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Effectiveness and efficiency of European Regional Development Fund on separate waste collection: evidence from Italian regions by a stochastic frontier approach

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Abstract The purpose of the present paper is to analyze the results of the impact of European Regional Development Fund (ERDF) in Convergence regions over the 2007–2013 on separate collection rate of Italian regions. The aim is twofold: propose a groundbreaking analysis that allows us to control both for the effectiveness of the Regulation (EC) No. 1080/2006, by a Difference in differences equation (DID), and the Regions' efficiency in the separate collection process, by a stochastic frontier analysis (SFA). Specifically, the SFA allows us to model the DID equation in order to take account the regions' efficiency in the separate collection process in terms of institutional quality. In particular, we use a panel with two dimensions: temporal—9 yearly observations from 2004 to 2012; and cross-sectional—20 regions. The estimates suggest that ERDF have not contributed to reducing the structural divide in Italy and its managerial slack has triggered in the failure of the convergence objective. Policy implications are discussed.

Keywords Government policy · Recycling · Panel data models · Difference-in-differences treatment effects · Stochastic frontier analysis · Structural fund

JEL Classification C21 · C22 · C23 · Q58 · Q59

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1 Introduction

Disparities across the European Regions have narrowed over the past decade. According to the Commission's communication regions suffering from structural weaknesses which limit their competitiveness and prevent them from contributing fully to sustainable economic growth in the EU tend to be those which suffer from structural problems. Development problems are more acute in lagging regions which lack the necessary infrastructure to be able to compete on equitable terms with other regions of the Union.[1] In this respect, the Regional Policy of the European Commission has set up financial tools with the aim of reducing regional disparities: the structural funds and the cohesion fund.

ERDF is the most intensively used policy tool set up by the EU included in the structural funds to enhance the speed up of the process of convergence between European regions as well as social development. This fund was introduced to overarching objectives and priorities in various areas. In particular, one particular area absorbed the bulk of funding (EC 2011): the environment and more specifically the waste management sector (total EUR 6.11bn in ERDF funding allocated by the Member States).[2]

The sector is regulated by The Waste Framework Directive (2008/98/EC) which sets out the basic principles for waste management across the EU, such as the "waste hierarchy". The waste hierarchy has an order of priorities for waste management with the preferred option of waste prevention, followed by re-use and recycling (EC 2010). Given that the vast majority of investments addressing these priorities are heavy infrastructure investments into waste management systems, the paper concentrates its efforts on the ERDF tool, as it provide nearly all the environmental infrastructures on recycling funding from the EU budget under the respect of the environmental legislation.[3]

In addition to EU legislation, the planning requirements of the recycling framework has led to the production of national waste management strategies. EU Regional Policy shows, in fact, that the main aim of Italian waste policy, in accordance with international objectives, is the achievement of a sustainable system based on the EU integrated waste strategy (APAT 2007).

The waste management sector in Italy in the programming period 2007–2013 is in a period of major change and still far from a consolidation at an industrial level. Various factors highlight the gap between Italian and European regions; unsophisticated management structures, both for dimension and territorial and industrial integration (dwarfism of the offer structure); lack of suitable facilities, both in terms of number and average size of facilities; low productivity of collection services, mainly due to the exceptionally small sizes of the businesses in Southern regions.

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[1] COMMISSION COMMUNICATION—third progress report on economic and social cohesion http://eur-lex.europa.eu/legal-content/ES/TXT/?uri=celex:52004DC0107 (accessed September 2016).

[2] DG Regio expenditure category 44 "Management of industrial and household waste" for the programming period 2007–2013.

[3] The importance of environmental integration is also reaffirmed in the 7th Environment Action Programme to 2020. It emphasizes that environmental integration in all relevant policy areas is essential to meet environmental targets.

On the other hand, there are examples of noteworthy efficiency, especially in the North, which show how the country appears divided, the northern regions being able to keep up with the best European examples.[4]

Italy, in fact, may be categorized under two waste generation and management "groupings", according to its regional strategy of modernizing or building waste facilities. The first group comprises the Northern regions with high levels waste generation and recycling (EEA 2013; Mazzanti et al. 2006) eligible under the Regional competitiveness and employment objective. The second group includes the Southern regions with low recycling rates and poor infrastructures of waste management eligible under convergence objective.[5]

In this regard, municipal waste requires largest infrastructure developments,[6] notably for the expansion of recycling capacities, composting and sorting plants and several initiatives have affected the development of EC regulations intended to harmonise environmental policy in Europe by creating common perceptions, standards and responsibilities for the Member States. Thus regional operational programmes (OPs) for the convergence regions were included, properly, as major ERDF-funded infrastructure projects managed at regional level.[7]

In conclusion, with the European Regional Development Fund Regulation No. 1080/2006 the Union invested in Italy[8] and across all of Europe's regions to allow the Convergence regions affected to catch up with the EU's more prosperous regions and Italy has been a unique national example of the use of explicit incentives to improve the performance of regional development in the southern area of greatest need[9] (OECD 2009).

However, although the regulation and the scope of EU Cohesion Policy, ERDF has undergone many implications. Since most of the convergence regions that benefit of this fund are the ones with a low institutional quality, the European Commission decided that in order to receive financial assistance from the EU Funds, the Member States are obligated to co-finance their regional projects, meaning that

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[4] http://www.gruppobiancamano.it/index.php?option=com_content&view=article&id=89&Itemid=110&lang=en (accessed September 2016).

[5] There are 11 outcome indicators and targets related to certain collective public services that convergence regions in Italy committed to improve. These services are education, child care and assistance to the elderly, water supply and waste management, all areas in which convergence regions lag behind the rest of the regions and which are considered crucial for increasing the effectiveness of cohesion policy.

[6] 40 actions for the upgrading of the regional waste management system. 15 infrastructures for waste recovery and disposal.

[7] The main field of intervention of the ERDF in the waste sector are the investments in infrastructure providing basic services to citizens in the area of environment, as provided for in Article 3 (1) of the ERDF Regulation.

[8] EC, 2015: Cohesion Policy in Italy http://ec.europa.eu/regional_policy/sources/docgener/informat/country2009/it_en.pdf (accessed September 2016).

[9] ERDF funds allocated to the waste sector were primarily oriented toward waste management rather than, for example, prevention measures or efforts to reduce waste production. These funds were largely used for projects in support of selective waste collection and sorting, as well as for the enhancement of recycling capacities in all of the Convergence Objective regions and in Sardegna for the programming period 2007–2013.

all the supporting payments from the EU are granted on specific conditions. This implies that the country's institutional capacity to distribute, invest and absorb the EU grants efficiently has become an essential determinant of European cohesion process and has attracted different considerations.

A wide variety of literature is trying to answer a question how effective ERFD are in speeding up the process of convergence in different priorities of interest as in our case the environment, another piece of debate emphasize that only for countries with "right" institutions any fund is effective, what suggests that institutional quality is a key-pillar for regional and cohesion policy effectiveness as well.

In this light, we consider that the impact of "untraditional" institutional variables on effectiveness of the EU Structural Funds is not to be neglected and therefore needs to be examined in more detail. While, the European Commission, in fact, does not have the general power to enforce European waste law directly in the Member States. Member States have the discretion, the duty and in theory should have the means to implement waste funds ensuring their effectiveness on national or regional/local level (BIO intelligence Service 2011) but sometimes the waste management structures are inadequate[10] and criminal activities counteracting the implementation of the funds.

This might not only, consequently, lead to an inefficient use of EU budget, but also have the adverse effect on the process of convergence. This is why the aim of this paper is to evaluate the effectiveness of the ERDF in the programming period 2007–2013 and analyze the efficiency of absorption[11] EU funds assistance in separate collection process matched with the quality of public institutions in Italy.

This goal is to be reached in two ways: first, our econometric analysis verifies the existence of common trends prior to the Regulation (EC) No. 1080/2006 between the two groups of regions considered. The existence of a common trends is essential for the estimation of the frontier function as well as specified by equation; secondly it illustrates the stochastic frontier analysis results putting the emphasis on the efficiency scores analysis.

The paper is structured as follow. Section 2 briefly reviews the related literature presenting evidence on ERDF on separate collection projects in Italy highlighting the need to intensify research in this environmental priority and the role played by institutions in fostering appraisal environmental actions. Section 3 reviews the methodology by a stochastic frontier approach, Sect. 4 presents the data used and shows the econometric analysis with a fourfold aim. Section 5 propose a significant contribution to the understanding that the effectiveness of public policies on recycling is related to institutional quality with emphasis on the efficiency score analysis. Section 6 makes the conclusions.

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[10] In Italy, specific organizations have been built, the ATOs (Ambiti Territoriali Ottimali, sort of waste union) that have at times not got the resources to guarantee proper waste management actions.

[11] Administrative absorption capacity, can be defined as the ability of central, regional and local authorities to prepare programs and projects, to decide on them, to organize coordination, to deal with administrative bottlenecks, work reports requested by the Commission and to finance and supervise applying their implementation properly, avoiding fraud as much as possible (Lupu and Asandului 2015).

