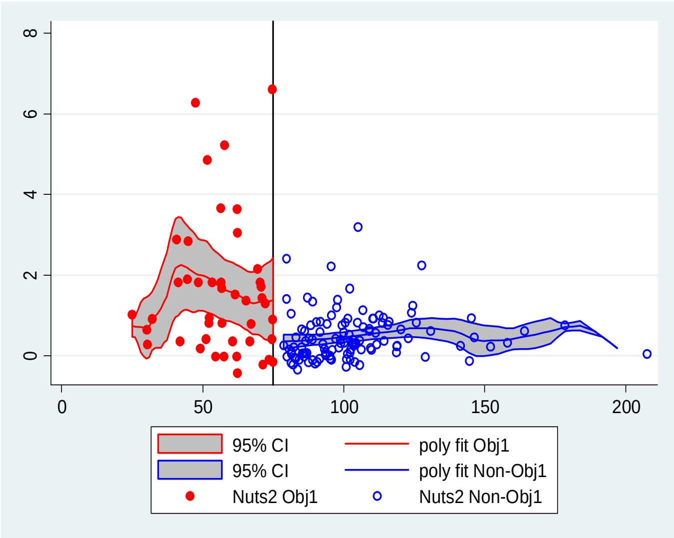
b) 1995-2003



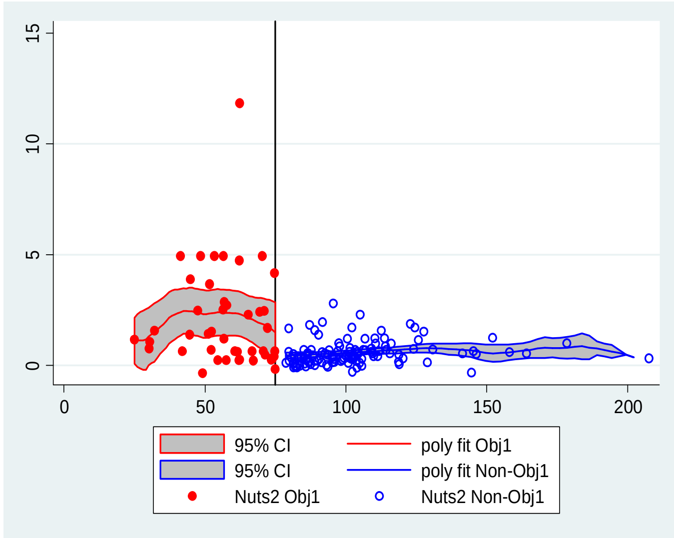
c) 2003-2010

Source: our elaboration on European Commission and Eurostat data

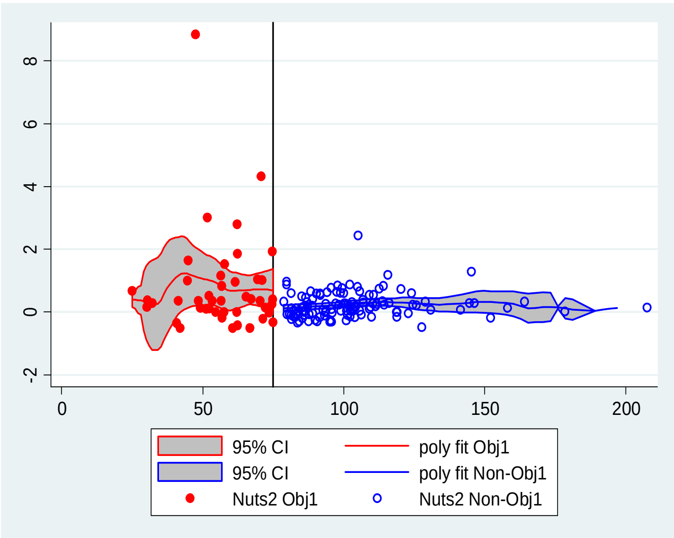
Fig 2- Comparison of the growth rate in patent applications between the Objective 1 and non-Objective 1 regions



