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On the effectiveness of EU structural funds during the Great Recession: Estimates from a heterogeneous local average treatment effects framework

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On the effectiveness of EU structural funds during the Great Recession: Estimates from a heterogeneous local average treatment effects framework*

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Abstract

This study investigates the heterogeneity of European NUTS-2 regions with regard to their ability to take advantage of European Union (EU) structural funds aimed at convergence. It considers a concept of absorptive capacity based on regional policy design, and additionally accounts for the programming period 2007-2013 in the empirical analysis. A fuzzy regression discontinuity design allowing for heterogeneous treatment effects is applied to evaluate convergence funds in 250 NUTS-2 regions from 2000 (and 1989) to 2013. The main results suggest a positive conditional impact of funds payments on regional GDP per capita growth. However, based on a time-varying treatment effects model, we are able to identify a deterioration in the effectiveness of convergence funds during the programming period 2007-2013. Furthermore, the analysis reveals an inverted U-shaped relationship between the share of committed funds paid out and GDP per capita growth. The latter finding indicates that the marginal benefits from EU convergence funds might be decreasing.

Keywords: Structural Funds, Heterogeneous Treatment Effects, Regional Heterogeneity, Absorptive Capacity, Cohesion, European Union
JEL Classification: C21, F35, H77, R11, R58

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1 Introduction

The developments since the economic and financial crisis and the European debt crisis have highlighted the heterogeneity of the member states and regions of the European Union (EU). However, achieving income convergence of European regions in terms of gross domestic product (GDP) per capita has been on the agenda of the European institutions since the 1980's. With the multi-annual financial framework (MFF) 2007-2013, the expenditure towards fostering competitiveness and cohesion for growth and employment has become the biggest item in the EU budget. With that, the European Commission's Directorate-General for Regional and Urban Policy (DG REGIO) conducts funding programs that provide transfers with which regional administrative authorities perform projects aimed at different objectives. The main regional policy instruments are the European Regional Development Fund (ERDF), the European Social Fund (ESF), together often called *structural funds*, and the Cohesion Fund (CF).[1] A major part of these funds, which we will refer to as *convergence funds* or former *Objective 1 funds* in this paper, is allocated to the relatively weakest regions, i.e., regions with a GDP per capita below 75 % of the EU average.[2]

Despite the importance of regional redistribution and cohesion, evaluations of the effectiveness of convergence funds point to different results across regions. Following the academic and political debate on the absorption of structural funds (e.g., Katsarova 2013, Healy and Bristow 2013, Tosun 2014, Tătulescu and Pătruţi 2014), two issues are expected to be crucial: Firstly, not all of the funds committed to the weakest regions at the beginning of the program period are actually paid out and, hence, used for convergence projects. Potential explanations for this phenomenon include that i) each project needs to be co-financed by the member state and the particular region, respectively, and ii) the administrative effort is high as detailed and profound operational programs, project and budget plans need to be provided by the region in order to receive the funds. Secondly, the effectiveness and likely success of funds that are paid out for projects might vary. Among the probable reasons discussed in the literature are regional absorptive capacity or regional structural characteristics such as human capital endowments.[3] From an institutional point of view, the success of structural funds projects may also depend on their quality of planning and implementation.

[1] There are two further regional funds, namely, the European Agricultural Guidance and Guarantee Fund (EAGG-F) and a Financial Instrument for Fisheries (FIF). The European Commission refers to the regional funds up from 2007-2013 as European Structural and Investment Funds (ESIF).

[2] Up to the EU's multi-annual financial framework 2000-2006, in line with which regional policy programs are organized, they have been called Objective 1 regions, thereafter the objectives were restructured and renamed. The funding programs have been designed for the periods 1989-1993, 1994-1999, 2000-2006, 2007-2013, and, now, 2014-2020. The regions in question in this research are on the NUTS-2 level following the *Nomenclature des unités territoriales statistiques* 2010 (NUTS 2010) (UNESCO 2006).

[3] The absorptive capacity of regions has been shown to be a relevant factor for the effectiveness of regional transfers like EU structural funds (see, among others, Becker, Egger and von Ehrlich 2013, Rodríguez-Pose 2013, Bachtler, Mendez and Oraže 2014).

Another issue related to the likely effectiveness of regional policies today is the economic downturn following the financial crisis and the European debt crisis. Camagni and Capello (2015) treat the topic of EU cohesion policies during the Great Recession and claim that structural, long-term projects are more difficult to conduct due to financial and political reasons. Having a look at the shares of funds available to the regions (*committed funds*) that are actually paid out for projects, its (national) average reduces from 98.2 % in 2000-2006 to only 62.09 % in 2007-2013. This implies that, indeed, the incentives to implement already agreed regional policy projects is relatively low in the latter period.

This paper investigates the heterogeneity of European NUTS-2 regions in their ability to take advantage of European structural funds, such that the regions' income per capita increases over the programming period. Its contributions are twofold: Firstly, the absorptive capacity concept used in this paper is motivated by the regional funds allocation procedure in practice, i.e., the focus lies on describing the capability of regional authorities and beneficiaries to reach the projects' goal of increased regional growth. Therefore, the definition of absorptive capacity is broadened by considering not only the share of the labour force with high education but their employment status.[4] The underlying hypothesis to be tested empirically is that a higher education level in a region may only be able to contribute to using European support effectively when it is employed (used productively). This is motivated by the observation that, since 2008, employment rates of graduates and people with upper secondary education are stagnating while the number of people attaining these levels of education is steadily increasing.[5]

Secondly, to the best of our knowledge, this is the first paper taking the full multi-annual financial framework 2007-2013 which coincides with the Great Recession into account for assessing the effectiveness of structural funds in a pan-European setting. Besides implementing a time-varying feature of the treatment effect, we further investigate the role of decreasing usage of available funds for the effectiveness of EU's regional policy measures. Therefore, the share of committed funds actually paid out is used for modeling treatment intensity in the particular programming periods.

The empirical analysis follows Becker et al. (2013) who apply a regression discontinuity design to estimate heterogeneous local average treatment effects of Objective 1 structural

[4] According to the literature on foreign direct investments and other (regional) transfers, the education of the labour force, the size of the research & development (R&D) sector as well as institutional quality are broadly accepted determinants of a region's absorptive capacity and, analogously, its growth potential (Becker et al. 2013, Nguyen, Duysters, Patterson and Sander 2009, Cohen and Levinthal 1990).

[5] The high unemployment rates, even among the population with upper secondary and higher education, in most European countries are not expected to decrease in the short or medium term, and rising long-term and youth unemployment will deepen the problem further (see, e.g., OECD 2014). Unemployment has crucial effects on the budgetary stability and budget formulation of the countries. Therefore, it gets even more relevant in the context of the European debt crisis and the implemented policy measures.

funds for the regional policy programming periods from 1989-1993 to 2000-2006.[6] This approach is used to evaluate the implications of absorptive capacity, modeled by the employment rates of the highly educated labour force of a region, institutional quality and the size of R&D expenditure in a region, on the success of structural funds aimed at convergence and, therefore, the European institutions' power to actually support convergence of the regions. Including the multi-annual financial period 2007-2013 into the analysis allows to assess the effectiveness of the EU's regional policy in the crisis period.[7]

Summing up the main findings, conditional on regional absorptive capacity and the respective programming period, convergence funds appear to have a positive and significant impact on regional GDP per capita growth across the programming periods. Better institutional quality appears to consistently improve GDP per capita growth. However, compared to former periods, the effectiveness of convergence funds significantly deteriorates in the crisis period 2007-2013. Examining this issue in more detail by taking the regional share of committed funds paid out into account suggests that there is an inverted U-shaped relationship between treatment intensity and GDP per capita growth in a period. This implies that the GDP per capita growth effect of an additional Euro of convergence funds paid out decreases with the amount already spent (even in a period of economic downturn). The results from several robustness checks like a sharp regression discontinuity design or controlling for spatial dependence of the treatment support these findings.

The structure of this paper is as follows. Section 2 treats EU regional policy and its varying effectiveness, discussing the policy design and previous literature on absorptive capacity as well as regional policy in crises. Section 3 motivates the model and Section 4 sketches the regression framework. Section 5 provides details on the data. Section 6 shows the estimation results and, finally, Section 7 concludes.

2 EU Regional Policy and its Effectiveness

The EU's regional policy has become the biggest budget item in EU budgets since 2007. In the multi-annual financial framework 2007-2013, the expenses for competitiveness for growth and jobs (9.25 %) and for economic social, economic and territorial cohesion (35.75 % of total commitments) exceeded the expenses for the common agricultural policy (42.29 %) (European Commission 2015*d*). Alike, 13.13 % of the EU commitments for the period 2014-2020 are allocated to promoting competitiveness for growth and jobs, and

[6] Becker et al. (2013) have used the education of the workforce (share of workers with at least upper secondary education) and a quality of government index as indicators for the absorptive capacity of a region.

[7] Due to data availability of pre-treatment variables as well as structural funds commitments and payments, the main results presented in this paper consider the multi-annual financial frameworks (MFFs) 2000-2006 and 2007-2013. Further estimation results taking into account also the programming periods 1989-1993 and 1994-1999 are provided in the appendix.

33.88 % for economic social, social and territorial cohesion, while the share of the common agricultural policy diminishes further to 38.80 % of the EU budget (European Commission 2015*e*). Thus, currently, its regional policy is the EU's most important redistributive policy instrument for promoting economic growth and supporting the convergence of European regions.

Basically, regional funds are allocated according to the following objectives: i) Convergence (former Objective 1), ii) regional competitiveness and employment (comparable to former Objective 2) and iii) European territorial cooperation (comparable to former Objective 3). Contrarily to the second and third target, the eligibility of regions for convergence funds is clearly regulated as this type of funds is available for the relatively weakest regions with a GDP per capita below 75 % of the EU average.[8] The committed ERDF and ESF transfers to the lagging regions amounted to about 137 billions for 2000-2006, in 2007-2013 to over 214 billions of Euros. These numbers mean a share of convergence or former Objective 1 funds of all ERDF and ESF payments of 70.32 % in 2000-2006 or rather 77.28 % in 2007-2013 (European Commission 2015*c*). Therefore, analyzing these parts of regional funds is likely to allow a proper picture on the effectiveness of EU regional policy.

2.1 The Varying Effectiveness of EU Regional Policy

There are several studies evaluating the EU's regional policy, however, with mixed empirical evidence (see, e.g., Sala-i Martin 1996, Boldrin and Canova 2001, Rodríguez-Pose and Fratesi 2004, Dall'Erba, Le Gallo et al. 2007, Dall'Erba and Le Gallo 2008, Ramajo, Márquez, Hewings and Salinas 2008, Esposti and Bussoletti 2008, Becker et al. 2013, Pellegrini, Terribile, Tarola, Muccigrosso and Busillo 2013, and, up to our knowledge most recently, Barone, David and de Blasio 2016, Ferrara, McCann, Pellegrini, Stelder and Terribile 2016 and Breidenbach, Mitze and Schmidt 2016). Most studies find a positive, but often very small effect of the regional transfers while others find none or even a negative impact on convergence. Moreover, statistical significance varies. One reason may be that, on the one hand, the analyses vary in terms of considered time periods, definitions of structural funds receipt and data on the national or regional level. On the other hand, they use different estimation approaches and methods. Methodologies used reach from manifold econometric studies and macroeconomic simulations (of the potential of the support of specific regions) to micro-level and case studies (see Hagen and Mohl 2009 for a survey).

In order to estimate the conditional convergence of regions in income levels or economic growth, various authors have analyzed (mostly on country level) under which circumstances the structural funds and Cohesion Fund are more effective in promoting convergence. Variables which are expected to influence the consequences of regional transfers are

[8] Furthermore, this type of funds is directed to regions which are geographically isolated or, e.g., face severe challenges, e.g. Northern Ireland. Note that, having a deeper look at actual expenditure data, also a few regions which would not be eligible have received payments (see Section 3).

human capital (the share of workers with high education, as in Becker et al. 2013), institutional quality (e.g., Rodríguez-Pose 2013), the degree of decentralization of administration (Tosun 2014), corruption, the size of the R&D sector (expenditure) or openness to trade (Hagen and Mohl 2009). Further literature treats the relatively new concept of territorial capital (Camagni 2008) and its implications for regional policy (Fratesi and Perucca 2014).

In this paper, another potential source for variation in the effectiveness of regional policy is examined. Up to our knowledge, no study has included the full crisis period 2007-2013 in a pan-European setting into a microeconometric evaluation framework yet. Related research is provided by Camagni and Capello (2015) who conduct an interesting analysis of regional divergence triggered by the economic crisis and the role of regional policy, and Ciani and De Blasio 2015 investigating the impact of structural funds in the crisis in Southern Italy. The empirical results of this paper contribute the finding that, intuitively not surprisingly, the effectiveness of regional policy declines significantly in 2007-2013 relative to previous periods.

2.2 The Design of EU Regional Policy and its Implications on the Absorptive Capacity for Structural Funds

As indicated in the introduction, it is probable that the design of the EU's regional policy influences the effectiveness of the funds assignment. In general, the European Commission and national managing authorities approve operational programs which motivate projects and how they may contribute to a particular objective.[9] There are two issues that are likely to affect the regions' success in thoroughly implementing their planned projects: Firstly, each project needs to be co-financed by public funds of the member state and, partly, the recipient itself, which limits the regions' ability to actually call transfers (get them paid out) that would be available for them (have been committed). Secondly, setting up and implementing these programs requires much ongoing administrative effort and project planning expertise of public authorities and the beneficiaries, and might make it hard to access the funds especially for new member states. Both points indicate that not all countries and regions indeed receive the amount of transfers that was committed to them, which is proven to be true in the data.

Table 1 shows the national shares of committed transfers at the beginning of the program periods 2000-2006 and 2007-2013, respectively, that were paid out (in literature sometimes referred to as absorption rates). There seems to be some variation across countries in their usage of committed funds in 2000-2006. However, what becomes immediately apparent, is that the shares decrease tremendously for the years 2007-2013, especially considering payments until 2013, the end of the actual budget period. Considering not only funds

[9] Either, these operational programs correspond to one (NUTS-2) region and an objective (like convergence) or they summarize projects targeting at areas of strategic importance (like transport or environment) on the national level.

aimed at convergence and Objective 1 funds, respectively, but structural funds assigned to all of the three main objectives, yields a similar picture. Their shares actually paid out are shown in column 4 of Table 1, with an average share of only 64.10 %. Regions are allowed to call committed funds until two years after the programming period but still, for 2007-2013, the share paid out until 2015 (last column of Table 1) indicates that the total amount of available funds has not been used in any country. As an extreme case, Croatia has only received 50.65 % of the committed funds.