2 Background literature: environment and institutional quality

The links between environmental actions such as recycling, institutions and structural funds may be not so univocal as argued in literature, as the variables may influence and reinforce each other. Since the understanding of this relationship is important for evaluate the efficacy of ERDF and environmental policies, we investigate also how stronger institutions imply a regional efficiency on separate collection process.

As EU structural funds together with the cohesion fund are the most intensively policy instruments used by the EU to promote the speed up of convergence among less developed regions in areas of detriment and since most of the regions belonging to convergence objective are among the ones with the lowest institutional quality the debate has intensified on the fact that only for regions with "right" institutions any EU aid is effective (Ederveen et al. 2006) and suggests also that institutional quality is a foundation—stone for regional and cohesion aid effectiveness as well. According to Nifo and Vecchione (2014) study, the latter result is obtained for a wide range of conditioning variables, such as voice and accountability (V&A), government effectiveness (GE), corruption (C) and other indicators for good governance.[12]

Improvements of solid waste management operation rarely occur without incurring the state intervention and, therefore, the quality of governance. Thus the gap among convergence and competitiveness region is surely a core part of the issue of waste management and other institutional-economic-environmental 'convergence failures' (Mazzanti et al. 2012). These forces and dynamics cannot be overlooked. For instance, the implementation actions and outcome of the government policy, reflecting the capacity to manage environmental issues i.e. separate collection in a process of policy decentralization, has characterized many critical public provisions with delegates competencies to regions and provinces (e.g. mainly for waste tariff), is a key factor behind institutional performances on governance (Barca 2009).

However stronger institutions imply environmental awareness, thus opting for environmental protection as active regional policies. Consequently, institutional quality has not only been linked to social and economic development, but also to environmental actions (Damania et al. 2003; Welsch 2004). In fact, poor governance results in bad policy formulation, management, and enforcement, and this can become apparent through problems with waste management sustainability (Damania et al. 2004).

Moreover, regarding the links between recycling actions and institutions, some studies have demonstrated that the successful implementation of environmental policies is determined by the institutional strength. For example, corruption has been shown to have a negative effect on environmental quality, undermining the effectiveness of environmental regulations (Cole 2007; Damania et al. 2003). Reinforcement of the rule of law is found to reduce the degree of environmental damage and improve the regions' performance in the separate collection process (Bhattarai and Hammig 2004). Government institutions may impact the

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[12] See Nifo and Vecchione (2014) for more details.

environmental regulations of own and neighboring countries. For example, corruption may result in less stringent environmental policies (Pellegrini and Gerlagh 2006) and affect several areas. This is indeed the case with respect to waste management, as the recent crisis in Southern Italian regions testifies (D'Alisa et al. 2010).

On the EU level, a recent Transparency International Europe report on the EU Integrity System (Transparency International Europe 2014) revealed that more than a half of EU citizens believe corruption as a signal of low Quality of Institutions raising the concern that Convergence Regions, which receive extensive support from the EU funds in ERDF and are widely users of services needed to implement EU-supported environmental projects (i.e. separate collection ones), risk being undermined by the weak way in which the European Commission is currently using its powers to exclude and deter corruption in participating in public tendering by EU institutions. In the detail, as for the case of Italy, recent anecdotal evidence has highlighted how the phenomenon of corruption affects the disposal of waste and especially recycling. The report on "Ecomafia" revealed (Legambiente 2011), in the context of the environmental crimes, local authorities and supervisory bodies often interact and give rise to illegal networks that undermine the correct management of waste collection and disposal. Consequently, it might not only lead to inefficient use of EU budget, but also have the adverse effect on the process of convergence (Dijkstra 2012).

Moreover, in a state with a low institutional quality, policy-makers and bureaucrats tend to reduce the accountability of local public policy-making, especially in areas such as environment, so as to be in a better position to extract some private benefits (Infante and Smirnova 2009). In such a context, characterized by high opacity about the monitoring of results of political decision-making processes, the advantage for governments trying to push public services providers to pursue waste management goals and specifically, separate collection rates, is rather weak.

In addition another possible inefficiency impact on waste management of the decentralized decision making is pointed out. ERDF payments may provide profitable options for rent-seeking by public officials on national and regional level (Ederveen et al. 2006). Those administrative bodies are involved in partnership based decision making process to specify the National Strategic Programs, to define the specific project priorities and are particularly concerned with implementation of operational programs (Katsaitis and Doulos 2009).

However, a key issues require further investigation Institutional quality may impact the environmental regulations of own and neighboring regions. For example, corruption may result in less stringent environmental policies (Pellegrini and Gerlagh 2006).

This work contributes to the existing literature by estimating an empirical model that allows to explain how environmental factors could influence the effectiveness of ERDF and the inefficiency of government institutions to impact regulations in the regions analyzed in a view of neighboring policies.

3 Methodology: effectiveness and efficiency analysis by a stochastic frontier approach

In this paper, we propose a groundbreaking analysis that allows us to control both for the effectiveness of the Regulation (EC) No. 1080/2006, by a difference in differences equation (DID), and the Regions' efficiency in the separate collection process, by a stochastic frontier analysis (SFA). Specifically, the SFA allows us to model the DID equation in order to take account the regions' efficiency (inefficiency) in the separate collection process in terms of institutional quality. In other words, this method allows us to verify simultaneously if the Regulation (EC) No. 1080/2006 has been effective in promoting the convergence objective and what are the Italian regions more efficient in the separate collection process.

In particular, the DID setting is suitable when before and after intervention data is available for treated and comparison groups. It accounts for unobserved time-invariant selection bias (Abadie 2005). Overall, the DID treatment effects are obtained by estimating ordinary least squares model with several pre- and post-treatment years over the period 2004–2012, with the intervention starting in 2007 and No. exposure to the programme prior to 2006 (Imbens and Wooldridge 2009). The approach here considers a pre- and post-treatment period of analysis as specified by Card and Krueger (1994). This considers the pooled dataset of regions comparing those before and after the introduction of Regulation (EC) No. 1080/2006. In this sense, a linear regression is specified as follows:

$$Y_{ist} = \alpha + \gamma Treatment_i + \varphi After_t + \beta Treatment_i \times After_t + X_{it}\delta + \mu_s + \varepsilon_{ist}, \quad (1)$$

where Y_{ist} is the outcome of interest and measures the average rate of separate collection of regions in region i in macro area (North, Centre, South Italy) s, in year t. The variable Treatment allows us to control for the unobserved time-invariant characteristics that may differ across regions in the two groups, whereas After captures the temporal trend common to both groups. $Treatment_i \times After_t$ is the interaction term between the two dummies and measures the treatment effect of our interest. X_{it} is a vector of control variables including the population density, annual tourist attendances per capita and regional yearly value added per capita. μ_s are the dummies for each macro area (North, Centre, South Italy) and account for the characteristics that are common to regions in the same macro area and are constant over time. Finally, ε_{ist}. is an error term.

Identification of the treatment effect in a DID framework requires some assumption relating trends for controls and treated in absence of treatment, the most common being the assumption of parallel paths. In particular, the key identifying assumption in our analysis is the existence of parallel trends prior to the of the Regulation (EC) No. 1080/2006 between the two groups of regions, which we state as follows: in the absence of the Regulation (EC) No. 1080/2006 the difference in the outcome between the treatment and the control group would have remained the same

$$E[\varepsilon_{it}|Treatment_i, After_t, X_{it}] = 0.$$

Furthermore, in order to have a regional efficiency measure into separate collection process, we specify the Eq. (1), in the following form:

$$Y_{ist} = \alpha + \gamma Treatment_i + \varphi After_t + \beta Treatment_i \times After_t + X_{it}\delta + \mu_s + v_{ist} - u_{ist}$$

(2)

$$\varepsilon_{ist} = v_{ist} - u_{ist}$$

$$v_{ist} \sim N\left(0, \sigma_v^2\right)$$

$$u_{ist} \sim N^+\left(m_{ist}, \sigma_u^2\right)$$

$$m_{ist} = p'_{ist}\delta,$$

where v_{ist} is the conventional random noise; heteroscedasticity across regions is allowed through the inefficiency term, u_{ist}, here defined as explicit function of the index of institutional quality and its single five dimensions (i.e. voice and accountability, government effectiveness, regulatory quality, rule of law, and control and corruption) (p'_{ist}) which could influence the efficiency of the regions, which vary over time. In particular, we will consider the technical efficiency. The technical efficiency can be obtained by $TE_{ist} = \frac{Y_{ist}}{(c+w_i)+\gamma Treatment_i+\varphi After_t+\beta Treatment_i*After_t+X_{it}\delta+\mu_s}$, with $0 \leq TE_{ist} \leq 1$. If $TE_{ist} = 1$, the region i, in macro area (North, Centre, South Italy) s, in year t is fully efficient. In other words, the resulting measure of technical efficiency is equivalent to the technically efficient capacity utilization; accommodating both the impacts of technical inefficiency and deviations from full utilization of the capacity base. That is, it represents the ratio of the potential capacity output (the separate collection rate) that could be achieved if all fixed inputs were being utilized efficiently and fully to observed output.

