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ORIGINAL PAPER

The separate collection of recyclable waste materials as a flywheel for the circular economy: the role of institutional quality and socio-economic factors

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Abstract

The separate collection of individual recyclable waste materials is the basis for any recycling process. This produces important advantages, especially in terms of resource savings. This paper investigates the drivers of the separate collection process of recyclable materials (i.e., organic, paper, glass, plastic) and its total in the 103 Italian provinces (NUTS-3), in the years 2004–2011. Results show that the pillars of institutional quality (such as, voice and accountability, rule of law and regulatory quality), value added per capita and participation to ecological associations are important factors for an effective implementation of the waste separation process. In particular, these factors do matter for an effective collection of organic waste, paper, glass and plastic. Furthermore, the analysis shows marked differences among macro-areas (North, Central and Southern Italy). Policy considerations are discussed.

Keywords Environmental issues · Recycling · Circular economy · Government policy · Solid waste · Land use patterns · Panel data models

JEL Classification Q5 · Q53 · Q57 · Q58 · R5

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1 Introduction

In the last decades, significant concerns over the environmental impact of waste, primarily involving human health and the environment, have emerged in the European countries. In this context, a development strategy achieving zero waste is crucially relevant in the path towards circular economy (European Commission Report 2014), since it allows to keep products at their highest value for as long as possible through recycling. Recycling reduces the quantity of total disposed waste, conserves natural resources, reduces demand for virgin materials and consumes less manufacturing energy (Connett and Sheehan 2001). In addition, it reduces environmental and economic costs, as well as health and environmental risks (Bolaane 2006; Kinnaman 2006; Martin, Williams and Clark 2006; Van den Bergh 2008).

However, it is not possible to achieve recycling targets, without taking into account the effectiveness issue of separate waste collection. In particular, collecting recyclable materials is the basis for the processes of recovery, reuse and recycling. For instance, if paper mills convert their plants to the production of recycled paper, they must be able to rely on enough raw material deriving from separate waste collection. In other words, higher levels in the separate collection of recyclable materials may imply more recycling and the reduction in the amount of unsorted waste to be disposed in landfills or incinerators. In turn, this allows to keep more resources within the economy, treating waste as a resource itself (Wilts et al. 2016).

From the legislative point of view, the Directive 2008/98/EC established specific targets,[1] in order to limit the production of waste, using it as a resource, so as to create a "*recycling society with a high level of efficiency*". The Directive has been transposed in Italy by the Legislative Decree 205/2010, which set the targets for separate waste collection, recovery and recycling, defining the responsibilities among the actors of the national waste management system. In particular, Italian regions are responsible for the design of waste management plans aimed at promoting waste reduction, while Italian provinces (defined as optimal management areas, ATO) are responsible for managing and collecting waste. Therefore, institutions (i.e., regions, provinces and municipalities) play a crucial role in promoting the societal shift towards the circular economy paradigm. Italian regions however are still far from achieving the recycling targets established (Sustainable Development Fundation Dossier 2016). According to ISPRA (Istituto Superiore per la Protezione e la Ricerca Ambientale) (2017), the overall extent of separate waste collection in Italy has increased from 25.8% in 2006 to 52.5% in 2016. Concerning individual materials, the organic fraction results to be the most collected, accounting for 41.2% of the overall separate waste collection. The second most collected material is paper (20%

[1] This Directive includes two new recycling and recovery targets to be achieved by 202"0: … "(a) the preparing for re-use and the recycling of waste materials such as at least paper, metal, plastic and glass from households and possibly from other origins as far as these waste streams are similar to waste from households, shall be increased to a minimum of overall 50% by weight; …." "(b) the preparing for re-use, recycling and other material recovery, including backfilling operations using waste to substitute other materials, of non-hazardous construction and demolition waste … shall be increased to a minimum of 70% by weight" (art.11 Directive 2008/98 EC).

of the total) and significant growth is recorded for glass (from 12.8% in 2015 to 18% in 2016). Plastic is the least collected material (7.8% in 2016). This point represents a missed opportunity, since the plastic recycling industry is the most labor intensive (+4500 jobs) and it entails the highest savings of resources (1560 kg of CO_2 eq/ton) (Sustainable Development Foundation Dossier 2016).

An effective separate waste collection system requires, first of all, that local institutions provide the necessary resources, policies, processes and technologies, and monitoring which are suitable for the specific local circumstances. Moreover, it requires that citizens make an effort to separate their waste (see Agovino et al. 2018). About that, several contributions investigated the role of institutions in waste management issues. Paavola (2007) points out that environmental governance is best interpreted as the affirmation or change of institutions in solving environmental issues. Lucarelli (2007), Raimondi (2007) and Rabitti (2008) emphasise the institutional responsibilities related to waste mismanagement. Agovino et al. (2016c) show that institutional quality is an important determinant of the landfill disposal reduction and, indirectly, of the extent of separate waste collection. Mazzanti and Montini (2014) highlight that the recent waste crises in many advanced countries are due, among other things, to institutional failures. According to Tonglet et al. (2004), citizens can be incentivised to adopt pro-environmental behaviours if they have opportunities, facilities and knowledge. The effort of citizens may also depend on the type of programme operated by public agents and, therefore, on socio-demographic and economic factors. When the costs of waste separation rise (on the citizen's side in terms of time and effort, and on the public agent's side in terms of cheaper disposal alternatives), the collection of recyclable materials may decrease. For instance, if public agents do not offer easy separate collection programmes (e.g. kerbside collection) due to their low economic resources or because the cost of alternative disposal (e.g. landfill) is lower, the level of effort required to recycle is high. As a consequence, only citizens with a strong intrinsic motivation and strong pro-environmental attitudes will differentiate their waste.

Based on the above, this paper aims to investigate the institutional and socio-economic drivers of the separate collection process of individual materials (i.e., organic, paper, glass, plastic) and its total in the 103 Italian provinces (NUTS-3), in the years 2004–2011.