Table 1: Share of committed convergence (Objective 1) funds actually paid out in EU member states in MFFs 2000-2006 and 2007-2013 (excl. payments in years afterwards)

Member State	2000-2006 ERDF & ESF Convergence	2007-2013 ERDF & ESF Convergence	2007-2013 ERDF & ESF All objectives	2007-13 - Status 2015 ERDF & ESF All objectives
Belgium	99.21%	57.22%	68.80%	93.05%
Cyprus	-	-	66.35%	95.00%
Czech Republic	99.29%	48.73%	55.00%	87.40%
Denmark	-	-	54.40%	95.00%
Germany	98.38%	70.45%	71.45%	92.50%
Estonia	99.90%	83.40%	84.45%	95.00%
Greece	99.28%	64.57%	65.65%	97.00%
Spain	97.11%	57.22%	62.55%	80.40%
France	98.29%	55.02%	59.90%	92.20%
Ireland	97.20%	-	70.10%	90.00%
Italy	93.14%	49.00%	54.55%	82.65%
Latvia	100.00%	78.60%	79.05%	95.00%
Lithuania	100.00%	79.39%	79.20%	95.00%
Luxembourg	-	-	67.80%	95.00%
Hungary	99.84%	57.26%	60.50%	84.35%
Malta	100.00%	45.55%	51.55%	82.10%
Netherlands	100.00%	-	63.85%	91.15%
Austria	99.97%	71.81%	70.55%	93.35%
Poland	99.81%	70.76%	71.80%	94.85%
Portugal	102.57%	80.36%	80.45%	95.00%
Slovenia	100.00%	72.71%	73.45%	95.00%
Slovakia	96.58%	51.42%	52.90%	87.30%
Finland	100.00%	-	76.25%	95.00%
Sweden	100.00%	-	67.50%	94.75%
United Kingdom	98.39%	62.58%	57.30%	87.95%
EU-25	**98.20 %**			
Bulgaria		52.57%	55.10%	89.85%
Romania		38.62%	39.10%	66.55%
Croatia		0.00%	11.50%	50.65%
EU-28		**62.09 %**	**64.10 %**	**88.60 %**

Data source: European Commission. 2000-2006, 2007-2013 (convergence funds): European Commission (2015*c*); 2007-2013 (all objectives): European Commission (2016*b*)

In practice, private and public companies and institutions, research institutes, non-governmental organization, clusters, networks, etc. apply for project support, and the responsible regional administrative authority allocates them to an appropriate operational program.

This procedure entails a high administrative effort for regional (and national) administration and the potential beneficiaries. Thus, getting one step further, a region's potential to provide comprehensive, well-planned operational programs and implement the prepared projects depends on two characteristics which have been assumed to be crucial for regional absorptive capacity in previous literature (see Section 1): Firstly, institutional quality and corruption are important indicators for the ability of regions to effectively and efficiently prepare operational programs including the choice of convenient projects. Secondly, in the end firms, public and private institutions, etc. propose projects, receive payments and realize the projects aimed at regional convergence. Therefore, we will test the hypothesis that the employment rate of the workforce with high education may matter for regional policy effectiveness as a larger share of regional workers with high education might be more capable to design and carry out successful project ideas. Finally, companies that invest more in R&D may be associated with a higher probability of proposing promising projects. Therefore, the R&D expenditure of companies and entities in all sectors is considered as a further variable contributing to the absorptive capacity of regions.[10]

In the remainder of this study, we investigate the effectiveness of structural funds (ERDF and ESF) allocated to the convergence objective. It will be examined whether the heterogeneity of European regions in terms of their absorptive capacity, modeled by the indicators introduced above, affects the success of regional policy.

2.2.1 Absorptive Capacity and Employment

The concept of absorptive capacity of a country or region for external funds has been widely discussed in literature regarding foreign direct investments (FDI). Nguyen et al. (2009) have emphasized that there are principally two stages of absorption of FDI in an economy: the ability and possibility to implement FDI projects and, in a second step, to absorb the technology or other benefits from FDI into own competencies. Crucial factors for the absorptive capacity that have been discussed in the literature are the technology of the country receiving FDI, the education of the labour force, the extent and quality of the country's research and development sector, the development of the financial sector, as well as the institutional system (De Mello Jr 1997, Blomström and Kokko 2003, Cohen and Levinthal 1990, Fu 2008, Hermes and Lensink 2003, Kalotay 2000, Durham 2004). Nguyen et al. (2009) group these characteristics into the absorptive capacity of the recipient country's firms, comprising the technological development and the education level of workers, and national absorptive capacity. The latter is driven by the technological level,

[10] Given the variety of variables that have been assumed to influence the outcome of regional policy as absorptive capacity or territorial capital, this paper focuses on the execution of regional policy in practice. Thus, two variables corresponding to the final beneficiaries of the transfers (employed share of the labour force with upper secondary and higher education, and R&D expenditure by companies, the public sector, universities and nonprofit organizations) and one representing the regional authorities' capability of organizing the projects in an effective way are chosen (institutional quality with a focus on corruption). Still, this choice does not mean that further concepts like territorial capital may not be important for the effectiveness of structural funds.

next to human capacity (population size) and the financial and institutional system.

There is relatively little literature concerning the absorptive capacity of the EU's regional transfers. Tosun (2014) has referred to the *Europeanization* literature, e.g., Bachtler et al. (2014), which treats the implementation of EU policies on the national level, as the first stream of literature changing the focus from the eligibility to EU structural funds alone to the way of their usage. Zaman and Georgescu (2009) have analyzed the situation in Romania as regards the structural funds absorption rate. They indicate that the rate is mainly determined by institutional variables: i) the financial capacity to co-finance the structural funds projects across the whole programming period and ii) the national and regional administrative capacity for preparing efficient project plans and coordinating the participants. There are various country studies on absorption rates, e.g., Milio (2007) and Bachtler et al. (2014), likewise, from a multinational perspective, Tosun (2014) has empirically shown that the administrative capacity of a country or region affects the absorption of ERDF funds for the period 2000-2006.

Various studies have analyzed the impact of the educational distribution on funds effectiveness. However, employment rates of people with upper secondary and tertiary education have decreased over the last decades and especially since 2008 (OECD 2006, 2014). Figures 1 and 2 show rising shares of high education but decreasing employment rates of the workforce having attained upper secondary or higher education. Next to the hypothesis that better educated workers might be able to plan and implement regional projects more effectively, these numbers are another reason why the employment rates of the labour force with upper secondary and higher education (ISCED levels 3 and higher) are likely to be relevant for the regional absorptive capacity for convergence funds.[11] [12]

2.3 European Regional Policy During the Economic and Financial Crisis

In the past section, we have referred to an important issue in the process of structural funds allocation that seems to be influenced by the Great Recession. As shown in Table 1, there is a sharp fall in the share of committed funds paid out in the regional policy programming period 2007-2013 relative to the previous period. Camagni and Capello (2015) offer an intuitive explanation for that, namely, that it is more difficult for politicians to uphold expenditure targeted at longer-term objectives, like structural funds projects, in

[11] For the measurement of the education level, the International Standard Classification of Education (ISCED 2011) by UNESCO Institute for Statistics (UIS) is used. Level 0: Early childhood educational development, pre-primary education; Level 1: Primary education; Level 2: Lower secondary education (general, vocational); Level 3: Upper secondary education (general, vocational); Level 4: Post-secondary non-tertiary education (general, vocational); Level 5: Short-cycle tertiary education (general, vocational); Level 6: Bachelor's or equivalent level; Level 7: Master's or equivalent level; Level 8: Doctor or equivalent level.

[12] To look at the productive share of the labour force with upper secondary and higher education from a different angle, it can also be interpreted as structural characteristic of a region in the sense that it is able to employ the produced human capital. A higher value in a region may imply that there are enough jobs (or public services) requiring high educated labour which points to a well-developed sectoral structure.

periods when public budget balances need to be strengthened. The authors claim that the current crisis period could threaten the efforts towards cohesion across European regions in the past two decades.

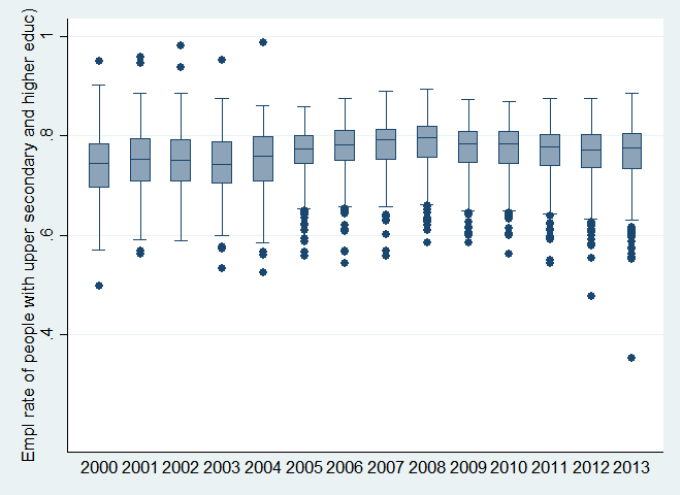

Figure 1: *Employment rates of labour force with at least upper secondary education (ISCED level 3 and higher)*

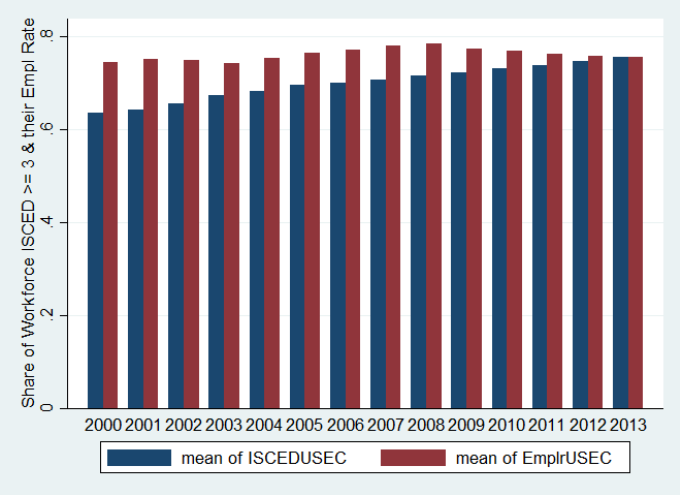

Figure 2: *Share of population aged between 25 and 64 with at least upper secondary education (ISCED level 3 and higher) and their employment rate*

Data source: Eurostat. Considered ISCED levels are level 3 and higher. 250 NUTS-2 regions of EU-25 from 2000 to 2013 (104 of 3500 observations missing). Due to data limitations (employment rate per education level, which is one main variable of interest), the four French overseas-departments and two Portuguese regions (Acores and Madeira) are skipped.

As response to the crisis, the European institutions have installed an European economic recovery plan with two key goals in 2008: i) restoring demand and confidence in the economy, and ii) preparing the recovery of European competitiveness in the long term by an adjustment of investment priorities towards, beside others, smart specialization and green energy (Commission of the European Communities 2008). One of the mitigation measures in this plan is increasing the speed of structural funds implementation by providing

extra funds in advance of project exertion and facilitating administrative procedures and the implementation of projects with high priority (European Commission 2008). In 2010, the European Commission published a report in which it the assesses the adaptations of cohesion policy in the course of the European economic recovery plan. Certain measures like more flexibility in the payment of committed funds (advance and intermediate) and co-financing as well as the modification of operational programs are listed as having been adopted relatively quickly (European Commission 2010). According to the share of available funds actually paid out in the whole programming period 2007-2013, the mitigation measures do not seem to have achieved a full implementation of all agreed projects.

To the best of our knowledge, so far there has been no evaluation of regional policy considering the whole programming period 2007-2013 for all regions of the European Union. Ciani and De Blasio (2015) analyze structural funds payments between 2007 and 2013 on the local level in Southern Italy and find that the additional resources made available by the European Commission in order to respond to the crisis were not able to outweigh the worsening of the economic situation. Turning into the same direction, the results presented in Section 6 show that the initiatives undertaken by the European institutions could not ensure the same effectiveness of the execution of regional policy projects during the crisis as in former periods.

3 The Assignment of Convergence Funds and the Heterogeneity of the Treatment

The empirical analysis follows Becker et al. (2013) who have used a regression discontinuity design (RDD) for the evaluation of EU convergence funds. Adding interaction variables to the model allows estimating a heterogeneous local average treatment effect (HLATE) that varies with regional characteristics. The RDD identification is based on a non-random treatment assignment in a way that the eligibility of individuals (regions in our case) for treatment depends on some threshold in a so-called forcing variable. In this way, it offers the advantage of ensuring a treatment assignment to observations around this threshold that is as good as random.[13] In the following, the assignment procedure of convergence funds which gives rise to a regression discontinuity design is outlined. The estimation of the heterogeneous local average treatment effects is described in Section 4.

[13] See, e.g., Lee and Lemieux (2010) and Angrist and Pischke (2009) for a comprehensive discussion of regression discontinuity designs.

3.1 The Assignment Procedure as Forcing Variable

The convergence target (former Objective 1) captures the least developed regions, namely those with a GDP per capita below 75 % of the EU average.[14] Regions that would have been eligible before enlargements of the European Union (especially before the entrance of ten new member states in 2004) but succeed the threshold due to the contracting effect on the EU average GDP per capita can still receive convergence funds. Moreover, geographically remote regions, like the four French overseas regions Guadeloupe, Martinique, Guyane and Reunion, as well as regions facing severe social problems, e.g., the conflict in Northern Ireland, are eligible to convergence funds.

