Original Articles

Kuznets curve in municipal solid waste production: An empirical analysis based on municipal-level panel data from the Lombardy region (Italy)

Salvatore Ercolano[a] (please, add also the affiliation c for this author)

ercolano@issm.cnr.it

Giuseppe Lucio Lucio (The author first name is 'Giuseppe Lucio', not 'Giuseppe Lucio Lucio') Gaeta[b, c, *]

glgaeta@unior.it

Stefano Ghinoi[d] (Please, change the affiliation for this author as follow: Department of Economics and Management, University of Helsinki, Latokartanonkaari 5, P.O. Box 27 00014, Helsinki, Finland)

stefano.ghinoi2@unibo.it (Please, change this email with the following: stefano.ghinoi@helsinki.fi)

Francesco Silvestri[e, f]

francesco.silvestri@unimore.it

[a]National Research Council (CNR) Institute of Studies on Mediterranean Societies (ISSM), Via Cardinale Guglielmo Sanfelice, 8, 80134 Napoli, Italy

[b]Department of Human and Social Sciences, University of Naples L'Orientale, Largo San Giovanni Maggiore 30, 80134 Napoli, Italy

[c]c.MET05, Inter-University Centre for Applied Economic Studies on Industrial Policy, Local Development and Internationalization, Via Voltapaletto 11, 44121 Ferrara, Italy

[d]Department of Agricultural Sciences, University of Bologna, Viale Fanin, 44, 40127 Bologna, Italy

[e]Department of Communication and Economics University of Modena and Reggio Emilia, viale Antonio Allegri, 9 – Palazzo Dossetti, 42121 Reggio Emilia, Italy

[f]Eco&Eco Ltd, Via Guglielmo Oberdan, 11, 40126 Bologna, Italy

[*]Corresponding author at: Department of Human and Social Sciences, University of Naples L'Orientale, Largo San Giovanni Maggiore 30, 80134 Napoli, Italy.

Abstract

By using a novel database that observes 1,497 municipalities from the Lombardy region in Italy between 2005 and 2011, this paper provides an empirical test of the Waste Kuznets Curve (WKC) hypothesis.

Fixed effects regression analyses, generalized method of moments models and a number of robustness checks strongly indicate that among the municipalities under scrutiny there is an inverted U-shaped relationship between economic development and waste generation. Nevertheless, only a few of the municipalities under scrutiny reach the turning point of the estimated curve. These findings contribute to the expanding empirical literature that tests WKC by using municipal data, considered the most appropriate for this kind of analysis.

Keywords: Waste generation; Kuznets; Panel data

1 Introduction

Over the last decade (2001–2010), the European Union has observed a consistent increase in municipal waste (MW) per capita in 18 out of its 28 members (European Environment Agency, 2013). Even if MW only accounts for approximately 10% of total waste generated in the EU, it has a relevant socio-environmental impact (Eurostat, 2016a,b). In this perspective, studies that investigate the determinants of MW generation are particularly valuable since they might inform policies aimed at incentivizing MW reduction, that are very important in the waste management strategy (Beigl et al., 2008).

This paper aims to contribute to the literature by empirically addressing a highly debated issue, namely the existence of a link between economic wealth and waste production as modeled by the Waste Kuznets Curve (WKC), which predicts an inverted U-shaped dependence of waste production on economic development (Stern, 2004).

The empirical evidence concerning the WKC hypothesis is controversial. While cross-national studies (Cole et al., 1997; Karousakis, 2009; Mazzanti and Zoboli, 2009) mostly reject it, single country cross-regional (provincial) studies provide mixed results (Managi and Kaneko, 2009; Mazzanti et al., 2009, 2008). Municipal-level analyses, meanwhile, are much rarer, although those recently published seem to support the WKC hypothesis (Ichinose et al., 2015).

Our paper aims to add to this latter group of contributions by proposing an econometric analysis based on a large and newly constructed municipal-level dataset that considers municipalities from the Lombardy region of Northern Italy (n = 1497), which were longitudinally observed between 2005 and 2011.

There are a number of reasons why the use of single country municipal-level data is appropriate for testing the WKC hypothesis. On the one hand, it makes it possible to inspect the consistent within-country heterogeneity in MW generation that exists among municipalities. On the other hand, it is worth noting that MW management strategies are developed by local governments (even if this is done within the framework provided by the EU and national directives; Reggiani and Silvestri, 2017) and this makes the inspection of municipal-level determinants of MW particularly valuable.