Relatively to the existing literature in the field, which considers the overall separate collection rate as a whole, our contribution is twofold. First, we analyze the separate treatment of each recyclable material. Understanding what determines the collection rates of each material is a fundamental pre-condition for the achievement of high overall recycling rates and high-quality recycling, in line with the prescriptions of the European Commission (Directive 2008/98 /EC). This is actually very important for policy makers.

Second, we show the crucial relevance of institutional quality factors for the implementation of an effective separate collection of individual recyclable waste materials in each Italian macro-area. We differentiate among macro-areas because of significant differences among Italian regions, ascertained both in the overall separate waste collection and with respect to each material (Crociata and Mattoscio 2015; Agovino et al. 2016b). Residency in Southern Italy is indeed associated with

the lowest probability of recycling all materials (Fiorillo 2013). The differences among Northern, Central and Southern Italy are surely at the core of the issue of waste management and other 'convergence failures' of institutional, economic and environmental nature (Mazzanti et al. 2012; Agovino et al. 2016). In part, the responsibility for these differences may be attributed to the quality of local institutions, which are directly and indirectly involved in the waste management process (regions, provinces, environmental associations, schools etc.). The empirical literature shows a delay in the economic development of Southern Italy, basically due to the lower level of institutional quality (high corruption, excessive bureaucracy, inefficient organisation of public services, low endowment of infrastructures and a lack of security) relative to Northern Italy (see Nifo 2011; Nifo and Vecchione 2014; Lasagni et al. 2015; Cesi et al. 2017). This gap may as well cause dissimilarities in the implementation of waste management policies on the part of the local administration (e.g. European Regional Development Fund Regulation), thus affecting separate waste collection negatively.

This paper is organised as follows: Sect. 2 presents the empirical strategy and provides a theoretical justification of the variables used in the analysis, as well as the datasets and the econometric model employed. Section 3 shows the results. Section 4 provides our discussions. Finally, Sect. 5 concludes.

2 Empirical strategy

The purpose of this section is threefold. First, it describes the variables employed in the analysis and explains their relevance as supported by the literature (Sect. 2.1). Second, it reports summary statistics (Sect. 2.2). Finally, it describes the econometric strategy used in order to analyse the drivers factors of the Total Separate Collection Rate (from now, TSCR) and its recyclable materials (Sect. 2).

2.1 Variable choice and theoretical justification

Our empirical analysis focuses on TSCR and on four recyclable waste materials (i.e., organic, paper, plastic and glass) as dependent variables. An indicator of separate collection is given by the urban waste separately collected as a percentage of total urban waste.[2] Moreover, the art. 183 of Legislative Degree 152/06 refers to the following materials within the separate collection: 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

[2] Art. 183 of Legislative Degree 152/06 (paragraph f) provides a definition of separate collection i.e., "the collection which aims to: (i) group urban waste into homogeneous categories; (ii) group 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".

(batteries and accumulators, expired medicines, paints and inks, vegetable and mineral oils, etc.).

In addition, the analysis controls for two sets of variables: (**I) external** or **environmental variables** (see Blake 1999) i.e., the single pillars of institution quality and the geographical interaction variables; (**II) socio-demographic** and **economic variables** i.e., value added per capita (VA), population density (PD); unemployment rate (Unemployed) and the percentage of people participating in ecological associations (Ecologic).

With regard to the first set of variables, we measure institutional quality employing the Institutional Quality Index (IQI) proposed by Nifo and Vecchione (2014). IQI is based on five groups of elementary pillars:

- *Voice and Accountability* (V&A) (the degree of freedom of press and association). It is made up by the participation rate in public elections, the number of associations and of social cooperatives and cultural liveliness measured in terms of books published and purchased in bookshops;
- *Government Effectiveness* (GE) (the quality of public service and the policies formulated and implemented by the local government). It measures the endowment of social and economic structures in the Italian provinces and the administrative capability of provincial and regional governments in terms of health policies, waste management and environment;
- *Regulatory Quality* (RQ) (the ability of the government to promote and formulate effective regulatory interventions). It concerns the degree of openness of the economy, indicators of business environment, business density and the rate of firms mortality;
- *Rule of Law* (RL) (the perception concerning law enforcement both in terms of contractual fulfilment, property rights, police forces, activities of the magistracy and crime levels). It summarises data on crime against persons or property, magistrate productivity, trial times, tax evasion and shadow economy;
- *Control and Corruption* (C&C) (the degree of corruption of those performing public functions both in terms of illegal gains and private proceeds acquired to the detriment of society). It concerns data on crimes committed against the Public Administration (PA), the number of local administrations overruled by the federal authorities and the Golden-Picci Index.

Concerning the GE pillar of IQI, it includes the TSCR and this could create endogeneity problems in the estimates (TSCR and IQI could be simultaneously determined). Although we believe that the problem of endogeneity is very remote,[3] the IQI and GE are excluded from the model.

The inclusion of the other four pillars among the regressors is meant to capture specific attributes of provincial institutions, considered to be relevant for

[3] TSCR is one of the many variables that end up in the GE. In the calculation of the index and during the transformation, normalization and aggregation phases of the elementary variables, the specific effect of TSCR is marginal.

environmental issues and policy formulation. For example, an important aspect of *RL* is the effectiveness and the efficacy of legal institutions (the courts and the judiciary). Meiners and Yandle (1998) indicate that the *rule of law* can be effective in protecting environmental rights. A number of theoretical studies on the other hand show *corruption* to reduce the stringency of environmental regulations (Fredriksson and Svensson 2003; Lopez and Mitra 2000; D'Amato et al. 2015), whilst environmental degradation tends to increase with the level of corruption (Desai 1998; Wilson and Damania 2005; Damania et al. 2003; Cole 2007). Corruption, extortions, and framing reduce deterrence (Polinsky and Shavell 2000) and thus could result in an increase in illicit burning or dumping by households (see also Fullerton and Kinnaman 1995). Cesi, D'Amato and Zoli (2017) show that illegal disposal is higher under corruptible authorities in charge of monitoring disposal waste.