Having a look at data on structural funds allocation reveals that the discontinuity in the eligibility criterion (forcing variable), i.e., the 75 % threshold of the average GDP per capita in respective years, does not match exactly with the actually treated and non-treated regions per programming period.[15] In order to keep regions which do not comply with the treatment rule in one or more programming periods, a fuzzy RDD is applied that employs the eligibility rule as an instrument for actual treatment. Regardless of whether a fuzzy or sharp design is used, regional GDP per capita in corresponding years is the forcing variable determining the probability of treatment or treatment itself. Referring to data in past years (e.g., 2000-2002 average for treatment eligibility in 2007-2013) ensures that the outcome variable (GDP per capita growth in the program years) is independent of the forcing variable (Becker et al. 2013).

In this study, the effectiveness of convergence funds actually paid out (not only assigned according to EU regulations) is analyzed. As shown in Figure 3, in the multi-annual financial framework 2000 to 2006, 67 regions (in total 250 regions in EU-25 countries are considered) have a GDP per capita below the threshold value of 75 % of the EU-25 average from 1994 to 1996. 66 of them have received convergence funds (have been treated), while Bratislava, a Slovak region, should have been treated according to its GDP per capita level but has not got funds paid out. Moreover, 39 regions should not have received funds according to the treatment rule but did.

[14] The relevant average for the programming period 2007-2013 is the EU-25 average of GDP per capita in the years 2000 to 2002, for the period 2000-2006 the EU-25 average for the years 1994-1996, for the period 1994-1999 the EU-15 average for 1988-1990, and for the MFF 1989-1993 the EU-12 average for 1984-86 (European Council 1988, 1993, 1999, 2006).

[15] The following amendments to the basic eligibility criterion defined in Council Regulations 1260/1999 point into this direction: Firstly, regions with a remote spatial location, relatively very low population density, Northern Ireland due to societal challenges, as well as transition from previous Objective 1 regions are supported. Secondly, the Commission decision in European Commission (1999) does not include the Eastern European countries that were to access the EU in 2004. However, the final regional expenditure study in SWECO (2008), that is provided on the DG REGIO website, shows that all Estonian, Latvian, Lithuanian, Maltese, Czech, Hungarian, Polish, Slovenian and Slovakian NUTS-2 regions have received Objective 1 structural funds from the European Regional Development Fund and European Social Fund. Therefore, the ten countries that have become member states of the EU in 2004 are included in our sample.

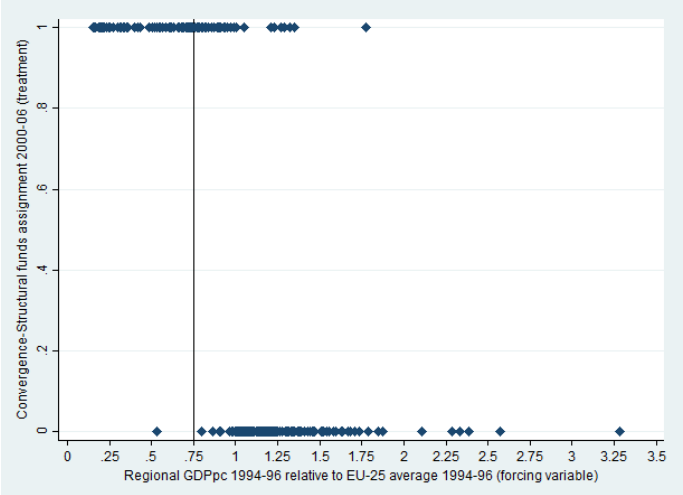

Figure 3: *Relationship between forcing variable (75 % of the EU-25 average of GDP per capita 1994-1996) and the actual assignment of convergence funds in 2000-2006*

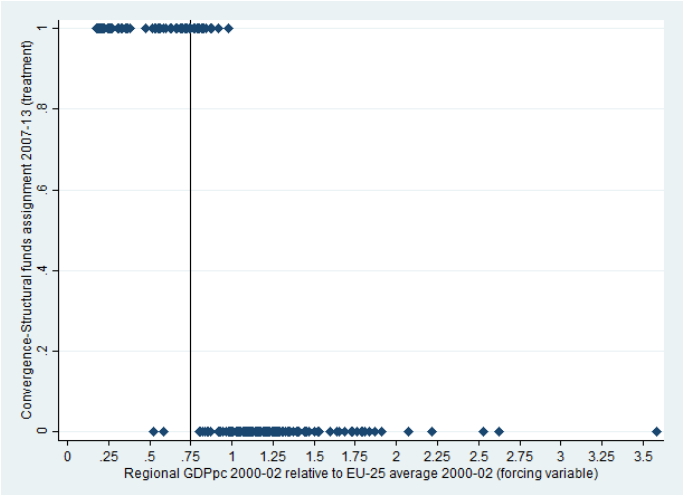

Figure 4: *Relationship between forcing variable (75 % of the EU-25 average of GDP per capita 2000-2002) and the actual assignment of convergence funds in 2007-2013*

Data source: DG Regional Policy, Eurostat. Data for EU-25 on NUTS-2 level (250 regions), excluding Romania, Bulgaria and Croatia. The four French overseas departments Guadeloupe, Martinique, Guyane and Reunion and two Portuguese regions Acores and Madeira are excluded due to a lack of data. The upper graph includes five observations (treated although their forcing variable lies above 1.25) that are excluded in the empirical analysis.

To mention a rather extreme case, Stockholm has received convergence payments in 2000-2006 although its GDP per capita has been nearly twice as high as the EU average in 1994-1996, which may bias results. Therefore, extreme outliers, namely regions with a GDP per capita in the corresponding threshold years equal to or higher than 1.25 times the EU average (five observations in 2000-2006) and below one quarter of the EU average (no observations) are excluded in the empirical analysis.[16]

[16] As robustness check, a sharp regression discontinuity design is estimated that excludes non-compliers with the treatment rule and uses a GDP per capita below 75 % of the EU average (in corresponding years) as clear indicator for treatment.

For the programming period from 2007 to 2013, there are 66 regions (of 250), whose GDP per capita averaged over the years 2000 to 2002 is lower than the EU-25 average for the same period (see Figure 4). Only 64 of these 66 regions have actually received structural funds payment (Bratislava and one region each in Hungary are the exceptions). Again, note that 18 regions have been treated although they have not met the treatment rule, i.e., the forcing variable does not lie below 75 % of the EU-25 average. One reason is that regions that have been treated as Objective 1 regions before, are part of a phasing out program in order to finalize projects and achieve targets set. In this period, there are no outliers as defined above for 2000-2006.

This leads to the treatment rule used for the estimation of the local average treatment effect (LATE) which is a deterministic function of the forcing variable in the sharp design. In the fuzzy design, the treatment rule serves as an instrument for actual treatment status:[17]

$$T_i = 1(x_i \leq x_0) \tag{1}$$

where T_i is a binary variable indicating treatment or non-treatment of a region i and x_0 is the EU-25 average of GDP per capita in the years 1994 to 1996 (for MFF 2000-2006) and 2000 to 2002, respectively (for MFF 2007-2013).

The aim of this research is to estimate the local average treatment effect of the treatment defined above on GDP per capita growth (of the treated regions). In the baseline results, the dependent variable is average GDP per capita growth per programming period, i.e., the mean of GDP per capita growth rates from 2000 to 2006 and 2007 to 2012 (following Becker et al. 2013).[18] Table 2 shows that mean outcomes are statistically significantly different from each other in regions that received convergence funds and those that did not.[19] In treated regions, average GDP per capita growth turns out higher than in non-treated regions, which supports the convergence argument that relatively weaker regions grow faster than more developed regions, probably also triggered by the structural funds allocation. The only exception is when considering the budget period 2007-2013 which coincides with the economic and financial crisis. Here, there is no statistically significant difference in growth rates which seem to fall in general. That may imply that the process of decreasing divergence between regions, i.e., the catching-up of the relatively weakest regions, has been disrupted (see also Camagni and Capello 2015).

[17] See, beside others, Angrist and Pischke (2009) or Cameron and Trivedi (2005) for details on the econometric framework.

[18] 2013 data on GDP per capita is not available neither from Cambridge Econometrics nor from Eurostat.

[19] For the years 1989-1999, those regions are considered as treated that are mentioned in corresponding EU regulations as Objective 1 funds recipients. For consequent years, data of actual payments (not only the lists of regions in EU regulations) is adopted.

Table 2: Mean outcome comparison between regions that did and did not receive payments

Actual transfers (2000-2013) and EU Regulations (1989-1999)				
	Mean $T_i = 1$	Mean $T_i = 0$	Difference	Obs.
1989-1993				
Outcome	0.017	0.015	-0.002^{**}	890
1994-1999				
Outcome	0.027	0.026	-0.002^{*}	1248
2000-2006				
Outcome	0.029	0.017	-0.012^{***}	1750
2007-2013				
Outcome	0.000	−0.001	−0.001	1750
2000-2013				
Outcome	0.017	0.008	-0.009^{***}	3500

Data: Cambridge Econometrics (transformed to NUTS-2010 classification), DG Regional Policy, EU Commission. The four French overseas departments and two Portuguese regions are not included in the dataset.

3.2 The Heterogeneity of the Treatment Effect

Having these insights on the treatment outcome in mind, we can now turn to the heterogeneity of the treatment effect that is dependent on regional characteristics. We are not only interested in the treatment effect but in its conditionality on the absorptive capacity of a region and the time period, as the last one, 2007-2013, is characterized by an economic downturn in whole Europe. As discussed in Section 2, we would like to test whether the share of labour force with upper secondary and higher education that is in employment, institutional quality as well as R&D expenditure in a region have an impact on the extent of the treatment effect. For the correct identification of the model, it is necessary to consider pre-treatment observations of these variables such that it is ensured that they are not themselves influenced by the treatment. Consequently, an essential requirement for estimating the local average treatment effect (LATE) is that the pre-treatment covariates are not discontinuous at the 75 % threshold of the forcing variable. The corresponding graphs controlling for this issue are provided in the appendix. In this study, data in 2000 (as 1999 data is not available) and 2006 are chosen as pre-treatment variables for 2000-2006 and 2007-2013, respectively.[20] These regional characteristics enter the regression as separate term as well as in interaction with the treatment and are modeled as deviation from their respective sample mean.

For the evaluation of convergence funds in all programming periods starting in 1989, the problem arises that data on the absorptive capacity variables is only available up from 2000. After testing for their stability over time, working with their mean values from 2000 to 2013 seems to be justifiable. Moreover, Table 11 in the appendix presents estimation results for the years 2000 to 2013 using the average values. The treatment effect and

[20] Thereby, some observations are lost for which no data for 2000 is available. For R&D expenditure, data is not provided for each year for each region (with different time intervals), therefore, the first observation per programming period is used as pre-treatment value. As this variable is highly correlated over time (Spearman coefficient 0.961), this procedure should not bias results.

influence of the crisis period are shown to be robust in this specification.[21]

Beside the productive share of the high educated labour force and R&D expenditure, as suggested by literature, the institutional quality of a region is examined. The European Quality of Government Index 2013 (EQI 2013) is applied and interacted with the corruption perception index (CPI) by Transparency International that is created based on perceptions of the degree of corruption in the public administration of a country. The European Quality of Government Index 2013 (introduced by Charron, Dijkstra and Lapuente 2015) builds on three main characteristics, namely, corruption, quality and impartiality of the public system. Among the considered areas are the educational system, the health sector, media, elections or rule of law. The EQI 2013 builds on regional survey data on the population's perception of the quality of public services, while CPI data is collected by different (also international) institutions (Transparency International 2012). The EQI 2013 is provided as a cross-section on the regional level, whereas the CPI is provided on a yearly basis since 2000 for most countries on the national level. The reasons for interacting these two indicators are twofold: Firstly, for the research question of this study, corruption is expected to be a major indicator for institutional quality in terms of project organization and allocation to different companies. Secondly, the CPI is only available on the national level but for a time series from 2000 to 2011, whereas the EQI 2013 covers the regional level. Thus, interacting these two indicators enables analyzing both the time and regional dimension.[22]

For the subsequent analysis, it is of interest to know whether the means of the absorptive capacity variables are different from each other in the treatment and control (non-treated) group. Table 3 compares them for the actually treated and non-treated regions, i.e., those who have received payments.[23] It turns out for all interaction terms that they are significantly different from each other across treatment and control group. Hence, they are likely to influence regional GDP per capita and the local average treatment effect. Looking at the differences between coefficients that represent the extent of heterogeneity in the

[21] Also Becker et al. (2013) have tackled the issue in that way. The Spearman correlation coefficient of the productive (employed) share of the labour force with upper secondary and higher education (employment rate times the education share) in 2000 and 2013 turns out to be significant and amounts to 0.894. Alike, the regional institutional quality measure in these years is strongly correlated and, thus, seems to be stable (0.940). Turning to R&D expenditure in a region, the correlation coefficient between (the mean of) observations before and after 2009 equals 0.961. Note that data on R&D expenditure, as a percentage of GDP, of private companies, the public sector, universities and private nonprofit organizations for some regions is only available up from 2009 and with different frequency. Therefore, the correlation is calculated in that way. Still, the correlation between R&D expenditure as a fraction of GDP between 2000 and 2013 amounts to 0.853 for regions with both observations. Thus, after having controlled the stability of the regional characteristics, the averages of all interaction terms are taken into account for analyzing all MFFs up from 1989.

[22] For the average term used in the estimation of treatment effects from 1989 to 2013, we only consider the CPI data from 2000 to 2011 as the index creation procedure has changed thereafter, not allowing comparisons across years anymore.

[23] In order to allow more detailed insights, the productive share of the highly educated labour force is split into their components, the share of labour force with upper secondary and higher education (USEC) and their employment rate (EMPLR OF USEC).

respective variable across treated and non-treated regions in a programming period, there seems to be a convergent development until 2000-2006 as differences decrease. However, in the crisis period, this trend appears to continue only for education levels, while the treatment and control group (relatively weaker vs. stronger regions in terms of GDP per capita) diverge again in terms of employment rate of the labour force with high education as well as R&D expenditure and the institutional quality measure.

For further investigation of the heterogeneity of regions in terms of the forcing and absorptive capacity variables, Table 4 shows descriptive statistics for the period considered in the baseline regressions (2000-2013). There appears to be high variation in the employment rate of people with upper secondary and higher education, R&D expenditure and the institutional quality measure. To give an example, the productive share of the regional population between 25 and 64 years old with high education varies from the minimum of 13.08 % in a year between 2000 and 2013 to a maximum value of over 80 %.