The focus on municipalities from Lombardy, one of the richest and most highly populated NUTS2 regions in Europe (Eurostat, 2014) and the one that reports the highest total production of urban waste in Italy (ISPRA, 2013), is appropriate for our empirical investigation since this region has been suggested to be an appealing case study for inspecting waste production and waste management (Gaeta et al., 2017).

The paper is articulated as follows: section two provides a review of the empirical literature concerning the WKC. Section 3 presents the data used in the analysis, and Section 4 discusses the methodological issues of the analysis. The results and their discussion are reported in Section 4. Finally, Section 5 draws the conclusions arising from this study.

2 The environmental Kuznets curve and the waste Kuznets curve hypotheses

In the scholarly debate about how economic growth affects environmental quality, the WKC hypothesis has gained substantial attention over recent years. This hypothesis draws on seminal works by Grossman and Krueger (1991), Holtz-Eakin and Selden (1992), and the World Bank (1992) on the EKC, and suggests an inverted-U shaped relation between deterioration of environmental measures and economic development.

According to scholars, the EKC’s non-linear trend might be explained by a number of driver mechanisms that do not exclude each other. Firstly, a scale effect explains the ascending part of the curve. Indeed, the greater the output produced by an economy, the higher the inputs used in the production should be. This, in turn, is presumed to exert a positive impact on environmental degradation (Tsurumi and Managi, 2010). Secondly, non-linearity might arise because of the link existing between economic development and an economy’s structure (composition effect). Indeed, compared with countries based on subsistence agriculture, those that are specialized in advanced manufacturing are richer, and yet at the same time more resource-intense and polluting. This implies a positive and monotonic link between development and environmental degradation. Nevertheless, once they reach a certain stage of development, economies tend to shift from manufacturing towards services, and this translates into a reduction of environmental degradation. This would explain the descending part of the EKC (Tsurumi and Managi, 2010). Thirdly, the positive effect of the expansion of economic activities on environmental deterioration that characterizes the first part of the EKC might be inverted thanks to the evolution of technological progress fostered by economic growth (Grossman and Krueger, 1991; Hettige et al., 2000; Selden et al., 1999). Fourthly, the explanation of the EKC shape might depend upon the fact that public opinion interest for “environmental goods” only emerges once their scarcity is perceived (Unruh and Moomaw, 1998; Torras and Boyce, 1998).

Subsequent studies have specified the EKC hypothesis by considering different indicators of environmental degradation, e.g. greenhouse gas emissions, water pollution, and change in forest area (Bhattarai and Hammig, 2001; Lee et al., 2016; Mazzanti and Zoboli, 2009; Sinha and Bhattacharya, 2017; Wang et al., 2016; Wong and Lewis, 2013). Nevertheless, until recent years surprisingly little attention has been given to the application of the EKC to waste generation, i.e. to the WKC hypothesis, even if the number of contributions specifically focused on this topic is increasing (Abrate and Ferraris, 2010; Mazzanti et al., 2009).

As in the case of studies focused on the EKC, most tests of the WKC hypothesis are carried out through cross-national empirical investigations. By analyzing cross-national solid waste generation data from 1960– to 1990 provided by the Organisation for Economic Co-operation and Development (OECD) for 39 countries, Shafik (1994) finds a monotonic and direct relationship between waste production and income. According to his interpretation, this is because thanks to landfills “solid waste disposal can be transformed into a localized and potentially harmless problem” (p. 767). The same result, i.e. waste generation monotonically increasing throughout the income range examined, is found by Cole et al. (1997), who focus on cross-national municipal waste data collected in 13 OECD countries over the period 1975–1990. Following a perspective similar to Shafik (1994), these authors suggest that an increase of income determines an increase of waste generation. The idea that waste generation monotonically increases with income is also supported by Johnston and Labonne (2004) and Karousakis (2009), who both analyze cross-national OECD data on municipal solid waste from 1980– to 2000. Based on 1995–2005 data from 25 European countries, Mazzanti and Zoboli (2009) reach the same conclusion, even if the elasticity of municipal solid waste production to income drivers found by their analysis is lower than that observed by previous contributions. While all the contributions just mentioned suggest a rejection of the WKC hypothesis, this result is not univocal since it is contested, for example, by Raymond (2004). His analysis focuses on data from 142 countries and finds that the waste/consumption stress indicator[1] exhibits an inverted U-shape relation with income.