In summary, citizens operate within a regulatory framework determined by institutions (such as government, public administration, the regions, schools, universities), and this framework can change their behaviour (Acemoglou et al. 2001, 2005; Acemoglu and Robinson 2008). A considerable part of the economic literature, both theoretical and empirical, shows that better institutions create a favorable environment for economic growth, encouraging businesses to invest in new technologies and R&D and facilitating the development of human capital (see Acemoglu et al. 2001, 2005; Acemoglu and Robinson 2008; Chanda and Dalgaard 2008; Hall and Jones 1999; Knack and Keefer 1997). Many pro-environmental behaviours can only take place if the necessary information and guidance are provided or if appropriate separate waste collection programmes work. '*Individuals must accept responsibility for the future, but conditions, institutions and their own day-to-day responsibilities constrain their actions*' (Myers and Macnaghten 1998, p. 346; Macnaghten and Jacobs 1997; Munton 1997).

Finally, in order to take into account geographical differences in the level of institutional quality, we also control for geographical interaction variables (Northern Italy, Central Italy and Southern Italy).

Regarding the second set of regressors, *socio-economic factors* may affect waste-related activities in various ways. Grossmann et al. (1974) and Al-Momani (1994) found that the relationships obtained among several socio-economic factors vary across countries. This has been attributed to variations in consumer behaviour and lifestyles (Stern et al. 1995; Kaiser 1998; Kaiser et al. 1999; Barr et al. 2001a, b). A number of studies on recycling behaviours indeed (i.e., waste sorting at source), present mixed results on the influence of socio-economic and demographic characteristics. In particular, there is evidence to show that variables such as age, education, income and the type of household are correlated with recycling behaviour (Kishino et al. 1999; Hansmann et al. 2006; Bandara et al. 2007; Martin et al. 2006; Kollmuss and Agyeman 2002; Franzen and Meyer 2010; Paraskevopoulos et al. 2003; Troschinetz and Mihelcic 2009; Fiorillo 2013; Cerciello et al. 2018; Agovino et al. 2019).

The perception about the opportunity cost of time is one of the most important determinants of recycling behaviours. Recycling is often considered by citizens as a time consuming, annoying activity to be eschewed when possible (Nordlund and Garvill 2002). In fact, recycling requires considerable effort by citizens since waste must be sorted, prepared and stored (Boldero 1995). According to Hage et al. (2009)

the opportunity cost of the time spent on recycling is likely to be lower for unemployed people. One can therefore expect that they will spend relatively more time on waste sorting activities. *Based on the above, we control for the* ***unemployment rate****, expecting its positive effect* (+) *on both TSCR and individual recyclable materials*.

Among the predictors of recycling behaviours, the literature reports moral norms, information and environmental concern (see Chan 1998; Hornik et al. 1995; Schultz et al. 1995; Thøgersen 1996; Barr et al. 2003; Halvorsen 2012; Saphores et al. 2012; Miafodzyeva and Brandt 2013). In particular, Hage et al. (2009) suggest that the presence of moral norms has positive effects on pro-environmental behaviour. Moral norms are activated through social interaction, e.g. participation in meetings of formal organisations (voluntary service, ecological cultural, political party and unions), meetings with friends, etc. (Fiorillo 2013). Social interaction is also responsible for the flow of information on environmental issues (Jones et al. 2010). *Based on the above, we control for the percentage of people participating in ecological associations, expecting its positive effect* (+) *on both TSCR and individual recyclable materials*.

For richer countries, the literature shows a strong positive correlation between per capita income and the extent to which environmental protection measures are adopted (Grossman and Krueger 1995; Selden and Song 1994; Callan and Thomas 1997; Torras 2005; Mazzanti et al. 2008; Andersen et al. 2007; Lamla 2009). *In light of that, we control for value added per capita variable as a proxy of provincial prosperity, expecting its positive effect* (+) *on both TSCR and individual recyclable materials*. We include VA among the regressors, in order to capture the effect of the different models implemented for collecting recyclable waste materials. Significant economic resources are indeed required to implement an effective waste segregation model (e.g. mono-material collection). This is the first step in moving away from landfill and incineration toward recovery and recycling (Xevgenos et al. 2015). The waste collection models applied in the European countries can be classified by (i) type of waste segregation model (e.g. mono-material vs. multi-material); (ii) location of the collection system (kerbside collection vs bring points). The main collection systems operated in Italy are kerbside collection (primary for paper and organic materials), bring points (primary for glass material) and kerbside mixed-integrated systems (kerbside and bring points) (Ricci et al. 2003; BiPRO/CRI 2015). Kerbside collection requires more economic resources than the bring points, but it may reduce the waste to be disposed in landfill. This implies a decrease in waste disposal costs if the cost of landfills is higher than the cost of recycling (e.g. due to high landfill taxes).[4] Since the mid-1990s, integrated kerbside collections have spread out. This is especially true in the geographical areas where the costs of landfills were higher

[4] Landfill taxes can act as a stimulus to local authorities to activate waste sorting at source. In Italy the Law 549/1995 introduced landfill tax at regional level (Nuts-2), defining the upper and the lower level of the tax. The tax levels varies among Italian regions from 5.2 € per tonne in Campania to 25.8 € per tonne in Piemonte, as an average of the years 1998 to 2008. Since 2007, both the increase of the landfill tax and the higher separate collection rates produced a strong reduction in the amount of disposable waste (ETC/SCP 2013).

Table 1 Expected signs of covariates on the dependent variables

	TSCR	Paper	Glass	Plastic	Organic
C&C	–	–	–	–	–
RQ	+	+	+	+	+
RL	+	+	+	+	+
V&A	+	+	+	+	+
VA	+	+	+	+	+
PD	+/–	+/–	+/–	+/–	+/–
Unemployed	+	+	+	+	+
Ecologic	+	+	+	+	+

+; –; +/– if the expected sign is positive, negative and uncertain respectively

(e.g. Lombardy) or where the regional policy has encouraged the reduction of the organic waste from residual waste (e.g. Veneto) (Ricci et al. 2003).

In summary, kerbside collection results both in the highest yields of recyclables (BiPRO/CRI 2015) and in higher costs. For these reasons, it could be more difficult to implement in the low-VA provinces (especially where the costs of landfills are low).

