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Evaluating waste collection management: the case of macro-areas and municipalities in Italy

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Abstract The purpose of the present paper is to analyse the gap among Italian macro-areas performances in terms of separate waste collection rate and density of separate waste collection. The aim is twofold: (1) to investigate if clear and effective infrastructure policies, in Southern Italy, have been realized that are able to reduce the gap in the separate waste collection process with the rest of Italy and (2) to evaluate if Southern Italian municipalities have improved their operational capacity in the separate waste collection process. In particular, we exploit data collected in 2012 by several Italian sources (ISPRA and ISTAT). We implement a recentered influence function regression technique that allows us to put two macro-areas in comparison (North vs. South and Centre vs. South). This technique, once measured the territorial gaps, allows to disentangle the gap in the two spatial units of analysis (at municipalities level and at macro-areas level). The estimates suggest that while in the North the issue of waste is managed effectively and responsibly with respect to the Southern area, the latter has exhibited an advantage with respect to the Central Italy; furthermore, Southern municipalities appear to be unable to pursue a virtuous

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waste management system generating the persistence of a marked territorial gap in terms of both SCR and DSC. The main policy implications are discussed.

Keywords Waste management · Government policy · Recycling · Selective collection rate · RIF regression

JEL Classification C21 · Q5 · Q53 · R11 · R5 · R52

1 Introduction

Waste management is a prominent indicator of environmental sustainability representing nowadays a public environmental concern. It increased its prominence over years in terms of development and design of separate waste collection schemes and practices, of definition and monitoring of appropriate targets deployment and testing of policy strategies and so on. Simões et al. (2010) focused on environmental context and found significant influence of the gross domestic product per capita, distance to treatment facilities, population density, regulation, type of management, composting and incineration on the solid waste utilities' performance.

In this light, Europe enabled over time, specific regulations regarding the waste management and performance of a country with a view of encouraging a sustainable development. EU waste policy sector has evolved over the last 30 years through a series of environmental action plans and a framework of legislation that aims to reduce negative environmental impacts and create a resource-efficient economy. The EU's Sixth Environment Action Programme (2002–2012) identified waste prevention and management as one of four top priorities. Its primary objective is to ensure that economic growth does not lead to more and more waste. This led to the development of a long-term strategy on waste pursued in the ambitious environment policy, which is now an integral part of the Europe 2020 Strategy for smart, sustainable and inclusive growth. The 2005 Thematic Strategy on Waste Prevention and Recycling resulted in the revision of the Waste Framework Directive (75/442/EEC), the cornerstone of EU waste policy bringing to a modernized approach to waste management marking a shift away from thinking about waste as an unwanted burden to seeing it as a valuable resource.[1] This directive was last amended in 2008 (2008/99/CE), but the definition of waste remained the same (Cruz et al. 2014). The EU authorities realized that the priority of EU funding in the waste sector required to be addressed to targets in decreasing waste volumes, while also rapidly increasing separate waste collection. In addition to EU legislation, the planned framework on separate waste collection has led to the production of national waste management strategies. EU Regional Policy shows, in fact, that the main aim of Italian waste policy is the achievement of a sustainable system based on the EU integrated waste strategy (APAT 2007).

The separate waste collection rate has thus become an imperative practice and a critical environmental issue. For instance, Kinnaman (2006), Martin et al. (2006) and Van den Bergh (2008) showed linkages between waste materials and landfilling in terms of economic costs, health and environmental risks.

[1] The directive introduced a five-step waste hierarchy where prevention is the best option, followed by reuse, recycling and other forms of recovery, with disposal such as landfill as the last resort. EU waste legislation aims to move waste management up the waste hierarchy.

The increasing international concern about waste management and the following research interest has been recognized and systematically reviewed by Simões and Marques (2012) in a literature overview that analyses costs and efficiency of the waste sector. The results that the literature overview figures out are the presence of economies of scale and economies of density while the benefits of the private sector participation in the waste services provision seem to be not widely accepted.

Most of the waste management literature takes households as the main unit of analysis to understand the determinants of separate waste collection. The issue has stimulated a stream of interdisciplinary research (economics, psychology, sociology, engineering, law, to list a few ones).

The interdisciplinary meta-analysis of Hornik et al. (1995) groups the variables affecting separate waste collection into five categories: extrinsic incentives, intrinsic incentives, internal facilitators, external facilitators and Demographic Variables. Among the five meta-factors, the strongest predictors of separate collection turned out to be Internal Facilitators such as consumer knowledge and education. Some External Incentives, such as social influence and monetary rewards, also played a significant role, even if the effect of the latter usually lasts only as far as the incentive is in place, and may even cause motivational crowding out when it ceases (Frey and Jegen 2001).

Barr et al. (2001) developed a conceptual accounting for three predictors: environmental values, situational variables and psychological variables, pointing out that situational variables are significant in shaping separate collection behaviour (more specifically, logistical factors such as the presence of recycling services and facilities). The lack of facilities as a barrier to waste management is a common finding in the empirical literature (Coggins 1994; Perrin and Barton 2001; Omran et al. 2009).

A more recent contribution is the predictors analysis of recycling provided by Miafodzyeva and Brandt (2013) that classify variables affecting separate collection into four groups: socio-psychological, technical-organizational, individual socio-demographic and study specific. In this conceptual accounting, moral norms, information and environmental concerns seem to be the strongest predictors of households' separate collection rate. By moving from this stream of the literature, Crociata et al. (2015) provided a possible estimation of the impact of cultural participation upon households' behaviour within the meta-issue of sustainability, focusing on the cognitive and social determinants of pro-environmental behaviour.

Crociata et al. (2016) go beyond the individual perspective of the household and consider social transmission effects, and in particular socio-spatial ones, to evaluate how separate collection evolves in the society. Moving from the domain of socio-spatial analysis, they found that proximity to socio-spatial contexts characterized by virtuous recycling behaviour could positively influence those living in less virtuous contexts, thereby bringing about pro-social behavioural change.

Spatial pattern analysis highlights a clear degree of performance between regions, and Italy is a paradigmatic case study for stressing this issue. Italy may be categorized under two waste management groups, according to its regional strategy of coping with environmental problems. The first group comprises Northern regions with high levels of waste management and relatively high levels of separate collection. The second group includes Southern regions with low recovery rates, poor waste management infrastructures and relatively low dependence on separate collection (Agovino et al. 2016b).

Even if separate collection rates of municipal waste increased in all the Italian regions and Italy seems to be on the right path to reach the EU recycling target of 50% in 2020, it continues to suffer from huge cross-regional differences: in 2013, the EU separate waste

collection target (up to 40%) was achieved only by 7 out of 20 regions (EEA 2013). In particular, there is a mix of technical–administrative errors and political, industrial and criminal interests that links the regions of Southern Italy to their ineffective waste management system: delays in planning and preparation of suitable landfills; delays in planning and in the construction of incinerators and composting plants; low levels of separated waste collection (see Distaso 2012; Armiero and D'Alisa 2012; D'Alisa and Kallis 2016). Despite the studies carried out, analyses that seek to explain the gap between Southern Italy and the rest of the country in terms of separate waste collection are still few. Therefore, it is important to investigate the causes that have generated the gap among macro-areas and provide useful policy recommendations in order to reduce it.

The assessment of municipal separate waste collection policies in order to analyse their effectiveness among different spatial units is an emerging topic not widely covered in the existing literature, except, to our knowledge, for recent studies by Guerrini et al. (2017), Rogge and De Jaeger (2012) and Expósito and Velasco (2018). All the three studies identify the environmental and operational variables affecting the efficiency and quality of waste collection services by applying a nonparametric method. The first of the three identifies the performance drivers that should be monitored by policymakers and managers in order to improve efficiency and safeguard service quality. The drivers have been clustered as (1) customer features, (2) household features and (3) operational features. The study demonstrates that all variables affect the cost efficiency and as for the policy implications the achievement of the standard of efficiency has a direct impact on household expenditure, since the costs of collection are recovered through citizens' taxes. By moving from the same policy implications, the second of the three studies measures the aggregate performances of the municipalities in the collection and processing of municipal solid waste (MSW) and the partial cost efficiency, i.e. per distinct waste fractions. The third of three studies measures efficiency analysis take into account the mandatory goals of reducing mixed collected municipal solid waste and the augmentation of selective collection of recyclable materials. As for the policy recommendations this final study suggests to plans specific initiatives to encourage public involvement, to raise public awareness regarding the need for selective MSW disposal and recycling, the promotion of technological learning, innovation and development of new recycling and waste management systems and regional plans aim to assure full and convenient access of the population to selective waste collection schemes through selective street-side containers for recyclable materials.

On the basis of the above, the aim of this paper is to understand the driving forces of the municipal separate waste collection in Italy comparatively for its three macro-areas (Northern, Central and Southern Italy). In particular, our empirical framework moves from the recentered influence function (RIF), a regression technique that allows us to put the groups in comparison (North vs South and Centre vs South), in order to evaluate the territorial gaps in terms of performances in separate collection rate (hereafter "SCR") and density of separate collection (hereafter "DSC"). Once measured the gaps, we disentangle them in two spatial units of analysis (at municipal level and at macro-areas level). In this way, we get results both at the macro-area level and at the municipal one. In particular, our analysis will enable us to answer the following questions: (1) have, in Southern Italy, been realized clear and effective infrastructural policies able to reduce the gap in the separate waste collection system with the rest of Italy?; (2) have Southern Italian municipalities improved their operational capacity in the process of separate waste collection? In terms of policy, answering to these two questions will mean verifying whether there has been a convergence process among Southern Italy and Northern/Central areas of the country. In other words, this will show if Southern Italy has carried out effective policies aimed at improving

the separate waste collection performance of its regions reducing, in this way, the gap with the other macro-areas of the country (question 1). Finally, the analysis of the results at municipal level provide useful insights to understand which share of performance gap can be attributed to the waste operative management carried out by municipalities (question 2).