More generally, it is worth noting that while all the cited WKC studies have their merits, cross-national empirical investigations also have notable limits. Firstly, they estimate “average” international curves (Mazzanti and Zoboli, 2009), which might not hold when the analysis is addressed to sub-national administrative units that might reveal high heterogeneity in waste generation (Ichinose et al., 2015). This is a crucial limitation since, in EU countries, as well as in the USA and Japan, local authorities are mainly responsible for the implementation of waste policies, and therefore the empirical investigation of waste generation determinants can produce policy-relevant findings only when it is carried out with these taken into consideration as units of analysis. Secondly, since cross-country studies are based on cross-national heterogeneity in income and waste generation, they do not allow us to check whether the Kuznets curve hypothesis holds for all the countries under scrutiny (Mazzanti et al., 2009; Lim, 1997).

In order to overcome these issues, scholars have recently started to focus on single-country case studies and to use more refined data, such as those acquired from sub-national jurisdictions. Apart from the issues noted above, compared with cross-national studies, these within-country empirical studies may benefit from the high number of subnational observations that can usually be collected. The literature that focuses on these sub-national data is expanding, but still not extensive (Mazzanti et al., 2009).

Part of this literature exploits provincial or regional data. This is the case of Managi and Kaneko (2009), who analyse Chinese provincial-level data for 1992–2003 and find that solid waste generation monotonically increases with per capita GDP. Mazzanti et al. (2009) exploit a panel dataset covering the 103 Italian provinces from 2000 to 2004. Their findings strongly support the WKC hypothesis by highlighting the existence of a non-linear U-shaped relationship between municipal solid waste generation and per capita added value (which is used as a proxy of level of economic development). The rather high income at which the Kuznets curve turning point is observed unfortunately suggests that only a few provinces reach the level of wealth where waste generation would be expected to lower.

Another stream of the literature, this consisting of the most recent contributions, is based on the use of municipal-level data, particularly appropriate when the focus is on those institutional contexts where municipalities do play a crucial role in waste management. Studies that belong to this stream seem to confirm the WKC hypothesis. Ichinose et al. (2011) use cross-sectional Japanese municipal-level data on solid waste production that were collected in 2005; their analysis finds evidence of a WKC with a turning point whose value is significantly lower than the maximum income observed in the sample under scrutiny. Trujillo Lora et al. (2013) rely on Colombian data from 707 municipalities observed over the period 2008–2011. According to their analysis, the quantity of landfilled solid waste (which represents more than 90% of total waste generated) reported by each of these municipalities exhibits a WKC relationship with economic development, whose turning point is heterogeneous across the regions of the country. To the best of our knowledge there is only one Italian example of such a municipal-level WKC analysis, this provided by Abrate and Ferraris (2010), who observe an unbalanced panel of 547 selected Italian municipalities from 2004 to 2006. They find an inverted U-shaped relationship between non-separated waste and economic development, proxied by per capita declared income. Unlike their study, the empirical analysis we propose in the following section focuses on a single Italian region, Lombardy. Our data does not cover a set of selected municipalities from the region, but almost all the existing ones, and this allows us to build a comprehensive and large (n = 1447) dataset to be employed in our econometric investigations.

3 Data

According to data availability, our analysis considers an unbalanced panel made up of 1497 municipalities from the Lombardy region of Northern Italy (out of a total of 1527 existing municipalities) that were observed over a seven-year period from 2005 to 2011. This sample of municipalities is highly heterogeneous in terms of size (from a minimum of approximately 1 km^2 reported by Fiorano al Serio to a maximum of 244 km^2 observed for Valdidentro) and population (from a minimum of 30 reported by Pedesina in 2011 to a maximum of 1,250,000 inhabitants reported by Milan in 2005).

Table 1 presents the variables considered in the empirical study and shows for each of them the corresponding label, definition and data source.

Table 1 Labels, description and data sources for variables used in the empirical analysis.

Label	Description	Source
MWG	Per capita waste produced per day (kg)	ARPA Lombardy (Regional Enrivornmental Protection Agency)[A]
ECONOMIC_DEV	Average tax return per inhabitant (total tax return in €/number of inhabitants) expressed in real terms (base year = 2005)	Own elaboration based on data from the Italian Revenue Agency (Agenzia delle Entrate)[B]
DENSITY	Density of inhabitants (number of inhabitants per squared km)	ISTAT (Italian National Institute of Statistics)[C]
OLDSHARE	Share of people more than 65 years old (%)	ISTAT (National Institute of Statistics)[C]
ACCOMODATION	Sleeeping accomodation (per capita; number of sleeping accommodation facilities/total population)	Own elaboration on data from ISTAT (Italian National Institute of Statistics)[C]