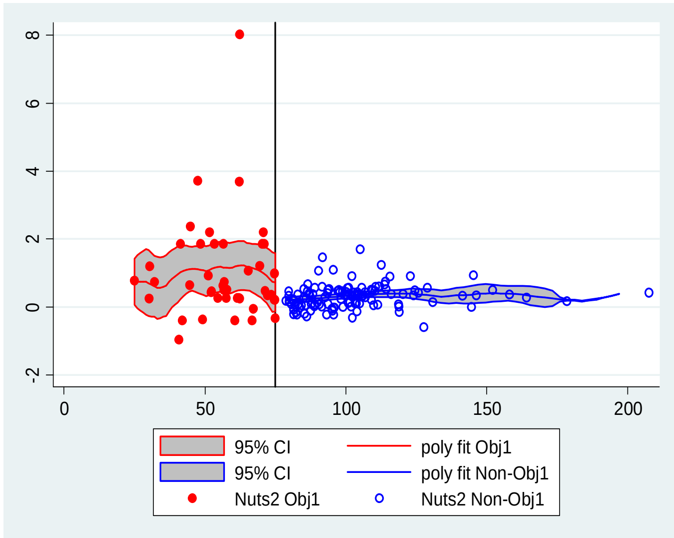
a) 1999-2010



b) 1999-2007



c) 2002-2010

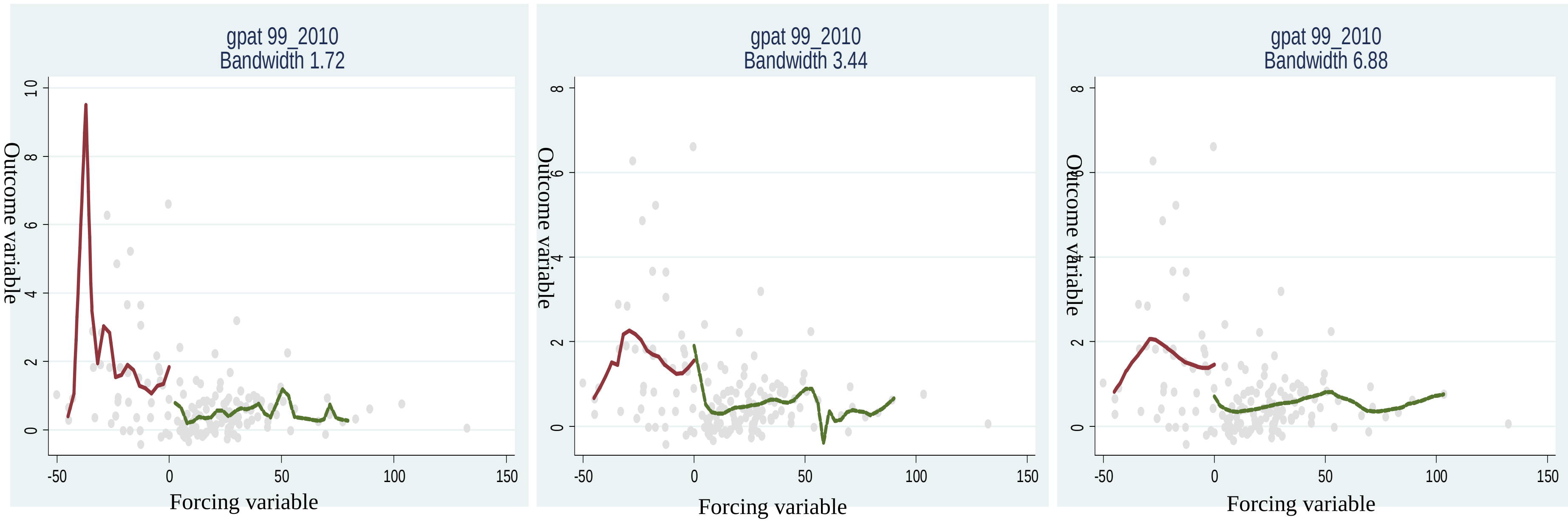


d) 2002-2007

Source: Our elaboration on European Commission and OECD data

Fig 3-Robustness check: Epanechnikov kernel, different bandwidths, cut-off=0.

Outcome variable: patent applications growth rate (1999-2010), forcing variable (GDP per capita in PPS (75%EU15=0), 1988-90)

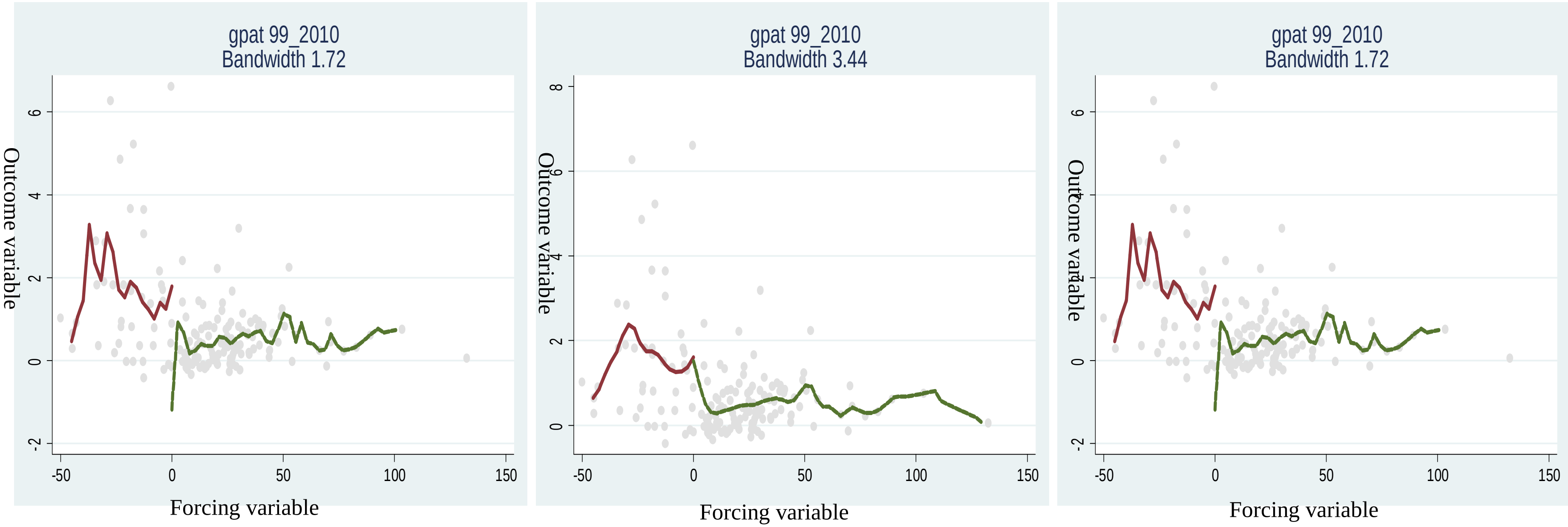


(a) half bandwidth (b)optimal bandwidth (c) double bandwidth

Source: Our elaboration on DG Regio and OECD data

Fig 4-Robustness check: Gaussian kernel, different bandwidths, cut-off=0.

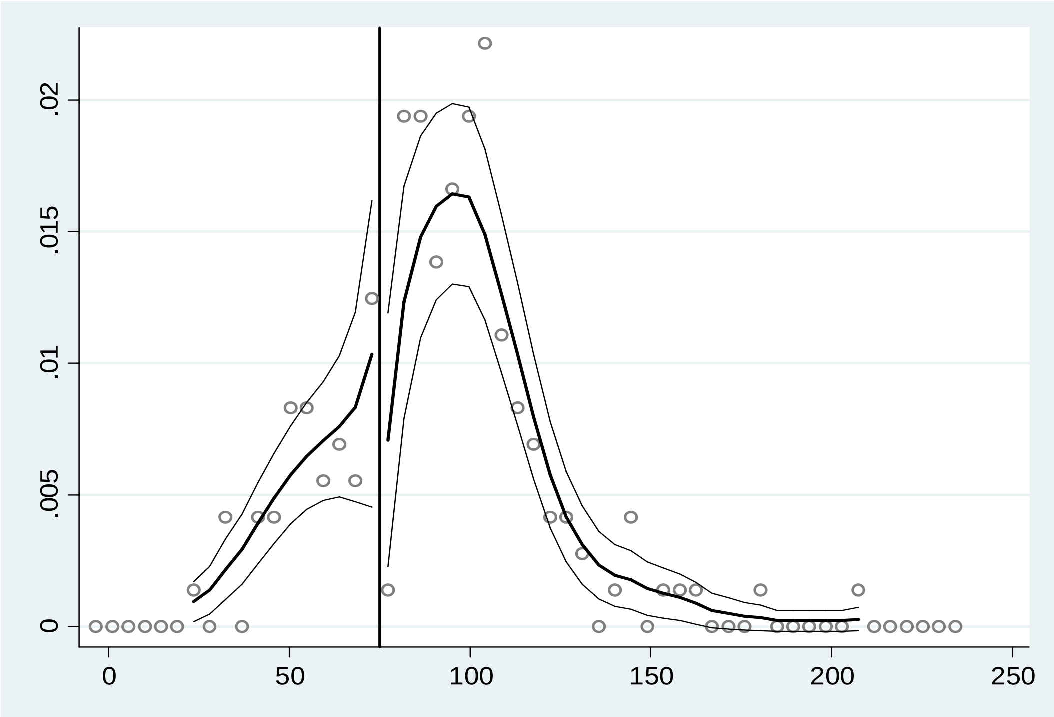
Outcome variable: patent applications growth rate (1999-2010), forcing variable (GDP per capita in PPS (75%EU15=0), 1988-90)