Finally, we control for **population density,** as a proxy for different land values, as well as for the presence of agglomeration and scale effects (Mazzanti et al. 2008; D'Amato et al. 2015). On the one hand, densely populated municipalities (with high urbanisation rates) imply shorter distances from public and private agents to sorting infrastructure, and, other things equal, the actions required to separate and collect waste are more viable [i.e., *positive transport cost effect* (expected sign +)]. On the other hand, high population densities are likely to drive up land prices, and, therefore, increase the costs for landfilling as well as the costs for establishing recycling stations [*negative land cost effect* (*expected sign* –)) (Passarini et al. 2011). Table 1 summarises the expected signs of the covariates on the dependent variables.

2.2 Data description

Our analysis employs a dataset containing information on the 103 Italian provinces corresponding to the European NUTS-3 level for the years 2004–2011. The data on the four components of institutional quality are provided by Nifo and Vecchione (2014) and the information on the remaining variables is provided by ISTAT (Italian National Statistical Institute). Table 4 in the Appendix describes the variables in our dataset, listing their names and providing their descriptions. The lack of an update of the institutional quality index and its components has not allowed us to extend the analysis until 2016. This prevents us from grasping the improvement that has taken place in recent years in the provinces of southern Italy in terms of separate waste collection.

Table 2 reports the statistical summary of the variables analysed. It shows that, on average, 161 kg per inhabitants of separate waste are collected. Among the recyclable waste materials, organic reports the highest value (66.7 kg per inhabitant), while

Table 2 Summary statistics

Variable	Mean	Std. Dev.	Min	Max
Dependent variables				
TSCR	161.443	98.302	6.841	460.757
Paper	59.366	32.631	0.089	180.381
Glass	22.042	15.281	0.058	135.285
Plastic	10.090	10.129	0.051	72.207
Organic	66.788	52.893	0.059	233.958
External factors or environmental factors				
Control and corruption * North Italy	0.046	0.074	0	0.535
Control and corruption * Central Italy	0.018	0.046	0	0.370
Control and corruption * South Italy	0.111	0.189	0	1
Regulatory quality * North Italy	0.255	0.303	0	1
Regulatory quality * Central Italy	0.124	0.256	0	1
Regulatory quality * South Italy	0.106	0.174	0	0.803
Rule of law * North Italy	0.255	0.302	0	0.858
Rule of law * Central Italy	0.157	0.316	0	1
Rule of law * South Italy	0.166	0.258	0	0.977
Voice and accountability * North Italy	0.213	0.257	0	1
Voice and accountability * Central Italy	0.092	0.188	0	0.915
Voice and accountability * South Italy	0.093	0.144	0	0.534
Socio-demographic and economic variables				
Unemployed	7.601	4.173	1.900	21.500
Ecologic	1.873	0.577	0.500	4.100
AV	21,495.910	5393.787	11,181.000	42,718.750
PD	251.792	334.537	37.310	2640.920

the lowest value is registered for plastics (10 kg per inhabitant). Regarding socio-demographic and economic variables, we show that the average unemployment rate is 7.6%, average value added per capita is € 21.495,910, average population density is about 252 people per square km. In addition, the rate of participation in ecological associations is very low and is equal to 1.8%. On average, the provinces of Northern Italy have a better institutional quality (high values of regulatory quality, rule of law, voice and accountability, and low values of control and corruption). Figure 1 shows the gap between the provinces of Central and Northern Italy in terms of single pillars of IQI. In particular, we show that the provinces of Central Italy are in a better position than those of Northern Italy, both in terms of the perception of law enforcement and in terms of contractual fulfillment, property rights, police forces, activities of the magistracy and crime levels (Rule of Law). The same argument is also valid, from 2007 onwards, for the ability of the government to promote and formulate effective regulatory interventions (Regulatory Quality). The other indicators are below the ones of the provinces of Northern Italy (Voice and Accountability and Government Effectiveness). It is interesting to note that the level of corruption in

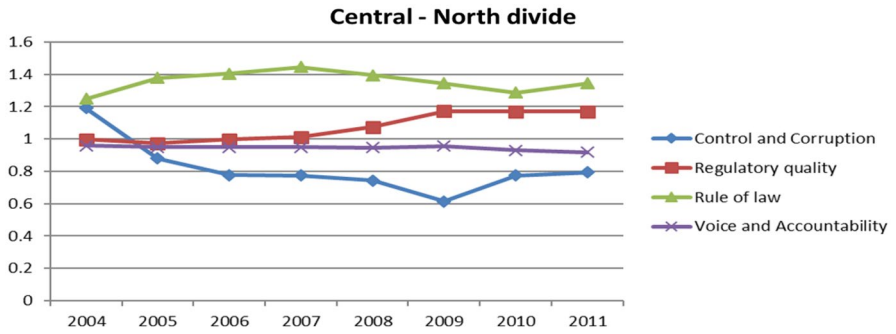

Fig. 1 Pillars of IQI: Central-North divide, (2004–2011) Source: our elaboration on Nifo and Vecchione (2014) data

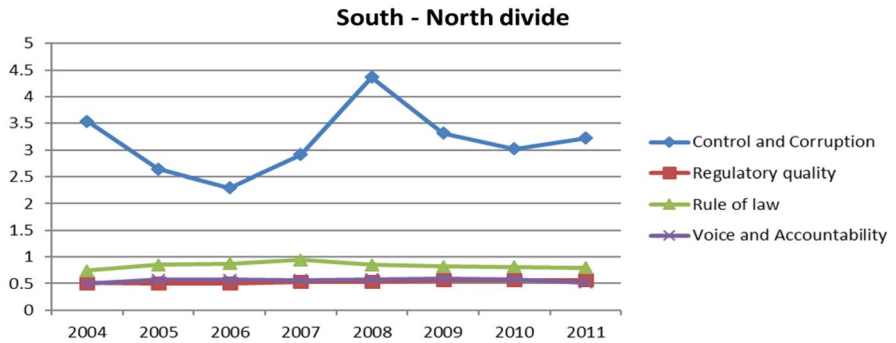

Fig. 2 Pillars of IQI: South-North divide, (2004–2011) Source: our elaboration on Nifo and Vecchione (2014) data

the provinces of Central Italy is much smaller than those of the Northern Italy (Control and Corruption). Conversely, Fig. 2 shows a wide gap between the provinces of Southern Italy and those of Northern Italy in terms of the single pillars of IQI. The gap is very pronounced and persistent throughout the period of analysis. The little convergence is observed only for the Rule of Law indicator. In addition, Fig. 2 shows a high gap between the provinces of Southern and Northern Italy in terms of Control and Corruption, with a peak in 2008, when the degree of corruption in the provinces of Southern Italy was about 4.5 times as large as in Northern Italy.