The remainder of the paper is organized as follows. In Sect. 2, we identify the study area and present waste performance indicators and stylized fact connected with them. In Sect. 3, we introduce our econometric strategy. We present our data in Sect. 4. Then, we present our results in Sect. 5. Policy recommendations and concluding comments can be found in Sect. 6.

2 Case study

In this section, we first identify the study area (Sect. 2.1); then, we present the stylized facts associated with the waste performance indicators studied (Sect. 2.2).

2.1 The study area: macro-areas and municipalities

Italy is a unitary parliamentary republic in Europe. Located in the heart of the Mediterranean Sea, it covers an area of 301,338 km^2 and has a largely temperate seasonal and Mediterranean climate. With 61 million inhabitants, it is the fourth most populous EU member state. The country is composed of three macro-areas[2]—North, Centre and South—that are characterized by deep socio-economic disparities that lead to a sharp division between a more developed North and a backward South. In 2012, the GDP per capita of Italy as a whole was 25,991 euro (ISTAT online dataset[3]). The territorial differentials emerge decomposing the analysis by macro-areas. In fact, according to the analysis of GDP in 2012, Northern Italy had an amount of GDP per capita above the national average (31,212 euro)—as well as the Centre (28,848 euro)—while, with a GDP per capita of around 17,400 euro, Southern Italy was very far from the national average. The same differences can be found in demographic characteristics such as population density. In 2012, the population density of Italy as a whole was of 200 inhabitants. Southern Italy was below the national average (167 citizens) and very far from Northern and Central Italy (231 and 208 inhabitants, respectively). Italy has four administrative levels: national, regional, provincial and municipal. Each of them is responsible for waste management (see Agovino et al. 2016b). In particular, the L.D. 152/2006 ("Norms Concerning the Environment", commonly called "Single Environmental Text") defines the tasks of the administrative units responsible for the waste management and the operations of separate waste collection. The Decree establishes an administrative hierarchy that attributes to: (i) the regions the task of planning the waste management process (art. 196); (ii) the provinces the monitoring of the

[2] From a historical and geographical point of view, three macro-areas are identified: the North, the Centre and the South. The North includes Liguria, Lombardy, Piedmont, Valle d'Aosta, Emilia-Romagna, Friuli-Venezia Giulia, Trentino South-Tyrol, Veneto regions. The Centre includes the Lazio, Marche, Tuscany and Umbria regions. The South includes Abruzzo, Basilicata, Calabria, Campania, Molise, Apulia, Sardinia, and Sicily regions. The North covers an area of 120,260 km² with 27,801,460 inhabitants. The Centre covers an area of 58,052 km² with 12,067,524 inhabitants. The South covers an area of 123,732 km² with 20,630,685 inhabitants. In general, the macro-area is an aggregate of regions, each with decision-making autonomy in the planning of the waste management process.

[3] http://dati.istat.it/.

waste collection process (art. 197); (iii) the municipalities the definition and implementation of the operational strategies through which the waste is handled (art. 198). In addition, L.D. 152/2006, besides placing the administrative hierarchy among the competent administrative units, provides that the various administrative authorities cooperate synergistically in the preparation of regional waste management plans. In particular, Art. 196 stipulates that the regions shall set up—*heard the provinces, municipalities and territorial authority*—regional waste management plans. We can conclude that the success of waste management (landfill reduction and increase in separate waste collection) does relate not only to the definition of standards, but also to the capacity of local administrative authorities to communicate and cooperate in order to achieve their goals.

Although there are many areas of the country characterized by good performances in waste management (i.e. Northern Italian regions), there are central and southern regions characterized by a particularly critical profile in the waste management process.[4] The problem of backwardness of Southern Italy emerges not only in the economic variables but also in the waste management process (see Agovino et al. 2016c, 2017b). The problem of non-convergence between Southern Italy and the rest of the country has also been taken into account by the European Union authorities by the allocation of funds in order to reduce the gap between the country's macro-areas. In the specific case of separate waste collection, empirical analyses conclude in a failure of the European Regional Development Fund (ERDF hereafter) to reduce the gap between South and the rest of Italy in terms of the percentage of separate waste collected (see Agovino et al. 2016a, 2017a). The cause of this failure relates to the lack of clear and structured policies in this area of action: a credible long-term infrastructural policy, beyond mere the endless lists of works contained in the structural measures guidance. This means that often structural funds programmes draw actions that are badly connected to national or that must be implanted from scratch—with the connected load of delays and uncertainties (Agovino et al. 2016b, c, 2017b).

Another final consideration deserves municipalities as important administrative unit to be investigated in the separate waste collection process. Municipalities are the main actors involved in waste management operations (art. 198). In particular, since municipalities have the task of collecting waste through firms owned by themselves or through private firms participating in a tender, local inefficiencies and the level of managerial culture could impact on waste performance too, as pointed out by other research (Mazzanti et al. 2011; Greco et al. 2015). This makes the municipality the ideal study unit. Few studies have been conducted on separate waste collection on Italian municipal data. In particular, Sarra et al. (2017) investigate environmental and cost performance in municipal waste management systems. This interesting study is limited to the municipalities of Abruzzo (Southern Italian region). In order to reduce this gap in the empirical literature on waste management in Italy, we consider in our analysis not only data at the macro-area level but also data at the municipal level.

2.2 The waste performance indicators and stylized facts

In line with Guimarães et al. (2010), we introduce some waste performance indicators in order to compare the Italian macro-areas. In studies on separate waste collection, the most studied indicator is the separate collection rate (SCR), which represents the percentage of

[4] http://ec.europa.eu/environment/waste/framework/pdf/IT_SOUTH_Roadmap_FINAL.pdf.

municipal waste separately collected on the total municipal waste generated (SCR = $\frac{SC}{WG}$) (see Agovino et al. 2016b, c, 2017b).

D'Alisa et al. (2012) proposed the following relationship:

$$\frac{WG}{KM^2} = \frac{WD}{KM^2} + \frac{SC}{KM^2} \quad (1)$$

where WG, SC, WD and KM^2 are: waste generated, separate waste collection, waste disposed and square kilometres, respectively. By starting from this relationship, the authors identified the following indicators: (i) DWG = $\frac{WG}{KM^2}$, the density of waste generated; (ii) DWD = $\frac{WD}{KM^2}$, the density of waste disposed or the amount of waste not separately collected; (iii) DSC = $\frac{SC}{KM^2}$, the density of separate collection. D'Alisa et al. (2012) suggested the use of DSC as complementary indicator to SCR because it offers a measure of the demographic pressure that the observed phenomenon exerts on the territory. In other words, the two indicators (SCR and DSC) provide different and interesting information for policy makers. In particular:

SCR (separate collection rate) This index captures the effect of the joint action of the citizens and the authorities responsible for the separate waste collection. It is a measure of the pro-environmental attitude that binds the two actors involved (citizens and local governments). In particular, the action of the citizen and his/her sensitivity on environmental issues is captured. A municipality in which citizens with a pro-environmental attitude are living should be characterized by high differentiated collection rates and low waste generated rates. In practice, in this municipality we should observe an increase in the index numerator and a reduction in its denominator. In this case, one could speak of the prevalence of the intrinsic motivation on the extrinsic one (see Cecere et al. 2014; Lemos and Verissimo 2014; Hung et al. 2011; Tonglet et al. 2004). On the contrary, if an increase in separate waste collection is followed by an increase in the waste generated, it will be also possible to speak of the prevalence of the extrinsic motivation on the intrinsic one. In this case, the separate waste collected increases but less than proportional to the waste generated. In other words, the extrinsic motivation allows us to conclude that citizens do separate waste collection only to be "appreciated by their neighbours". The separate waste collection requires that waste is disposed in bins arranged and collected outside the houses and this generates visibility from neighbours generating appreciation (judgment) by the action accomplished. On the contrary, for the waste generated, produced and handled inside the houses, there is no possibility of a judgment expressed by the neighbours because it is a private action. Citizens actions are not visible from outside during waste production, and there is no obligation to prove to someone that they have predisposition to pro-environmental behaviour (which is different in the case of separate waste collection). In conclusion, if during the production of waste, the citizen is driven by an intrinsic motivation, in addition to do the separated collection he/she will also take care to reduce the waste generated; whereas, when there is an extrinsic motivation, the separate collection and the waste production increase both.