More in detail, in this panel data frontier model the non-negative technical inefficiency term, u_{ist}, is assumed to follow an truncated normal distribution with different means for each region, depending on the observable variables included.[13] Therefore, the inefficiency effects are assumed to be independently but not identically distributed.

Modeled in this way the index of institutional quality and its single five dimensions are interpreted as determinants of inefficiency because they directly explain the inefficiency results of regions.

Greene (2005) proposes the following model where the regional constant terms (c_i) are placed in the stochastic frontier:

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[13] We consider, in addition to truncated normal distribution, three other different distributions of the inefficiency term: half-normal, exponential, and gamma distribution. We omit these results because very similar. Interested readers are welcome to request these results from the authors.

$$Y_{ist} = c_i + \gamma Treatment_i + \varphi After_t + \beta Treatment_i \times After_t + X_{it}\delta + \mu_s + v_{ist} - u_{ist}$$
(3)

$$\varepsilon_{ist} = v_{ist} - u_{ist}$$

$$v_{ist} \sim N\left(0, \sigma_v^2\right)$$

$$u_{ist} \sim N^+\left(m_{ist}, \sigma_u^2\right)$$

$$m_{ist} = p'_{ist}\delta$$

The assumption on the random noise and inefficiency term are the same as of the Battese and Coelli's model (1993, 1995).

Greene refers to this extended model as "true fixed effects model" (TFE) to underline the difference with the FE framework commonly used. In the TFE model, fixed effects represent the unobserved cross regional heterogeneity, not the inefficiency as in the original FE model. This approach will become impractical, however, as the number of regions in the sample, and the number of parameters in the model, becomes large (see Greene 2005).[14] Greene shows that although the fixed effects may be largely biased, as far as the structural parameters and inefficiency estimates are concerned, the model performs reasonably well. In order to overcome this problem, we decide to implement a true random effects model (TRE) (see Belotti et al. 2013).

In particular, Greene (2005) proposes an extension also to the random effects model which is called the true random effects model (TRE). The model specification is:

$$Y_{ist} = (c + w_i) + \gamma Treatment_i + \varphi After_t + \beta Treatment_i \times After_t + X_{it}\delta + \mu_s + v_{ist} - u_{ist}$$
(4)

$$\varepsilon_{ist} = v_{ist} - u_{ist}$$

$$v_{ist} \sim N\left(0, \sigma_v^2\right)$$

$$u_{ist} \sim N^+\left(m_{ist}, \sigma_u^2\right)$$

$$m_{ist} = p'_{ist}\delta$$

Now the additional regional specific time invariant random effect $(c + wi)$ is included to represent the unobserved heterogeneity among regions. The inefficiency component now varies freely across time and regions. It is thus assumed that the unobserved differences of separate collection rate across regions, that remain

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[14] This problem is known in the empirical literature as the "incidental parameters problem".

constant over time, are driven by unobserved characteristics rather than by inefficiency.

In the model TRE all time invariant inefficiency is interpreted as regional specific heterogeneity and this part is now captured to the frontier and thus it does not appear as inefficiency anymore. This part of "unobserved inefficiency" is assumed to be caused by such time invariant network characteristics which are beyond the region's control; on the contrary, the "observed heterogeneity" is taken into account through inclusion of some covariate to explain the mean of inefficiency distribution (m_{ist}).

However, even if a flexible form is used to represent the frontier function or effectiveness function, such an approach might suffer from misspecification problems due to imposing a specific functional form on the separate collection process and assuming known statistical distributions on the errors terms (see Guilkey et al. 1983). The use of nonparametric methods could serve to relax these restrictive parametric assumptions. Moreover, using recent developments in nonparametric frontier literature (Cazals et al. 2002; Daraio and Simar 2005, 2007; Bădin et al. 2012; Mastromarco and Simar 2015; Halkos et al. 2015), it is possible to disentangle the potential effects of conditioning variables (in our case, institutional quality index and individual dimensions that contributed to its formation) to identify effects on the boundary (the shape of the frontier) and effects on the distribution of the inefficiencies in a full nonparametric setup. Unfortunately nonparametric methods do not allow the estimation of parameters for economic interpretation, and because we are interested to know the impact of covariates on the dependent variable (separate collection rate), we prefer the SFA to the conditional nonparametric frontier analysis.

4 Data and results

The purpose of this section is fourfold. First, it presents the data used in the empirical analysis (Sect. 4.1). Then, it verifies the existence of common trends prior to the Regulation (EC) No. 1080/2006 between the two groups of regions (Sect. 4.2). The existence of a common trends is essential for the estimation of the frontier function as well as specified by Eq. (1). The third part Illustrates the Stochastic frontier analysis results (Sect. 4.3). Finally, emphasis is placed on the efficiency scores analysis (Sect. 4.4).

4.1 Data

In this study the stochastic frontier approach is used in order to evaluate the performance of the Italian regions with respect to the separate collection rate. The data, which is balanced panel data, required are based on an administrative dataset provided by the National Italian Institute of Statistics (ISTAT). In particular, we use a panel with two dimensions: temporal—9 yearly observations from 2004 to 2012; and cross-sectional—20 regions. In this section, we describe more accurately the variables used in the analysis.

In particular, we consider two sets of variables:

1. one set for the frontier function or effectiveness function ($Y_{ist} = (c + w_i) + \gamma Treatment_i + \varphi After_t + \beta Treatment_i \times After_t + X_{it}\delta + \mu_s$);
2. one set for the inefficiency function ($m_{ist} = p'_{ist}\delta$).

In the case of effectiveness function, we use the separate collection rate (SCR) as the output. Art. 183 of LD 152/06 (paragraph f) provides a definition of separate collection rate (our dependent variable). Separate collection (SC) is defined as: "the collection which aims to: (1) group the urban waste into homogeneous categories; (2) group the packaging waste materials separately from other waste. Moreover, an important condition is that the waste should be collected for recycling. Finally, the separate collection must be performed according to the cheapness, efficiency, transparency and efficiency criteria". An indicator of separate collection is given by the urban waste separately collected as a percentage of total urban waste. In particular, Art. 183 makes provision for the following items within the separate collection (SC): organic waste (wet waste and garden waste); packaging waste (paper and cardboard, plastic, glass, wood, metal) and multi-material; bulky waste subject to recovery (plastic, glass, wood, metal); electrical waste; textile waste and second-hand clothing; waste from selective collections (batteries and accumulator, expired medicines, paints and inks, vegetable and mineral oils, etc.). Waste from building sites is not included in the calculation of urban waste because it is classified as special waste.

Data on separate collection rate are provided to ISTAT (National Italian Institute of Statistics) by ISPRA (The Institute for Environmental Protection and Research). ISPRA acts under the vigilance and policy guidance of the Italian Ministry for the Environment and the Protection of Land and Sea (Ministero dell'Ambiente e della Tutela del Territorio e del Mare). In particular, the data on the production and collection of municipal waste are collected through questionnaires sent and compiled by public and private organizations dealing with the management of municipal waste (i.e. regions and provinces).[15]

Table 1 shows descriptive statistics on the average separate collection rate in the two groups of regions (treatment and control group). In particular, we implement a mean-comparison test (t test). The outcome of this test is the acceptance or rejection of the null hypothesis (H_0). The null hypothesis generally states that: "Any differences, discrepancies, or suspiciously outlying results are purely due to random and not systematic errors". The alternative hypothesis (H_a) states exactly the opposite. The averages are calculated using data on the regions before and after the entry into the force of the Regulation (EC) No. 1080/2006. The statistics show that the separate collection rate is on average higher in the control group, both in the before (about three times higher) and after (about two times higher) periods. All differences are statistically significant to conventional levels. We also provide graphical evidence of the shift in the distribution of the separate collection rate of regions in treatment group before and after the entry into the force of the Regulation (EC) No. 1080/2006. Figure 1 illustrates the rightward shift of the distribution, resulting from an increase in the separate collection rate by the treated regions. In

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[15] http://www.isprambiente.gov.it/en/ISPRA (accessed November 2015).