Table 3: Comparison of means of interaction variables (regional averages) between treated and non-treated regions

Actual payments (2000-2013) and EU Regulations (1989-1999)				
	Mean $T_i = 1$	Mean $T_i = 0$	Difference	Obs.
USEC				
1989-1993	0.474	0.710	0.236***	890
1994-1999	0.559	0.725	0.166***	1248
2000-2006	0.687	0.722	0.035***	1750
2007-2013	0.694	0.713	0.019**	1750
2000-2013	0.690	0.717	0.027***	3500
EMPLR of USEC				
1989-1993	0.722	0.780	0.058***	890
1994-1999	0.728	0.784	0.056***	1248
2000-2006	0.731	0.783	0.053***	1750
2007-2013	0.722	0.780	0.058***	1750
2000-2013	0.727	0.782	0.055***	3500
R&D				
1989-1993	0.686	1.779	1.093***	880
1994-1999	0.974	1.896	0.922***	1236
2000-2006	0.994	1.868	0.874***	1736
2007-2013	0.770	1.858	1.087***	1736
2000-2013	0.896	1.862	0.966***	3472
EQICPI				
1989-1993	14.645	28.816	14.171***	880
1994-1999	18.355	30.060	11.705***	1230
2000-2006	18.064	29.193	11.128***	1729
2007-2013	15.194	29.035	13.841***	1729
2000-2013	16.810	29.108	12.298***	3458

Data: Cambridge Econometrics (transformed to NUTS-2010 classification), DG Regional Policy, EU Commission. The four French overseas departments and two Portuguese regions, Acores and Madeira, are not included in the dataset. For comparison of means of interaction variables among treatment and control group before and after 2000, a regional average of these means is used. USEC represents the share of the labour force with upper and secondary education, EMPLR of USEC the share of USEC that is employed, R&D the regional R&D expenditure as fraction of GDP, and EQICPI denominates the institutional quality variable. EQICPI ranges from 0 to 60 (highest institutional quality and lowest corruption).

Table 4: Descriptive Statistics

	Mean	Std Dev	Min	Max	Obs.
Reg. avg. GDP pc relative to EU-25 average 2000-2013	1.000	0.465	0.150	3.580	3500
Regional productive population with ISCED >= 3 (/%)	53.314	12.675	13.083	80.339	3396
Reg. share of population with ISCED >= 3 (%)	70.173	15.775	15.592	97.049	3442
Reg. employment rate of ISCED >= 3 (%)	76.077	6.256	35.116	98.639	3396
Reg. average CPI(avg.) x EQI 2013	24.552	10.451	3.625	54.970	3458
National avg. Corruption Perception Index (CPI)	6.862	1.670	4.167	9.508	3500
Regional EQI 2013	3.412	0.808	0.758	5.781	3458
Reg. avg. R&D expenditure / GDP (%)	1.498	1.189	0.099	7.909	3472

Data: Cambridge Econometrics (transformed to NUTS-2010 classification), Eurostat, Transparency International, Charron, Dijkstra and Lapuente (2014). EQI is rescaled to range from 0 to 6 (best institutional quality), EQICPI ranges from 0 to 60. Sample 2000-2006 and 2007-2013: Averages of interaction variables are calculated for EU-25 (250 NUTS-2 regions), from 2000-2013 (employment rates per education level), 2000-2011 (CPI) and 2000-2013, respectively (R&D expenditure relative to GDP). The four French overseas departments and the two Portuguese regions Acores and Madeira are not included in the dataset. 58 observations of the education variable and 104 observations of the employment rate are missing. For two German regions, employment data is only available up from 2011, for the five Danish regions data on education and employment is missing before 2007. EQI2013: Data is missing for two Spanish regions (Ciudad Autónoma de Ceuta and Ciudad Autónoma de Mellila) and one Finnish region (Helsinki-Uusimaa). R&D expenditure: Data for two German regions (Niederbayern and Oberpfalz) is missing.

4 The Heterogeneous Local Average Treatment Effects (HLATE) Estimation Framework

Having introduced all components, i.e., the forcing and outcome variable as well as the interaction terms (absorptive capacity variables), of the estimation model in the last section, the following three equations show the estimation model (notation is according to Angrist and Pischke 2009 and Becker et al. 2013):

$$y_i = \alpha + f_0(\tilde{\boldsymbol{x}}_i) + \bar{z}_i + D_i[\rho + f_1^*(\tilde{\boldsymbol{x}}_i) + \bar{\boldsymbol{z}}_i] + \epsilon_i \tag{2}$$

with

$$D_i = P(D_i = 1|x_i) = E[D_i|x_i] = \gamma + f_0(\tilde{\boldsymbol{x}}_i) + T_i[\pi + f_1^*(\tilde{\boldsymbol{x}}_i)] + \bar{\boldsymbol{z}}_i \tag{3}$$

where

$$T_i = 1(x_i \leq x_0)$$

where y_i denotes the regional average GDP per capita growth from 2000 to 2006 and 2007 to 2012, respectively, subscript 1 indicates treatment and 0 stands for non-treatment.

$\tilde{\boldsymbol{x}}_i = \boldsymbol{x}_i - \boldsymbol{x}_0$ denotes the forcing variable (GDP per capita in threshold years as deviation from 75 % of the EU-25 average), $\bar{\boldsymbol{z}}_i = \boldsymbol{z}_i - \boldsymbol{z}_{smean}$ the vector of interaction variables in terms of deviation from the respective sample mean. $f_0(\tilde{\boldsymbol{x}}_i)$, and $f_1^*(\tilde{\boldsymbol{x}}_i)$ are polynomial functions of the forcing variable that have to be sufficiently smooth to capture the treatment effect at the threshold. Figure 5 shows that the outcome as a function of the forcing variable is not a linear function and different on both sides of the threshold, that

is why the forcing variable enters the model as separate and interaction term (with the treatment).[24] In line with Lee and Lemieux (2010) the same number of polynomials is considered in the first and second stage estimation.

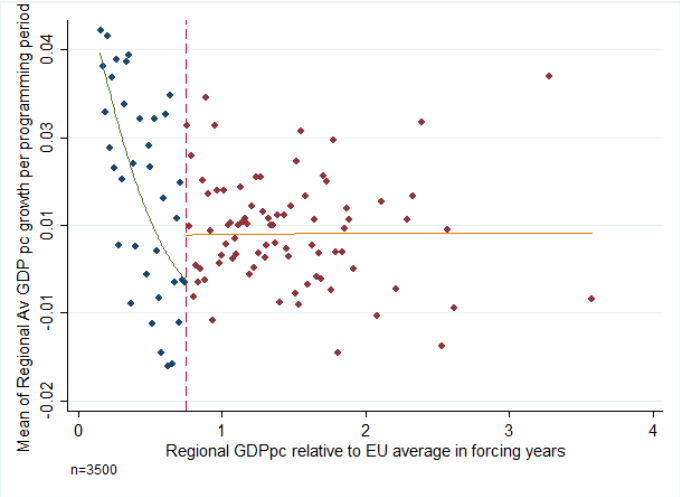

Figure 5: *Regional average GDP per capita growth in treated and non-treated regions, both MFFs 2000-2006 and 2007-2013*

Data source: Eurostat. Data are in 1.5 % bins, line is quadratic of best fit. NUTS-2 regions of EU-25 from 2000 to 2013. Due to data limitations, the four French overseas-departments and two Portuguese regions (Acores and Madeira) are skipped.

As we estimate a fuzzy RDD, in which also regions that receive convergence funds but do not comply with the eligibility criterion set by the European Commission are considered, the treatment rule $T_i = 1(x_i \leq x_0)$ serves as an instrument for the treatment probability D_i.[25] In other words, the probability of being treated is discontinuous (jumps) at the 75 % threshold of the forcing variable (see, e.g., Angrist and Pischke 2009).

The local average treatment effect (LATE) of the convergence funds allocation on the outcome y_i (average GDP per capita growth over the programming periods 2000-2006 and 2007-2013) is measured by ρ while the polynomials of the forcing variable serve as controls for the functional form. In order to assess the sensitivity of results, a second-, third- and fourth-order polynomial specification of the forcing variable is estimated. Heterogeneity of the LATE comes in via the absorptive capacity variables, separately and interacted with the treatment indicator. For estimating time-varying treatment effects, the instrumented treatment D_i is as well interacted with dummies representing the programming periods. Moreover, when taking into account the share of committed funds that has been paid out (also modeled as deviation from the sample mean) as treatment intensity, the treatment

[24] Note that the jump at the threshold of 75 % indicates a negative, unconditional treatment effect of convergence funds from 2000 to 2013.

[25] The treatment rule (Equation 1) implies heterogeneity of the units before treatment, i.e., the assignment of convergence funds is not random but depends on the regions' average GDP per capita during a certain period. See Brand and Thomas 2013 for a discussion of the different types of heterogeneity in the treatment effects estimation framework.

indicator is multiplied by this share. In further specifications, country-, time- and regional fixed effects as well as, for a robustness check, a dummy for the ten European member states entering the EU in 2004 and other controls are added.

5 Data

The sample is based on 250 NUTS-2 regions in the EU-25, excluding Bulgaria, Romania and Croatia. Due to data limitations, the four French overseas-departments as well as two Portuguese regions (Acores and Madeira) are excluded. For the treatment eligibility, i.e., the forcing variable GDP per capita in the relevant years for each funding period, 2000-2002 (EU-25; for MFF 2007-2013), 1994-1996 (EU-25; for MFF 2000-2006), 1988-1990 (EU-15; for MFF 1994-1999) and 1984-1986 (EU-12; for MFF 1989-1993), respectively, data on GDP and population from Cambridge Econometrics is adopted.[26] The same data source determines the outcome variable, namely, regional average GDP per capita growth over each multi-annual financial framework (2007-2012 for the latest, as data is not available yet for 2013).

In order to see which regions are complying with the treatment rule, that is, regions whose GDP per capita lies above 75 % of the EU-average and that do not receive convergence (or Objective 1) funds and vice versa, we investigate structural funds expenditure data that is available for 2000-2006 and 2007-2013. For the two previous MFFs 1989-1993 and 1994-1999, lists of eligible regions in EU regulations are taken as a basis (European Council 1993, 1988).[27] Regarding the MFF 2007-2013, data on the operational programs under the convergence objective that have actually been financed per region is employed, available on the website of the European Commission's DG Regional Policy, are considered as indicator for actual treatment in a region (European Commission 2015*a*,*b*). For 2000-2006, the DG Regional Policy provides a regional expenditure study (SWECO 2008) and we consider a region as treated if there is a corresponding expenditure reported under Objective 1. Treatment intensity data, i.e., the shares of initially committed funds paid out, are taken from European Commission (2016*a*).

For the interaction variables, information on the regional distribution of the highest attained level of education of the population between 25 and 64 years and regional employment rates per education level for the workforce aged between 25 and 64 years is taken from Eurostat. These two variables are multiplied in order to get the productive share of the population with upper secondary and higher education (PRODUSEC). As already

[26] In order to be comparable with further data sources, they are transformed to the NUTS-2010 classification of European regions. Refer to European Council (1988, 1993, 1999, 2006) and DG REGIO regarding the respective threshold years per programming period.

[27] Note that eight Eastern German regions that became part of the EU in 1990 after the German reunification are treated as missing values in 1989-1993.

indicated above, education is measured according to the International Standard Classification of Education (ISCED 2011) by UNESCO Institute for Statistics (UIS).[28] Moreover, data on regional R&D expenditure in all sectors as a percentage of GDP (R&D) from 2000 to 2013 is taken from Eurostat.[29] Finally, the variable measuring institutional quality (EQICPI) is based on the corruption perception index (CPI) by Transparency International (available, in a comparable way for 2000-2011) and the European Quality of Government Index 2013 (EQI2013) by Charron et al. (2015). The newly created index is transformed to range from 0 to 60, the latter indicating highest institutional quality and lowest corruption.

6 Estimation Results

To start, Table 5 presents the parametric and non-parametric estimation results for the homogeneous LATE for 2000 to 2013, i.e., without considering heterogeneity across regions. The picture in Figure 5 which points to a negative treatment effect, as well as in Figures 6 and 7 that indicate the deterioration of the effectiveness in the second period, is mirrored by the negative or non-significant treatment effect and the robust negative impact of the crisis period. However, note that the figures and non-parametric estimation results do not consider any heterogeneity across observations, while in the parametric estimations it is only controlled for time and country-fixed effects. What sticks out is that when including the latter (refer to the second column of each specification in Table 5), the coefficient of the treatment effect turns positive in all specifications with a different number of polynomials considered.

However, one can expect that structural characteristics of the region and treatment intensity (amount of funds used in projects) matter for the effectiveness of EU regional policy. In the next step, the model is augmented by the absorptive capacity variables and shares of committed funds paid out, and the HLATE is estimated following Equation 2.

[28] We refer to upper and secondary and higher education as ISCED levels 3-8. Level 0: Early childhood educational development, pre-primary education; Level 1: Primary education; Level 2: Lower secondary education (general, vocational); Level 3: Upper secondary education (general, vocational); Level 4: Post-secondary non-tertiary education (general, vocational); Level 5: Short-cycle tertiary education (general, vocational); Level 6: Bachelor's or equivalent level; Level 7: Master's or equivalent level; Level 8: Doctor or equivalent level.

[29] Note that there are missing data points for different years across regions.