DSC (density of separate collection) This index is a measure of the separate waste collection methods carried out by the municipalities. It takes into account technological and economic possibilities of the municipalities to implement a type of separate waste collection process (D'Alisa et al. 2012). A high index provides information on the method of separate waste collection implemented by municipalities (e.g. door-to-door, new technologies applied to the separate collection process). This index reflects the

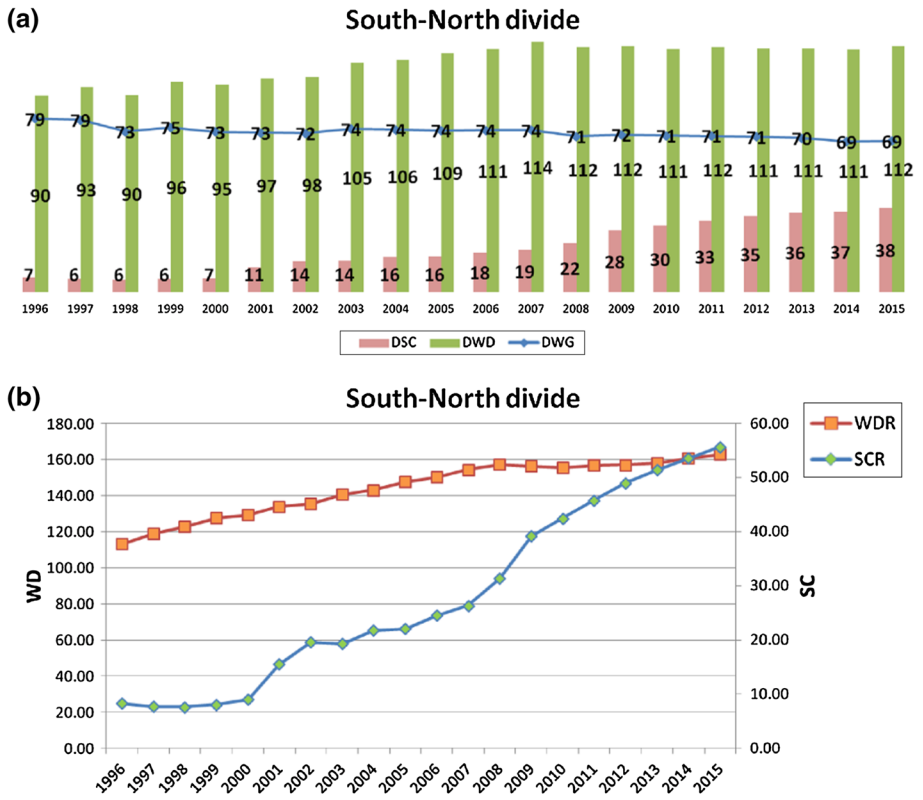

Fig. 1 South–North divide, 1996–2015. *Source*: Our elaboration on ISPRA data; **a** DSC, DWD, DWG variables; **b** WDR and SCR variables

specific action of local institutions in facilitating the separate waste collection process. Higher is DSC, lower will be the density of waste disposed (see Eq. 1).

Figure 1a shows that the dichotomy in terms of density of waste generated $((DWG^{South}/DWG^{North}) * 100)$ between North and South Italy has decreased by 10% (from 79% in 1996 to 69% in 2015). In addition, the density of separate collection $((DSC^{South}/DSC^{North}) * 100)$ in Southern Italy has increased over the years but continues to be low: in 2015, it is just 38% of that in Northern Italy. Unfortunately, the density of waste disposed (DWD) of Southern Italy shows a growing trend compared to one recorded in Northern Italy (from 90% in 1996 to 112% in 2015). Figure 1b shows slightly more positive results but partially confirms what is shown in Fig. 1a. In particular, the gap between North and South in terms of separate collection rates $((SCR^{South}/SCR^{North}) * 100)$ is much lower; In fact, the SCR of South Italy in 2015 is about 55% of that in Northern Italy. Waste disposed rate (WDR) shows a growing trend that tends to stabilize in 2007 and showing a value of 160%. Figure 2a shows the dichotomy between South and Central Italy. In particular, it emerges that Southern Italy is well placed in terms of DSC compared to Central Italy, but the gap is still important. In addition, the South has almost the same amount of DWD of Central Italy. (In 2015, the DWD is 95%.) Even in this case, when we consider SCR and WDR, the results are a bit different. In 2015, the SCR of Southern Italy is about 75% of

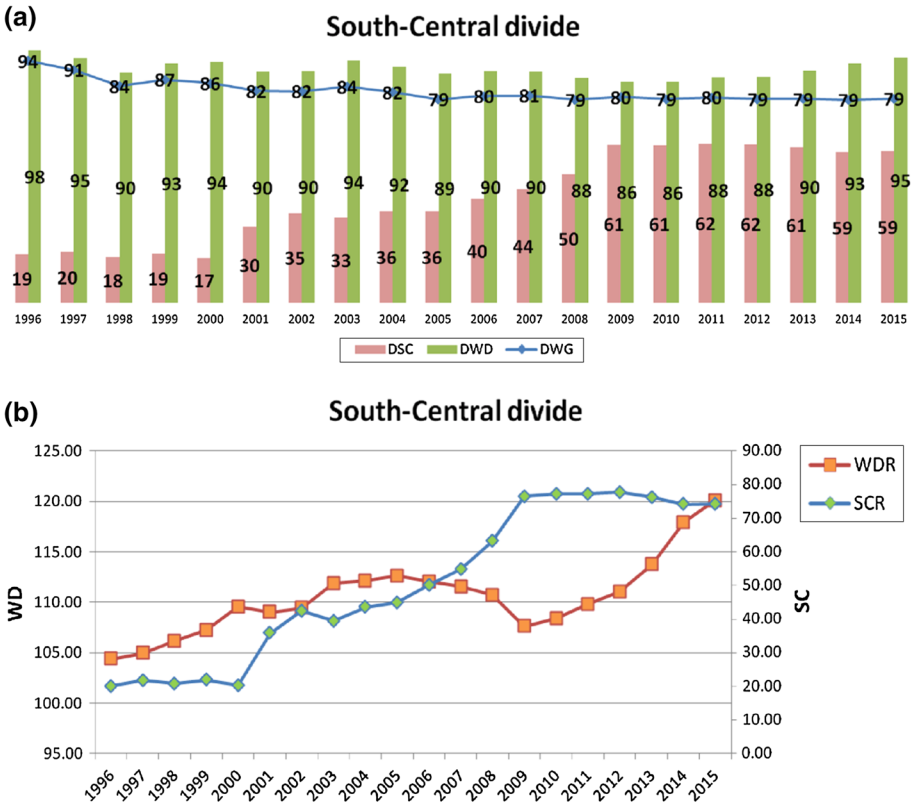

Fig. 2 South–Central divide, 1996–2015. *Source*: Our elaboration on ISPRA data; **a** DSC, DWD, DWG variables; **b** WDR and SCR variables

SCR of Central Italy. In addition, WDR reaches its minimum in 2009 but shows a growing trend since 2009 onwards (Fig. 2b). We conclude by showing data for Italian municipalities and referring to 2012 (reference year of our study). Figure 3a, b, c shows that the municipalities that in the North West of Italy have a high DSC and also have high density of waste generated (DWG) and DWD; Conversely, some municipalities in the North–East of Italy have more efficient waste management systems (the municipalities of the Veneto region) and are characterized by high DSC and low DWG and DWD. Conversely, the municipalities of Central and Southern Italy have low DSCs; in particular, the municipalities of the Lazio (Central Italy) and Sicilian Regions (Southern Italy) are characterized by high DWG and DWD. Finally, Fig. 3d, e provides clearer information about SCR and WDR. In particular, the municipalities in North–East Italy confirm their virtuosity, while the municipalities of Central and Southern Italy are characterized by waste management problems (low SCR and high WDR), in line with the document of the European Commission "Roadmap for South Italy". The Campania Region is a positive exception; the region shows, in fact, a good improvement in the waste management process.

These results show that South Italy has improved its waste management system of separate collection, but there are still important structural problems that need to be addressed (high DWD and DWG, low DSC); citizens seem to be more aware of separate waste

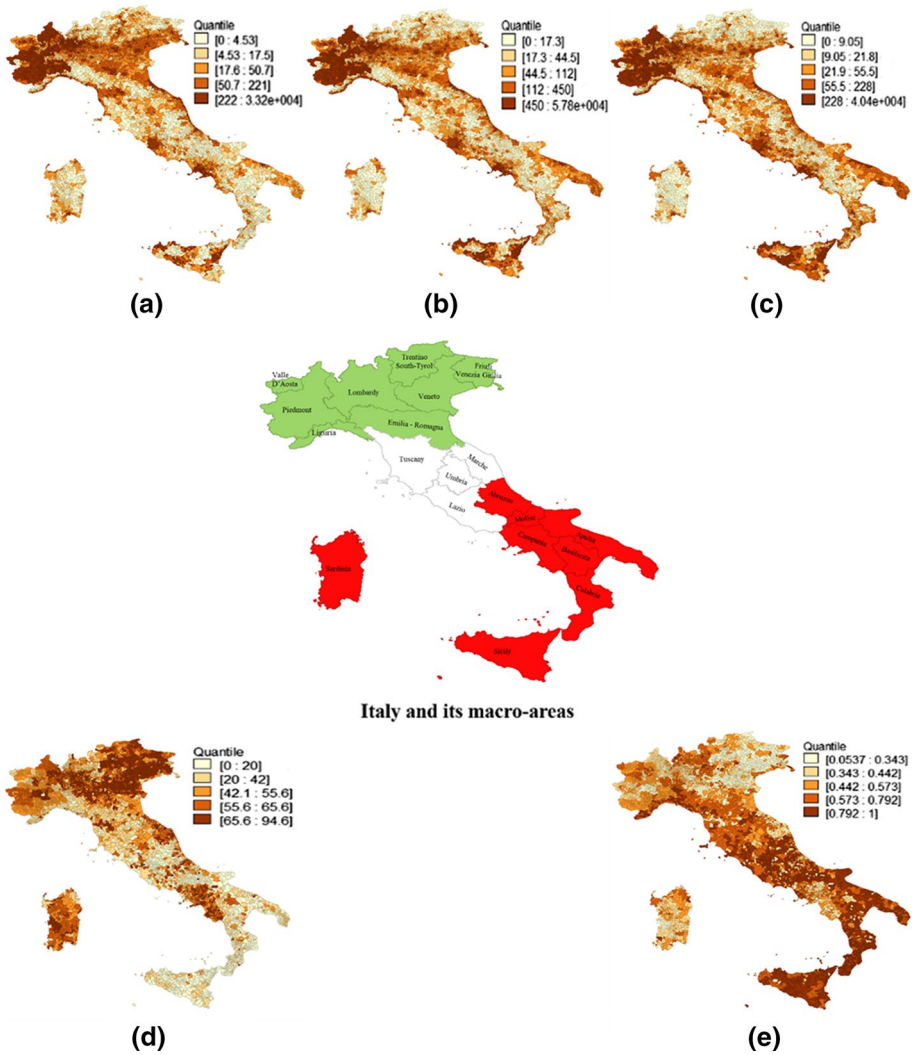

Fig. 3 DSC, DWD, DWG, WDR and SCR at municipal level, 2012. *Source*: Our elaboration on ISPRA data; **a** DSC, **b** DWG, **c** DWD variables on top; **d** SCR and **e** WDR variables on bottom

collection but still produce too much waste diverted to landfill (increasing SCR levels but WDR remains high). There are obvious problems related to the lack of concrete and targeted policies. The European Union has provided a number of recommendations and directives that can be summarized in the three following points: (1) high priority level in the waste management hierarchy to recycling and reduction of waste disposed to landfills; (2) increase in the landfill tax which in Southern Italy is very low and this encourages the abuse of landfills; (3) introduction of the "pay as you throw" (PAYT) scheme[5] in order

[5] The PAYT approach is an economic fee allocated according to the amount of waste collected in order to motivate separate waste promotion or recovery giving a contribution towards material reuse and recycling objectives for the new circular economy.

to prevent waste generation and achieve the separate waste collection targets provided by the Legislative Decree 152/2006 (Cruz et al. 2014); The realization of these measures and the presence of awareness-raising campaigns on environmental issues will enable a more active participation of citizens in the process of separate waste collection and reduction of waste generation.