(a) half bandwidth (b)optimal bandwidth (c) double bandwidth

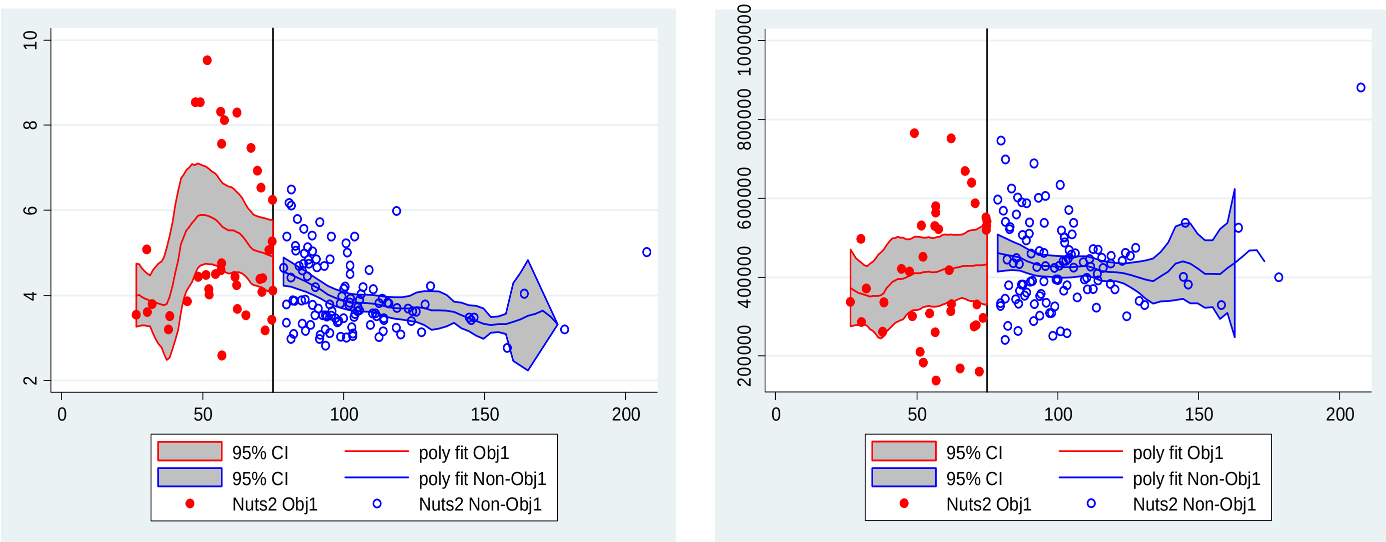
Source: Our elaboration on DG Regio and OECD data

Fig 5- Estimation of the density function of the forcing variable (GDP per capita in PPS, average 1988-1990) at the threshold, sample R2



Source: Our elaboration on European Commission and Eurostat data

Fig 6- a) Comparison of the growth rate in potential road accessibility between the Objective 1 and non-O objective 1 regions, sample TR1, (2000-2012); b) Comparison of the difference in levels in potential road accessibility between the Objective 1 and non-Objective 1 regions, 2000-2012



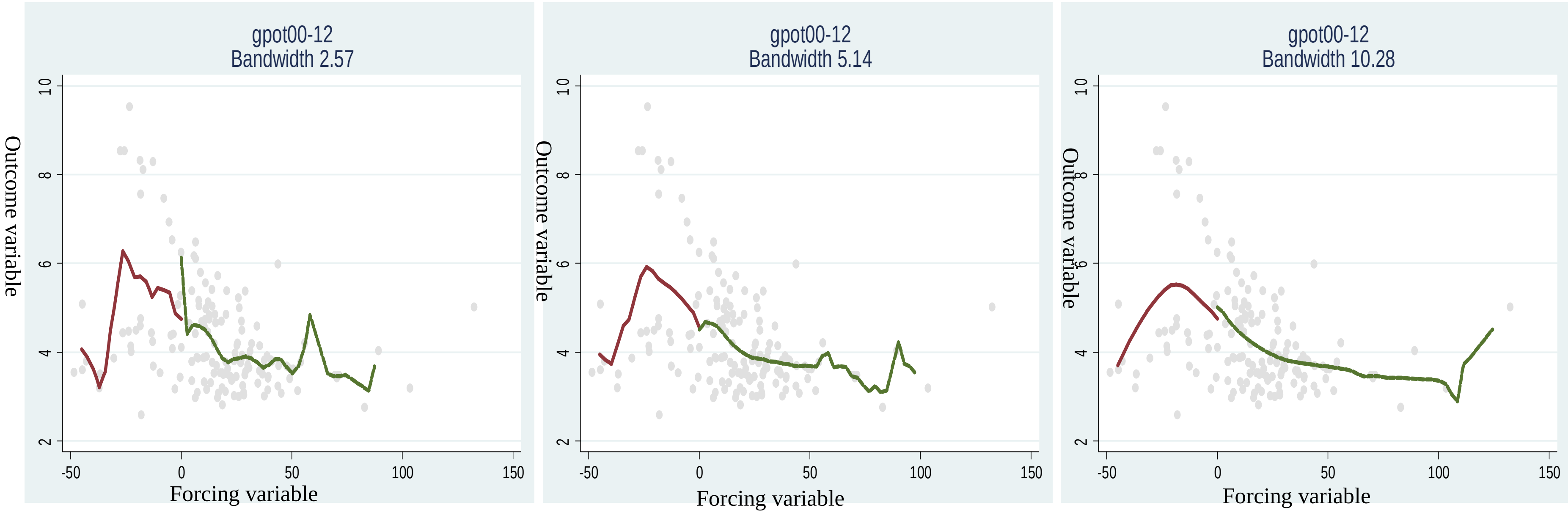
a) Growth rate

b) Difference in levels

Source: our elaboration on European Commission and Stelder (2014) data

Fig 7- Robustness check: Epanechnikov kernel, different bandwidths, cut-off=0.

Outcome variable: road road accessibility growth rate (2000-2012), forcing variable (GDP per capita in PPS (75%EU15=0), 1988-90)