Table 5: Homogeneous Local Average Treatment Effect of convergence funds on GDP per capita growth across programming periods 2000-2006 and 2007-2013 (excl. five treated regions with a forcing variable >= 1.25)

	Second-order polynomial		Third-order polynomial		Fourth-order polynomial	
	(1)	(2)	(1)	(2)	(1)	(2)
Non-parametric	−0.011		−0.026**		−0.027**	
	(0.009)		(0.011)		(0.011)	
Parametric						
Treatment	−0.008	0.005	−0.002	0.006	0.006	0.003
	(0.005)	(0.004)	(0.005)	(0.004)	(0.009)	(0.006)
MFF 2007-2013	−0.024***	−0.023***	−0.024***	−0.023***	−0.022***	−0.024***
	(0.002)	(0.003)	(0.002)	(0.001)	(0.002)	(0.002)
Constant	0.023***	0.025***	0.019***	0.025***	0.011	0.030***
	(0.004)	(0.005)	(0.004)	(0.004)	(0.009)	(0.006)
Country FE	No	Yes	No	Yes	No	Yes
Observations	500	500	500	500	500	500
Adjusted R^2	0.450	0.587	0.466	0.588	0.427	0.494

Notes: Fuzzy regression discontinuity design, non-parametric (conventional structural estimate) and 2-stage least squares estimation with probit in first stage (incl. interactions of polynomials of forcing variable with treatment). *** denotes significance at the 1% level, ** at the 5% level, * at the 10% level. Standard errors (in parentheses) are clustered at regional level. Dependent outcome variable: regional average GDP per capita growth per programming period, i.e., 2000-2006 and 2007-2012 (data for 2013 is not available). Treatment is determined by the forcing variable $\tilde{\boldsymbol{x}}$, i.e., regional average GDP per capita 1994-1996 and 2000-2002, respectively, as deviation from the 75 % EU-25 average. Sample: 250 NUTS-2 regions in EU-25.

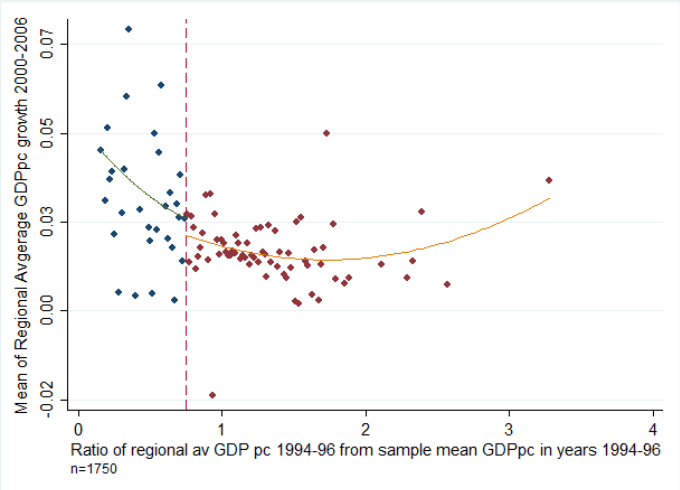

Figure 6: *Regional average GDP per capita growth in treated and non-treated regions 2000-2006*

Data source: Eurostat. Data are in 1.5 % bins, line is quadratic of best fit. NUTS-2 regions of EU-25 from 2000 to 2013. Due to data limitations (employment rate per education level, which is one main variable of interest), the four French overseas-departments and two Portuguese regions (Acores and Madeira) are excluded from the sample. Outliers are included in this graph.

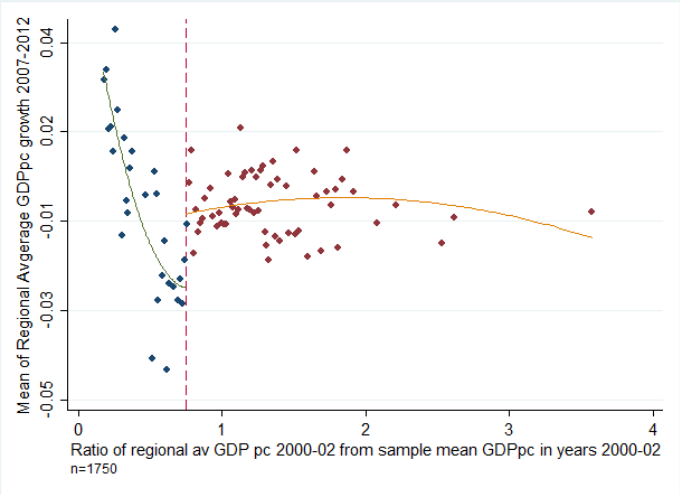

Figure 7: *Regional average GDP per capita growth in treated and non-treated regions 2007-2013*

Data source: Eurostat. Data are in 1.5 % bins, line is quadratic of best fit. NUTS-2 regions of EU-25 from 2000 to 2013. Due to data limitations (employment rate per education level, which is one main variable of interest), the 4 French overseas-departments and two Portuguese regions (Acores and Madeira) are excluded from the sample.

6.1 Turning to the Heterogeneity of the Treatment Effect

The following tables show the estimation results according to the HLATE specification in Equation 2 for the programming periods 2000-2006 and 2007-2013. The reasons for focusing on these two periods in this paper are twofold: Firstly, it is possible to use pre-treatment values of the variables describing absorptive capacity.[30] Secondly, as the latter results already indicate an important influence of the crisis period on the effectiveness of regional policy, we are interested in whether the sharply decreased paid-out shares of funds that have been committed at the beginning of the programming period in 2007-2013 affect the treatment effect. This parts of funds actually used are only available up from 2000.

In order to ensure robustness of the results, second- to fourth-order polynomials of the vectors of the forcing variable (regional GDP per capita in threshold years in terms of deviation from the 75 % EU-25 average). Additionally, estimations are done using country- and regional fixed effects (FE) and as well as time-specific fixed effects which should account for the economic recession up from 2008. A fuzzy RDD is estimated taking into account 250 European NUTS-2 regions. Remember that five observations which are treated although having a GDP per capita in the corresponding threshold years equal to or higher than 1.25 times the EU average (in 2000-2006) are excluded. Moreover, 38 observations are left out

[30] As mentioned above, when including all programming periods into the analysis, it is necessary to use average values the absorptive capacity variables across 2000-2013 (or 2000-2011 in the case of CPI). Table 11 in the appendix shows the regression analysis of the latest two periods when using not pre-treatment but average values. An apparent difference in results concerns the productive share of the labour force with upper secondary and higher education (PRODUSEC) which becomes positive and significant in most specifications. The local average treatment effect appears to be significant and slightly higher. Moreover, the negative effect of the crisis period is evident. The results are robust to including regional fixed effects.

due to missing pre-treatment values. Thus, 457 observations remain in the baseline sample.

Table 6 shows that, conditional on the variables representing regional absorptive capacity and country dummies, the treatment effect across 2000-2013 turns out positive. Though, its significance varies across the specifications with different polynomial fits of the forcing variable. This result holds when including a dummy representing the crisis period which is shown to be negative and significant throughout the large majority of estimated models. Another robust finding is the positive effect of better institutional quality (and lower corruption) on the outcome variable. This result is in line with Rodríguez-Pose (2013) and Hagen and Mohl (2009) who find that, on the national level, cohesion policy seems to be effective only conditional on institutional quality. However, when including NUTS-2 region-specific fixed effects standard errors increase strongly leaving no variable with an significant impact. This may be the case as these fixed effects take away much of regional variation.[31]

In the third column of Table 6, the model allowing for a time-varying treatment effect is presented. The crisis period 2007-2013 appears to have a significant impact on GDP per capita growth not only as a separate explanatory variable but also in interaction with the treatment. This indicates that the effectiveness of convergence funds assignment decreases in the programming period 2007-2013 relative to the previous one. Table 10 in the appendix contains analogous results for all programming periods up from 1989, revealing that the effectiveness of convergence funds has stayed constant in former periods but deteriorated significantly in the last one.

6.1.1 Robustness Checks

Table 7 comprises several robustness checks controlling for issues that could bias the results. In general, one can conclude that the positive (and significant) treatment effect and the negative impact of the crisis period on regional GDP per capita growth is robust.[32] One potential issue is that in 2000-2006, the eligibility status of the EU-15 regions has been determined considering the EU-15 average while in 2004 ten new member states entered the EU putting downward pressure on the EU average GDP per capita. However, for the baseline results in this paper, we consider the EU-25 average for the treatment rule as in the MFF 2000-2006 also the Eastern European regions have received convergence funds. That is, many non-compliers with the treatment rule in that programming period arise from this issue. In order to control for this, first, a sharp RDD is calculated, i.e., the regions that do not comply with the treatment rule are eliminated. By that, also regions in phasing-out phases of their previous convergence funds programs are excluded from

[31] Moreover, 82.7 % of the regions have the same treatment status in 2000-2006 and 2007-2013. Note that the impact of the crisis period and the coefficient of the treatment effect in Table 11, when considering average values of the absorptive capacity variables, are robust to the inclusion of regional fixed effects.

[32] The first column, BASE, for the second-order and third-order polynomial specifications shows the model with the time-varying treatment effect from Table 6.

the analysis. Second, a dummy representing the new Eastern European member states is added to the baseline regression in the first and second estimation stage. Third, the fourth column shows results when the new member states are excluded from the analysis and the GDP per capita average of the EU-15 is considered as forcing variable for 2000-2006 (EU15&2TRs).

Focusing on a second potential source of bias, testing for spatial autocorrelation of the error terms resulting from the baseline regressions (per programming period, second-order polynomial fit) reveals a slightly positive and significant Moran's I when country dummies are not considered, thus, indicating spatial dependence. However, when taking into account country-fixed effects, Moran's I becomes insignificant which may provide evidence that the spatial dependence does not bias estimation results.[33] Furthermore, as another way to check this, in the model presented in the fifth column (per polynomial specification) of Table 7, spatial lags of the polynomial terms of the forcing variables are included in the first and second stage estimation. These spatial lags are calculated using a spatial weights matrix built on inverse distance between regions for the programming period 2000-2006 and 2007-2013 each. Without putting too much emphasis on this result (as the spatial analysis should just serve as an robustness check), it is interesting that when including the spatial lags of the forcing variable, the coefficient of the local average treatment effect increases. Investigating this relationship further remains for future research.[34]

6.2 Treatment Intensity

The previous exercises have revealed that the crisis period is crucial for the success of convergence funds. Therefore, it is of interest examining possible determinants of this issue. As discussed in Section 2.2, not all committed funds (at the beginning of the budget period) are actually paid out to the regions. It seems to be a common trend that, in the budget period coinciding with the outbreak of the economic crisis, 2007-2013, shares paid out declined notably compared to the previous period. In the next step, we investigate whether there is a correlation with the regional policy outcome. For that, the treatment indicator is supplemented by the shares of committed funds actually used as treatment intensity (Treat x PAIDOUT).

Table 8 shows corresponding results, with all specifications using second- to fourth-order polynomials including time- and country-fixed effects. Considering region-fixed effects (in

[33] A spatial weights matrix based on five nearest neighbours and inverse distance is taken into account each. To be precise, for the second-order polynomial fit with country-fixed effects, when considering the five nearest neighbours, for 2007-2013, Moran's I amounts to 0.06 and is significant at the 10 % level. Using weights that build on inverse distance, the test shows no spatial autocorrelation of the forcing variable determining treatment in this programming period. The same holds true when the Moran's I is calculated for the error terms of the estimation including treatment intensity where there seems to be no spatial dependence with both spatial weight matrices.

[34] Beside others, Dall'Erba and Le Gallo (2008) have evaluated regional policy using spatial econometric methods.

column FE) again raises standard errors, likely to capture much of regional variation also pictured by other variables. However, the coefficients appear to be robust. Interestingly, considering a simple linear function of the share of committed funds actually used (as deviation from the respective sample mean) does not show any effect on regional GDP per capita growth, however, when furthermore taking its quadratic term into account, both related coefficients turn significant. The signs of the coefficients of the linear and the quadratic term point to an inverted U-shaped relationship, i.e., higher regional policy transfers aimed at convergence appear to improve regional policy performance only until a certain point. This suggests that the effect of an additional Euro of convergence funds paid out on regional GDP per capita growth decreases with the amount already spent, even in a period of economic downturn with a significant negative impact on regional policy effectiveness. This interesting finding is in line with Becker, Egger and Von Ehrlich (2012) who provide maximum desirable levels of structural funds to a region and find that in 18 % of European regions reduced funds allocation would not hamper economic growth. Moreover, this result indicates that making more funds accessible (in crisis) does not necessarily help fostering GDP per capita growth. Instead, estimation results show that improving institutional quality is robustly associated with a better outcome.

Finally, the third column of Table 8 (per polynomial specification), by allowing for time-varying treatment intensity, shows whether a higher share paid out in the crisis period affects the success of convergence funds. A greater fraction (which could imply that the region is relatively more able to cope with the consequences of economic downturn) seems to dampen (Treat x PAIDOUT x 2007-2013) the negative relation between funds paid out and regional GDP per capita growth (Treat x 2007-2013) during the programming period. However, significance is not robust across the polynomial specifications of the forcing variable shown in the table.

6.2.1 Treatment Intensity: Robustness Checks

Table 9 presents the robustness checks already described in the previous section, with reference to the specification (BASE) in which the inverted U-shaped relationship between the share of committed funds paid out and regional GDP per capita growth per programming period got visible (column (3) each in Table 8). When taking into account the potential interference factors, apart from the restriction of the dataset to the EU-15 countries (EU15 & 2 Treatment Rules), the results confirm the found picture.