Table 1 Descriptive analysis on the average separate collection rate

	Before	After	Difference
Treatment group	8.621691	19.74852	−11.12683***
s.e.	(0.7907718)	(2.149965)	(2.290779)
N	18	36	
Control group	26.90623	37.95748	−11.05124***
s.e.	(1.983077)	(1.61616)	(2.558235)
N	42	84	
Difference	18.28454***	18.20895***	
s.e.	(2.134928)	(2.689669)	
N	60	120	

The average rate of separate collection of regions in treatment and control group before (before period) and after (after period) the entry into the force of the Regulation (EC) No. 1080/2006. Standard errors are in parentheses

The following symbols indicate different significance levels: *** significant at 1%, ** significant at 5%, * significant at 10%
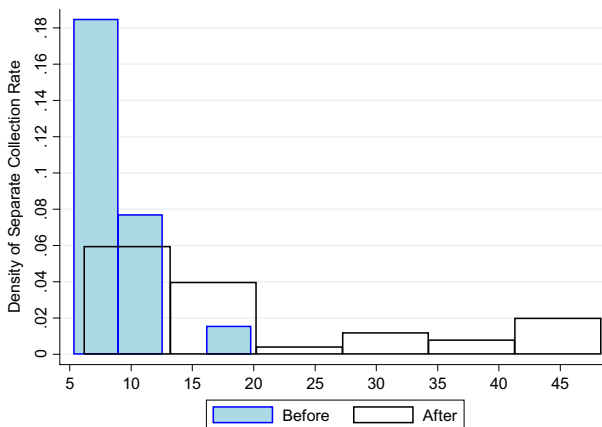
Fig. 1 Treatment group regions

particular, the new distribution (after) is much more flattened than the previous one (before); this result shows an increase of variability among the treated regions in terms of separate collection rate.

As economic drivers which gave rise to literature focusing on separate collection we consider, among the regressors (X_{it}), population density (PopDens), annual tourist attendances per capita (Tourism) and value added per capita (VA) (see Mazzanti et al. 2008; D'Amato et al. 2015). Demographic factor can have an impact on separate collection in various way. The variable, population density represents the scarcity of space. In general, can be assumed that societies living in densely populated areas are more conscious about waste management (Leisher et al. 2013).

It may control for different land values, and for the presence of agglomeration and scale effect so we assume that it is positively correlated to recycling, though the latter sign is not to be taken for granted and is valid only if economies of scale are operating (Mazzanti et al. 2008; D'Amato et al. 2015). Moreover, population density is an important factor in influencing government and public attitudes toward recycling. Higher densities demand better management of recycling because of sanitation problems and the scarcity and cost of land (Matsunaga and Themelis 2002). Tourist flows, on the other side, control for different choices made by tourism-oriented regions, in which the amenity value of landscapes may play an important role in waste management. For this reason, the highly statistically significant effects indicate that this is an important parameters of control for an analysis of this type. The influx of visitors to a municipality has a large effect on the average number of recycled material per person. (Hage and Soderholm 2008; Mazzanti et al. 2008; D'Amato et al. 2015). Finally, value added per capita is used as main economic driver (Mazzanti et al. 2009). In particular, as noted in Andersen et al. (2007) in analysis of waste trends, consumption is often the more coherent driver, but in our case consumption regional level data are not available, so we choose value added as best alternative (Mazzanti et al. 2008; D'Amato et al. 2015). In particular, a good level of economic well-being (val ue added per capita) can address high costs of recycling (e.g., the curbside collection). In the case of southern Italy regions (see Agovino et al. 2015, 2016a), characterized by a low value added per capita, make the separate waste collection is a problem. In this view, the most effective and cheapest way to reduce waste is to convince people to differentiate but perception of recycling as inconvenient and/or difficult is related to recycling behaviour (Bezzina and Dimech 2011; Bruvoll and Nyborg 2004). Separate waste operations cost the individual citizen time and effort and can also be unpleasant (think of the smell of organic waste, the lack of time for recycling, the difficulty of moving recycling bin or barrel to curb and the inconvenient locations of drop-off sites), whereas the economic and ecological benefits go to the entire community. It is now recognized, in fact, that the rates of recycling recommended by the EU targets are achievable only through domestic separate collection. Paradoxically, this is precisely the problem. Reward incentives or sanctions can encourage households to take into account the benefits that the collection door to door brings the whole society and the problem of waste would be partly solved but if controls are not planned there will always be the temptation to live parasitically the situation of waste or let doing recycle the others (Agovino et al. 2016b). Both variables are provided by ISTAT.

Finally, we check for the dummies for each macro-area (North, Centre, South Italy). In this way, we check for large differences recorded in terms of separate collection among the Italian macro-areas. In particular, the data show that the regions of northern Italy have a higher separate collection rate than the central and southern Italy ones (see Agovino et al. 2015, 2016a).

Social psychology literature argues that the presence of moral norms has positive effects on separate collection rate (Hage et al. 2009). Moral norms are active through social interaction, e.g. participation in meetings of formal organisations (voluntary service, ecological cultural, political party and unions), meetings with

friends, etc. (see Fiorillo 2013). Numerous studies have found that moral norms are important for explaining recycling behaviour (see Barr et al. 2006; Hornik et al. 1995; Schultz et al. 1995). More recently, Halvorsen (2012) and Saphores et al. (2012) confirmed these results. Unfortunately we do not have these variables and consequently we omit them from our analysis.

Table 2 reports averages of the variables in treated and control regions. The statistics show that, while the two groups do not differ in terms of population density, control regions have a higher annual tourist attendances and value added per capita. In particular, we show that the value added per capita of the control group is 1.7 times higher than the one of the treated group. Finally, we show that the annual tourist attendances of the control group is 2.7 times higher than the one of the treated group.

In addition, we consider a second set of inputs (environmental factors) which could influence the inefficiency of the regions analyzed (Charnes et al. 1981; Thanassoulis 2001). In particular, these inputs are included in the analysis through the inefficiency function (m_{it}). It is important to highlight that a negative sign of the parameters associated to environmental factors has the effect of reducing the inefficiency of the regions in the separate collection process. Among these variables we include in a preliminary estimate:

- Institutional Quality Index (IQI). IQI is an index which summarizes the institutional quality in the Italian regions. This index, which has been introduced by Nifo and Vecchione (2014), summarizes five different dimensions of quality such as: voice and accountability, government effectiveness, regulatory quality, rule of law, and corruption (crimes against the public administration). This index assumes value in the range [0, 1].[16]

Then, in a second estimate, we include the five different dimensions of IQI among the factors that influence the regions' inefficiency in the separate collection process. In particular:[17]

- voice and accountability (V&A): it aims to detect citizens' participation to public elections, number of associations and social cooperatives;
- government effectiveness (GE): it measures the endowment of social and economic structures and quality of public polices in areas such as health, waste management, environment protection;
- regulatory quality (RQ): it measures the ability of local administrators to promote and protect business activity;
- rule of law (RL): it measures crime levels, shadow economy, magistrate productivity, trial times;
- corruption (C): it provides a measure of crimes against the public administration.

Table 3 summarizes the descriptive statistics of the IQI and its five components. The statistics show that, the two groups differ in terms of IQI; in particular, control

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[16] See Nifo and Vecchione (2014) for more details on the construction of the index.

[17] See Nifo and Vecchione (2014) for more details.

Table 2 Baseline covariates

	Treatment	Control	Difference
PopDens	180.2444	183.723	3.478572
s.e.	(16.78872)	(8.53145)	(18.83207)
N	54	126	
Tourism	3.9	10.70556	6.805556***
s.e.	(0.197114)	(0.9284343)	(0.9491281)
N	54	126	
VA	15333.17	26280.84	10947.68***
s.e.	(326.8474)	(378.1236)	(499.8066)
N	54	126	

Pre-treatment baseline covariates in treatment and control regions and their difference. Covariate are: population density, inhabitants/km^2 (PopDens), total touristic presences (Tourism), value added per capita (VA). Standard errors are in parentheses

The following symbols indicate different significance levels: *** significant at 1%, ** significant at 5%, * significant at 10%

Table 3 Covariates of inefficiency function

	Treatment	Control	Difference
IQI	0.3461906	0.6818186	0.335628***
s.e.	(0.0174442)	(0.012207)	(0.0212911)
N	54	126	
Five dimensions of IQI			
V&A	0.2746678	0.5022152	0.2275475***
s.e.	(0.0132252)	(0.0089418)	(0.0159643)
N	54	126	
GE	0.2417096	0.4137015	0.1719919***
s.e.	(0.009217)	(0.0126468)	(0.0156491)
N	54	126	
RQ	0.2685454	0.57722	0.3086746***
s.e.	(0.0152934)	(0.0104554)	(0.0185257)
N	54	126	
RL	0.4415531	0.6050661	0.163513***
s.e.	(0.0210684)	(0.0142017)	(0.025408)
N	54	126	
C	0.6473118	0.8810135	0.2337016***
s.e.	(0.0287043)	(0.0075539)	(0.0296817)
N	54	126	

Pre-treatment baseline covariates in treatment and control regions and their difference. Covariate are: Institutional Quality Index (IQI), voice and accountability (V&A), government effectiveness (GE), regulatory quality (RQ), rule of law (RL), corruption (C). Standard errors are in parentheses

The following symbols indicate different significance levels: *** significant at 1%, ** significant at 5%, * significant at 10%

regions have a higher IQI than treatment ones (about two times higher). We observe that even in the case of five components of IQI, the control regions have higher values than the treatment ones. All differences are statistically significant to conventional levels.

4.2 A preliminary analysis: parallel-trends assumption

The existence of common trends prior to the Regulation (EC) No. 1080/2006 between the two groups of regions is the key to our identification. Figure 2 shows the regional separate collection rate for treated and control groups defined for the operation of the programme in 2007–2012.[18] Nonetheless, the most striking observation that emerges from this figure is that before the programme was introduced, treated and comparison groups experienced similar increasing trends. After the year 2007 the separate collection rates of both continue to behave the same way. This result highlights a lack of convergence of the regions falling under the "convergence" objective.