2.3 Econometric models

In this section, we present the econometric techniques employed in order to stress the links among dependent variables and selected covariates, which have been analysed in the previous section in purely descriptive terms. In particular, we implement a panel data analysis that has both a cross-sectional and a time series dimension,

where all the cross-sectional units (provinces) are observed throughout the period. In our case, we consider the following equation:

$$Y_{\mathrm{it}} = \alpha + \beta_1 \mathrm{VA}_{\mathrm{it}} + \beta_2 \mathrm{PD}_{it} + \beta_3 \mathrm{Unemployed}_{it} + \beta_4 \mathrm{Ecological\ associations}_{it} + \sum_{j=1}^{4} \sum_{i=1}^{3} \gamma_{ij} D_i * \mathrm{Pillars\ of\ IQI}_j + \mu_i + \lambda_t + u_{it},$$

Y_{it} are our dependent variables (total separate collection rate (TSCR) and its four waste materials (organic, paper, plastic and glass), expressed in kg per inhabitant. The subscript i refers to the statistic unity (the province) and t refers to the time; $\alpha, \beta_1, \beta_2, \beta_3, \beta_4, \gamma_i, \gamma_{ij}$ are the parameters that must be estimated. u_{it} is the stochastic error term.

$\mathbf{D_i} * \mathbf{Pillars of IQI_j}$, are the external factors or environmental factors. In particular, $\mathbf{D_i} * \mathbf{Pillars of IQI_j}$ are the geographical interaction variables with the four components of IQI, where $\mathbf{D_i}$ is a polytomous variable that is equal to 1 for Northern Italy provinces, 2 for Central Italy provinces and 3 for the Southern Italy ones. Finally, $\boldsymbol{VA_{it}}$, $\boldsymbol{PD_{it}}$, $\mathbf{Unemployed_{it}}$,$\mathbf{Ecologicalassociations_{it}}$ are a set of socio-demographic and economic variables. $\boldsymbol{VA_{it}}$ is value added per capita. $\boldsymbol{PD_{it}}$ is the population density. $\mathbf{Unemployed_{it}}$ is the unemployed rate. $\mathbf{Ecological\ associations_{it}}$ is the percentage of people aged 14 and over who have attended a voluntary association in the last 12 months.

In the panel analysis we distinguish between fixed effects (FE) and random effects (RE). The error term can be decomposed as: $u_{it} = \mu_i + \lambda_t + v_{it}$, where μ_i represents a specific individual effect,[5] λ_t represents a specific temporal effect[6] and v_{it} is the stochastic error term. In the panel with random effects, these three variables are an independent and identically distributed random noise, assumed uncorrelated with the explanatory variables included in the model. In the panel with fixed effects, on the contrary, μ_i is not a random variable, but a parameter to be estimated and it is specific to each province; it captures a structural aspect of the province that differentiates it from the other provinces. λ_t is a parameter that captures annual changes that are common to all province. The choice between FE and RE is not straightforward and may be sorted out through the Hausman test, that allows to compare the alternative estimators. Specifically, under the null hypothesis of zero correlation between the error terms and the covariates, the RE model is the best (the generalized least squares [GLS] estimates are BLUE), while under the alternative hypothesis, the statistical properties of the GLS estimator of the RE model no longer apply. The estimates of the FE model are consistent both under the null hypothesis and under the alternative hypothesis, but the estimator is not efficient under the null hypothesis. Consequently, under the null hypothesis, the estimates are statistically similar and,

[5] The province-specific variable, time-invariant and activated by provincial dummies, captures how each province deviates from the average structural relationship common to all provinces (the provincial fixed effect).

[6] It is the time-specific variable, activated by time dummies, useful to purify the structural relationship, which is common to all provinces, from cyclical variations that are also common to all provinces.

therefore, we choose the RE model; vice versa, under the alternative hypothesis, we will choose the FE model because it is consistent.

In addition, before proceeding with the econometric exercise, we test for the presence of multicollinearity among the regressors. In particular, the Variance Inflation Factor (VIF) allows us to control for multicollinearity and to exclude it, as $VIF < 10$ for each variable. The highest VIF value, found for the variable VA (value added per capita), is 7.34, which is well below the threshold. The tolerance associated with each variable, 1/VIF, is > 0.1, which allows to exclude multicollinearity (a tolerance value < 0.1 is comparable with a VIF equal to 10). Moreover, the Hausman test rejects for all estimates the null hypothesis and leads us to prefer the FE model over the RE model. Consequently, we focus on the FE results.

3 Results

The results are reported in the Table 3. The estimated coefficients are standardised, and we can compare them to assess the relative strength of each of the predictors. For instance, when the dependent variable is the **TSCR**, the Unemployed variable has a coefficient equal to 0.147. Thus, a one standard deviation increase in Unemployed leads to a 0.147 standard deviation decrease in TSCR, with the other variables held constant.