Table 6: GDP per capita growth, convergence funds, the crisis period and regional absorptive capacity (excl. five treated regions with a forcing variable >= 1.25); Programming periods 2000-2006 and 2007-2013, pre-treatment values of interaction variables

	Second-order polynomial				Third-order polynomial				Fourth-order polynomial			
	(1)	(2)	(3)	FE	(1)	(2)	(3)	FE	(1)	(2)	(3)	FE
Treatment	0.008*	0.008**	0.014***	−0.302	0.003	0.005	0.009*	−0.003	0.015	0.011	0.018**	0.009
	(0.004)	(0.004)	(0.004)	(3.926)	(0.007)	(0.005)	(0.005)	(0.096)	(0.009)	(0.007)	(0.007)	(0.194)
Treat x PRODUSEC	0.006	0.005	−0.001	−1.279	0.001	−0.002	−0.009	−0.157	0.039	0.038	0.037	−0.074
	(0.025)	(0.020)	(0.020)	(14.213)	(0.025)	(0.022)	(0.022)	(0.320)	(0.038)	(0.032)	(0.031)	(0.909)
Treat x R&D	−0.001	0.000	0.000	−0.143	−0.001	0.000	0.000	−0.026	−0.003	−0.002	−0.002	−0.037
	(0.003)	(0.003)	(0.003)	(1.577)	(0.003)	(0.003)	(0.003)	(0.052)	(0.003)	(0.003)	(0.003)	(0.114)
Treat x EQICPI	0.000	0.000	0.000	0.041	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.007
	(0.000)	(0.000)	(0.000)	(0.504)	(0.000)	(0.000)	(0.000)	(0.013)	(0.000)	(0.000)	(0.000)	(0.033)
Treat x 2007-2013			−0.014***	−0.044			−0.014***	−0.035			−0.017***	−0.039
			(0.004)	(0.191)			(0.004)	(0.023)			(0.004)	(0.039)
PRODUSEC	−0.005	−0.005	−0.003	0.680	−0.006	0.007	0.012	−0.115	−0.035	−0.029	−0.028	−0.209
	(0.018)	(0.013)	(0.014)	(9.124)	(0.018)	(0.019)	(0.020)	(0.112)	(0.023)	(0.019)	(0.020)	(0.259)
R&D	0.001*	0.001	0.001	0.001	0.001**	0.000	0.000	−0.003	0.002***	0.001*	0.001*	−0.002
	(0.000)	(0.000)	(0.000)	(0.097)	(0.000)	(0.001)	(0.001)	(0.008)	(0.001)	(0.001)	(0.001)	(0.010)
EQICPI	0.001**	0.001***	0.001***	−0.002	0.001**	0.001**	0.000**	−0.002	0.001**	0.001***	0.001***	−0.004
	(0.000)	(0.000)	(0.000)	(0.028)	(0.000)	(0.000)	(0.000)	(0.007)	(0.000)	(0.000)	(0.000)	(0.015)
MFF 2007-2013		−0.022***	−0.017***	−0.048		−0.024***	−0.019***	−0.009		−0.022***	−0.016***	−0.007
		(0.001)	(0.001)	(0.437)		(0.002)	(0.002)	(0.009)		(0.001)	(0.001)	(0.010)
Constant	0.015***	0.020***	0.019***	0.116	0.017***	0.027***	0.027***	0.015	0.010	0.022***	0.022***	0.000
	(0.004)	(0.003)	(0.003)	(1.227)	(0.006)	(0.004)	(0.004)	(0.018)	(0.007)	(0.006)	(0.005)	(0.037)
Country-FE	Yes	Yes	Yes	-	Yes	Yes	Yes	-	Yes	Yes	Yes	-
Observations	457	457	457	457	457	457	457	457	457	457	457	457
Adjusted R^2	0.283	0.613	0.635	-	0.312	0.543	0.553	-	0.286	0.605	0.626	-

Notes: Fuzzy regression discontinuity design, 2-stage least squares estimation with probit in first stage (incl. interactions of polynomials of forcing variable with treatment), linear interaction terms. *** denotes significance at the 1% level, ** at the 5% level, * at the 10% level. Standard errors (in parentheses) are clustered at regional level. 2000 and 2006 data are used as pre-treatment values (for R&D expenditure the earliest observation).

Table 7: Robustness Checks: GDP per capita growth, convergence funds, the crisis period and regional absorptive capacity (excl. five treated regions with a forcing variable >= 1.25); Programming periods 2000-2006 and 2007-2013, pre-treatment values of interaction variables

	Second-order polynomial					Third-order polynomial				
	BASE	SHARP	EAST	EU15&2TRs	SPATIAL	BASE	SHARP	EAST	EU15&2TRs	SPATIAL
Treatment	0.014***	0.014*	0.013***	0.011	0.018***	0.009*	0.007	0.009*	0.005	0.014***
	(0.004)	(0.009)	(0.004)	(0.013)	(0.005)	(0.005)	(0.010)	(0.005)	(0.020)	(0.005)
Treat x PRODUSEC	−0.001	0.016	−0.004	−0.062**	0.002	−0.009	0.030	−0.006	−0.070***	0.005
	(0.020)	(0.020)	(0.019)	(0.031)	(0.021)	(0.022)	(0.019)	(0.020)	(0.025)	(0.021)
Treat x R&D	0.000	−0.002	0.000	0.003	0.000	0.000	−0.003	0.000	0.003	−0.001
	(0.003)	(0.006)	(0.002)	(0.003)	(0.003)	(0.003)	(0.006)	(0.002)	(0.002)	(0.002)
Treat x EQICPI	0.000	0.000	0.000	0.000	0.000	0.000	−0.001	0.000	0.001	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Treat x 2007-2013	−0.014***	−0.015***	−0.014***	0.004	−0.014***	−0.014***	−0.018***	−0.014***	0.009	−0.016***
	(0.004)	(0.004)	(0.004)	(0.020)	(0.004)	(0.004)	(0.004)	(0.004)	(0.027)	(0.004)
PRODUSEC	−0.003	−0.010	−0.002	0.006	−0.004	0.012	−0.016	0.010	0.015	0.025
	(0.014)	(0.011)	(0.014)	(0.026)	(0.015)	(0.020)	(0.011)	(0.018)	(0.020)	(0.016)
R&D	0.001	0.001*	0.001	0.000	0.001	0.000	0.001*	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.000)
EQICPI	0.001***	0.001***	0.001***	0.001***	0.001***	0.000**	0.001***	0.000**	0.001***	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
MFF 2007-2013	−0.017***	−0.018***	−0.017***	−0.017***	−0.017***	−0.019***	−0.018***	−0.019***	−0.017***	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.004)
EASTERN EUROPE			0.035***					0.027***		
			(0.009)					(0.009)		
Constant	0.019***	0.023***	0.020***	0.018***	0.014***	0.027***	0.025***	0.027***	0.019***	0.018*
	(0.003)	(0.002)	(0.003)	(0.003)	(0.004)	(0.004)	(0.002)	(0.004)	(0.004)	(0.010)
Spatial lag forcing var	No	No	No	No	Yes	No	No	No	No	Yes
Country-FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	457	457	457	328	457	457	457	457	328	457
Adjusted R^2	0.635	0.648	0.637	0.635	0.622	0.553	0.661	0.564	0.603	0.693

Notes: Fuzzy regression discontinuity design, 2-stage least squares estimation with probit in first stage (incl. interactions of polynomials of forcing variable with treatment), linear interaction terms. *** denotes significance at the 1% level, ** at the 5% level, * at the 10% level. Standard errors (in parentheses) are clustered at regional level. 2000 and 2006 data are used as pre-treatment values (for R&D expenditure the earliest observation).

Table 8: GDP per capita growth, treatment intensity of convergence funds, the crisis period and regional absorptive capacity (excl. five treated regions with a forcing variable >= 1.25); Programming periods 2000-2006 and 2007-2013, pre-treatment values of interaction variables

	Second-order polynomial				Third-order polynomial				Fourth-order polynomial			
	(1)	FE	(2)	(3)	(1)	FE	(2)	(3)	(1)	FE	(2)	(3)
Treatment	0.014***	−0.208	0.013***	0.013***	0.009*	−0.003	0.010**	0.009*	0.017**	0.010	0.019**	0.018**
	(0.004)	(2.364)	(0.004)	(0.004)	(0.005)	(0.098)	(0.005)	(0.005)	(0.007)	(0.181)	(0.007)	(0.007)
Treat x PAIDOUT	0.008	0.048	0.038***	−0.297*	0.010	0.029**	0.038***	−0.309	0.010	0.030*	0.037***	−0.295
	(0.009)	(0.240)	(0.014)	(0.179)	(0.008)	(0.014)	(0.013)	(0.199)	(0.008)	(0.018)	(0.013)	(0.203)
Treat x PAIDOUT^2			−0.053***				−0.050***				−0.051***	
			(0.017)				(0.016)				(0.017)	
Treat x PAIDOUT x				0.305*				0.319				0.305
2007-2013				(0.179)				(0.198)				(0.202)
Treat x 2007-2013	−0.014***	−0.042	−0.011***	−0.014***	−0.014***	−0.036	−0.011***	−0.014***	−0.017***	−0.040	−0.014***	−0.017***
	(0.004)	(0.126)	(0.004)	(0.004)	(0.004)	(0.024)	(0.004)	(0.004)	(0.004)	(0.037)	(0.004)	(0.004)
Treat x PRODUSEC	0.000	−0.940	−0.006	−0.002	−0.007	−0.165	−0.011	−0.009	0.038	−0.071	0.032	0.036
	(0.020)	(8.563)	(0.020)	(0.020)	(0.022)	(0.337)	(0.022)	(0.022)	(0.032)	(0.854)	(0.032)	(0.032)
Treat x R&D	0.000	−0.104	0.001	0.000	0.001	−0.025	0.001	0.001	−0.001	−0.035	−0.001	−0.001
	(0.003)	(0.945)	(0.003)	(0.003)	(0.003)	(0.053)	(0.003)	(0.003)	(0.003)	(0.106)	(0.003)	(0.003)
Treat x EQICPI	0.000	0.029	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.006	0.000	0.000
	(0.000)	(0.304)	(0.000)	(0.000)	(0.000)	(0.013)	(0.000)	(0.000)	(0.000)	(0.030)	(0.000)	(0.000)
PRODUSEC	−0.004	0.446	−0.005	−0.002	0.010	−0.120	0.009	0.012	−0.030	−0.213	−0.030	−0.028
	(0.014)	(5.411)	(0.014)	(0.014)	(0.019)	(0.114)	(0.019)	(0.018)	(0.020)	(0.248)	(0.020)	(0.020)
R&D	0.001	0.000	0.001*	0.001	0.000	−0.003	0.000	0.000	0.001*	−0.002	0.001*	0.001*
	(0.000)	(0.063)	(0.000)	(0.000)	(0.001)	(0.008)	(0.001)	(0.001)	(0.001)	(0.010)	(0.001)	(0.001)
EQICPI	0.001***	−0.001	0.001***	0.001***	0.000**	−0.002	0.001**	0.000**	0.001***	−0.004	0.001***	0.001***
	(0.000)	(0.019)	(0.000)	(0.000)	(0.000)	(0.008)	(0.000)	(0.000)	(0.000)	(0.014)	(0.000)	(0.000)
MFF 2007-2013	−0.017***	−0.037	−0.017***	−0.017***	−0.019***	−0.008	−0.019***	−0.019***	−0.016***	−0.006	−0.016***	−0.016***
	(0.001)	(0.258)	(0.001)	(0.001)	(0.002)	(0.009)	(0.002)	(0.002)	(0.001)	(0.010)	(0.001)	(0.001)
Constant	0.019***	0.088	0.018***	0.019***	0.026***	0.017	0.024***	0.026***	0.021***	0.002	0.019***	0.020***
	(0.003)	(0.740)	(0.003)	(0.003)	(0.004)	(0.018)	(0.004)	(0.004)	(0.005)	(0.034)	(0.006)	(0.005)
Country-FE	Yes	-	Yes	Yes	Yes	-	Yes	Yes	Yes	-	Yes	Yes
Observations	456	456	456	456	456	456	456	456	456	456	456	456
Adjusted R^2	0.635	-	0.644	0.638	0.563	-	0.582	0.558	0.623	-	0.635	0.633

Notes: Fuzzy regression discontinuity design, 2-stage least squares estimation with probit in first stage (incl. interactions of polynomials of forcing variable with treatment), linear interaction terms. *** denotes significance at the 1% level, ** at the 5% level, * at the 10% level. Standard errors (in parentheses) are clustered at regional level. 2000 and 2006 data are used as pre-treatment values (for R&D expenditure the earliest observation). Standard deviation of share paid out in terms of deviation from sample mean: 0.090.

Table 9: Robustness Checks: GDP per capita growth, treatment intensity of convergence funds, the crisis period and regional absorptive capacity (excl. five treated regions with a forcing variable >= 1.25); Programming periods 2000-2006 and 2007-2013, pre-treatment values of interaction variables

	Second-order polynomial					Third-order polynomial				
	BASE	SHARP	EAST	EU15&2TRs	SPATIAL	BASE	SHARP	EAST	EU15&2TRs	SPATIAL
Treatment	0.013***	0.015*	0.012***	0.012	0.017***	0.010**	0.005	0.009**	0.005	0.015***
	(0.004)	(0.008)	(0.004)	(0.013)	(0.005)	(0.005)	(0.009)	(0.005)	(0.020)	(0.005)
Treat x PAIDOUT	0.038***	0.038**	0.040***	−0.006	0.038***	0.038***	0.039**	0.039***	−0.009	0.029**
	(0.014)	(0.018)	(0.014)	(0.028)	(0.014)	(0.013)	(0.016)	(0.013)	(0.029)	(0.012)
Treat x PAIDOUT^2	−0.053***	−0.053**	−0.054***	0.031	−0.054***	−0.050***	−0.046**	−0.052***	0.015	−0.027**
	(0.017)	(0.021)	(0.017)	(0.082)	(0.017)	(0.016)	(0.019)	(0.016)	(0.077)	(0.012)
Treat x 2007-2013	−0.011***	−0.012***	−0.012***	0.003	−0.012***	−0.011***	−0.016***	−0.012***	0.008	−0.016***
	(0.004)	(0.004)	(0.004)	(0.021)	(0.004)	(0.004)	(0.005)	(0.004)	(0.028)	(0.004)
Treat x PRODUSEC	−0.006	0.014	−0.008	−0.061**	−0.002	−0.011	0.026	−0.008	−0.069***	0.004
	(0.020)	(0.020)	(0.019)	(0.031)	(0.021)	(0.022)	(0.018)	(0.021)	(0.025)	(0.021)
Treat x R&D	0.001	0.000	0.001	0.003	0.001	0.001	−0.001	0.001	0.003	−0.001
	(0.003)	(0.006)	(0.003)	(0.003)	(0.003)	(0.003)	(0.006)	(0.003)	(0.002)	(0.003)
Treat x EQICPI	0.000	−0.001	0.000	0.000	0.000	0.000	−0.001**	0.000	0.001	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
PRODUSEC	−0.005	−0.009	−0.005	0.007	−0.006	0.009	−0.015	0.006	0.015	0.022
	(0.014)	(0.011)	(0.015)	(0.026)	(0.016)	(0.019)	(0.011)	(0.018)	(0.020)	(0.016)
R&D	0.001*	0.001*	0.001*	0.000	0.001*	0.000	0.001*	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.000)
EQICPI	0.001***	0.001***	0.001***	0.001***	0.001***	0.001**	0.001***	0.001***	0.001***	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
MFF 2007-2013	−0.017***	−0.018***	−0.017***	−0.017***	−0.016***	−0.019***	−0.018***	−0.019***	−0.017***	0.002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)	(0.004)
EASTERN EUROPE			0.039***					0.033***		
			(0.009)					(0.009)		
Constant	0.018***	0.023***	0.018***	0.018***	0.012***	0.024***	0.024***	0.025***	0.019***	0.017*
	(0.003)	(0.002)	(0.003)	(0.003)	(0.004)	(0.004)	(0.002)	(0.004)	(0.004)	(0.010)
Spatial lag forcing var	No	No	No	No	Yes	No	No	No	No	Yes
Country-FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	456	457	456	328	456	456	457	456	328	456
Adjusted R^2	0.644	0.655	0.646	0.630	0.630	0.582	0.667	0.593	0.597	0.700

Notes: Fuzzy regression discontinuity design, 2-stage least squares estimation with probit in first stage (incl. interactions of polynomials of forcing variable with treatment), linear interaction terms. *** denotes significance at the 1% level, ** at the 5% level, * at the 10% level. Standard errors (in parentheses) are clustered at regional level. 2000 and 2006 data are used as pre-treatment values (for R&D expenditure the earliest observation).