In fact, when we consider the percentage of separate collection of treated on the percentage of separate collection of control group (TG/CG), we observe that the gap decreases over time. In particular, if in 2006 (maximum value reached in the years 2004–2006) the percentage of recycling in the control group was only 36%, in 2007 [year of entry into force of the Regulation (EC) No. 1080/2006] we observe that this percentage reaches 39%. In addition, we verify an increase of this percentage, reaching 59% in 2012. From these results it would appear that the gap has been reduced and seems that the Regulation has produced the expected effect.

In a nutshell, the fact that both groups experience a similar trend prior to the treatment is an important visual asset in the identification strategy of the DID setting.

Despite visually treated and comparison groups showed similar separate collection trends prior to the intervention, the parallel-paths assumption was tested following Mora and Reggio (2012). This assumption indicates that in absence of the programme the separate collection rates of treated and comparison groups would follow the same trend. In other words, it implies that the differences in the separate collection level before and after the intervention are time-invariant.

Mora and Reggio (2012) propose a method that focuses on the behavior of the double difference of the outcome variable to test a parallel-trends assumption. It is based on the analysis of q baseline periods before the treatment and s periods after it. If the parallel-trends assumption is met, then the comparison group is an accurate counterfactual for the treated group. Table 4 shows the results of the test based on Mora and Reggio (2014). In our case the test is overcome for all years of analysis (2004–2006). In particular, for each baseline period the hypothesis of parallel-trend is not rejected, while the overall test of hypothesis of common pre-dynamics is also not rejected. Thus, the DID identification strategy denotes that, on average, comparison regions are a suitable counterfactual for the treated group. However, it is important to stress that tests based on pre-treatment observations give an indication, but the common trend assumption after/during treatment can never be checked as data are counterfactual.

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[18] Although the Regulation (EC) No 1080/2006 is operational for the 2007–2013 period, we consider only the 2007–2012 period because the data on the Institutional Quality Index are available until 2012.
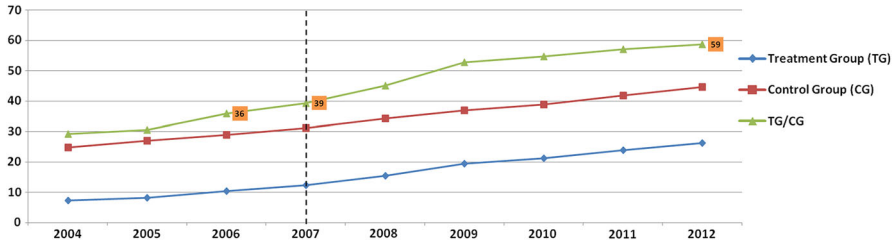
Fig. 2 Regional separate collection rate, 2004–2012

Table 4 Parallel-trends assumption test, Regulation (EC) No. 1080/2006

Post-treatment (s)	s = 1	s = 2	s = 3	H_0: q = q − 1	H_0: s = s − 1
Pre-treatment (q)					
q = 1	−0.3904338	−0.3000088	1.07617		0.0518528
	(6.6296)	(7.1512)	(7.9538)		[1.0000]
q = 2	−0.6413592	−0.8018596	0.3233935	0.2509254	0.0378475
	(10.5201)	(15.7083)	(21.2117)	[0.9641]	[1.0000]
q = 3	−2.130865	−5.270376	−8.613639	1.489505	0.0860908
	(17.8177)	(40.3484)	(72.3108)	[0.8697]	[0.9999]

H_0: Common pre-dynamics = 0.06882; p-value = 0 .9662. Sample period: 2004–2012; treatment period: 2007–2012; robust standard errors in parenthesis; p-values in brackets

4.3 Stochastic frontier analysis results

The stochastic frontier analysis is implemented by using the maximum likelihood (ML) procedure in the Stata software package (version 11, StataCorp, College Station, TX, see Wang and Ho 2010, for details about the ML procedure).

We estimate two models: a model with only the Institutional Quality Index (IQI) as factor that influence the regions' inefficiency in the separate collection process (Model 1), and a second model that consider separately the five different dimensions of IQI among the factors that influence the regions' inefficiency in the separate collection process (Model 2).

The estimates are presented in Table 5. The following results emerge. First, the percentage of variance explained by technical inefficiency, $\sigma_u^2/\left(\sigma_u^2 + \sigma_v^2\right)$ is 61% for the Model 1 and 40% for the Model 2, respectively, indicating that region-specific technical inefficiency is an important contributor in explaining total variability of separate collection rate.

(a) With regard to the frontier function (or effectiveness function), the coefficient on the *Treatment* variable is positive and statistically significant only in case of Model 1: this indicates that the treated regions have on average a higher separate collection rate than the one of the control regions. We observe a

Table 5 Stochastic frontier analysis results, true random effects model (TRE)

Dependent variable: separate collection rate	Model 1			Model 2		
	Coefficient	s.e.	p-value	Coefficient	s.e.	p-value
Frontier function or effectiveness function						
Treatment	14.59053***	4.733571	0.002	6.846209	4.811975	0.155
After	0.785189***	3.755605	0.003	1.039716***	3.796983	0.002
Treatment × After	−0.1133955	1.555675	0.942	−1.78124	1.325356	0.179
Value added per capita (VA)	0.0011829***	0.000261	0.000	0.0010073***	0.000268	0.000
Population density (PopDens)	−0.0052397	0.009488	0.581	−0.0089001	0.008663	0.304
Tourist attendances per capita (Tourism)	−0.0464553	0.098450	0.637	0.3828022***	0.115492	0.001
Southern Italy (northern Italy as reference group)	−36.76933***	5.381157	0.000	−30.79578***	5.588947	0.000
Central Italy	−16.30215***	2.319925	0.000	−13.70548***	2.195227	0.000
Constant	−5196.826***	197.5788	0.000	−5093.927***	163.6104	0.000
Inefficiency function						
Institutional Quality Index (IQI)	−5.658775***	1.659448	0.001			
Voice and accountability (V&A)				0.1198888	5.122947	0.981
Government effectiveness (GE)				−17.15214***	5.509779	0.002
Regulatory quality (RQ)				5.688219	4.895056	0.245
Rule of law (RL)				7.874052**	3.845437	0.041
Corruption (C)				5.474256	5.484888	0.318
Constant	5.81493***	0.660739	0.000	3.359759	3.604467	0.351
Theta	8.835591***	0.962675	0.000	8.361811***	0.551835	0.000
E (σ_u^2)	4.244098			2.04849		
σ_v^2	2.697346***	0.330464	0.000	3.197741***	0.207410	0.000
Log−likelihood	−526.6884			−520.7717		
Wald test	1266.39***		0.0000	1592.91***		0.0000

Table 5 continued

Dependent variable: separate collection rate	Model 1			Model 2		
	Coefficient	s.e.	p-value	Coefficient	s.e.	p-value
Mean efficiency	0.2420243			0.4879019		
AIC	1081.377			1077.543		
BIC	1135.017			1126.078		
# observations	180			180		

***, **, * 1, 5 and 10% levels of the two-sided test that the corresponding coefficient equals 0

positive time trend in the regional separate collection rate. In particular, the *After* coefficient is statistically significant and positive in both Models, indicating an increase in the separate collection rate. Most importantly, the coefficient on the interaction term Treatment × After is not statistically significant and negative in both models. The estimates suggest a failure of Regulation (EC) No. 1080/2006. Namely, after the introduction of the Regulation, the average rate of separate collection of regions in the treatment group not exceed the ones in the control group. Regarding the other covariates (X_{it}), consistently with previous analysis on waste generation, the coefficient on the value added per capita (VA) is positive and significant on both models (Mazzanti et al. 2008). This evidence connects to the increasing marginal cost of recycling options (Pearce and Brisson 1995). In other words, it is reasonable to expect that separate collection is higher in regions where government finances are more conspicuous. Population density (PopDens) is not significant in both models. Conversely, the coefficient on the tourist attendances per capita (Tourism) is positive and significant only in the case of Model 2. The tourist attendances as expected has the effect to stimulate the separate collection (Mazzanti et al. 2008).

Furthermore, we observe that Central Italy regions have a 16%, in the Model 1, and 14%, in the Model 2, separate collection rate lower than Northern regions.[19] Southern Italy regions are in the worst position, in fact they have a 37%, in the Model 1, and 31%, in the Model 2, separate collection rate lower than Northern regions.

These results highlight the regional disparities in terms of separate collection, with Northern regions characterized by a better performance than the Southern and Central ones; moreover, Southern regions have on average a 15% advantage compared to the central ones.