FOREIGN	Share of foreigners over population	Own elaboration on data provided by ISTAT (Italian National Institute of Statistics)[C]

Notes: [A] Data are available at the following link: http://ita.arpalombardia.it/ITA/servizi/rifiuti/grul/rif_urb.asp [last access on 3/3/2018]; [B] data are available online and accessible through the following link http://www.comuni-italiani.it/03/[last access on 3/3/2018]; [C] data are available through the "Atlante Statistico dei Comuni Italiani" (Statistical Atlas of Italian Municipalities) app developed by the Italian National Institute of Statistics and downloadable at the following link: https://www.istat.it/it/archivio/113712.

Yearly municipal-level data concerning daily per capita waste generation (MWG) are provided by the Lombardy Regional Environmental Protection Agency (ARPA). MWG reveals a remarkable cross-municipality heterogeneity in the Lombardy region The descriptive statistics displayed in Table 2 show that MWG varies from 0.35 kg per day (reported by the municipality of Dosso del Liro in 2010) to 7.22 kg per day (reported by Limone sul Garda in 2011). The average value is 1.33 kg and it is in line with figures reported by Abrate and Ferraris (2010), who investigated a small sample made up of the biggest Italian municipalities. MWG is used as the dependent variable in our regression analyses where a wide set of regressors is considered.

Table 2 Descriptive statistics of variables used in the analysis.

Variable		Mean	Std. Dev.	Min	Max	Observations
MWG	overall	1.331	0.398	0.352	7.223	N = 10346
	between		0.382	0.459	6.711	n = 1497
	within		0.107	0.495	3.065	T-bar = 6.91116
ECONOMIC_DEV	overall	12406.470	2573.561	1566.194	44588.430	N = 10346
	between		2447.824	1803.834	29643.670	n = 1497
	within		765.527	3164.296	31107.270	T-bar = 6.91116
DENSITY	overall	549.979	770.979	2.524	7806.509	N = 10346
	between		767.518	2.885	7637.363	n = 1497
	within		22.187	246.639	801.359	T-bar = 6.91116
OLDSHARE	overall	0.197	0.049	0.044	0.511	N = 10346
	between		0.049	0.049	0.500	n = 1497
	within		0.008	0.133	0.250	T-bar = 6.91116
ACCOMODATION	overall	0.031	0.163	0.000	5.104	N = 10346
	between		0.161	0.000	4.821	n = 1497
	within		0.018	−0.408	0.405	T-bar = 6.91116
FOREIGN	overall	0.067	0.041	0.000	0.291	N = 10346
	between		0.037	0.000	0.235	n = 1497
	within		0.016	−0.025	0.195	T-bar = 6.91116

Given the objective of the paper, the covariate this study is mainly interested in is a municipal-level proxy of economic development. Due to data availability, measures of economic development adopted in WKC studies and in contributions on the determinants of municipal solid waste generation vary according to the territorial level investigated. The existing cross-national empirical literature on WKC measures economic development through variables such as final consumption expenditure of households or gross domestic product per capita (Mazzanti and Zoboli, 2009, 2005; Arbulú et al., 2015; Fischer-Kowalski and Amann, 2001). Meanwhile, within-country analyses focusing on the regional or provincial level use gross regional product (Managi and Kaneko, 2009) or per capita value added (VA) (Mazzanti et al., 2008, 2009, 2011, 2012; Mazzanti and Zoboli, 2009; D'Amato et al., 2015).

Nevertheless, to the best of our knowledge none of the above-mentioned variables are longitudinally available for Italian municipalities. For this reason, our study relies on data on per capita declared income as calculated on the basis of municipal-level information reported by the Italian Revenue Agency (*Agenzia delle Entrate*). For each Italian municipality the Agency provides yearly data concerning the total amount of income declared by its residents. A similar variable has been adopted by Ichinose et al. (2011), whose analysis of the WKC with data from Japanese municipalities measures economic development in terms of total taxable gains, and by Abrate and Ferraris (2010), whose investigation of Italian data from a sample of municipalities relies on fiscal data from the Italian Ministry of Internal Affairs.

When relying on fiscal data one has to bear in mind that not all the residents of a municipality declare income. According to our data, in Lombardy the share of contributors who declared income over total population ranges from 13.7% (reported by the municipality of Val Rezzo in 2009) to 89.8% (Golferenzo in 2008). For this reason, we measure a given municipality's economic development through the ratio between the total amount of income declared by its residents and the total number of residents. The resulting per capita municipality income is expressed in real terms (euro, base year = 2005), and is labeled as ECONOMIC_DEV.