3 Empirical strategy

The empirical strategy is based on the recentered influence function (RIF) regression (Firpo et al. 2007, 2009; Fortin et al. 2011) that is a multistage procedure belonging to the decomposition methods family. These methods are extensively used with the purpose of study the differences between two groups in some topics of labour economics, as income inequality or pay gap, in time or space perspectives (see Castellano et al. 2017, 2018; Heckley et al. 2016; Garofalo et al. 2017). In this work, we attempt to use the RIF regression in the framework of waste management with the main aim of evaluating the territorial divides considering the role and the responsibilities of macro-areas and municipalities in a hierarchical structure, in the separate collection rate (SCR) and density of separate collection (DSC) performances, separately. Thus, we believe that this methodology well suits to the objective of our study because RIF enables to identify the leading determinants that drive the territorial gaps in SCR and DSC (in both *intensity* and *inequality* viewpoints).

Methodologically, the SCR and DSC (the dependent variables, Y, to be investigated) are replaced with the RIF of the generic distributional statistic of interest (mean and Gini index). The RIF regression equation is defined as follows:

$$\mathrm{RIF}_g(Y;v) = \mathrm{IF}(Y;v) + v \quad \text{for } g = A, B \tag{2}$$

The groups (g) are composed of municipalities located in Southern Italy ($g = A$) and those in Northern (or Central) area ($g = B$). IF is the influence function of the distributional statistic, which measures the relative effect of a small change in the underlying outcome distribution on the statistic of interest (Hampel 1974). Lastly, v is, alternatively, the mean or the Gini index.[6] Grouping the explanatory variables by macro-factors, we can describe the models as follows:

$$\begin{aligned} &\mathrm{RIF}_g(\mu) \text{ or } \mathrm{RIF}_g(\mathrm{GC}) \text{ on } \log \text{ SCR (DSC)} \\ &= \alpha_g + \beta_{1g} \log(\text{geographic}) + \beta_{2g} \log(\text{demographic}) \\ &\quad + \beta_{3g} \log(\text{socio-economic}) + \beta_{4g} \text{ institutional quality} + \varepsilon_g \end{aligned} \tag{3}$$

[6] Further methodological details can be found in the works of Firpo et al. (2007, 2009) and Fortin et al. (2011). In these works, the RIF for some distributional statistics has been introduced. Focusing on mean and Gini coefficient, the RIF, in the mean case, is:

$$\mathrm{RIF}(Y;v^{\mu}) = \lim_{\varepsilon \to 0} \frac{\left[(1-\varepsilon)\cdot\mu + \epsilon \cdot y - \mu\right]}{\epsilon} + \mu = y$$

for the Gini coefficient is:

$$\mathrm{RIF}\left(y;v^{\mathrm{GC}}\right) = 1 + 2\mu^{-2}R\left(F_y\right) - 2\mu^{-1}\left[y\left[1-p(y)\right] + \mathrm{GL}\left(p(y);F_y\right)\right].$$

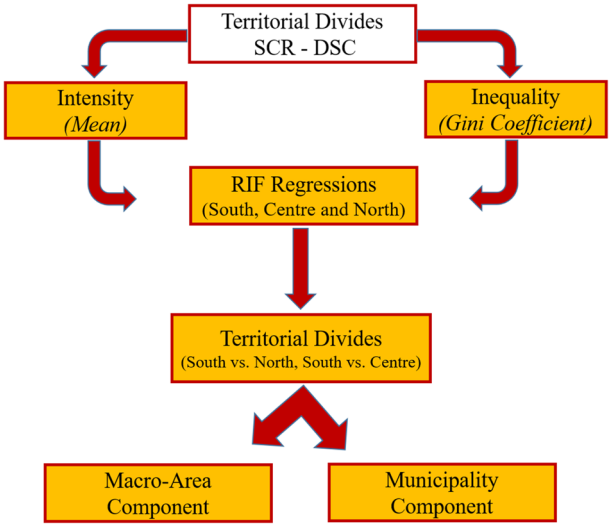

Fig. 4 Graphical representation of empirical strategy

Once the estimates of mean and Gini coefficient have been obtained, the territorial divides are decomposed into the macro-area and municipality components. In general, for $v =$ mean or Gini coefficient, we have:

$$\Delta_o^v = v_B - v_A = \left(v_B - v_C\right) + \left(v_C - v_A\right) = \Delta_{MA}^v + \Delta_M^v \tag{4}$$

v_c is the counterfactual distribution and the key term for decomposing the total SCR and DSC gaps. It represents the distributional statistic that would have prevailed if municipalities observed in the macro-area A had the same structure as those in the macro-area B. Intuitively, Δ_{MA}^v and Δ_M^v are the macro-area and municipal components, respectively. Finally, RIF allows computing the two components by covariate to quantify their contribution to territorial divides. Figure 4 describes graphically our empirical strategy.

4 The data and descriptive analysis

Our empirical analyses are based on municipalities data collected in 2012 by several Italian sources. The dependent variables are the separate collection rate (SCR) and density of separate collection (DSC). The SCR is calculated as the ratio of tons of separate waste to total tons of municipal waste produced. The DSC is calculated as ratio between waste separately collected and square kilometres of area. The yearly waste report of Italian Institute for Environmental Protection and Research (ISPRA) is the source of the dependent variables. This report provides a very rich set of waste data including information on production, management, packaging of urban waste and information on separate waste collection at national, regional, provincial and municipal levels. To analyse the driving forces of the separate waste collection, we merged the data on SCR and DSC with a set of covariates taken from the 2011 census conducted by National Institute of Statistics (ISTAT). These covariates concern, in particular, some geographic/demographic, socio-economic, and institutional quality factors identified by the literature.

Geographic/demographic variables are commonly used in the literature as factors that potentially may affect waste management and its costs. A first potential factor that may

affect the SCR (DSC) is the *overall surface area*, which refers to the square kilometres of the entire municipality. The influence of this variable on SCR (DSC) is ambiguous. In fact, if it increases, then the collection costs decrease through the presence of economies of scale (Domberger et al. 1986; Simões et al. 2012); however, larger areas may render the SCR (DSC) activities costlier due to the service inefficiency (Stevens 1978; Callan and Thomas 2006). In the same way, the *elevation above sea* may make the SCR service more difficult influencing its operational complexity and, thence, its costs (Sarra et al. 2017). *Population density* is the ratio between the total population and total square kilometres of municipality. It may control for different land values and for economies of scale in waste management (D'Amato et al. 2015; Mazzanti et al. 2008). *Metropolitan area* is a dummy variable with 1 if the municipality belongs to a metropolitan city and 0 otherwise. They were imposed by the Law 56/2014, which defined fourteen metropolitan cities in Italy. In this work, we have four metropolitan cities in Northern Italy, three in Central Italy and seven in Southern Italy. They are included in our analysis because the size of municipality could make harder the separate waste collection process (Fiorillo 2013).

Turning to socio-economic variables, many researchers argue that *education* has a strong link with efforts in SCR (DSC) because higher educated people have higher environmental values devoting more attention to the future time (Schultz et al. 1995; Callan and Thomas 1997, 2006; Hage and Söderholm 2008). In this work, education is expressed as the rate of young people (aged 19–34) who concluded upper-secondary education. Also the rate of *couples with children* is a proxy of the pro-environmental attitude and the participation in the separate waste collection process of the citizens. It is calculated as the ratio between the number of couples with children and the total number of couples. Through this variable, we capture the parents' wish to keep the environment in the best possible conditions for their children. In other words, it measures the altruistic values that represent the basis of the altruism theory of Schwartz (1977). This theory assumes that pro-environmental actions increase when people care about the other people's wellbeing and, at the same time, people become responsible for increasing this wellbeing. Many studies show that altruistic people are more likely to take part in pro-environmental behaviours (see, among others, Stern et al. 1995; Corraliza and Berenguer 2000). Labour market characteristics may influence the opportunity cost of time devoted to waste management efforts (D'Amato et al. 2015). To capture this aspect, we have considered the *unemployment rate,* which may encourage the pro-environmental behaviour because the opportunity cost of the time spent to differentiate the garbage is likely to be lower for unemployed people (Hage and Söderholm 2008). This variable involves those people, aged 16–64, that were unemployed in 2011. As one of the main economic drivers, we have considered the *value added per capita* at provincial level. It is considered one of the best proxies of the economic prosperity (Mazzanti et al. 2008) and one of the main drivers involved in the waste management process (Mazzanti et al. 2009; D'Amato et al. 2015; Agovino et al. 2017b).