Regarding the geographical interaction variables, Table 3 shows that an increase in corruption (C&C) reduces TSCR, and the collection of plastic, paper and glass in the provinces of Central Italy. Instead, **C&C** negatively affects all recyclable waste materials in Southern Italian provinces. For both macro-areas (Central and Southern Italy) the collection of plastic is most affected by an increase in corruption (-0.899 for the provinces of Central Italy, -0.782 for the provinces of Southern Italy). The presence of corruption in public office undermines the separate collection targets, and therefore contributes to the environmental degradation (Gani and Scrimgeour 2014). The **RQ** coefficient d positive expected sign as expected and is statistically significant only for paper glass in the case of Central Italy, while it is positive and statistically significant for paper and glass in Southern Italy. The ability of the government to promote and formulate effective regulatory interventions does not matter in the separate collection process in Italy. The **RL** coefficient features a positive sign as expected and is statistically significant only for paper in Central Italy and for TSCR and organic in Southern Italy. In general, the presence of legal institutions successfully enforcing the law, favours the separate waste collection process through monitoring and deterrence measures (e.g., financial penalties). Finally, the **V&A** coefficient shows the expected positive sign and is statistically significant only for organic waste collection in Central Italy. This result applies to all materials except the organic one in Southern Italy and allows us to conclude that the free flow of information through the media (e.g., television, newspapers, etc.) positively affects the civic engagement of citizens and policy makers, promoting recycling, and in our case the collection of plastic as well.

Regarding the socio-demographic and economic variables, we show that the **population density** has a negative impact on waste sorting at source. In particular, the

Table 3 Results of the model with single pillars of IQI and geographical interaction variables

Variables	TSCR	Paper	Glass	Plastic	Organic
VA	0.000	0.165	0.000	0.000	0.000
	(0.12)	(1.78)*	(0.25)	(0.55)	(0.46)
C&C *Central Italy	− 0.800	− 0.699	− 0.858	− 0.899	− 0.547
	(3.79)***	(2.17)**	(2.54)**	(2.61)***	(1.61)
RQ*Central Italy	− 0.022	0.247	0.334	− 0.003	0.081
	(0.28)	(2.15)**	(2.67)***	(0.02)	(0.64)
RL*Central Italy	− 0.099	0.317	− 0.164	− 0.266	-0.227
	(0.87)	(1.90)*	(0.90)	(1.23)	(1.24)
V&A*Central Italy	− 0.003	0.057	− 0.028	0.015	0.453
	(0.03)	(0.39)	(0.18)	(0.08)	(2.79)***
C&C *South Italy	− 0.401	− 0.315	− 0.382	− 0.782	− 0.574
	(6.03)***	(3.24)***	(3.60)***	(6.16)***	(5.38)***
RQ*South Italy	0.076	0.158	0.154	0.066	0.084
	(1.44)	(2.04)**	(1.83)*	(0.65)	(0.99)
RL*South Italy	0.111	− 0.104	0.060	0.142	0.0447
	(1.74)*	(1.11)	(0.59)	(1.15)	(4.34)***
V&A*South Italy	0.120	0.310	0.202	0.306	0.062
	(1.72)*	(3.02)***	(1.80)*	(2.29)**	(0.55)
Ecological	0.044	0.063	0.073	0.081	0.050
	(3.06)***	(2.96)***	(3.15)***	(2.92)***	(2.14)**
PD	− 0.185	− 0.532	− 0.590	− 0.165	− 0.562
	(1.06)	(2.17)**	(2.16)**	(0.53)	(2.07)**
Unemployed	0.147	0.141	0.135	0.160	0.198
	(4.28)***	(2.82)***	(2.46)**	(2.44)**	(3.60)***
Temporal dummies					
2005	− 0.059	− 0.063	− 0.041	− 0.073	− 0.056
	(4.72)***	(3.44)***	(2.04)**	(3.03)***	(2.80)***
2006	− 0.100	− 0.116	− 0.084	− 0.111	− 0.087
	(7.53)***	(5.99)***	(3.96)***	(4.38)***	(4.09)***
2007	− 0.142	− 0.161	− 0.133	− 0.152	− 0.119
	(9.48)***	(7.37)***	(5.57)***	(5.31)***	(4.95)***
2008	− 0.213	− 0.201	− 0.194	− 0.220	− 0.172
	(13.27)***	(8.54)***	(7.57)***	(7.18)***	(6.65)***
2009	− 0.243	− 0.198	− 0.201	− 0.262	− 0.204
	(18.52)***	(10.28)***	(9.57)***	(10.45)***	(9.65)***
2010	− 0.278	− 0.220	− 0.218	− 0.308	− 0.234
	(19.49)***	(10.55)***	(9.56)***	(11.28)***	(10.23)***
2011	− 0.316	− 0.175	− 0.216	− 0.311	− 0.256
	(21.95)***	(8.32)***	(9.38)***	(11.31)***	(11.09)***
Hausman test	124.92***	55.81***	29.21***	76.76***	48.49***
R^2	0.64	0.29	0.28	0.35	0.37
N	824	824	824	824	824

t-statistics are in parentheses; *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

PD coefficient is negative and statistically significant only for paper, organic and glass. The magnitude varies among materials, and it is higher for glass (− 0.590) than organic (− 0.562) and paper (− 0.532). We can conclude that in the more densely populated areas, the separate collection process is hampered by the high cost of land especially in the case of glass. Indeed, this recyclable material is more collected through bring points, which require a lot of space. For this reason, disposal sites can take place in suburban areas far from the city centre, where the cost of land is lower. However, in that case the costs of transporting waste rises (for both public and private agents; see Ricci et al. (2003)).

The coefficient of **value added per capita** is statistically significant and has a positive expected sign only for paper (0.165), meaning that the collection of paper is positively influenced by increases in the provincial VA. Paper material indeed is primary collected through the kerbside collection in Italy (BiPRO/CRI 2015). The implementation of this collection system requires more economic resources than the bring points (see Sect. 2.1). Our result is also consistent with Berglund and Söderholm (2013) arguing that rich countries tend to recover relatively more paper than low-income countries.