Consistently with the existing literature on WKC, the empirical investigation also considers four other time-variant covariates.

First, the literature suggests that higher population density has a positive effect on MW since "in more densely populated areas, only economies of scale spurred by urbanisation could invert the trend and reduce generation" (Mazzanti and Zoboli, 2009, p. 215). Therefore, municipality population density (labeled DENSITY) is included among regressors.

Second, consumption by elderly people might be presumed to be lower than the one reported by younger people, and therefore the same should apply to waste generation (Ichinose and Hosoda, 2014). To take this into account a variable (*OLDSHARE*) measuring the share of people aged >65 in each municipality is added to the set of covariates considered.

Third, some contributions highlight that tourism has a notable impact on MW (Arbulú et al., 2015). In order to test this hypothesis, we introduce a regressor that measures tourist receptivity rate to our models, given by the number of facilities for tourist accommodation existing in each municipality divided by the number of residents. This variable is labeled *ACCOMMODATION*.

Finally, our estimates also consider the share of foreign residents over population among the regressors. This variable is labeled *FOREIGN* in the following sections. The presence of foreigners has been considered as one of the possible determinants of municipalities' recycling performance, since people coming from abroad may face notable difficulties in understanding recycling rules in host countries, especially when their immigration is recent (Hage et al., 2008). The connection between the share of foreigners and waste generation is less obvious. Nevertheless, since in Italy families made up of foreign residents report income levels lower than those declared by their Italian counterparts, the inclusion of this variable might catch the effect of the presence of low-income families on waste generation, while the income variable catches the effect of average income. Prades et al. (2015) observes a positive, but not statistically significant, influence of foreigners on waste generation.

Descriptive statistics for all the variables presented in this section are displayed in Table 2.

4 Methodology

The data analysis is carried out by using both a static (fixed effects/random effects) and a dynamic panel data approach. Following the existing literature, an empirical test of the Kuznets curve hypothesis may be carried out by estimating the following equation:

$$MWG_{it} = \beta_1 ECONOMIC_{DEVit} + \beta_2 ECONOMIC^2_{DEVit} + \beta_k X_{it} + \zeta_t + u_i + \varepsilon_{it} \quad \textbf{(1)}$$

where MWG is the daily per capita waste generation in the *i*-th municipality at year t, ECONOMIC_DEV is a proxy of economic development; β_1 and β_2 are the coefficients to be estimated for this variable and its squared values, and an inverted U-shaped relationship between waste generation and income, consistent with the WKC hypothesis, is verified if $\beta_1 > 0$ and $\beta_2 < 0$. X is the $1 \times k$ vector of control variables and β_k is the associated vector of coefficients while ζ_t represents time fixed effects. Finally, u_i is the municipal (individual)-level effect and ε_{it} is the disturbance term.

Correlation between u_i and X covariates leads to the fixed effects estimation strategy (FE) that treats u_i as additional parameters to be estimated (Baum, 2006) and assumes orthogonality between the regressors and the error ε_{it} . On the other hand, when u_i is presumed to be uncorrelated with the X covariates, the municipality-level effects can be modeled as additional random disturbances and the model may be estimated through random effects (RE). This additional orthogonality condition is identifiable as an overidentifying restriction. Our analysis estimates both the FE and the RE models by considering heteroscedasticity-robust standard errors. In order to choose between these two estimation strategies, a Sargan/Hansen test is run with the aim of testing the extra restrictions imposed by RE.

To control whether the generation of municipal waste depends on its own past realizations, the lagged value of the dependent variable (MWP_{it-1}) might be included on the right hand of equation (1). As a preliminary attempt, the resulting equation might be estimated through Ordinary Least Squares (OLS). Nevertheless, the resulting estimates would be biased because of the correlation between the lagged dependent variable and the fixed effects in the error term (Roodman, 2009). In order to overcome this issue, one might carry out a within-group estimate of the same equation which, nevertheless, is still biased because of the correlation between the lagged regressand and the error term (Bond, 2002; Roodman, 2009).