The *Institutional Quality Index* (IQI), which is inspired to the World Governance Indicator (WGI) proposed by Kaufmann et al. (2010), represents a measure of the Italian institutional quality. This variable assumes values in the range [0, 1], and it is a composite indicator obtained by the combination of five dimensions of institutional quality: voice and accountability, government effectiveness, regulatory quality, rule of law and corruption (Nifo and Vecchione 2014). Each dimension is build up by the combination of several elementary indexes. More in detail, *voice and accountability* capture the citizens' participation to political, social and cultural life (e.g. public elections, the number of associations and of social cooperatives, number of books published or purchased in bookshops). *Government effectiveness* measures the endowment of social and economic structures in Italian

provinces and the administrative capacity of their governments in relation to policies concerning health and environment. *Regulatory quality* evaluates the ability of local administration to promote and protect business activity (e.g. indicators of business environment, business density and business mortality). *Rule of the law* summarizes the data on crime against the person or property (e.g. tax evasion and shadow economy), while *corruption* measures the criminality against the public administration and the corruption level through the Golden–Picci index [for any further details on the construction of IQI, see Nifo and Vecchione (2014)]. The importance of introducing IQI is due to the relevant role that local institutions (e.g. regions and municipalities) play for the success or failure of the waste management process (Agovino et al. 2017b). According to Mazzanti and Zoboli (2008), policy failure, in terms of waste management, was a leading determinant of the waste crises that involved some Italian regions; the Southern Italy regions were the most affected. In other words, the differences in quality of the local institutions might be able to explain an important part of the SCR (DSC) divides among the macro-areas of Italy. The descriptive analyses of the explanatory variables are shown in Table 1 and in Fig. 5 (in "Appendix").

5 Results

We perform a two-step analysis with the aim of exploring the separate collection rate (SCR) and density of separate collection (DSC) divides among the Italian macro-areas. In the first step, as macro-area of reference, Southern Italy is compared with Northern and Central areas, alternatively, in order to consider both *intensity* (size of gap) and *inequality* dimensions (Sect. 5.1). In the second step, we analyse the determinant of the territorial gaps through the evaluation of macro-area (Sect. 5.2) and municipality (Sect. 5.3) components.

5.1 The overall territorial divide

The dual perspective of analysis allows to provide evidence of the territorial disparity in terms of *intensity* (mean levels) and *inequality* (distribution of SCR/DSC across municipalities within the macro-areas). The territorial divides are shown in Table 2, and each overall gap is obtained as the sum of the macro-area and municipality components. In more detail, we describe what the two component represent. The macro-area effect measures the capacity of local institutions to carry out waste management policies able to lead a convergence among the several Italian macro-areas. Historically, Italy has been characterized by deep socio-economic differences among Northern, Central and backward Southern areas. These differences are also observable in the waste management framework and the different performances among the macro-areas, in terms of separate waste collection (as well as waste management in general), are relevant issue for the country. In the last years, the Southern area was unable to carry out clear and effective waste management policies able to narrow these differences with the rest of Italy (see Agovino et al. 2016a, 2017a for the failure of ERDF funds). In other words, the effect on the macro-area allows us to investigate if waste management, 6 years after the Legislative Decree 152/2006 and almost at the end of renewed programming period (2007–2013) of the ERDF funds, has been improved in Southern Italy and if there has been a process of convergence among the macro-areas investigated.

Table 1 Descriptive statistics for the outcome and explanatory variables. *Source*: Our elaboration on ISTAT data

	North				Centre				South			
	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD
Outcome variables												
SCR	0.2	89.71	54.74	16.90	0.1	89.05	32.37	21.43	0.001	94.63	32.46	23.67
DSC	3.40	3.32e+07	833,365	2,276,736	0.47	887,997.8	39,008.63	78,225.56	1.76	1.36e+07	96,963.3	486,750.5
Geographic/demographic												
Overall surface	0.14	653.82	26.53	33.47	1.74	1287.35	58.81	73.07	0.12	593.93	48.411	58.28
Elevation ab. sea	0	2035	335.36	318.81	1	1070	355.27	222.81	1	1433	397.95	280.22
Population density	1	7601	315.33	544.82	3	3500	191.83	301.71	3	12,224	312.45	846.9
Metropolitan area	0	1	0.13	0.34	0	1	0.16	0.37	0	1	0.19	0.39
Socio-economic												
Education rate	16.67	100	61.17	8.42	38.56	88.14	68.41	6.82	32.76	96.23	67.28	9.57
Unemployment rate	0.64	20	6.25	2.18	2	25.2	9.74	3.67	1.43	42.18	17.29	5.79
Couples with children	0.10	0.85	0.59	0.07	0.22	0.86	0.60	0.05	0.22	0.87	0.65	0.06
Value added per cap	2063	44,959.9	26,370.9	4262.3	6485.42	32,370.3	22,970.11	5237.3	12,493.6	22,203.7	16,379.21	2589.4
Institutional quality												
IQI	0.42	0.87	0.71	0.07	0.52	1	0.72	0.12	0	0.85	0.37	0.20

Before clarifying the meaning of the municipality effect, it is important to keep in mind that the municipalities are the lowest Italian administrative unit level in the field of the waste management (Art. 198 of L.D. 152/2006). Through this component, we compare the operational management of local government according to the directives of the higher administrative levels. Thus, municipality effect explores how much of the gap is due to the action of the municipal governments in turning the national and regional plans into operational strategies of separate waste collection.

In Sect. 2.2, we have introduced the dependent variables of the analyses: SCR and DSC. Shortly, the SCR explains the consequences of the action carried out, at the same time, both from citizens and from the authorities responsible for SCR. In this way, it is possible to evaluate their environment friendly attitude. The DSC measures the different methods of separate waste collection implemented by municipalities. This variable takes into account the technologies and the economical possibilities that municipalities have to implement a particular method of separate waste collection.

Regarding the analyses based on SCR, South Italy is the worst performer in waste management in both territorial comparisons (*South–North* and *South–Centre*). The analysis on *South–North* divides highlights how macro-area component plays a leading role in determining the better results of the Northern area. The best waste management performance of the municipalities in North Italy comes out only in the *intensity* comparison. (Municipality component is not statistically significant in the case of Gini index.) More surprising are the results of the comparison between *South* and *Centre*, in which despite that the overall gaps reward the Central area, the macro-area component is in favour of the Southern Italy (in both *intensity* and *inequality* comparisons). The distance between *South* and *Centre* is generated exclusively in the municipality component. It means that the regional waste management performances of the Southern regions may be more successful than those in the Central area, but this advantage is completely influenced by the implementation step carried out by municipalities.

The analysis on DSC confirms the results obtained in SCR-based explorations although two remarkable differences emerge in *inequality* comparison. Firstly, in *South versus North,* the overall territorial divide is due to the macro-area component (similar to SCR case), but municipality component rewards the Southern area. It might mean that the majority Southern municipalities tied to close the gap with respect to the most virtuous ones and to implement best practices in order to increase the sorting of municipal waste.[7] The main separate collection systems operated in Italy are door-to-door collection, bring points and mixed-integrated systems (a mix of door-to-door and bring points). The most common method has been the adoption of the door-to-door collection. In fact, the 39.53% of the Italian municipalities have set up a door-to-door system, 14.27% have a bring point system while 45.95% maintain a mixed system (BiPRO 2012). Secondly, in *South versus Centre*, both municipality and macro-area components contribute to create the Centre's advantage (while in SCR analysis this advantage is explained only by municipality component). In terms of DSC, the results suggest a higher variability of the separate collection methods used by Southern municipalities with respect to those used in the Central area. Inequality results, according to DSC, could be interpreted in this way: on the one hand, just few municipalities implement more efficient but expansive SCR methods. On the other

[7] Efficacy of kerbside schemes is reported in many municipalities even in Southern regions with separate collection rates of 65–70% and more (e.g. Salerno and pilot neighbourhoods in Naples, achieving 70%) (BiPRO 2012).

Table 2 RIF decomposition of mean and Gini on log-SCR and log-DSC. Territorial divides, 2012

	Measures	Mean	Gini coefficient
SCR rates comparison			
South versus North	Total divide	−1.020*** (0.028)	0.183*** (0.006)
	Macro-area component	−0.194*** (0.041)	0.167*** (0.026)
	Municipality component	−0.825*** (0.359)	0.016 (0.259)
South versus Centre	Total divide	−0.176*** (0.047)	0.049*** (0.011)
	Macro-area component	0.952*** (0.109)	−0.054*** (0.019)
	Municipality component	−1.129*** (0.105)	0.103*** (0.016)
DSC comparison			
South versus North	Total divide	−2.250*** (0.057)	0.030*** (0.002)
	Macro-area component	−0.596*** (0.193)	0.055*** (0.009)
	Municipality component	−1.653*** (0.192)	−0.024*** (0.008)
South versus Centre	Total divide	−0.148* (0.077)	0.028*** (0.003)
	Macro-area component	1.018*** (0.119)	0.014** (0.006)
	Municipality component	−1.166*** (0.125)	0.014** (0.005)

*Significant at 10%; **significant at 5%; ***significant at 1%, standard errors in brackets

hand, older waste infrastructures, that are less environment friendly, are still very used by the local administrations. In addition, inequality is an important topic because it may have impact on the use of the funds. (One of the problematic consequences related to the lack of monitoring of these funds is the fact that it does not allow to understand their final destination and use.) Governance and capacity issues a particular hurdle in Italy that faced difficulties in making quick use of cohesion policy funds for waste: at end of 2011, only 56% of funding allocated to infrastructural projects (vs. 75% for overall cohesion policy) (EC 2010). The development of infrastructure, in fact, despite seems to be dynamic in our years' analysis faced obstacles related to funding, administration and public omissions. Data suggest that only 3/4 of the planned waste infrastructures' projects started. Separate collection and sorting are still challenges in Southern Regions. In the 2007–2012 were financed from the ERDF of approximately 109 projects for a total amount of 20,779,516.32 million Euros, but only 1/4 have been concluded.[8] Authorities, political and administrative leaders of these interventions do not intervene in the discussion by providing us useful data for a more motivated evaluation. The discussion assumes failures as a postulate that requires no demonstration (ECA 2012).