The coefficient associated with **participation to ecological associations** has the expected positive sign and is statistically significant for both TSCR and its waste materials. The highest impact is observed for plastic. Participation in environmental organizations generates stronger awareness of environmental issues (moral norms (Hage et al. 2009) and also promotes the circulation of information about the importance of the environment and its protection (Jones et al. 2010). Schultz et al. (1995) argued that when recycling requires much effort, only people who are environmentally concerned would recycle. In addition, the results show that the **unemployment rate** has a positive and significant impact on TSCR and individual materials. The highest impact is associated with the collection of organic waste. The opportunity cost of the unemployed is lower than for the employed, and this generates a stronger pro-environmental behaviour in unemployed people (Hage et al. 2009). This problem would be partly solved by devising monetary reward. However, Deci (1971) found that monetary rewards contingent upon performance reduce the intrinsic motivation to carry out an activity (crowding-out effect). In addition, this disappearance of intrinsic motivation tends to be permanent because the task is no longer performed when payment is withdrawn (see Iyer and Kashyap 2007). In contrast, the effects of non-monetary interventions (e.g. public information and awareness campaigns) persist after they have been withdrawn (Iyer and Kashyap 2007). Moreover, these policies can preserve intrinsic motivation or increase it (crowding-in effect) (see also Deci 1971; Frey and Jegen 2001).

Finally, we observe that the **time dummies** are negative and statistically significant. In particular, a continuous reduction in separate collection process emerges, persisting throughout the period considered in our analysis. This is partially due to the economic crisis of 2008, which has encouraged the emergence of economic concerns replacing environmental concerns. Our result is consistent with Kollmuss and Agyeman (2002), Lovelock et al. (2013), Franzen and Meyer (2010), Carter et al. (2013).

4 Discussions

Overall, our results show the crucial relevance of the RQ, RL and V&A pillars of institutional quality for the implementation of an effective separate collection in each macro-area. On the other hand, the analysis shows the negative effect of corruption, especially in Central and Southern Italy where it is higher, on recyclable waste materials. For both these areas, the collection of plastic is most affected by an increase in corruption.

In addition, the analysis shows a considerable importance of institutional factors in Southern Italy provinces on both TSCR and the main recyclable waste materials. Moreover, in all instances, the Hausman test suggests the adoption of a 'fixed effects' representation: this means that the unobserved provincial component is highly correlated with the set of regressors that explain TSCR and the four recyclable waste materials. At this point, it seems interesting to show the estimated fixed effects for single provinces. Nevertheless, due to the abundance of Italian provinces, we show the graphs of fixed effects at the regional level (NUTS-2). The estimates of the fixed effects are represented in Fig. 3. The graphs associated with the regions of Northern Italy are characterised by the highest values of TSCR and of the main recyclable waste materials. In particular, the Veneto region emerges as the most virtuous. The regions of Central Italy on the other hand, display positive values for their fixed effects (excluding Latium, which shows positive values only for plastic and organic) but lower than those recorded for the regions of Northern Italy. The regions of Southern Italy present the lowest values, highlighting the already known difficulty of the Southern Italian regions in converging to the results achieved by the most virtuous regions of Northern Italy (see Agovino et al. 2016, 2017). Moreover, Southern Italian regions show positive values only for plastics and organic waste. The responsibility for this gap can be mainly attributed to local governments. In Central Italy, local management problems hampering the waste management process are persistent. It is hard for the Optimum Territorial Unit to come into force, and in Latium—where separate collection in 2013 was about 35%, well below the 65% threshold set by the Legislative Decree 152/2006 (Norms Concerning the Environment)—the persistent emergency has so far acted as a barrier to convergence between Central Italy and Northern Italy in terms of waste management performance (BiPRO 2012). The intense complexity of the bureaucracy is widely felt to be unnecessary and counterproductive. The administrative process of waste management started to take place slowly, following severe delays due to a lack of reactivity from local authorities and widespread corruption among public officials. The waste management crises previously affecting Campania (see D'Alisa and Armiero 2013; Armiero 2014; De Biase 2009; Armiero and Fava 2016; Armiero and D'Alisa 2012; D'Alisa and Kallis 2016) and now concerning Latium (e.g., the recent waste crisis in the city of Rome) thus appear to be primarily driven by policy failures that include delays in introducing more economically-oriented instruments and a lack of new diversified tools in waste management and disposal facilities (Mazzanti et al. 2008).

The territorial gap issue emerging from our analysis has been addressed by the European Commission through European Regional Policy. With the European

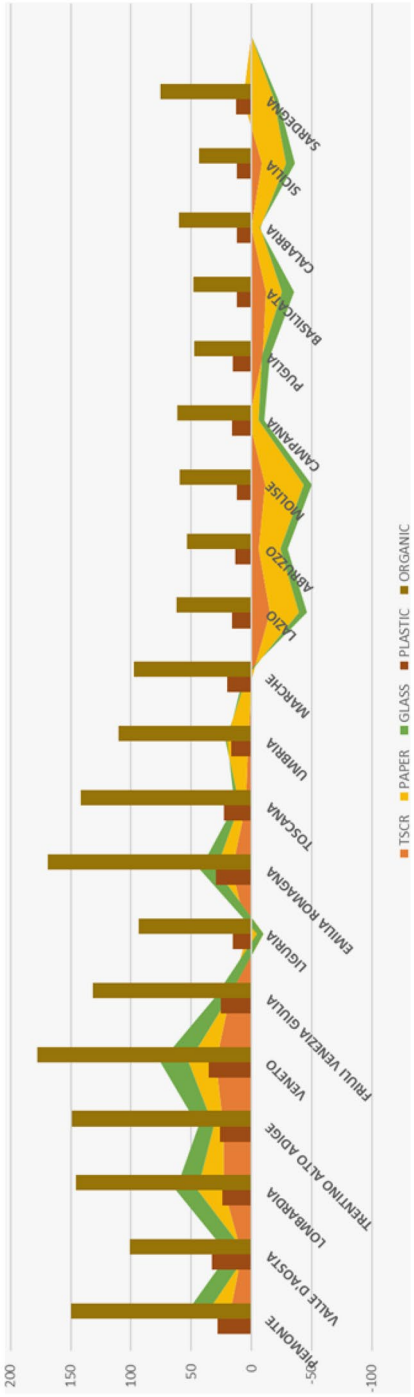

Fig. 3 Regional fixed effects. Regions of northern Italy: Piedmont, Valle d'Aosta, Lombardy, Trentino Alto Adige, Veneto, Friuli Venezia Giulia, Liguria, Emilia Romagna; regions of central Italy: Tuscany, Umbria, Marche, Latium; regions of southern Italy: Abruzzo, Molise, Campania, Apulia, Basilicata, Calabria, Sicily, Sardinia