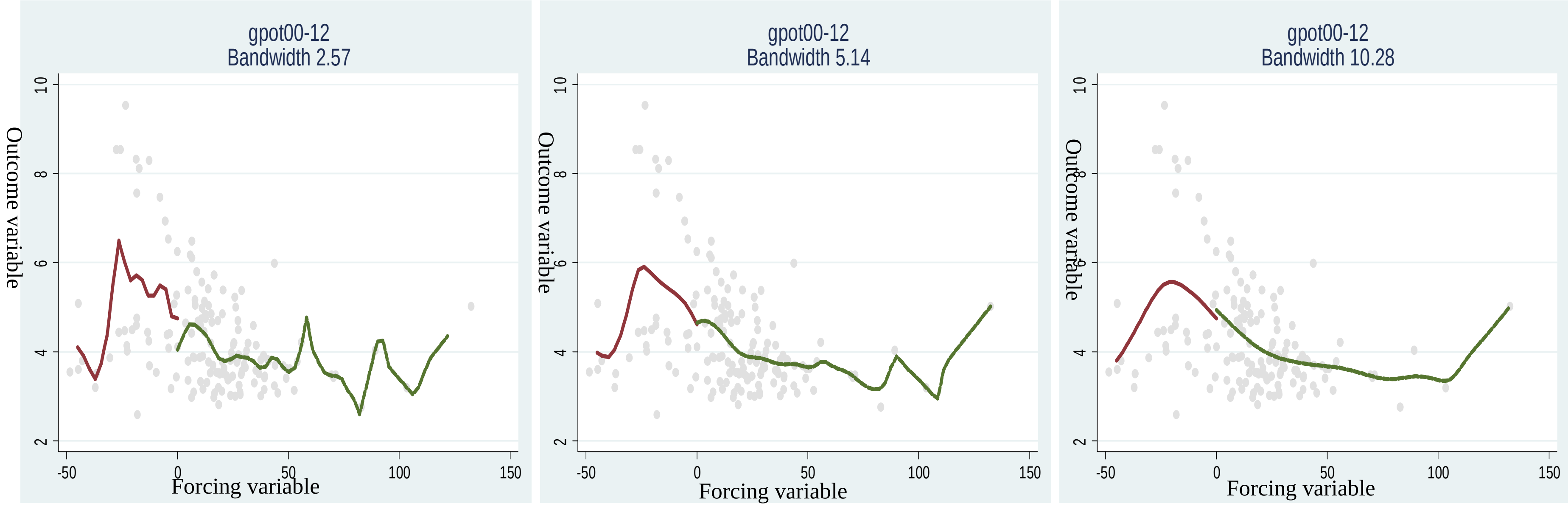


(a) half bandwidth (b)optimal bandwidth (c) double bandwidth

Source: Our elaboration on DG Regio and Stelder (2014) data

Fig 8- Robustness check: Gaussian kernel, different bandwidths, cut-off=0.

Outcome variable: road road accessibility growth rate (2000-2012), forcing variable (GDP per capita in PPS (75%EU15=0), 1988-90)



(a) half bandwidth (b)optimal bandwidth (c) double bandwidth

Source: Our elaboration on DG Regio and Stelder (2014) data

TABLES

Table 1- Main results of the previous literature on the impact of structural funds (SF) on economic growth.

Authors	Year	Approach	Methodology	Outcome variable	Results	Notes (model simulation and case studies)
Bradley	1992	Model simulations	EU-HERMES model		positive effect	ran only for Ireland
Bradley, Fitz Gerald and Kearney	1992	Model simulations	EU-HERMES model		positive effect	ran only for Ireland
Gaspar and Pereira	1992	Model simulations	two-sector endogenous growth model of private, public and human capital accumulation		positive effect	Portugal
Modesto and Neves	1994	Model simulations	EU-HERMIN model		positive effect	Portugal
Goybet and Bertoldi	1994	Model simulations	consider models that range from a neo-Keynesian to a dynamic general equilibrium with endogenous growth		positive effect	
Lolos and Zonzilos	1994	Model simulations	general equilibrium model		Mixed effects	Greece
Bradley, Whelan, and Wright	1995	Model simulations	EU-HERMIN model		positive effect	Ireland
de la Fuente, Vives, Dolado, Faini.	1995	Econometric-regression	growth model	Income per- capita	positive effect	
Herce and Sosvilla-Rivero	1995	Model simulations	EU-HERMIN model		positive effect	Spain
Modesto and Neves	1995	Model simulations	EU-HERMIN model		positive effect	Portugal
Lolos, Suwa-Eisenmann, and Zonzilos	1995	Model simulations	general equilibrium model		Mixed results	Greece
Gaspar and Pereira	1995	Model simulations	endogenous growth model		positive effect	Greece, Ireland and Portugal
Fagerberg and Verspagen	1996	Econometric-regression	Growth model	Growth rate per-capita GDP	No effects	

Authors	Year	Approach	Methodology	Outcome variable	Results	Notes (model simulation and case studies)
Bachtler and Taylor	1996	Case study			difficulty to achieve coherence in these big projects ad hoc	Combine the evaluations of the projects and the official EU surveys
Bachtler and Turok	1997	Case study			difficulty to achieve coherence in these big projects ad hoc	Focus: UK, Germany, The Netherlands, Austria, Finland and Sweden
Huggings	1998	Case study			difficulty to achieve coherence in these big projects ad hoc	Focus: Objective 2 programmes in industrial South Wales
Daucè	1998	Case study			difficulty to achieve coherence in these big projects ad hoc	Focus: most depressed area of Burgundy
Lolos	1998	Case study			difficulty to achieve coherence in these big projects ad hoc	Focus: macroeconomic and structural policies in Greece and Portugal
Pereira	1999	Model simulations	endogenous growth model		positive effect	Greece, Ireland and Portugal
Pereira and Gaspar	1999	Model simulations	endogenous growth model		positive effect	Greece, Ireland and Portugal
Boldrin and Canova	2001	Econometric-regression	Convergence regression	Growth rate per-capita income	No effect- Redistributive function	
Garcia-Milà and McGuire	2001	Econometric-regression	Difference in difference model	Growth per-capita GDP	negative effect	
Cappelen, Castellacci, Fagerberg, Verspagen	2003	Econometric-regression	growth model	Productivity as a multiplicative function in three meanings of knowledge	positive effect	
de Freitas, Pereira, & Torres.	2003	Econometric-regression	Barro equations	Income convergence	No effect-not significant	
Rodrìguez-Pose and Fratesi	2004	Econometric-regression	cross-sectional and panel data analysis	Per-capita GDP	positive effect	
Puigcerver-Penalver	2004	Econometric-regression	“hybrid” growth model	Growth rate per-capita income	positive effect(/programming period)	

Authors	Year	Approach	Methodology	Outcome variable	Results	Notes (model simulation and case studies)
Beugelsdijk, Eijffinger	2005	Econometric-regression	GMM	growth rate GDP	positive effect	
Antunes and Soukiazis	2005	Econometric-regression	Panel data analysis	Growth rate regional per-capita income	positive effect(/regional area of Portugal)	
Percoco	2005	Econometric-regression	Supply side model	Regional production growth	High volatility	
Ederveen, de Groot, Nahuis	2006	Econometric-regression	Cross-country panel	Growth rate GDP	positive effect (/ institution)	
Bähr	2008	Econometric-regression	pooled cross sectional regression	Growth rate per-capita GDP	positive effect(/decentralization)	
Falk and Sinabell	2008	Econometric-regression	Spatial econometric approach and Blinder-Oaxaca decomposition	Growth rate per-capita GDP	positive effect	
Mohl and Hagen	2008	Econometric-regression	Panel data analysis	Growth rate per-capita GDP	Negative effect or not significant	
Esposti and Bussoletti	2008	Econometric-regression	Augmented conditional regional convergence model	Growth rate Regional GDP	Mixed effects	
Dall'Erba and Le Gallo	2008	Econometric-regression	Neoclassical growth model	Growth per-capita GDP	No effect	
Hagen and Mohl	2008	Econometric-treatment effect	Generalized Propensity Score (GPS)	Average GDP growth rate real GDP per-capita (in PPP)	positive effect but not satistically significant	
Woster and Slander	2009	Econometric-regression	Panel data analysis	Structural expenditures (the sum of all public spending at all levels of government, for economic purposes)	Increase of the expenditure but effectiveness depends on other conditions	
Bouvet	2010	Econometric-regression	Panel data analysis	Interregional inequalities	Depending on sector	
Becker, Egger, von Ehrlich	2010	Econometric-treatment effect	Fuzzy RDD	Growth rate per-capita GDP	positive effect	
Aiello and Pupo	2012	Econometric-regression	growth model	Growth rate per-capita GDP	No effect- Redistributive function	
Becker, Egger, von Ehrlich	2012	Econometric-treatment effect	Generalized Propensity score	Annual average growth rate of per-capita GDP	positive effect	