In sum, based on the analyses conducted, we are able to draw the following guidelines: (i*)* the results of the macro-area component comparison are heterogeneous: while in the North the issue of waste is managed more carefully with respect to the Southern area, the latter has exhibited an advantage with respect to Central Italy (especially in SCR-based analyses); (ii*)* Southern municipalities appear to be unable to pursue a virtuous waste operational management system (as defined by Art. 198 of L.D. 152/2006) compared to their counterpart of the rest of the country.

[8] http://www.opencoesione.gov.it/progetti/?q=RIFIUTI&territorio_com=&territorio_prov=&territorio_reg=&selected_facets=is_pubblicato:true.

5.2 Macro-area comparison

As discussed in Sect. 5.1, the effects of this component are heterogeneous. Despite some differences, our analyses highlight that Northern area has a better position with respect to the Southern one while in this latter area the cooperation is more successful than in Central Italy. In this section, we investigate the main determinants that drive the macro-area divides.

The contribution of covariate to macro-area and municipal components, comparing the *South* with the *North*, is shown in Table 3 (SCR) and in Table 4 (DSC). It is remarkable that socio-economic and institutional quality factors play a leading role in explaining the different levels of waste management that exist in the two areas of country. The analysis of socio-economic factors (in both SCR and DSC studies) highlights how the *value added per capita* is one of the main factors in favour of Northern area. Many empirical studies argue that separate collection and prosperity of a region are positively correlated (Callan and Thomas 1997; Di Vita 1997; Berglund and Söderholm 2003). The advantage of the richest North (Table 1) may mean that a good level of economic wellbeing can lead to more expensive methods (Agovino et al. 2017b), and consequently, it can increase the share of separate waste collection (e.g. door-to-door collection). Thus, in areas with weaker economies, as those in Southern Italy, good performances of waste management may be difficult. The use of waste management methods less performing (information captured by DSC study) could be compensated by persuading people to differentiate, by leveraging on their intrinsic motivation and pro-environmental behaviour. The results of the SCR analysis show that, on the one hand, citizens of South Italy still perceive the separate waste collection as an inconvenient and less attractive activity and, on the other hand, the waste management authorities have failed in encouraging the pro-environmental attitude of their residents.

Institutional quality variable gives us information about the virtuosity of the local management in public affair. In this work, we consider IQI as a proxy for good waste management in the three macro-areas covered. As expected, in the comparison between *South* and *North*, this factor favours Northern Italy. The weakness of the institutions is a historical issue of Southern Italy that has allowed the proliferation of the illegal activities, especially in waste management field (D'Alisa et al. 2010). Because of the opacity of the local political actions, in the context of the Southern Italy, it is difficult to trace the flows of funds used for the implementation of separate waste collection, which helps the increase of private interests with speculative purpose (Infante and Smirnova 2009).

Moving on comparison between *South* and *Centre*, it is noteworthy that macro-area component favours the Southern Italy. The results of both SCR (Table 5) and DSC (Table 6) analyses highlight that this advantage is explained by some *demographic* (in particular, metropolitan area) and *socio-economic* (e.g. education rate, unemployment rate, couples with children) determinants. Regarding the metropolitan area factor, our results suggest that the widest number of big city in the Southern Italy (7 and 3 metropolitan areas in Southern and Central macro-areas, respectively) facilitates the waste management of the area. In some way, the presence of highest number of metropolitan areas may reflect the presence of economies of scale in the separate waste collection process reducing waste management costs (Domberger et al. 1986; Bello and Szymanski 1996). Thus, the results of the DSC-based comparison suggest how the local governments of the metropolitan areas are able to provide more expensive waste management methods. The *socio-economic* variables are linked to pro-environmental behaviours (education rate, couples with children)

Table 3 RIF decomposition of mean and Gini on log-SCR by each variable. South versus North, 2012

	Mean		Gini index	
	Macro-area component	Municipality component	Macro-area component	Municipality component
Geographic/demographic				
Overall surface	−0.485 (0.761)	−0.269*** (0.022)	−0.227 (0.165)	−0.017 (0.035)
Elevation ab. sea	0.250* (0.137)	−0.021*** (0.002)	0.013 (0.033)	0.002 (0.002)
Population density	−0.285 (1.091)	0.111*** (0.017)	−0.471 (0.304)	0.013 (0.016)
Metropolitan area	0.171** (0.066)	0.006*** (0.001)	−0.101*** (0.030)	0.002** (0.001)
Socio-economic				
Education rate	1.201 (0.770)	0.238*** (0.004)	−0.879*** (0.196)	−0.024*** (0.005)
Unemployment rate	−0.715*** (0.209)	0.044*** (0.015)	−0.105*** (0.035)	−0.064*** (0.019)
Couples with children	0.462 (1.317)	0.169*** (0.020)	0.434 (0.325)	0.010 (0.022)
Value added	−12.459*** (2.063)	0.150*** (0.025)	1.518*** (0.564)	−0.104*** (0.026)
Institutional quality				
IQI	−0.039** (0.015)	−1.041*** (0.035)	0.010*** (0.002)	0.198*** (0.013)
Constant	−10.274*** (2.254)	–	−0.023 (0.588)	–

*Significant at 10%; **significant at 5%; ***significant at 1%. Standard errors in brackets

Table 4 RIF decomposition of mean and Gini on log-DSC by each variable. South versus North, 2012

	Mean		Gini index	
	Macro-area component	Municipality component	Macro-area component	Municipality component
Geographic/demographic				
Overall surface	−3.323*** (1.18)	0.737*** (0.113)	0.295*** (0.057)	0.076*** (0.012)
Elevation ab. sea	−0.349 (0.227)	0.027*** (0.010)	−0.024** (0.011)	0.002*** (0.0001)
Population density	−4.134** (1.718)	−0.061*** (0.095)	0.683*** (0.106)	−0.038*** (0.007)
Metropolitan area	−0.330*** (0.033)	0.120*** (0.022)	0.001 (0.001)	0.001*** (0.0004)
Socio-economic				
Education rate	−1.844 (1.369)	0.085*** (0.023)	−0.362*** (0.070)	−0.008*** (0.001)
Unemployment rate	1.280*** (0.373)	−0.078 (0.088)	−0.028** (0.012)	−0.011* (0.006)
Couples with children	8.296*** (2.071)	−0.624*** (0.091)	0.605*** (0.113)	−0.052*** (0.008)
Value added	35.956*** (3.941)	2.785*** (0.144)	1.142*** (0.208)	−0.047*** (0.008)
Institutional quality				
IQI	−3.456** (0.221)	−4.086*** (0.188)	−0.004 (0.014)	0.054*** (0.004)
Constant	−32.690*** (4.187)	–	−1.043*** (0.215)	–

*Significant at 10%; **significant at 5%; ***significant at 1%. Standard errors in brackets

and opportunity cost of time (unemployment rate). The pro-environmental behaviours, as well as the opportunity cost of time, are critical to explain the territorial divide in waste management. In particular, the higher unemployment rate of the Southern Italy (Table 1)—with respect to Central area—could be one possible explanation of the advantage of the South, in the macro-area component, because unemployed people have more time to spend in separate collection activities (Hage and Söderholm 2008). Finally, in line with what happened in the South–North comparison, the value added and institutional quality penalizes the Southern area.

5.3 Municipality comparison

Local governments make the national and regional plans operative (Art. 198. L.D. 152/2006). They are free to decide on infrastructural investment, disposal sites, and many other waste-related issues such as the waste collection systems (Mazzanti and Montini 2014). The results discussed in Sect. 5.1 highlight how the Southern area is lagging behind, in the waste management field, with respect to the rest of country due to this component.

In Tables 3 and 4, we have reported the results of the decomposition—for SCR and DSC analyses, respectively—concerning the comparison between *South* and *North*. In general, the advantage of the North Italy in this component is mainly due to some *geographic*, *demographic* (e.g. overall surface of municipality, elevation above the sea and population density) and *institutional quality* factors. In mean, Southern municipalities have the surface area and the elevation above the sea higher than those in Northern area (Table 1). In particular, the SCR-based analysis shows how these morphological characteristics make harder the cooperation between citizens and waste management authorities. Indeed, they can significantly influence the operational complexity of separate waste collection discouraging those citizens moved by an extrinsic motivation in carrying out a virtuous separate collection. In addition, territorial morphology makes more difficult the monitoring activities designed to control the assiduousness with which separate collection is performed by citizens (Sarra et al. 2017). In the same way, the higher mean of population density in Northern (Table 1) area may lead to the reduction of average separate collection costs mainly through the economies of scale (Bello and Szymanski 1996). This aspect emerges in the DSC-based analysis, suggesting how the presence of economies of scale helps the Northern municipalities to adopt improved methods, such as door-to-door, or new technologies applied to the waste management. Thus, in the context of funds management, institutional quality plays a crucial role in explaining the different performance between North and South in separate waste collection (as discussed in Sect. 5.2). To conclude the comparison between South and North, it is worth to stress how the value added favours Southern Italy in municipality dimension. In Sect. 5.2, we have argued that the prosperity of a region is positively correlated with separate waste collection. In this light, a highest economic wellbeing advantages Northern area. We can interpret the results of municipality component through the relation among value added and consumption (Mazzanti et al. 2008, 2009; D'Amato et al. 2015). Indeed, the richest areas have higher levels of consumption and, thus, a higher waste production making the separate collection activities more difficult.