(b) With regard to the factors that determine the inefficiency of separate collection process (*Inefficiency Function*), we observe that, as regards the Model 1, the Institutional Quality Index (IQI) variable is significant and shows and expected negative sign that indicates a reduction in the inefficiency of Italian regions in the separate collection process. In other words, regions' performance is more sensitive to the relative variation of the institutional context: regions with a high institutional quality, therefore, have experienced a higher separate collection rate. Finally, by examining the Model 2, that no longer considering the institution index as a whole, but the individual dimensions that contributed to its formation, we observe that only government effectiveness (GE) and rule of law (RL) variables are significant and show expected negative sign for the first variable and negative for the last variable. These results suggest that an increased of administrative capacity of local governments (GE) and a more efficient legal system and a lower propensity to the occurrence of crime or tax evasion tends to improve the regions' performance in the separate collection process.

[19] The northern regions are our benchmark (or reference group).

In order to choose the most suitable model, we use the AIC, the BIC and the Log-likelihood criteria.

Information-theoretic criteria such as Akaike's Information Criteria (AIC) (Akaike 1973) and Bayesian Information Criteria (BIC) (Schwarz 1978) are increasingly being used to address model selection problems; in particular, a model that minimize AIC and BIC criteria is selected. In our case, the Model 2 minimizes the AIC, BIC criteria and maximizes the Log-likelihood criteria.

4.4 Analysis of efficiency scores

According to the above estimation based on the stochastic frontier analysis, we are able to evaluate the separate collection process efficiency of Italian's regions. In particular, we will consider the technical efficiency. Given the results of AIC, BIC, and Log-likelihood criteria, the regional performance analysis in terms of separate collection rate will be performed on the efficiency scores obtained by estimating Model 2.

To get an impression on how efficiency changes over time, we plot mean efficiency for each year separately for the regions in the treated and control group (Fig. 3). In the observation period, the average efficiency is estimated at the level of 0.42 in the case of treatment group and 0.52 in the case of control group. In other words, this means that the control group (treated group) produced on average only 42% (52%) of its potential separate collection rate. For both groups, we observe an increasing trend until 2007 (the year of entry into force of the Regulation (EC) No.
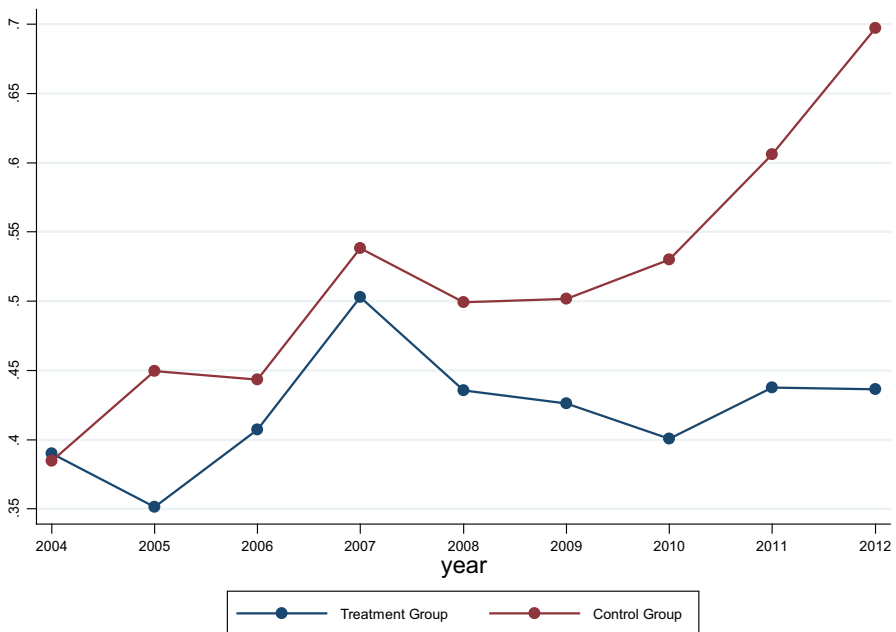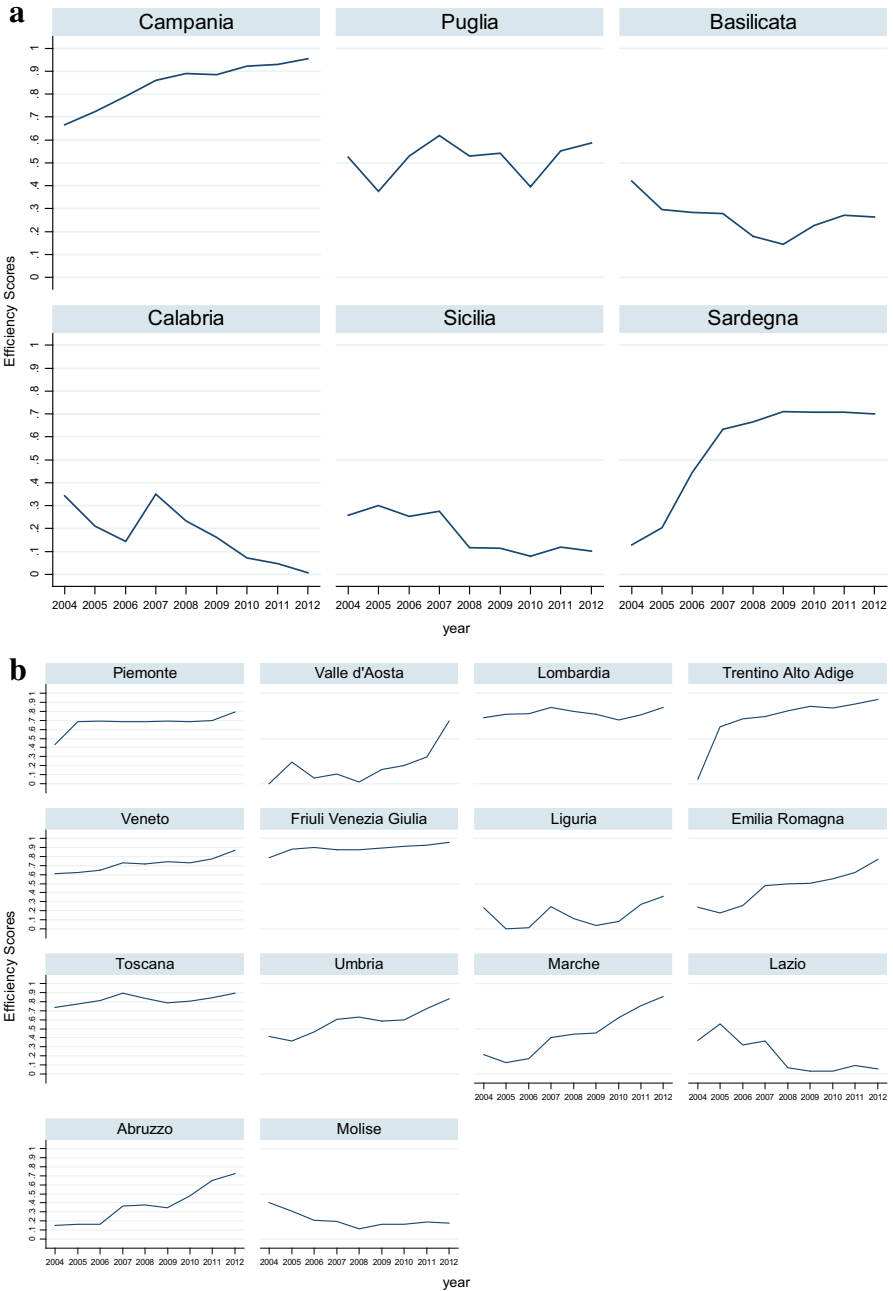

Fig. 3 Efficiency scores across control and treatment group, 2004–2012

1080/2006), the trend becomes descending until 2010 and after resumes its upward trend. It is interesting to note how the efficiency distribution of the control group always dominates the one of the treated group. Moreover, the gap between groups increases from 2007 onwards; this result is driven by a decrease in the institutional quality (factor driving efficiency of the regions in the separate collection process) in the regions of the control group that becomes more pronounced from 2007 onwards. How this result be explained? The Regulation (EC) No. 1080/2006 providing for the allocation of funds in favor of those regions, in order to achieve the objective of convergence, could have triggered the unorthodox behavior (e.g. corruption) in the local authorities responsible for their management and implementation of the infrastructure needed to improve the separate collection process. These behaviors are reflected not only in the failure of the objective of convergence but also in the institutional quality and consequently in the low efficiency of these regions in the separate collection process.

Figure 4 shows efficiency change over time but across regions in the two groups. In particular, we verify that among the regions of the treated group (Fig. 4a), the Campania region is the one with the best performance, followed by the Sardegna region. In particular, we show how from 2007 onwards these regions show a significant improvement in their performance in the separate collection process. In fact, the Campania region shows an increasing trend due to a growth of 7% in the institutional quality recorded in the period 2007–2012. Conversely, the Sardegna region after 2007 shows a constant and not increasing trend; this result is explained by the reduced institutional quality in this region in the period 2007–2012. In particular, the Sardegna region shows in this period a negative growth rate of institutional quality and equal to -15%. Puglia region is stationary around an efficiency level about 0.5, with a downward trend from 2007 onwards. Also this region shows a deterioration in the institutional quality after 2007 (a growth rate equal to -16%). Basilicata, Calabria and Sicilia regions are the ones with the worst performance, with a negative growth rate of institutional quality in the period 2007–2012 about -18, -36 and -12%, respectively. Figure 4b shows efficiency change over time among the regions of the control group. The majority of these regions show an improvement in their performance in the separate collection process, only the Liguria, Valle d'Aosta, Lazio and Molise regions show a downward trend.