Authors	Year	Approach	Methodology	Outcome variable	Results	Notes (model simulation and case studies)
Becker, Egger, von Ehrlich	2013	Econometric-treatment effect	RDD with HLATE	Growth rate per-capita GDP	positive effect(/absorptive capacity)	
Pellegrini, Terribile, Tarola, Muccigrosso, Busillo	2013	Econometric-treatment effect	Sharp RDD	Growth rate per-capita GDP	positive effect	
Rodriguez-Pose and Novak	2013	Econometric-regression	Neo-classical empirical model	Growth rate per-capita GDP	Increasing of the effectiveness in successive periods	
Gagliardi and Percoco	2013	Econometric-treatment effect	RDD with spatial heterogeneity	Average GDP growth rate	positive effect(/location)	
Accetturo, de Blasio & Ricci	2014	Econometric-treatment effect	RDD	Local endowments of social capital	Negative effect	

Table 2- Annual average growth rate of per-capita GDP period 1995-2010, non-parametric estimations with different kernels and bandwidths.

Bw/Kernel	(1) tri	(2) rect	(3) gau	(4) epa
4.71	-5.477*	0	-0.193	-0.249
	(2.838)	(0)	(0.271)	(0.266)
2.35	0	0	0.0459	0.134
	(0)	(0)	(0.346)	(0.360)
9.43	0.611	1.003	-0.110	-0.0815
	(0.748)	(2.375)	(0.244)	(0.241)
Observations	165	165	165	165

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: our elaboration on European Commission and Eurostat data

Table 3- Annual average growth rate of per-capita GDP, period 1995-2003, non-parametric estimations with different kernels and bandwidths.

Bw/Kernel	(1) tri	(2) rect	(3) gau	(4) epa
3.27 (optimal)	0	0	0.0541	0.0195
	(0)	(0)	(0.0946)	(0.106)
1.63	0	0	0.182	0.239
	(0)	(0)	(0.122)	(0.152)
6.53	0.358	0.258	0.0967	0.113
	(0.548)	(2.019)	(0.0849)	(0.0924)
Observations	165	165	165	165

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: our elaboration on European Commission and Eurostat data

Table 4- Annual average growth rate of per-capita GDP, period 2003-2010, non-parametric estimations with different kernels and bandwidths.

Bw/Kernel	(1) tri	(2) rect	(3) gau	(4) epa
2.81	0	0	-0.141	-0.147
	(0)	(0)	(0.117)	(0.116)
1.40	0	0	-0.110	-0.107
	(0)	(0)	(0.148)	(0.158)
5.61	0.0867	-2.583	-0.113	-0.106
	(1.103)	(1.942)	(0.102)	(0.0970)
Observations	165	165	165	165

Source: our elaboration on European Commission and Eurostat data

Table 5- Parametric estimations with different polynomial orders (sample GDP 2, 1995-2010)

	(1) mod1	(2) mod2	(3) mod3	(4) mod4	(5) mod5	(6) mod6	(7) mod7	(8) mod8
X	8.10e-06		1.08e-05	0.000112	0.000135	0.000152	0.000711	0.000874
	(1.63e-05)		(2.21e-05)	(9.64e-05)	(0.000184)	(0.000190)	(0.00128)	(0.00129)
X2				-3.16e-09	-3.84e-09	-4.38e-09	-3.87e-08	-4.87e-08
				(2.94e-09)	(5.41e-09)	(5.59e-09)	(7.63e-08)	(7.63e-08)
X3							0	0
							(0)	(0)
D		-0.0188	-0.343	0.227	0.410	1.271	3.999	11.84
		(0.149)	(0.615)	(0.261)	(1.352)	(2.005)	(6.704)	(8.809)
DX			4.85e-05		-1.72e-05	-0.000236	-0.000694	-0.00416
			(6.92e-05)		(0.000127)	(0.000440)	(0.00115)	(0.00283)
DX2						1.37e-08	3.33e-08	5.28e-07
						(2.86e-08)	(5.36e-08)	(3.77e-07)
DX3								-0
								(0)
Constant	0.826***	0.930***	0.777**	-0.00628	-0.187	-0.323	-3.263	-4.123
	(0.217)	(0.0703)	(0.318)	(0.773)	(1.482)	(1.524)	(6.969)	(6.990)
R-squared	0.001	0.000	0.005	0.007	0.007	0.008	0.009	0.017
AIC	394.34959	396.5249	397.76652	395.44778	397.43222	399.27012	401.13024	399.77287

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: the dependent variable is the annual average growth rate in patent applications (1999-2010); X= Gdp per capita in pps (EU-15=100, average 1988-1990), D=Objective 1 dummy variable; robust standard errors in parentheses.

Source: our elaboration on European Commission and Eurostat data

Table 6- Growth rate of patent applications, sample R2, period 1999-2010, non-parametric estimations with different kernels and bandwidths

Bw/Kernel	(1) tri	(2) rect	(3) gau	(4) epa
3.44 (optimal)	0	0	-1.061*	-1.072**
	(0)	(0)	(0.548)	(0.509)
1.72	0	0	-0.957	-0.969
	(0)	(0)	(0.717)	(0.676)
6.88	-0.443	-4.191	-1.161**	-1.184**
	(28.07)	(26.17)	(0.481)	(0.460)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: our elaboration on European Commission and OECD data

Table 7- Growth rate of patent applications, sample R2, period 1999-2007, non-parametric estimations with different kernels and bandwidths

Bw/Kernel	(1) tri	(2) rect	(3) gau	(4) epa
6.77 (optimal)	-0.484	-2.776	-1.397***	-1.433**
	(27.90)	(24.64)	(0.539)	(0.586)
3.39	0	0	-1.149**	-1.213**
	(0)	(0)	(0.563)	(0.592)
13.54	-0.607	-0.725	-1.551***	-1.586***
	(0.991)	(0.945)	(0.534)	(0.566)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: our elaboration on European Commission and OECD data

Table 8-Growth rate of patent applications, sample R2, period 2002-2010, non-parametric estimations with different kernels and bandwidths

Bw/Kernel	(1) tri	(2) rect	(3) gau	(4) epa
3.08 (optimal)	0	0	-0.571	-0.597*
	(0)	(0)	(0.352)	(0.354)
1.54	0	0	-0.530	-0.576
	(0)	(0)	(0.392)	(0.429)
6.16	-0.0499	-0.631	-0.600*	-0.613**
	(10.37)	(11.91)	(0.320)	(0.308)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: our elaboration on European Commission and OECD data