The results of the comparison between *South* and *Centre* are reported in Table 5 (SCR) and 6 (DSC). This comparison highlights the relevance of *socio-economic* factors, linked with pro-environmental behaviours (education rate, couples with children) and opportunity

Table 5 RIF decomposition of mean and Gini on log-SCR by each variable. South versus Centre, 2012

	Mean		Gini index	
	Macro-area component	Municipality component	Macro-area component	Municipality component
Geographic/demographic				
Overall surface	1.901 (1.192)	0.383*** (0.100)	−0.710** (0.333)	0.009 (0.019)
Elevation ab. sea	−0.165 (0.244)	0.001 (0.002)	0.061 (0.061)	0.0002 (0.0004)
Population density	2.256 (1.735)	−0.089 (0.055)	−0.853** (0.433)	−0.004 (0.006)
Metropolitan area	0.148*** (0.029)	−0.021* (0.012)	−0.018*** (0.006)	0.001 (0.0008)
Socio-economic				
Education rate	5.738*** (1.577)	0.007 (0.005)	−1.666*** (0.397)	0.002* (0.001)
Unemployment rate	2.930*** (0.398)	−0.413*** (0.068)	−0.467*** (0.080)	−0.036*** (0.010)
Couples with children	0.650*** (0.066)	−0.219*** (0.083)	−0.127* (0.075)	−0.004 (0.010)
Value added	−19.209*** (2.624)	−0.1260** (0.058)	2.957*** (0.700)	−0.071*** (0.018)
Institutional quality				
IQI	−4.342** (2.624)	−0.651*** (0.135)	1.306* (0.547)	0.207*** (0.014)
Constant	−11.045*** (3.121)	–	−0.533 (0.800)	–

*Significant at 10%; **significant at 5%; ***significant at 1%. Standard errors in brackets

Table 6 RIF decomposition of mean and Gini on log-DSC by each variable. South versus Centre, 2012

	Mean		Gini index	
	Macro-area component	Municipality component	Macro-area component	Municipality component
Geographic/demographic				
Overall surface	1.047 (1.405)	0.014 (0.094)	−0.196* (0.118)	−0.042*** (0.008)
Elevation ab. sea	0.221 (0.283)	−0.0009 (0.002)	0.097*** (0.022)	0.0001 (0.0003)
Population density	0.894 (2.039)	0.118* (0.066)	−0.129 (0.154)	−0.014* (0.007)
Metropolitan area	0.282*** (0.035)	−0.021* (0.012)	−0.001 (0.002)	0.0007 (0.0004)
Socio-economic				
Education rate	4.417** (1.793)	0.006 (0.004)	−0.559*** (0.145)	−0.0007* (0.0004)
Unemployment rate	2.637*** (0.456)	−0.312*** (0.072)	−0.079*** (0.029)	−0.006* (0.003)
Couples with children	−1.963 (2.451)	−0.011 (0.049)	−0.066** (0.027)	−0.022*** (0.008)
Value added	−23.472*** (3.244)	−0.103* (0.061)	1.337*** (0.247)	−0.032*** (0.006)
Institutional quality				
IQI	0.262 (0.173)	−0.857*** (0.145)	0.320* (0.194)	0.057*** (0.004)
Constant	16.691*** (3.779)	–	−0.708** (0.284)	–

*Significant at 10%; **significant at 5%; ***significant at 1%. Standard errors in brackets

cost of time (unemployment rate), *value added* and *institutional quality*. The environmental behaviours belong to intrinsic motivations. These motivations make people satisfied in participating in separate waste collection programmes because these actions help the community to preserve the natural resources (Hornik et al. 1995). Our results suggest that citizens and the local administrations of the Central Italy have greater appreciation for valuing future times (Bruvoll and Nyborg 2004) than those in Southern area. In particular, couples with children as well as educated people are more aware to understand the importance of waste reduction and they are more informed about separate collection programmes (Hornik et al. 1995). For the value added and institutional quality factors, we can come to the same considerations as stated in the previous comparisons.

6 Discussion and conclusion

Separate waste collection is one of the key enablers in the achievement of EU 2020 goals of recycling today playing a pivotal role in a sustainable society. One of the key objectives of the EU package is, in fact, to build momentum in this area. The intensifying governmental focus on improvements in the efficiency of municipal solid waste management has prompted a major development of public policies in recent decades (Expósito and Velasco 2018).

In Italy, regional and municipal governments are responsible for the development and management of separate waste collection services in their territories under European and national directives. Although heterogeneity among Italian areas is very high, and the economic resources into developing good performances in waste management for separate waste collection have increased in the last decades, our analyses show how the efforts to increase separate waste collection rates in Southern Italy remain largely insufficient. Within the EU 2020 Thematic Objective 6 on "Environment & resource efficiency", the European Commission addressed again the significant needs for investment in the waste sector to meet the requirements of the "environmental acquis". Today Italian regions collect separately 48% of all MSW with peaks of about 70% in the two best-performing regions such as Veneto and Trentino (with a population of about 6 million), so the 50% target for year 2020 will be met, considering the growth of separate collection of the past years. The effect can be clearly seen on the development of an infrastructure sector that boomed from about 30 facilities in year 1997 to more than 280 facilities in 2015. So today separate collection and effective recycling of organics represent the backbone of modern MSW management schemes in Italy. However, intensive sorting schemes continue to be adopted only in single municipalities and large districts of the Northern Italy (such as the experience in Treviso reaching about 85% separate collection and recycling) and including medium-size towns (such as Parma or Bolzano applying kerbside collection and PAYT charges) or metropolitan cities like Milan were significant amounts of waste are collected and contribute to achieve high recycling rates. So, it is worth linking Italian's regional data about separate collection to the recycling rates according to the EU Directive 2008/98/CE (see Table 10, in "Appendix", for the results reached by Italian macro-areas to achieve the EU targets). Table 7 summarizes the main results of empirical analyses.

The results of the SCR analysis show that the South area faces with disorganization of the separate collection system a lack of public awareness and limited plan to manage funding programmes. This Italian area has struggled for years to find a way to responsibly manage the country's ever-increasing issue of the separate waste collection. Many

Table 7 Main findings of empirical analyses (SCR and DSC)

	Measures	Gap in favour of	Main determinant of gap
SCR rates comparison			
South versus North	Mean	North	Macro-area Municipality
	Gini coefficient	North	Macro-area
South versus Centre	Mean	Centre	Municipality
	Gini coefficient	Centre	Municipality
DSC comparison			
South versus North	Mean	North	Macro-area Municipality
	Gini coefficient	North	Macro-area
South versus Centre	Mean	Centre	Municipality
	Gini coefficient	Centre	Macro-area Municipality

argue that the Southern poorly organized waste management scheme will continue to result into different separate collection methods (Hage and Söderholm 2008). Thus, the debate on the need for the revision of the Italian current model (captured by DSC study) has been opened since theory of planned behaviour (Zhang et al. 2015). Individual behaviours can have measurable and significant impacts. Building effective programmes in Southern area that increase the level of environmental responsibility can be an important part for creating positive environmental and behaviour change with the goal of maximizing resource reuse and increase the percentage of waste recycled. In the North, the good level of economic well-being leads to more expensive methods of recycling and may affect the performances of waste management in the South. This could be compensated by persuading people to differentiate, by leveraging on their intrinsic motivation and pro-environmental behaviour. Moreover, a range of policy instruments to encourage waste minimization (e.g. waste collection fees, landfill fees, product charges, deposit-refund system, voluntary agreements, information and education) are recommended. On the contrary, compared to Central area, Southern cooperation is more successful. Situational factors are individuals' objective. Unemployment assesses the extent to which citizens' situational factors, such as unlimited time, are not barriers to performing waste separation behaviour. At the more strongly individuals subscribe to values beyond their immediate own interests, that is, pro-social or altruistic values, the more likely they are to engage in pro-environmental behaviour. In fact, as highlighted in Table 1, higher unemployment rate of the Southern Italy with respect to the Central area could be one possible explanation of the advantage of South, in the macro-area component. Then, the key to improvement here is to start with a cultural change. The current culture for recycling is mostly negative, being based on a general fear of bad processes and a specific fear of behaviour becoming deskilled. In this regard, citizens' participation may be improved with campaigns that emphasize individuals' moral obligations to separate household waste (Zhang et al. 2015). Such campaigns should aim to improve individuals' environmental knowledge and individuals' waste separation abilities (perceived behavioural control). These campaigns should target a combination of government and residents.

As regards the municipal comparison, our results suggest that citizens and the local administrations of the Central Italy have greater appreciation for valuing future times

than those in Southern area. The effectiveness of behavioural interventions to separate generally increases when they are aimed at important antecedents (intrinsic) of the relevant behaviour and at removing barriers for change. When a goal is activated (that is, when it is the "focal" goal or "goal-frame"), it influences what some regional areas think of an issue, what information is sensitive to, what alternatives has to take (Steg and Vlek 2008). Moreover, it is the government's responsibility to formulate and implement relevant laws and regulations and to take action to implement these in numerous communities. Italian services connected with separate waste collection and treatment have shifted during the programmed period 2007–2013 their focus towards the governance of services and waste flows, which are directed towards new recycling processes leaving increasingly less waste destined for landfill. 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 European Regional Development funds (Agovino et al. 2016a). Thus, there are still many issues to overcome and problems to be faced before the municipalities can compare with their northern and central competitors. So, in some cases, it is not only important to consider intra-personal factors such as attitudes, norms and habits, but also contextual factors such as physical infrastructure and technical facilities. This distortion is the result of the different investment capacities of territories, in part tied to differences in operational approaches of the institutions. In the South of Italy, for instance, in-sourcing of services prevails; these entities have more difficulties to manage the investment capacity, especially from a qualitative point of view. According to Expósito and Velasco (2018), regional governments should determine which separate waste collection policies are more suitable for implementation in their territories and according to the funds received, given their community's standard of living. Southern municipalities were the regions with fewer facilities that have received the least funds. Increasing accessibility to separate collection facilities is the best means of promoting positive attitudes to solid waste separation activities.