In order to illustrate the separate collection efficiency in all the regions more clearly, we divide the 20 regions into nine categories according to their separate collection efficiency and separate collection rate. In Table 6, the mean of separate collection rate is 28.80% and the maximum is 62.64%. Thus, we use the mean and the maximum to divide the separate collection rate into three categories: [0; 28.80%], (28.80%; 57.6%], and (57,6%; 62.64%]. On the other hand, the mean of separate collection efficiency is 0.4879019 and standard deviation is 0.2895574. Following Lin and Long (2015), we employ 0.3431232 ($mean - 1/2 \times$ $standard\ deviation$) and 0.6326806 ($mean + 1/2 \times standard\ deviation$)) to divide separate collection efficiency into three levels: low efficiency into separate collection [0; 0.3431232]; middle efficiency into separate collection (0.3431232; 0.6326806] and high efficiency into separate collection (0.6326806; 1]. Finally,

Fig. 4 Efficiency scores across regions in the two groups, 2004–2012. **a** Treatment group. **b** Control group

Table 6 Nine categories classified by separate collection process efficiency and separate collection rate

	High Separate collection rate	Middle Separate collection rate	Low Separate collection rate
High efficiency	–	Piemonte[CG]; Toscana[CG]; Lombardia[CG]; Trentino Alto Adige[CG]; Veneto[CG]; Friuli Venezia Giulia[CG]	Campania[TG]
Middle efficiency	–	Emilia Romagna[CG]; Umbria[CG]; Marche[CG]; Sardegna[TG]	Abruzzo[CG]; Puglia[TG]
Low efficiency	–	Valle d'Aosta[CG]	Liguria[CG]; Lazio[CG]; Molise[CG]; Basilicata[TG]; Calabria[TG]; Sicilia[TG]

With TG and CG we indicate the regions of the treated and control group, respectively

Table 7 Nine categories classified by separate collection process efficiency and institutional quality (IQI)

	High institutional quality	Middle institutional quality	Low institutional quality
High efficiency	Piemonte[CG]; Toscana[CG]; Lombardia[CG]; Trentino Alto Adige[CG]; Veneto[CG]; Friuli Venezia Giuli[CG]	–	Campania[TG]
Middle efficiency	Emilia Romagna[CG]; Umbria[CG]	Marche[CG]; Abruzzo[CG]	Puglia[TG]; Sardegna[TG]
Low efficiency	Valle d'Aosta[CG]	–	Molise[CG]; Basilicata[TG]; Calabria[TG]; Sicilia[TG]

With TG and CG we indicate the regions of the treated and control group, respectively

given the relevance of the institutional quality in the separate collection process, in Table 7 we repeat the same exercise of Table 6, and we relate the efficiency scores with the Institutional Quality Index (IQI). In particular, while the three classes built for the efficiency scores remain identical to ones calculated in Table 6, for the IQI we proceed as follows: since the IQI assumes value in the range [0, 1], as the efficiency scores, we use the mean (0.5811302) and the standard deviation (0.2043637). Consequently, we employ 0.47894835 (*mean* $- 1/2 \times$ *standard deviation*) and 0.68331205 (*mean* $+ 1/2 \times$ *standard deviation*)) to divide institutional quality into three levels: low institutional quality [0; 0.47894835]; middle efficiency institutional quality (0.47894835; 0.68331205] and high institutional quality (0.68331205; 1].[20]

In the first row (Tables 6, 7), six regions of control group (Piemonte, Toscana, Lombardia, Trentino Alto Adige, Veneto and Friuli Venezia Giulia) are grouped in

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[20] In "Appendix", Table 8, we report the regional annual average of variables used for the construction of Tables 6 and 7.

middle-separate collection, high-efficiency, and high-institutional quality category. These regions are the benchmark for other ones. The institutional quality is a factor that justify the high efficiency in the separate collection process. In addition, a high efficiency in the separate collection process produces a good rate of separate collection. Campania region is the only one of the treated group to have a low separate collection rate, low institutional quality, and high efficiency in the separate collection process. This result shows that the Campania region performs considerable efforts to achieve a high separate collection rate. Unfortunately, the results are deterred by poor region's institutional quality.

In the second row (Tables 6, 7), the Sardegna region is the only one of the treated group to have a middle separate collection rate, low institutional quality, and middle efficiency in the separate collection process. This region presents results similar to those obtained by the Campania region; Sardegna differs from Campania only for the efficiency level. In particular, the Sardegna region faces the same obstacles faced by the Campania region (low institutional quality), but unlike to the Campania region, the Sardegna region performs less effort in the separate collection process (low efficiency). Finally, the Puglia region is grouped in low-separate collection, middle-efficiency, and low-institutional quality category. This region differs by Sardegna region only in the separate collection rate: middle in the case of Sardegna region and low in the case of Puglia region. Figure 4a allows us to understand this result. In particular, unlike the Sardegna region that shows a constant effort to improve its separate collection process (a increasing trend in efficiency scores), the Puglia region shows a constant but not increasing effort in the separate collection process (constant trend of efficiency scores), this does not allow this region to achieve a higher separate collection rate.

In the third row (Tables 6, 7), Basilicata, Calabria and Sicilia are three regions of treated group that fall within low-separate collection, low-efficiency, and low-institutional quality category. These three regions have the poorest performance in the separate collection process. Low institutional quality is only one factor that affects the poor results achieved by these regions. There are also historical and cultural factors that influence the separate collection process and that we do not consider in this paper [e.g. social capital as good culture (Guiso et al. 2008)].

5 Discussion

Despite structural measures funding for municipal waste management infrastructures on separate collection were conceived to help beneficiary regions to meet waste policy objectives set in EU directives and regional waste prevention was encouraged, separate collection progressed slow with respect to the need to fill the gap with treated regions. convergence regions increased their separate collection rate without achieving EU targets for recycling. Improvements of waste management actions rarely occur without incurring in two important factors. One is the state intervention and, therefore, the quality of government. Environmental protection measures, in fact, are hardly adopted without regulator stimuli.

The other factor, tightly linked to the first one, is the quality of institutional context. Institutions determine the implementation and outcome of government policy and local authorities, reflecting the capacity to manage environmental issues and funds. The institutional quality influences the degree by which the society is involved in the process of environmental renaissance. Stronger institutions imply environmental awareness, thus opting for environmental protection as active policies (Castiglione et al. 2013).

As regarding the first factor, normally structural measures funding do not influence the implementation of the ordinary administrative and economic supporting measures. The European Commission cannot intervene in the Member States by undertaking controls and inspections and therefore is hampered in guaranteeing good implementation of European waste legislation and environmental measures. Thus Italy has the discretion, the duty and in theory should have the means to implement waste measures and ensure their enforcement at regional or local level.[21] The Court of Auditors, instead, highlighted how Italy the effectiveness of ERDF was limited properly due to the poor implementation of supporting measures (EEA 2013).

Barriers in successful implementation of ERDF so include diverse factors ranging from inadequacy of waste management structures, diffuse responsibility for waste management and environmental enforcement to organized crime (BIO Intelligence Service 2011).

Implementation of environmental measures is mostly left to the regional or local authorities with the national level often dealing in drawing up general provisions and requirements in waste policy. Thus, the effectiveness of what is done, therefore is highly dependent on the connection with the ordinary, because the funds co-finance policies already in place and trigger new interventions mate to become ordinary. If this connection is missing, the effect becomes more modest.[22]

Moreover, a good implementation of the waste hierarchy can also be hampered by the fear of regional and local politicians that proper waste management strategies of sophisticated waste (involving high percentage of recycling) could lead to higher costs and higher waste fees for their constituents. Economic investments in the waste sector need to result in infrastructure and services that are affordable to operate and maintain for the mid and long term. The crises so appear to be primarily driven by policy failures that include inadequacy or a lack of diversified tools in waste management and a lack of collection infrastructure and processing facilities. (Mazzanti et al. 2006). Another specific problem can also be the inadequacy of waste authorities dealing with recycling. Despite in Italy were created the ATOs (Ambiti Territoriali Ottimali, kind of waste union responsible for the waste disposal), at times they had not got the resources to guarantee proper waste management and had a proven ability to manage and run projects funded by ERDF.

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[21] For ERDF funding, we noted that the operational programme selected did not contain information regarding specific administrative measures.

[22] Even if each ERDF project was individually assessed and approved by the Commission during the 2007–2013 programme period the level of detail concerning supporting measures requested by the Commission from Italy did not in general ensured their existence before the granting of EU funding.