Table 9- Growth rate of patent applications, sample R2, period 2002-2007, non-parametric estimations with different kernels and bandwidths

Bw/Kernel	(1) tri	(2) rect	(3) gau	(4) epa
5.55 (optimal)	-0.353	0	-0.792**	-0.838**
	(4.408)	(0)	(0.348)	(0.382)
2.77	0	0	-0.639**	-0.698**
	(0)	(0)	(0.290)	(0.349)
11.09	0.0168	-0.0879	-0.819**	-0.827**
	(0.329)	(4.389)	(0.366)	(0.387)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: our elaboration on European Commission and OECD data

Table 10- Parametric estimations with different polynomial orders

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
X	-9.02e-05***		1.77e-05	7.18e-07	0.000258**	0.000215**	0.000396	0.000260
	(2.52e-05)		(1.70e-05)	(0.000149)	(0.000108)	(0.000102)	(0.000623)	(0.000617)
X2				1.45e-10	-6.94e-09**	-5.72e-09**	-1.59e-08	-8.26e-09
				(4.14e-09)	(2.84e-09)	(2.62e-09)	(3.33e-08)	(3.29e-08)
X3							0	0
							(0)	(0)
Obj1		1.107***	2.081*	1.149**	3.624**	0.917	1.855	-4.468
		(0.258)	(1.165)	(0.451)	(1.415)	(1.948)	(3.866)	(6.770)
DX			-0.000104		-0.000234	0.000437	0.000290	0.00280
			(0.000139)		(0.000154)	(0.000493)	(0.000687)	(0.00253)
DX2						-4.09e-08	-3.51e-08	-3.57e-07
						(3.32e-08)	(3.68e-08)	(3.19e-07)
DX3								0
								(0)
Constant	1.923***	0.473***	0.219	0.431	-1.738*	-1.392	-2.407	-1.645
	(0.379)	(0.0542)	(0.258)	(1.265)	(0.948)	(0.905)	(3.718)	(3.684)
Observations	160	160	160	160	160	160	160	160
R-squared	0.096	0.195	0.204	0.198	0.212	0.219	0.220	0.227
AIC	478.30712	461.66263	462.02673	461.31083	460.47844	460.89608	462.86836	461.36874

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: the dependent variable is the annual average growth rate in patent applications (1999-2010); X= Gdp per capita in pps (EU-15=100, average 1988-1990), D=Objective 1 dummy variable; robust standard errors in parentheses.

Source: our elaboration on European Commission and OECD data

Table 11-Test for different thresholds of the forcing variable, optimal bandwidth (4.8) and different kernels

	(1)	(2)	(3)	(6)
Cut off	50	60	70	90
epa	-0.910	-1.242	-0.0689	-0.166
	(2.037)	(1.807)	(0.718)	(0.302)
gau	-0.549	-1.182	0.0809	-0.0673
	(2.934)	(1.364)	(0.828)	(0.234)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: our elaboration on European Commission and OECD data

Table 12- Robustness check, non-parametric estimation with local linear regression for average population at the threshold (75 percent)

Bw/kernel	(1) gau	(2) epa	(3) rect
44.36	-470.4	-513.3	-580.8
	(399.0)	(513.8)	(720.2)
22.18	-372.0	-432.8	702.9
	(515.4)	(648.0)	(1,931)
88.72	-442.1	-445.1	-458.0
	(412.8)	(547.1)	(487.3)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: our elaboration on European Commission and OECD data

Tab 13- Growth rate of potential road accessibility, sample TR1, period 2000-2012, non-parametric estimations with different kernels and bandwidths

	(1) tri	(2) rect	(3) gau	(4) epa
5.14 (optimal)	1.567	0	-0.462	-0.604
	(8.411)	(0)	(0.523)	(0.560)
2.57	0	0	0.0945	0.192
	(0)	(0)	(0.570)	(0.630)
10.28	-0.381	0.236	-0.839*	-0.901*
	(0.891)	(22.78)	(0.471)	(0.489)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: our elaboration on DG Regional Policy data and Stelder (2014) data

Tab 14- Difference in levels of potential road accessibility, sample TR1, period 2000-2012, non-parametric estimations with different kernels and bandwidths

	(1) tri	(2) rect	(3) gau	(4) epa
46.53(optimal)	29,724	31,559	24,835	22,482
	(90,561)	(93,939)	(55,445)	(52,223)
23.27	51,090	23,674	42,976	49,186
	(930,372)	(2.129e+06)	(69,644)	(70,661)
93.07	18,691	12,785	11,425	11,442
	(59,746)	(58,154)	(50,497)	(49,559)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: our elaboration on DG Regional Policy data and Stelder (2014) data

Tab 15- Parametric estimations with different polynomial orders

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
X	-0.000121***		-7.49e-05*	-0.000129	-0.000518***	-0.000633***	-0.000563	-0.000800
	(3.73e-05)		(3.87e-05)	(0.000200)	(0.000157)	(0.000140)	(0.000845)	(0.000847)
X2				2.12e-09	1.28e-08***	1.61e-08***	1.22e-08	2.56e-08
				(5.95e-09)	(4.30e-09)	(3.63e-09)	(4.50e-08)	(4.52e-08)
X3							0	-0
							(0)	(0)
Obj1		1.144***	-0.334	0.629	-3.182*	-10.91***	-10.55*	-22.79**
		(0.313)	(1.334)	(0.445)	(1.684)	(2.714)	(5.500)	(9.119)
DX			0.000121		0.000361**	0.00229***	0.00223**	0.00709**
			(0.000137)		(0.000161)	(0.000732)	(0.00104)	(0.00331)
DX2						-1.18e-07**	-1.16e-07**	-7.36e-07*
						(4.90e-08)	(5.68e-08)	(4.10e-07)
DX3								0
								(0)
Constant	5.832***	4.014***	5.083***	5.411***	8.690***	9.630***	9.240*	10.56**
	(0.531)	(0.0789)	(0.561)	(1.634)	(1.369)	(1.259)	(5.068)	(5.077)
Observations	150	151	150	150	150	150	150	150
R-squared	0.126	0.151	0.166	0.160	0.187	0.237	0.237	0.255
AIC	481.43973	481.62804	478.50243	477.47501	474.61663	467.13464	469.1317	465.54912

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: the dependent variable is the annual average growth rate in potential transport accessibility (2000-2012); X= Gdp per capita in pps (EU-15=100, average 1988-1990), D=Objective 1 dummy variable; robust standard errors in parentheses.