Moreover, the significant positive effect of per capita income on regional efficiency suggests that the Northern area with better living conditions show better performances at developing their regional and separate waste collection market. Along these lines, as the degree of engagement with recycling activities depends on income and education level, emphasis should be placed on increasing environmental awareness and a sense of responsibility among citizens particularly in handling waste.

However, despite that the three macro-areas and municipality follow a similar hierarchical structure of priorities with respect to the formulation and implementation of their waste management strategy (Rogge and De Jaeger 2012) also set by European targets, the environmental authorities have a mix of possible instruments at their disposal to reach this objective; local policy makers still enjoy a considerable degree of independency regarding the separate waste collection policy. Therefore, the practical details of the management models adopted and the behavioural attitudes tend to differ from macro-areas and municipalities. In fact, not to separate adequately represents not only environmental costs, loss of competitiveness and increased operating costs, but also the risk of fines paid by the European Union Member States for failure to comply with the legislation landfills (Directive 1999/31/EC) and Southern areas has unfortunately sad primate in the number of infringement proceedings. Thus, environmental policy and separate collection, indeed, need to be conducted within the spirit of properly functioning multilevel 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 (Agovino et al. 2016a).

Appendix

See Fig. 5 and Tables 8, 9 and 10.

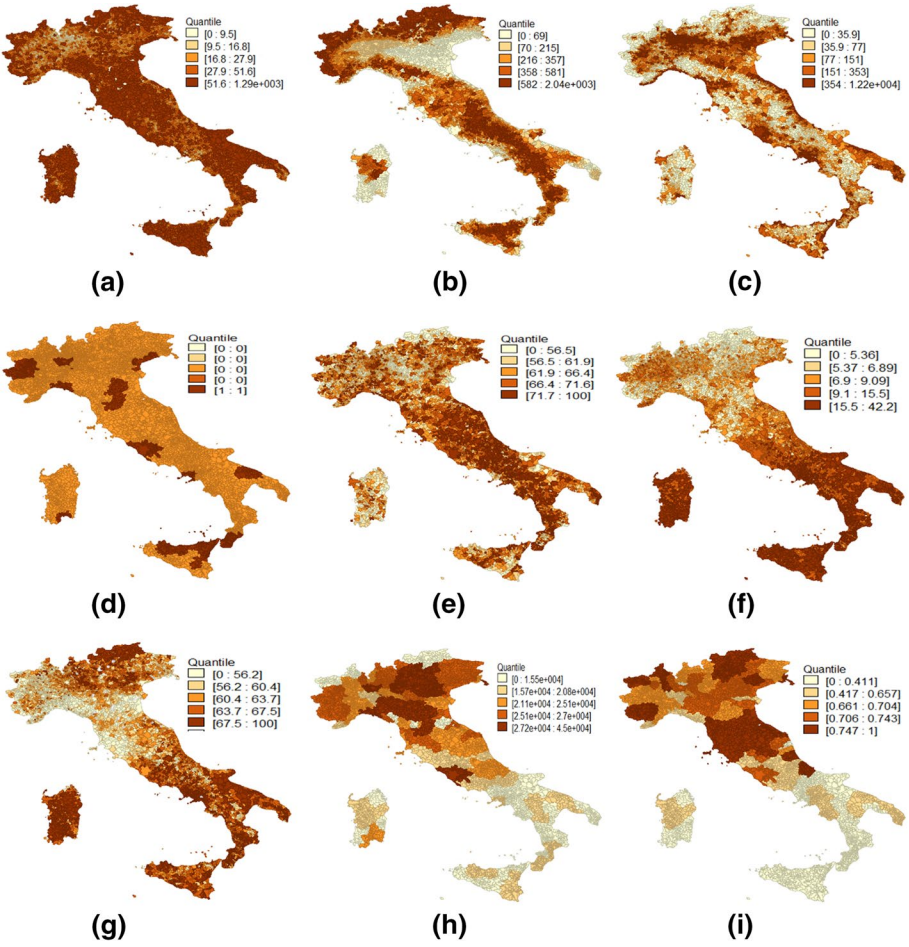

Fig. 5 Explanatory variables at municipal level, 2012. **a** Overall surface area, **b** elevation above sea, **c** population density, **d** Metropolitan area, **e** education rate, **f** unemployment rate, **g** couples with children, **h** value added per capita, **i** institutional quality index. *Source*: Our elaboration on ISTAT data

Table 8 RIF regression coefficients (mean and Gini index) on log-SCR by macro-area, 2012

	North		Centre		South	
	Mean	Gini coefficient	Mean	Gini coefficient	Mean	Gini coefficient
Geographic/demographic						
Overall surface	−0.457*** (0.033)	0.051*** (0.005)	−1.167*** (0.274)	0.162** (0.068)	−0.601*** (0.224)	−0.030 (0.059)
Elevation ab. sea	−0.052*** (0.004)	0.003*** (0.0007)	0.022 (0.037)	−0.004 (0.009)	−0.007 (0.024)	0.006 (0.006)
Population density	−0.411*** (0.035)	0.044*** (0.006)	−0.956*** (0.291)	0.135* (0.072)	−0.472** (0.231)	−0.051 (0.061)
Metropolitan area	0.125*** (0.019)	−0.027*** (0.003)	−0.778*** (0.119)	0.143*** (0.029)	−0.065 (0.071)	0.038** (0.018)
Socio-economic						
Education rate	0.227*** (0.039)	−0.016** (0.006)	−0.850** (0.329)	0.163** (0.081)	0.512*** (0.178)	−0.231*** (0.047)
Unemployment rate	0.045*** (0.016)	−0.007*** (0.002)	−0.751*** (0.123)	0.143*** (0.030)	0.303*** (0.073)	−0.066*** (0.019)
Couples with children	0.434*** (0.032)	−0.049*** (0.005)	1.218*** (0.266)	−0.180*** (0.065)	0.509** (0.212)	0.026 (0.056)
Value added per cap	−0.313*** (0.053)	0.068*** (0.009)	0.383** (0.175)	−0.077* (0.043)	−1.599*** (0.206)	0.217*** (0.054)
Institutional quality						
IQI	3.137*** (0.097)	−0.453*** (0.016)	1.868*** (0.388)	−0.421*** (0.096)	3.590*** (0.147)	−0.596*** (0.039)
Constant	4.929*** (0.534)	−0.327*** (0.093)	4.158* (2.224)	0.181 (0.550)	15.204*** (2.189)	−0.351 (0.581)

*Significant at 10%; **significant at 5%; ***significant at 1%, standard errors in brackets

Table 9 RIF regression coefficients (mean and Gini index) on log-DSC by macro-area, 2012

	North		Centre		South	
	Mean	Gini coefficient	Mean	Gini coefficient	Mean	Gini coefficient
Geographic/demographic						
Overall surface	1.254*** (0.184)	0.023*** (0.005)	0.045 (0.289)	0.183*** (0.026)	0.265 (0.301)	0.129*** (0.020)
Elevation ab. sea	0.067*** (0.025)	0.011*** (0.0007)	−0.036 (0.039)	−0.010*** (0.003)	0.003 (0.032)	0.006*** (0.002)
Population density	2.271*** (0.197)	0.003 (0.005)	1.192*** (0.307)	0.170*** (0.026)	1.383*** (0.311)	0.142*** (0.020)
Metropolitan area	2.184*** (0.109)	0.016*** (0.003)	−0.770*** (0.127)	0.033*** (0.011)	0.590*** (0.096)	0.027*** (0.006)
Socio-economic						
Education rate	0.812*** (0.219)	0.003* (0.006)	−0.674* (0.351)	0.047 (0.030)	0.374 (0.240)	−0.084*** (0.016)
Unemployment rate	−0.080 (0.091)	0.004 (0.002)	−0.569*** (0.131)	0.024** (0.011)	0.380*** (0.098)	−0.011* (0.006)
Couples with children	−1.608*** (0.180)	−0.030*** (0.005)	0.067 (0.280)	−0.186*** (0.024)	−0.253 (0.285)	−0.135*** (0.019)
Value added per cap	−5.819*** (0.297)	−0.012 (0.008)	0.313* (0.188)	−0.033** (0.016)	−2.108*** (0.277)	0.100*** (0.018)
Institutional quality						
IQI	12.305*** (0.542)	−0.157*** (0.015)	2.463*** (0.414)	−0.071** (0.036)	3.157*** (0.198)	−0.163*** (0.013)
Constant	52.503*** (2.979)	0.350*** (0.087)	3.121 (2.372)	0.015 (0.206)	19.813*** (2.942)	−0.692*** (0.196)

*Significant at 10%; **significant at 5%; ***significant at 1%, standard errors in brackets

Table 10 Waste management performances and European targets. Italian macro-areas, 2012. *Source*: Our elaboration on ISPRA data

	Separate waste collection		Landfilling		
	Separate collection rate (SCR)	Percentage of municipalities above the EU target value 2013 (SCR > 40%)	Landfilling rate (LR)	Percentage of municipalities below the EU target value 2009 (LR < 50%)	Percentage of municipalities below the EU target value 2016 (LR < 35%)
North	52.7	81.18	21.8	64.75	33.06
Centre	33.1	36.44	56.2	23.35	8.02
South	29.0	41.31	51.8	32.04	9.35

Target defined by EU Waste Directive 2008/98/EC and EU Landfill Directive 1999/31/EC

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