7 Conclusion

In this study, a fuzzy regression discontinuity design allowing for heterogeneous treatment effects is applied for empirically investigating the effectiveness of EU convergence funds payments. Thereby, first, a concept of absorptive capacity based on the design of regional policy is taken into account, which does not only consider education levels in a region but the productive share of the labour force with upper secondary and higher education. Secondly, a focus is put on the variation of the local average treatment effect over time. Up to the best of our knowledge, there is no paper that has empirically analyzed the implications of the complete programming period 2007-2013, that coincides with the economic and financial crisis, on the effectiveness of convergence funds in a pan-European setting.

Conditional on the absorptive capacity of a region as well as country- and time-specific effects, the estimation results indicate a positive (and significant) treatment effect on regional average GDP per capita growth across the programming periods. We find that better institutional quality (and lower corruption) has an important positive impact on GDP per capita growth in treated regions. Estimating time-varying treatment effects reveals that the effectiveness of structural funds aimed at convergence appears to deteriorate in the programming period 2007-2013. Therefore, in the next step, we have examined the impact of decreased usage of committed funds in the crisis period and estimated a model based on treatment intensity. The results indicate an inverted U-shaped relationship with regional GDP per capita growth, implying that the marginal benefits of EU convergence funds might be decreasing (even when considering the crisis period with a significant negative impact on regional policy effectiveness).

The latter results may contribute to the discussion of the design of regional policy for the case of economic crises. As one of the first reactions to the deterioration of the economic situation in the lagging regions, the European Commission facilitated access to the regional funds in 2010 (see Section 2.3). While this is an intuitively appealing policy response, the results presented in this paper indicate that a higher amount of funding does not necessarily improve the effectiveness of convergence funds payments. Indeed, results suggest that the effect of a higher share of convergence funds paid out turns even negative at some point. However, another finding is that regional institutional quality has a positive impact on GDP per capita growth, both in regions that receive convergence funds and those that do not. These may be two relevant points to be discussed when revisiting the current allocation system of regional funds to projects (including the co-financing scheme) in order to mitigate the empirically observed pro-cyclical effects of EU structural funds payments in the relatively weakest regions of the European Union.

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8 Appendix

8.1 Assumptions for Estimating the Heterogeneous Local Average Treatment Effect (HLATE)

In this study, a HLATE specification is applied for testing whether the treatment with convergence funds increases the average GDP per capita growth of a region across programming periods, and whether the interaction variables, assumed to depict the absorptive capacity of the regions, or the respective programming period influence this local average treatment effect. Following Becker et al. (2013) in stating three important assumptions of RDD estimation, firstly, one main assumption for identification of a RDD is that there is no discontinuity in any other explanatory variable (of the outcome) than in the forcing variable that splits observations into treatment and control group. Secondly, the interaction variables used for modeling the heterogeneity of the treatment effect must not be discontinuous at the 75 % threshold of the forcing variable, thus, not affecting the local average treatment effect. In the following tables the pre-treatment values of the absorptive capacity variables are plotted on the forcing variables for the programming periods 2000-2006 (average of GDP per capita in years 1994-1996 is relevant for eligibility) and 2007-2013 (average of GDP per capita in years 2000-2002).[35] Thirdly, the error term in Equation 2 needs to be uncorrelated with the vectors of interaction variables $\bar{z}$ conditional on the forcing variable, which is controlled for by using country- and region-fixed effects or estimating the model with average values of the absorptive capacity variables.

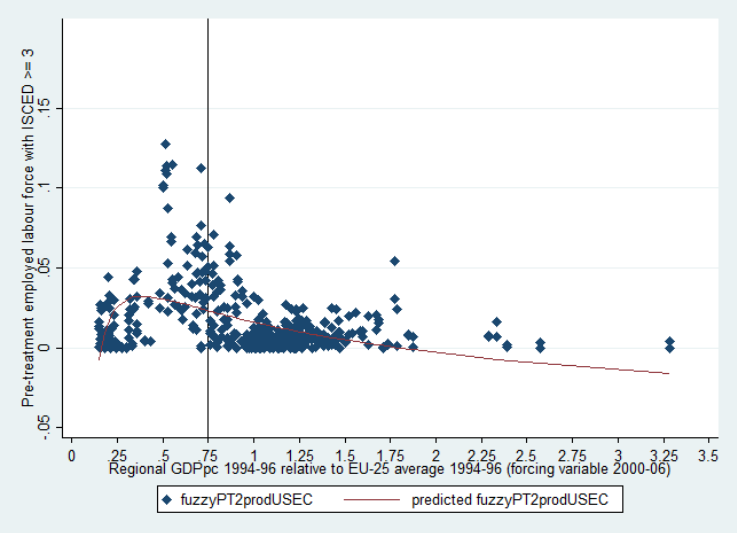

Figure 8: *Relationship between forcing variable (75 % of the EU-25 average of GDP per capita from 1994 to 1996) and the pre-treatment value (2000, 2006) of regional average employed labour force with upper secondary and higher education in terms of squared deviation from the sample mean*

[35] The graphs plotting the average variables of absorptive capacity that are applied when estimating the HLATE for all periods, starting from 1989, are not depicted in this paper but show an analogical relationship (the graphs are available from the author).

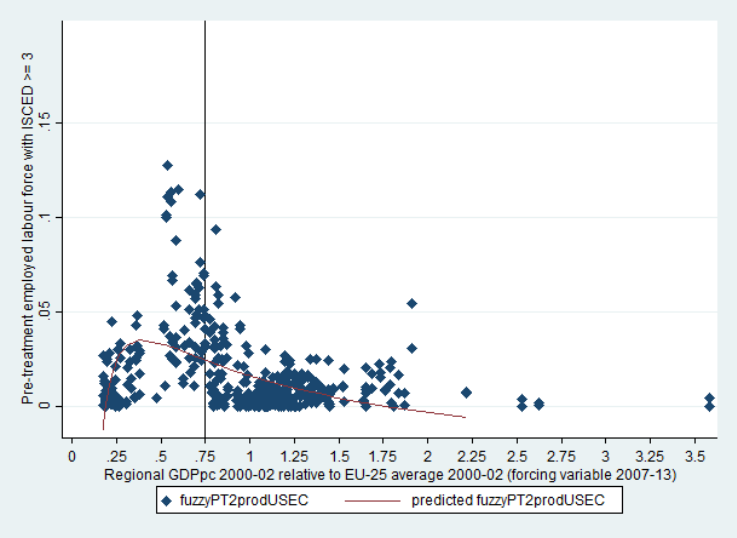

Figure 9: *Relationship between forcing variable (75 % of the EU-25 average of GDP per capita from 2000 to 2002) and the pre-treatment value (2000, 2006) of regional average employed labour force with upper secondary and higher education in terms of squared deviation from the sample mean*

Figures 8 and 9 considering 250 regions 2000-2013 (EU-25). Education data missing in 13 regions (58 observations) for 2000-2006: Denmark (5: 2000-2006), Slovenia (2: 2000), Germany (3: 2000,2001), Italy (1: 2000-2004), Finland (2: 2000-2004). Additionally, 46 observations of the employment rate of people with ISCED levels equal or over 3 are missing: Germany (2: 2000-2010), Finland (1: 2000-2004), Italy (1: 2000-2004), UK (2: 2000-2004). Data: Cambridge Econometrics, Eurostat.

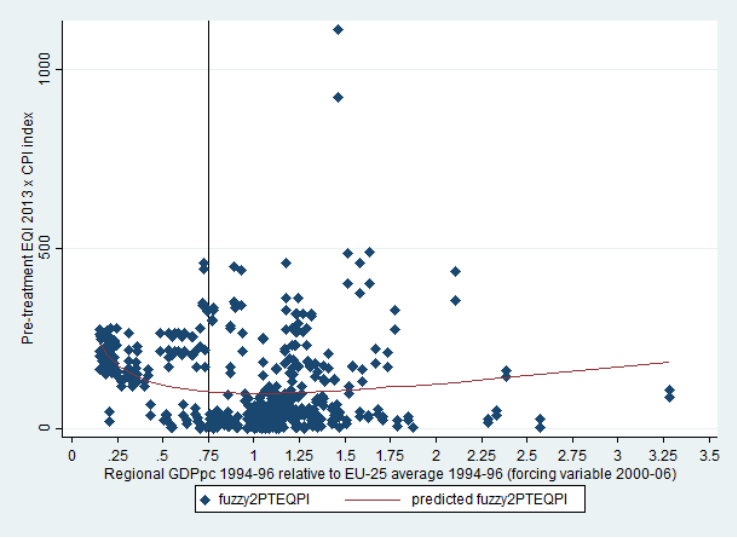

Figure 10: *Relationship between forcing variable (75 % of the EU-25 average of GDP per capita from 1994 to 1996) and the pre-treatment value (2000, 2006) of the regional average of EQI 2013 x CPI in terms of squared deviation from the sample mean*

Figure considering 250 regions from 2000 to 2011 (EU-25; CPI not available for Malta in the years 2000 to 2003 and for Cyprus from 2000 to 2002; EQI2013 not available for two Spanish regions and one Finnish region). Data: Charron et al. (2015), Transparency International.

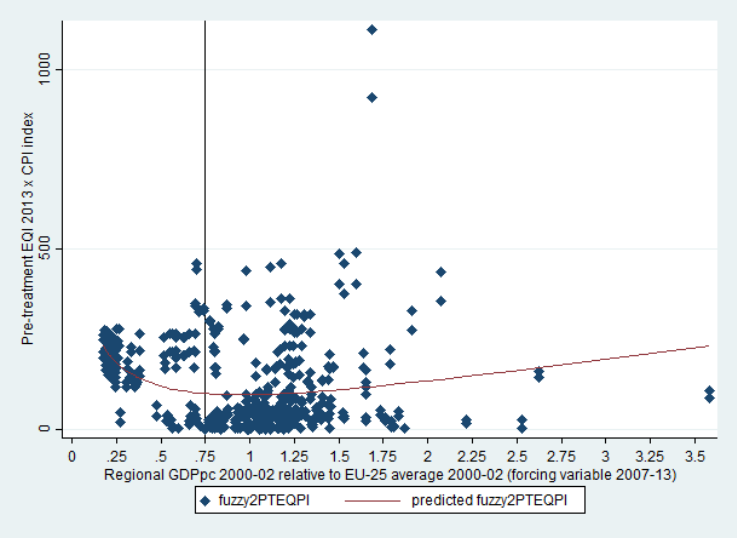

Figure 11: *Relationship between forcing variable (75 % of the EU-25 average of GDP per capita from 2000 to 2002) and the pre-treatment value (2000, 2006) of the regional average of EQI 2013 x CPI in terms of squared deviation from the sample mean*

Figure considering 250 regions from 2000 to 2011 (EU-25; CPI not available for Malta in the years 2000 to 2003 and for Cyprus from 2000 to 2002; EQI2013 not available for two Spanish regions and one Finnish region). Data: Charron et al. (2015), Transparency International.

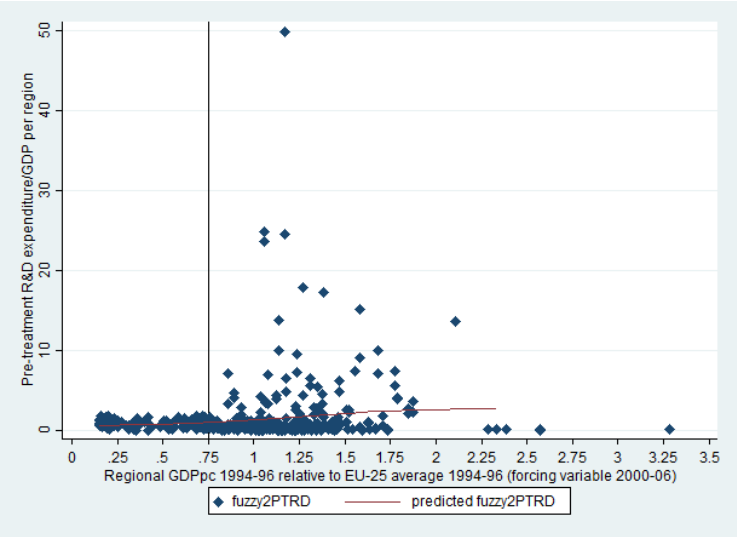

Figure 12: *Relationship between forcing variable (75 % of the EU-25 average of GDP per capita from 1994 to 1996) and the pre-treatment (earliest available) R&D expenditure relative to GDP in terms of squared deviation from the sample mean*

Figure considering 250 regions (EU-25; data is not annually or regularly available for most regions; not available for two German regions in Bavaria; additionally, no data before 2007 for two further German regions, five Danish, two Finnish and two UK regions). Data: Eurostat.