Source: our elaboration on DG Regional Policy data and Stelder (2014) data

APPENDIX

A1. Dataset construction

The construction of the dataset can be divided into three steps. Following Pellegrini et al. (2013), the first step aims at the definition of a sample that satisfy the hypothesis of the RDD approach and allow us to have regions included in the same group for two consecutive 'programming' periods (1994-1999 and 2000-2006). The second and the third steps are aimed to obtaining a panel structure for the dataset of the certified expenditure for the NUTS2 regions and the transformation of the outcome variables. The dataset consists of EU 15 regions at NUTS2 level with the Objective 1 recipient regions of the transfers being those NUTS2 regions with a per-capita GDP (in PPS) lower than the 75 percent of the community average. For the programming period 1994-1999, the Commission computed the eligibility threshold on the basis of data on per-capita GDP for the period 1988-1990 (per-capita GDP in PPS, ESA79 criteria)[17]. Therefore, in constructing the forcing variable, we considered the per-capita GDP for the period 1988-1990.

The initial sample included 213 regions classified as NUTS 2 (2003): 61 of these regions were Objective 1 in the programming period 1994-1999, the remaining 152 were not. In order to make the sample more homogeneous over the two programming periods, we excluded four NUTS 2 regions from the initial group of Objective 1. These are regions that experienced a level of per-capita GDP greater than 75 percent the community average in the period 1988-1990 (the reference period of the Commission for establishing eligibility to the funds) and that, however, became eligible for the funds for political reasons: Prov. Hainaut (BE), Corse (FR), Molise (IT), Lisboa (PT). The other 57 regions remained eligible for Objective 1 status also in the following programming period 2000-2006. In order to have a more comparable and stable control group we decided to exclude from our sample regions that were Objective 1 in the period 2000-2006, but not in the previous period. These were:

- five regions which were non treated in 1994-1999 but became eligible for Objective 1 in 2000-2006: Burgenland (AT), Itä-Suomi (FI), South Yorkshire (UK), Cornwall and the Isles of Scilly (UK), West Wales and the Valleys (UK);
- five non-Objective 1 regions in the period 1994-1999, that became partially eligible in 2000-2006: Länsi-Suomi (FI), Pohjois-Suomi (FI), Norra Mellansverige (SE), Mellersta Norrland (SE), Övre Norrland (SE).

Some non-Objective 1 regions also benefited from Cohesion policy transfers because they fell under other Objectives. Following Pellegrini *et al.* (2013), we took into account the per-capita intensity of financial resources among the different regions, distinguishing between *hard-financed* regions (Objective 1, treated regions) and *soft-financed* regions (non-treated regions). As many sources of financing - Structural Funds, Cohesion Fund, National co-financing, Private financing – existed in both programming periods 1994-1999 and 2000-2006, we needed to identify a threshold value of per capita transfer intensity. We fixed this at €1960, which is the minimum value of certified per-capita expenditure in Objective 1 regions (Pellegrini *et al.* 2013). The results show that nine non-Objective 1 regions had a level of per-capita expenditure higher than the fixed threshold. In particular, we excluded from analysis the non-Objective 1 Spanish regions that received aids from the Cohesion Fund: Pais Vasco, Comunidad Foral de Navarra, La Rioja, Aragòn, Comunidad de Madrid, Cataluña, Illes Balears as well as the Finnish regions of Etelä-Suomi and Åland that benefited from other funds. Finally, we excluded the regions that did not receive transfers in all the FOI of certified expenditures selected (Bruxelles, Provincia di Trento, Prov. Brabant Wallon, Prov. Vlaams Brabant, Bedfordshire, Hertfordshire, East Anglia, Eastern Scotland, Usimaa-Helsinki). Thus, our sample consisted of 180 NUTS 2 regions (54 treated and 126 untreated) which remained in the same group for both programming periods considered in the analysis; further, they are homogeneous groups also in terms of the amount of per-capita transfers: soft-financed (untreated) or hard-financed (treated). Our resulting sample met the requirements for the application of the Regression Discontinuity Design in the *sharp* version.

We derived data on the certified expenditure directly from the European Commission offices (DG-Regional policy) and from the Italian Ministry for Economic Development (Department for Development and Economic Cohesion). The data did not originally have a panel structure and the Structural Funds and Cohesion Fund were reported in two different tables, so we had to transform them before carrying out the econometric analysis (see for instance tables P1 and P2 in the Appendix). The main problem in using this database was the lack of a region name or code, which would allow to easily associate each value to a specific region. We selected two specific FOI (level 2) for the Structural Funds: Research and Innovation and Transport infrastructure[18]; as regards the Cohesion Fund we chose the Technical Assistance Project and Transport Project.

The panel dataset was constructed manually, observing the following rules:

- the total amount was fully imputed to the region where the name of the region was expressly and univocally specified in the identification name of the programme;
- programme expenditure for NUTS at a lower level than NUTS 2 were imputed to the respective NUTS 2 region;

[17] For a focus on PPS see Eurostat-OECD (2006).

[18] In particular: 18. Research, technological development and innovation, RTDI; 31. Transport Infrastructure.

- national programme expenditure was shared between all the regions of the country, using the population at the beginning of the programming period as a distribution criteria[19];
- municipality programmes, natural regions and consortiums expenditure was imputed to the NUTS 2 involved in the group (when identifiable), using the same criteria as for the previous point[20];
- expenditure for which recipient regions could not be identified from the name of the programme was deleted;
- data about cross border and interregional cooperation was not considered.

The third step involved in the construction of the dataset is described for each variable in the following section.

A2. The variables

After these preliminary transformations, the dataset presented a panel structure containing data regarding certified expenditure by year, fund and field of intervention for each NUTS 2 (table P3); the next step was the identification of the outcome variable for each field of intervention analysed.

Per-capita GDP

Traditionally, the economic literature considers GDP growth as the outcome variable of public transfers in studies differing from each other for model specifications, regional levels and time intervals considered. No unambiguous results have so far been reached.

In line with this strand of literature, we started our analysis of the effectiveness of Cohesion Policy by using per-capita GDP growth rate as the outcome variable and the RDD approach. To assess the evidence of a discontinuity among Objective 1 and non-Objective 1 regions, we referred to a period of fifteen years (from 1995 to 2010) and two different sub-periods: 1995-2003 and 2003-2010. Further, we analysed the full sample and two sub-samples that excluded, first, the highest and the lowest values and then the colonial regions.

Patent Applications

Schwab *et al.* (2007) point out that innovation is essential for developed economies, as they need new technologies and new cutting-edge products to maintain their competitive advantage. As Cantwell (2006) underlines, this requires an environment which is conducive to creating relationships between firms and the science infrastructure, between producers and users of innovation and the inter-firm level, and between firms and the wider institutional environment. Feldman (1993) suggests that the process of introducing innovations is facilitated by a firm's location. She demonstrates that product innovations tend to be concentrated in states where innovative inputs are present, in particular specialised knowledge resources that enhance the innovation process.

In recent smart specialisation developments related to EU Cohesion reform, support instruments for innovation are more focused on socio-economic influences on technological development and usage concerning smart growth, energy and sustainable growth and entrepreneurship promotion. Consequently, innovation promotion is much more linked than in the past to questions of transparent and appropriate governance systems (McCann and Ortega-Argilès 2013b).