Regional Development Fund Regulation (ERDF) (EC) No 1783/1999 and the next Regulation (EC) No 1080/2006, the EU invested in thousands of projects in Italy and in all the European territory, to foster a regional convergence process (repealing Objective 1 Regions of the programming period 2000–2006), that should allow the less developed regions to catch up with the more prosperous areas of the European Union. Among European countries, Italy has been the most particular example of the use of explicit incentives to improve the national performance of regional development policy on the provision of public goods and services in the areas in greatest need. In this regard, Agovino et al. (2016, 2017) analyse data on separate waste collection in the Italian regions to evaluate the effectiveness of the ERDF and show that the ERDF has not had an impact on the regional TSCR during the two programming periods mentioned above. In particular, the scholars conclude that, since the ERDFs are particularly exposed to managerial slack, especially in the absence of effective monitoring activities or appropriate absorption schemes, their implementation triggered not only the failure of the Objective of Convergence but also poor institutional quality and hence low efficiency of these regions in the separate collection process (see Agovino et al. 2016, 2017). Furthermore, the ERDF should have incentivised the introduction of an appropriate waste segregation model (such as mono-material and kerbside collection), requiring significant economic resources, in the low-income provinces (as in Southern Italy), favouring collecting recyclable material (e.g. paper).

In order to improve the separate collection process in the regions of Central and Southern Italy and to overcome the failures of the ERDFs, an efficient and transparent waste management is needed, promoting the citizens' trust in local institutions. One way to foster civic trust and engage residents in the separate collection process is a fair and transparent tariff plan. In this regard, the Veneto region—given the good performance shown over the years (see Bucciol et al. 2011, 2015)—and the waste management plans adopted in its provinces may be regarded as benchmarks for the provinces of Southern Italy. A case in point is the province of Treviso, where in 2000 kerbside collection and a PAYT (Pay-As-You-Throw) consumer charging system were introduced to the detriment of the drop-off system and of the standard flat rate system, calculated considering only the number of family members and the square metres of the house (Bucciol et al. 2011). Bucciol et al. (2015), decomposing the effect of PAYT and kerbside waste collection, have shown that the former has generated an increase of 17% in separate collection in the municipalities of Treviso, while the latter has increased recycling by 15.7%. The combination of both schemes (PAYT and kerbside) may represent a solution to the high production of waste in Southern Italy, as well as a useful tool to increase the percentage of separate collection in their provinces (Yeomans 2007).

In summary, there is still room to improve the Italian separate collection of individual recyclable materials, in order to achieve the EU recycling targets. Especially Southern provinces need to implement more strategies to bridge the gap with Northern provinces. First of all, institutions could resort more intensely to information instruments. For instance, the Province of Cremona set up an innovative project called "Look at packaging", a campaign aimed at the reduction and recovery of packaging waste, targeting supermarkets and consumers, to provide information,

promote sensitivity and impart a sense of responsibility on the waste issue. Moreover, institutions should consider more carefully the use of monetary incentives to citizens, because once adopted due to the incentives, correct behaviours persist only in the presence of the incentives. When the incentives stop, there may be a crowding-out effect (Frey and Jegen 2001, amongst others). At this point, it seems more useful, given the positive results achieved in the province of Treviso, to implement the PAYT tariff system (Kinnaman 2006, 2010). In this case, the amount of tax is no longer calculated solely on the basis of the size of the dwelling and the number of family members but also on the amount of non-differentiated waste produced.

5 Concluding remarks

Our paper has investigated the effect of the institutional quality and other socio-economic factors on TSCR and on the collection of organic, paper, plastic and glass materials, employing a dataset containing information on the Italian provinces (NUTS-3) for the years 2004–2011.

The results show that the pillars of institutional quality (RQ, RL and V&A), VA and Ecologic do matter for the implementation of an effective separate waste collection. From the citizen's point of view, separating waste requires time, space and inconvenience, as well as a sensitivity to pro-environmental issues. The analysis shows that when the cost of separate waste collection becomes too high (this is the case of the most populated areas and for the employed) different types of policy instruments must be introduced to incentivise citizens to separate their waste, such as: awareness-raising campaigns, regulatory instruments, monetary rewards and voluntary agreements. The most effective strategy is to encourage citizens to take into account the benefits that separate collection confers upon the whole society (by awareness-raising campaigns). In addition, our results suggest the implementation of kerbside collection, especially for the collection of glass in the most populated areas. However, the same policy instrument may be implemented in different ways by each local institution, entailing a higher or lower degree of effectiveness. This has important implications when considering the differences among North, Central and South. As a matter of fact, a marked difference between Central-Southern Italy and Norther Italy emerges. This gap is due, on the one hand to a higher RQ, RL and V&A in Northern Italy, that positively affect separate waste collection of recyclable materials, and on the other hand, to the higher extent of corruption in Central-Southern Italy that negatively affect TSCR.

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Appendix

Table 4 in the appendix.

Table 4 Symbol and description of variables

Symbol	Description
Dependent variables	
TSCR	Separate waste collection in kg per habitants
Paper	Separate waste paper in kg per habitants
Glass	Separate waste glass in kg per habitants
Plastic	Separate waste plastic in kg per habitants
Organic	Separate waste organic in kg per habitants
External factors or environmental factors	
$\mathbf{D_i * C\&C}$	Control and Corruption Index at macro-area level for $i =$,North, Central and South Italy
$\mathbf{D_i * RQ}$	Regulatory Quality Index at macro-area level for $i =$,North, Central and South Italy
$\mathbf{D_i * RL}$	Rule of Law Index at macro-area level for $i =$,North, Central and South Italy
$\mathbf{D_i * V\&A}$	Voice and Accountability Index at macro-area level for $i =$,North, Central and South Italy
Socio-demographic and economic variables	
Unemployed	The unemployed rate
Ecologic	Percentage of people aged 14 and over who have attended a voluntary association in the last 12 months
VA	Value added per capita
PD	Population density (rate of residents per square km)

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