Ultimately, environmental authorities do not have the power of tackling criminal activities that may counteract the implementation of waste management projects. The organised crime effectively competes with the legally empowered authorities or firms (Legambiente 2011; BIO Intelligence Service 2011). This can regard the collection and 'treatment' of waste or conditions the mode of waste management in a certain territory.

In this light, it is possible to deduct that, the primary responsibility of the failure of ERDF to achieve the objective of convergence is addressed to regions, as responsible for the management, the sub-allocation of European funds and monitoring. In other words, the responsibility of the European regulation failure can be attributed to poor functioning of local institutions and their insufficient public and business awareness and commitment. In this regard, our results show that the inefficiency of the recycling process is properly caused by low quality of regional institutions and local authorities.

Our descriptive analysis (Table 3) highlights significant differences between treated and control regions in terms of IQI and its five components. This substantial difference arises clearly from the empirical analysis (SFA results). Since most of the regions belonging to Convergence Objective are among the ones with the lowest institutional quality and as the European Commission decided that in order to receive financial assistance from the regions are obligated to co-finance their projects, meaning that all the supporting payments from the EU are granted on specific management conditions. This implies that the regional institutional capacity to distribute, invest and absorb the EU grants efficiently is an essential determinant of ERDF success and of the European cohesion process but local administrative and managerial problems hampering the institutional activity are even more persistent.

According to a recent Transparency International Europe report on the EU Integrity System (Transparency International Europe 2014) Italy is ranked lowest among all EU Member States and corruption had a negative impact on convergence regions and favours the misallocation of financial means. Deficits in waste management performance were identified and related to all criteria on waste management planning and decrease of municipal waste recycling in the last years. No national statement was submitted on request by the competent authority. In Sicily, the Optimum Territorial Unit's that can hardly come into force, and in Campania—where separate collection in 2007 increased by 25%—the persistent emergency prevented so far from filling the gap between the North and the South (BiPRO 2012).

Environmental policy and separate collection instead need to be conducted within the spirit of properly functioning multi-level governance, combined with an effective set-up for responding to the requests of the public, European objectives, and with transparent and innovative public procurement, all of which is crucial to enhancing the policy's impact; stresses, in this regard, that, notwithstanding the importance of decisions taken at EU and Member State levels, local and regional authorities often have primary administrative responsibility for public investment, and that cohesion policy is a vital tool enabling these authorities to play a key role in the EU. Local authorities here are understood as formal and informal structures guiding the behavior of individuals involved in the implementation of ERDF fund in separate collection.

Based on our analysis hypothesis the institutional quality has a significant impact on the effectiveness of the absorption of ERDF in convergence process, yet EU funded separate collection projects may also have side effects on the quality of institutions. Our results confirm, for example, the presence of a complex relationship between separate collection rate and the rule of law dimension. They demonstrate a positive double causality long-run relationship between the rule of law and separate collection, indicating that as separate collection increases more respect for the rule of law is acquired and vice versa. We also find that rule of law has a negative relationship with environment, confirming that the enforcement of rules is a *conditio sine qua non* to control environmental actions. The reinforcement of the rule of law is essential for controlling the environmental quality actions. Independently of the policies adopted (taxes, subsidies, emission standards, etc.) it is crucial that the rules are clear, applied and enforced. In turn, increasing separate collection does not necessarily call for environmental awareness, that, for some of the countries could mean the weakness of environmental regulations and unenforced rule of law.

Thus, at a time when public funds are so difficult to manage but not to find for projects that can help with much-needed development, it is hard to explain why ERDF is not "flying off the shelf" (Baldwinson 2012). A substantial reason for this failure is that ERDF remains a funding source which is perceived as impossibly hard to work with, and as a very high risk endeavour. The intense complexity of the back office function is widely felt to be unnecessary and counter-productive.

So far, in fact, we have paid attention to the regional administrations' ability to use all programmed funds and to respect the time of interventions. These arguments signal a weakness in regional institutional capacity to manage, monitor and deliver the funds effectively. This is particularly true in southern regions where public administration suffers from many constraints (Arpaia et al. 2009) which have prevented structural funds from being fully successful. In policy terms, it sometimes appears that the key interest at least regionally is focused on negotiating the overall sums involved, but with little or no interest in 'the details', and instead quickly moving on to something else more interesting (Baldwinson 2012).

In this respect, it is worth noticing that the initial poor working of regional administrations in the Convergence Regions has also impeded the building of institutions that, on the contrary, cohesion policy has accelerated in many other parts of Europe. What emerges clearly from the above discussion is that if regional institutions worked better than they have done and if the levels of institutional capacity were higher, the EU resources might have been entirely used and, as a consequence, they would have exerted, held constant, a right impact than that which our estimations revealed. Again, though, the quantity of spending is a necessary but not sufficient condition for EU policies to be effective: quantity cannot be separated from the quality of expenditure. The operational programme selected, in fact, did not contain information regarding specific administrative measures nor any reference to waste disposal taxes or types of waste management tariffs paid by households. The crises so appear essentially driven by policy failures and Italy needs a greater focus on the weaknesses of its institutions and, in this respect, the EU may exert a role in contributing to making local institutions more capable and

accountable. Even if each ERDF project was individually assessed and approved by the Commission during the two programming periods the level of detail concerning supporting measures requested by the Commission from Italy did not in general ensured their existence before the granting of EU funding.

Based on results from previous research on ERDF as well as this relationship between EU Funds and local administrations, hypothesis of this study is that quality of public institutions has a significant impact on the absorption of EU Funds, yet EU funded projects may also have side effects on the quality of institutions. If given the current strategy and policies the EU ERDF Funds indeed has more negative effect on institutional quality (while it is crucial to have good institutions in order to absorb aid), financial support in some cases could be self-destructive: funding might not only be absorbed in an inefficient way as in the case of separate collection, but also the goal of convergence and regional cohesion may be never reached. Consequently, it would be essential to reorganize the way assistance is managed or the way conditions for receiving it are set to avoid the paradox as the well-known "resource course", leading to divergence instead of convergence. This is a very relevant question since regional disparities will be only increasing with the time in case ERDF fund as it is and the way it is distributed now contribute to lower quality of institutions in Italy.

6 Conclusions

The implementation of ERDF on separate collection projects in convergence regions relies on factors such as protection of the environment, risk prevention and optimization of environmental resources with the main aim of reducing the regional structural gap persistent in years. As these resources devoted to environment constitute a very important part of the EU cohesion policy and budget, it has been necessary to closely follow the impact of ERDF on the trajectory of convergence processes during the EU programming periods 2007–2013.

However, in convergence regions, many local public services, including separate waste collection and disposal, are managed without "detail".

They are typically operated by local authorities with tight political connections, if not directly by the local government, usually under EU budget constraints. Local public utilities sharing the above characteristics may be particularly inefficient, due to the interplay of two factors, managerial slack and institutional quality tightly connected with different dimensions like corruption or rule of law.

To that respect, we analyzed data from 2004 to 2013 proposing a groundbreaking analysis that allows us to control both for the effectiveness of the Regulation (EC) No. 1080/2006, by a Difference in differences equation (DID), and the Regions' efficiency in the separate collection process, by a stochastic frontier analysis (SFA). Specifically, the SFA allowed us to model the DID equation in order to take account the regions' efficiency (inefficiency) in the separate collection process in terms of institutional quality. In the light of our results, the ERDF have not had an impact on the rate of separate collection of the regions during the programming period 2007–2013. As ERDF are particularly exposed to managerial slack, especially in the

absence of effective monitoring activities or appropriate absorption scheme, the unorthodox behaviors underpinned, usually perceived as a "social disorder" phenomenon, have triggered not only in the failure of the objective of convergence but also in the institutional quality and consequently in the low efficiency of these regions in the separate collection process.

Appendix

See Table 8.

Table 8 Annual average of efficiency scores, separate collection rate and IQI

Group	Regions	Efficiency	Separate collection rate	IQI
Control region	Piemonte	0.673	45.483	0.696
Control region	Valle d'Aosta	0.196	36.203	0.743
Control region	Lombardia	0.778	46.178	0.759
Control region	Trentino Alto Adige	0.719	53.314	0.836
Control region	Veneto	0.717	53.862	0.703
Control region	Friuli Venezia Giulia	0.890	42.241	0.706
Control region	Liguria	0.149	22.150	0.528
Control region	Emilia Romagna	0.454	40.924	0.709
Control region	Toscana	0.821	34.185	0.879
Control region	Umbria	0.582	29.033	0.698
Control region	Marche	0.449	29.356	0.675
Control region	Lazio	0.211	14.336	0.650
Control region	Abruzzo	0.380	23.343	0.662
Control region	Molise	0.213	9.224	0.302
Treated region	Campania	0.847	22.924	0.333
Treated region	Puglia	0.517	11.824	0.458
Treated region	Basilicata	0.263	11.302	0.454
Treated region	Calabria	0.174	11.070	0.126
Treated region	Sicilia	0.180	7.966	0.257
Treated region	Sardegna	0.545	31.152	0.450

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