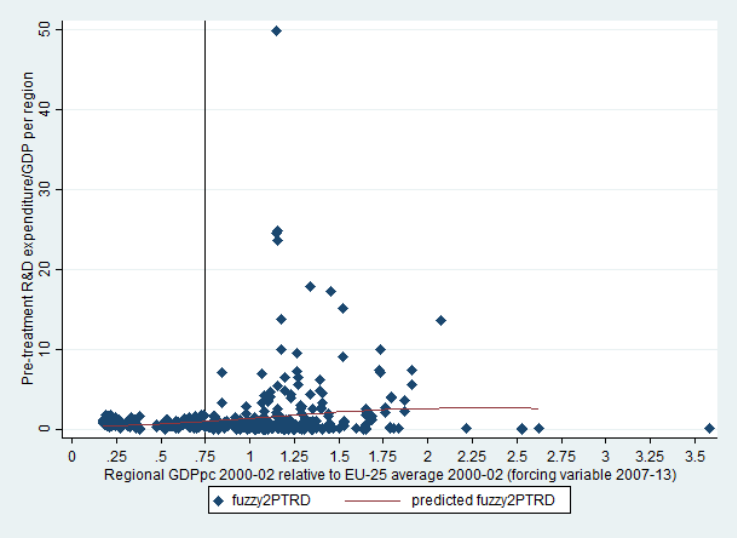

Figure 13: *Relationship between forcing variable (75 % of the EU-25 average of GDP per capita from 2000 to 2002) and the pre-treatment (earliest available) R&D expenditure relative to GDP in terms of squared deviation from the sample mean*

Figure considering 250 regions (EU-25; data is not annually or regularly available for most regions; not available for two German regions in Bavaria; additionally, no data before 2007 for two further German regions, five Danish, two Finnish and two UK regions). Data: Eurostat.

8.2 Time-varying Treatment Effects 1989-1993 to 2007-2013

Table 10 shows the treatment effect for all four programming periods from 1989-1993 on. The effectiveness measured by the LATE is not only allowed to vary with the absorptive capacity variables but also with time, i.e., the respective programming period (Treat x 1994-1999, Treat x 2000-2006, Treat x 2007-2013). For all specifications including the estimation with regional fixed effects, the effectiveness of convergence funds is shown to decrease in the crisis period, 2007-2013, relative to previous periods in which the effectiveness has stayed constant, i.e., has not improved or worsened significantly.

Table 11 reports the estimation results for the MFFs 2000-2006 and 2007-2013 using average absorptive capacity variables.

8.3 Robustness

Table 12 shows different adaptations of the RDD specification, i) the HLATE estimation without polynomials of the forcing variable but only the linear term, ii) the same linear and a second-order polynomial specification for a reduced sample around the 75 % threshold of EU-25 average GDP per capita, iii) the HLATE estimation with the linear forcing variable for an even closer window around the threshold determining treatment (60 % to 90 % of EU-25 average GDP per capita). Finally, as one could argue that considering only two periods in a panel setting may bias the estimation, results for the separate periods are reported utilizing the same first stage estimation.

Table 10: Time-varying treatment effects (excl. 13 treated regions with forc. var. >= 1.25); Program periods 1989-1993, 1994-1999, 2000-2006 and 2007-2013, average values (2000-2013) of interaction variables

	Second-order polynomial			Third-order polynomial			Fourth-order polynomial		
	(1)	(2)	FE	(1)	(2)	FE	(1)	(2)	FE
Treatment	0.025***	0.019***	−0.053	0.019***	0.015*	4.271	0.027**	0.048	0.055
	(0.006)	(0.006)	(0.258)	(0.007)	(0.008)	(552.413)	(0.013)	(0.039)	(0.100)
Treat x PRODUSEC	0.038	0.035	−0.618	0.015	0.018	31.275	0.046	0.141	0.283
	(0.028)	(0.022)	(1.340)	(0.020)	(0.023)	(4084.581)	(0.034)	(0.146)	(0.897)
Treat x R&D	0.006	0.004	−0.052	0.007**	0.004	2.713	0.005	−0.002	0.034
	(0.004)	(0.004)	(0.283)	(0.004)	(0.004)	(349.632)	(0.004)	(0.008)	(0.082)
Treat x EQICPI	0.001**	0.000	0.002	0.001**	0.000	−0.250	0.001**	0.000	−0.009
	(0.000)	(0.000)	(0.018)	(0.000)	(0.000)	(31.985)	(0.000)	(0.001)	(0.020)
Treat x 1994-1999	−0.001	0.000	−0.004	0.000	0.001	0.064	−0.001	−0.003	−0.004
	(0.006)	(0.006)	(0.007)	(0.006)	(0.006)	(8.876)	(0.006)	(0.008)	(0.007)
Treat x 2000-2006	0.000	−0.001	−0.001	0.000	0.000	−0.146	0.002	0.004	−0.002
	(0.005)	(0.005)	(0.013)	(0.005)	(0.005)	(19.181)	(0.005)	(0.008)	(0.009)
Treat x 2007-2013	−0.020***	−0.017***	−0.034*	−0.021***	−0.017***	0.065	−0.021***	−0.019***	−0.029***
	(0.005)	(0.005)	(0.020)	(0.004)	(0.004)	(12.308)	(0.005)	(0.005)	(0.007)
PRODUSEC	0.003	0.036**	-	0.018	0.044**	-	0.002	−0.031	-
	(0.013)	(0.018)	-	(0.013)	(0.020)	-	(0.019)	(0.102)	-
R&D	0.001*	0.001**	-	0.001	0.001**	-	0.001*	0.002	-
	(0.000)	(0.000)	-	(0.000)	(0.000)	-	(0.000)	(0.002)	-
EQICPI	0.000**	0.000	-	0.000**	0.000	-	0.000*	0.001	-
	(0.000)	(0.000)	-	(0.000)	(0.000)	-	(0.000)	(0.001)	-
MFF 1994-1999	0.010***	0.010***	0.012***	0.010***	0.010***	−0.062	0.010***	0.011***	0.012**
	(0.002)	(0.002)	(0.004)	(0.002)	(0.002)	(9.549)	(0.002)	(0.003)	(0.005)
MFF 2000-2006	−0.001	0.001	0.015	0.002	0.002	0.014	−0.002	−0.012	0.013
	(0.002)	(0.002)	(0.026)	(0.003)	(0.002)	(1.387)	(0.004)	(0.015)	(0.015)
MFF 2007-2013	−0.016***	−0.015***	0.003	−0.015***	−0.015***	−0.147	−0.016***	−0.019***	0.003
	(0.002)	(0.002)	(0.017)	(0.002)	(0.002)	(19.366)	(0.002)	(0.006)	(0.017)
Constant	0.012***	0.015***	0.023	0.015***	0.017***	−0.537	0.011*	−0.001	0.003
	(0.002)	(0.002)	(0.052)	(0.003)	(0.003)	(70.786)	(0.006)	(0.019)	(0.018)
Country-FE	No	Yes	-	No	Yes	-	No	Yes	-
Observations	854	854	854	854	854	854	854	854	854

Notes: 2-stage least squares estimation with probit in first stage (incl. interactions of polynomials of forcing variable with treatment), linear interaction terms. *** denotes significance at the 1% level, ** at the 5% level, * at the 10% level. Standard errors (in parentheses) are clustered at regional level.

Table 11: Economic growth, convergence funds and regional absorptive capacity (excl. 5 regions with treatment but a fravGDPpc >= 1.25); Program periods 2000-2006 and 2007-2013, average values (2000-2013) of interaction variables

	Second-order polynomial				Third-order polynomial				Fourth-order polynomial			
	(1)	(2)	(3)	FE	(1)	(2)	(3)	FE	(1)	(2)	(3)	FE
Treatment	0.009**	0.009***	0.015***	0.013	0.007	0.008*	0.012**	0.018	0.023**	0.019**	0.025***	0.024
	(0.004)	(0.003)	(0.004)	(0.033)	(0.006)	(0.004)	(0.005)	(0.041)	(0.011)	(0.009)	(0.009)	(0.051)
Treat x PRODUSEC	−0.007	0.006	0.001	−0.253	−0.002	0.002	−0.007	−0.148	0.056	0.063	0.057	−0.388
	(0.025)	(0.022)	(0.021)	(0.266)	(0.024)	(0.022)	(0.022)	(0.509)	(0.053)	(0.045)	(0.042)	(1.003)
Treat x R&D	0.001	0.001	0.002	−0.026	0.000	0.001	0.002	−0.018	−0.002	−0.001	−0.001	−0.018
	(0.003)	(0.002)	(0.002)	(0.029)	(0.003)	(0.002)	(0.002)	(0.024)	(0.003)	(0.003)	(0.002)	(0.035)
Treat x EQICPI	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.004
	(0.000)	(0.000)	(0.000)	(0.007)	(0.000)	(0.000)	(0.000)	(0.004)	(0.001)	(0.000)	(0.000)	(0.009)
Treat x 2007-2013			−0.014***	−0.026***			−0.014***	−0.027***			−0.019***	−0.036**
			(0.003)	(0.005)			(0.003)	(0.006)			(0.004)	(0.015)
PRODUSEC	0.042**	0.039**	0.051***	-	0.039**	0.041*	0.056**	-	−0.013	−0.015	0.000	-
	(0.018)	(0.019)	(0.019)	-	(0.019)	(0.021)	(0.022)	-	(0.042)	(0.035)	(0.033)	-
R&D	0.000	0.000	0.000	-	0.001**	0.000	0.000	-	0.002	0.001	0.001	-
	(0.000)	(0.000)	(0.000)	-	(0.000)	(0.000)	(0.000)	-	(0.001)	(0.001)	(0.001)	-
EQICPI	0.000	0.000	0.000	-	0.000	0.000	0.000	-	0.001	0.000	0.000	-
	(0.000)	(0.000)	(0.000)	-	(0.000)	(0.000)	(0.000)	-	(0.000)	(0.000)	(0.000)	-
MFF 2007-2013		−0.022***	−0.017***	−0.014***		−0.023***	−0.019***	−0.012*		−0.020***	−0.014***	0.001
		(0.001)	(0.001)	(0.005)		(0.001)	(0.001)	(0.007)		(0.002)	(0.002)	(0.023)
Constant	0.015***	0.022***	0.019***	0.016	0.013**	0.026***	0.026***	0.017	−0.001	0.014	0.014*	−0.017
	(0.004)	(0.003)	(0.003)	(0.015)	(0.006)	(0.004)	(0.004)	(0.015)	(0.010)	(0.009)	(0.008)	(0.062)
Country-FE	Yes	Yes	Yes	-	Yes	Yes	Yes	-	Yes	Yes	Yes	-
Observations	485	485	485	485	485	485	485	485	485	485	485	485
Adjusted R^2	0.280	0.618	0.642	-	0.319	0.591	0.602	-	.	0.319	0.358	-

Notes: Fuzzy regression discontinuity design, 2-stage least squares estimation with probit in first stage (incl. interactions of polynomials of forcing variable with treatment), linear interaction terms. *** denotes significance at the 1% level, ** at the 5% level, * at the 10% level. Standard errors (in parentheses) are clustered at regional level. Correlation between pre-treatment values and averages: 0.966 for prodUSEC, 0.972 for R&D, 0.988 for the institutional quality measure EQICPI.

Table 12: Robustness Checks RDD; Program periods 2000-2006 and 2007-2013, pre-treatment values of interaction variables

	Linear term			Sample forcvar >0.5 <1		Sample forcvar >0.6 <0.9	Second-order polynomial		Third-order polynomial	
	(1)	(2)	FE	Linear	2nd	Linear	2000-2006	2007-2013	2000-2006	2007-2013
Treatment	0.009***	0.015***	0.012	0.114	0.074	0.088***	0.011*	0.000	0.010	0.003
	(0.003)	(0.004)	(0.069)	(0.369)	(0.095)	(0.028)	(0.006)	(0.002)	(0.007)	(0.003)
Treat x PRODUSEC	0.012	0.010	−0.145	0.426	0.082	0.117	0.025	−0.008	0.021	−0.007
	(0.022)	(0.021)	(0.225)	(1.815)	(0.397)	(0.137)	(0.036)	(0.011)	(0.037)	(0.013)
Treat x R&D	0.000	0.000	−0.017	0.010	0.000	−0.040	0.000	−0.001	0.000	0.000
	(0.003)	(0.003)	(0.026)	(0.072)	(0.019)	(0.043)	(0.005)	(0.002)	(0.005)	(0.002)
Treat x EQICPI	0.000	0.000	0.003	−0.004	−0.001	0.002	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.008)	(0.018)	(0.003)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
Treat x 2007-2013		−0.015***	−0.023***	−0.042	−0.030**					
		(0.004)	(0.006)	(0.074)	(0.013)					
PRODUSEC	−0.010	−0.009	−0.056	−0.278	−0.005	−0.042	0.048**	0.028*	0.054**	0.019
	(0.014)	(0.013)	(0.132)	(1.423)	(0.310)	(0.116)	(0.024)	(0.016)	(0.026)	(0.017)
R&D	0.001*	0.001*	−0.005	−0.013	−0.002	0.039	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.006)	(0.070)	(0.018)	(0.041)	(0.001)	(0.001)	(0.001)	(0.001)
EQICPI	0.001***	0.001***	0.001	0.007	0.003	0.002	0.000	0.000	−0.001	0.000
	(0.000)	(0.000)	(0.001)	(0.020)	(0.004)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
MFF 2007-2013	−0.022***	−0.017***	−0.016***	0.001	−0.011	−0.018***				
	(0.001)	(0.001)	(0.006)	(0.069)	(0.013)	(0.006)				
Constant	0.018***	0.017***	0.021	−0.101	−0.052	−0.087***	0.018***	0.011***	0.020***	0.006*
	(0.003)	(0.003)	(0.034)	(0.382)	(0.103)	(0.031)	(0.005)	(0.003)	(0.007)	(0.003)
Country-FE	Yes	Yes	-	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	457	457	457	133	133	45	219	238	219	238

Notes: Fuzzy regression discontinuity design, 2-stage least squares estimation with probit in first stage (incl. interactions of polynomials of forcing variable with treatment), linear interaction terms. *** denotes significance at the 1% level, ** at the 5% level, * at the 10% level. Standard errors (in parentheses) are clustered at regional level. 2000 and 2006 data are used as pre-treatment values (for R&D expenditure the earliest observation).