Patents are a means of legally protecting inventions developed by firms, institutions or individuals, and they can thus be interpreted as indicators of inventions (Annoni *et al.* 2010). Patents are aimed at ensuring property and market exclusivity on the protected invention and are released by a national patent office (OECD, 2009). We considered patent applications per million inhabitants from the OECD *Regpat* dataset as the outcome variable for the field “Research and Innovation”.

As is well known, patent indicators give information on the output of the R&D. When comparing regional performance, the OECD Patent Manual (2009) recommends the use of fractional accounting for patents, in order to: i) attribute to each region its actual contribution to invention; ii) when summed up all regions give a total of 100%. Patent data can be regionalised considering the address of either the inventor or the holder. The inventor’s address usually indicates where the invention was made. The priority year is the year of first filing for a patent; it is the closest to the actual date of invention, and should therefore be used as the reference date when compiling patent indicators aimed at reflecting technological improvements (Maraut *et al.* 2008). We considered a fractional count by inventor and priority year patent data. The *Regpat* database used includes patent applications to the European Patent Office (EPO), to the Patent Cooperation Treaty (PCT) and to the United States Patent and Trademark Office (USPTO).

Data transformations and a summary of the main steps of the analysis are listed below:

- *Missing values*: for OECD patent data, missing values are equal to zero. However, when no data was available at NUTS 2 level we used the Eurostat variable “Employment in technology and knowledge-intensive sectors by NUTS 2 regions and sex” (1994-2008, NACE Rev. 1.1) for the calculation of the weight (countries involved: Greece, Belgium, France d'Outre-Mer, Germany, Netherlands, England) which allowed us to transform national statistics into data suitable for imputation at the regional level. Only for Greece and

[19] Otherwise, the first available year is used.

[20] For the Association of Portuguese Municipalities, for which there is a specific website, expenditure is attributed to the NUTS 2 of the Association's Headquarters.

Cumbria Eurostat data was not available: in these cases the imputed data is, respectively, the average NUTS 1 value (NUTS 1 value/nr. of NUTS 2) and the mean of the other NUTS 2.

- *Certified Expenditure*: we considered the Field of Intervention (FOI) "Research, Technological Development and Innovation (RTDI)" for Structural Funds and "Technical Assistance" (TA) for Cohesion Funds. All the regions with a positive TA were included in the RTDI sample.
- *Periods*: the whole period considered in the analysis covers the years from 1999 to 2010. However, we split the time interval of the analysis into three sub-periods: 1999-2007; 2002-2010; 2002-2007.
- *Samples*: in the first step, we considered the whole sample and the outcome variable was expressed as both growth rate and difference in levels. In a second step, we considered some restricted samples: in the first sample (R1), we excluded the regions of Martinique, Guyana, the Autonomous Region of the Azores, Melilla and Ceuta who have zero values for some years and always a negative growth rate; in the second sample (R2) we dropped also Alentejo which has the highest growth rate in the distribution in 1999-2010 and seemed to be an outlier.
- *Estimations*: we use parametric (OLS) and non-parametric estimations (local linear polynomial estimation with standard errors estimated with bootstrap method - 500 replications).

Potential road accessibility

As the Territorial Agenda of the European Union states: "Mobility and accessibility are key prerequisites for economic development of all regions of the EU". Consequently, transport infrastructure improvement is a key policy instrument to promote regional economic development (ESPON, 2006). Over the period 2000-2006, about 35% of Structural Funds and 50% of the Cohesion Fund were spent on infrastructure projects (Crescenzi and Rodriguez-Pose 2008). The quality of infrastructure is essential for the efficient functioning of an economy (Schwab *et al.*, 2007). Modern and efficient infrastructure endowments contribute to both economic efficiency and territorial equity as it allows for the maximization of the local economic potential and the efficient exploitation of resources (Crescenzi and Rodriguez-Pose 2008). High-quality infrastructures guarantee easy access to other regions and countries, contribute to better integration of peripheral and lagging regions, and facilitate the transport of goods, people and services. This has a strong impact on competitiveness as it increases the efficiency of regional economies (Annoni *et al.* 2013). The recent literature argues that the traditional cost-benefit analysis cannot capture the effects of infrastructures on regional development, but it is necessary to consider also the effects of the network externalities (OECD 2002). In McCann and Shefer (2004), the role of infrastructures in the regional development process is discussed. They analyse the relationship between infrastructure investment and regional development with a focus on the transportation infrastructure investment. They conclude that the different geography-firm transactions cluster types are of crucial importance in the evaluation of the role played by transportation infrastructure on regional development. However, empirical works on the role of infrastructure in the development process highlight a lack of data, especially for the road network. The EU recently financed a project aimed at the construction of a historical database of European road networks since 1960 with a time interval of ten years. Stelder's paper (2014) presents a first analysis rested on this database. We thus chose the potential road accessibility data collected in this EU project as the outcome variable of the certified expenditure of transport infrastructures.
In Stelder's paper, the accessibility concept is expressed with the functional form based on Reilly (1931):

$$A_i = \sum_j P_j D_{ij}^{-\beta} \quad (2)$$

with *A* for accessibility, *P* for population or any other local activity, *D* for distance or any other definition of transport costs, and a parameter β indicating the distance decay intensity.
In Stelder's analysis (2014), absolute accessibility A_j is scaled to relative accessibility a_j:

$$\alpha_j = \frac{A_i}{\sum_j A_j} \quad (3)$$

For each location, accessibility may be increasing at the same ratio, which may cause additional economic growth, but uniform in all locations, with the consequence that no one is benefiting more than others from infrastructure improvement[21].
Therefore we use the change in relative accessibility α_i is derived as:

$$\alpha_i(t) = \frac{\alpha_i(t)}{\alpha_i(t-1)} \quad (4)$$

With this transformation, the usual geographical bias that gives central locations the highest accessibility is eliminated.
The following points summarise some crucial steps of our analysis:

- *Exclusions*: some regions were eliminated from analysis as their values were missing: South Aegean, Crete, the Autonomous City of Ceuta, the Autonomous City of Melilla, the Canaries, the Autonomous Region of the Azores, the Autonomous Region of Madeira.
- *Certified expenditure*: we consider the FOI "Transport Infrastructure" both for the Structural and Cohesion Funds. All the NUTS 2 who received the Cohesion Funds also received Structural Transport Funds.

[21] For more details on transport cost functions in NEG models, see McCann (2005).

- *Period*: for the outcome variable we cannot split the analysis into sub-periods, because data on POT is only available for some specific years (1955, 1970, 1980, 1990, 2000, and 2012). We decided to consider the growth rate for the period 2000-2012.
- *Samples*: we first considered the whole sample; then we excluded the Reunion Island that has a growth rate equal to zero.
- *Estimations*: we used parametric (OLS) and non-parametric estimation (local linear polynomial estimation with standard errors estimated with bootstrap method - 1000 replications).

Our goal was to verify whether the treated units that received (and spent) EU transfers for these specific fields of intervention experienced a greater growth in the outcome variables of these transfers. As mentioned before, the samples used were different for each specific FOI, because not all the units received transfers for both sectors of intervention.