In order to face this issue, the difference Generalized method of moments (GMM) approach (Hansen, 1982; Arellano and Bond, 1991) proposes to take the first difference of the original regression equation and to instrument the first differenced lagged values of the dependent variable by using previous lagged levels. According to Eberhardt and Teal (2013) in a globalized world with interconnected economies the analysis of macroeconomic data through GMM models could be invalid in presence of heterogeneous equilibrium relationships (Lee et al., 1997). Indeed, the GMM estimator is specifically designed for the analysis of microeconometric data which are usually characterized by a time dimension far smaller and an individual dimension far greater than macroeconomic data. Nevertheless following Judson and Owen (1999) the GMM procedure represents a second best solution when a corrected least squares dummy variable (LSDV) is not practical, with biased estimates lower than the Anderson–Hsiao estimator. For this reason, the GMM estimator is also commonly used in order to estimate the EKC (see the literature quoted in Section 2).

5 Results

Table 3 reports the results obtained through our static estimates. In order to ease interpretation of the regression results, before running the analyses the original *ECONOMIC_DEV* values were divided by 1000.

Table 3 Panel regression results. Coefficients and robust standard errors in parentheses. The dependent variable is daily per capita waste generated expressed in kg(MSW). $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

	(1)	(2)	(3)
ECONOMIC_DEV (×1000)	0.0424***	0.0477***	0.0489***
	(0.0094)	(0.0121)	(0.0105)
ECONOMIC_DEV^2 (×1000)	−0.0009***	−0.0010***	−0.0010***
	(0.0003)	(0.0003)	(0.0003)
DENSITY			−0.0001***
			(0.0000)
OLDSHARE			1.0718***
			(0.1680)
ACCOMODATION			1.0530***
			(0.1055)
FOREIGN			−0.5691***
			(0.1790)
Observations	10,346	10,346	10,346
Number of ID	1,497	1,497	1,497
Year dummy	No	Yes	Yes
Fixed/Random	Random	Fixed	Fixed
Sargan-Hansen statistic	4.858	6842.367	264.143
p	0.088	0.000	0.000
Turning point	€23,555	€23,850	€24,450

Three alternative specifications are considered. In model 1, only *ECONOMIC_DEV* and its square value are considered as regressors; this model provides a first insight into the link between municipal waste generation and economic development but does not take other covariates into account. In model 2, year dummies are added to the model and this allows us to catch the effect that time exerts on municipal waste generation trends. Finally, in model 3 the set of regressors used in model 2 is augmented by adding the variables presented in the previous section; i.e. this model allows us to inspect the link between economic development and municipalities' waste generation when other relevant time-variant variables are also taken into account.

For each specification only the most appropriate model between FE and RE is reported. At the bottom of each column included in Table 3, the result of a Sargan/Hansen test is displayed in order to support the choice of the models. Only in the case of model (1) the RE model turns out to be preferable. Nevertheless, the FE estimates obtained for this model are almost identical to the RE ones (in FE the coefficient calculated for ECONOMIC_DEV is 0.0474 while the one calculated for ECONOMIC_DEV^2 is −0.0009).

The examination of the results suggests that the WKC hypothesis is strongly supported when looking at municipalities from the Lombardy region. Both *ECONOMIC_DEV* and its squared values turn out to be highly significant ($p < 0.001$) from a statistical point of view; moreover the signs of the coefficients calculated for these variables are in line with the expectations ($\beta_1 > 0$ and $\beta_2 < 0$), which confirms that there is an inverted U-shape relationship between MW and economic development.

These findings are robust to model shifting. As a matter of fact, the inclusion of year dummies (model 2) and of time variant covariates (model 3) does not affect the statistical significance of the two regressors we are mainly interested in, and the same is true for the signs of the estimated β_1 and β_2 .coefficients. Even the size of the coefficients does not dramatically change from one model to another.

One line at the bottom of the table shows the value of *ECONOMIC_DEV* at which the turning point of the WKC is observed. The resulting values range between € 23,555 and €24,450. All the estimated turning point values are significantly higher than the average (see Table 2) and the median (€ 12,253.85) *ECONOMIC_DEV* values observed in our dataset. Nevertheless, despite being rare (less than 0.5% in the sample), values higher than these turning points do exist in our dataset, i.e. there are few wealthier municipalities are on the descending curve tract. These values are reported by the following municipalities: Basiglio, Campione d'Italia, Cusago, and Galliate Lombardo. For the latter two, values higher than €25,000 are observed only for a subset of the years considered.

In addition to these main findings, the control variables included in the model also exhibit interesting results. DENSITY shows a slightly negative coefficient, which means that densely populated municipalities generate less waste per capita. This is in contrast with the findings of Mazzanti and Zoboli (2009). *OLDSHARE* and *FOREIGN* also display an opposite sign to findings in the current literature: the higher the percentage of people older than 65, the higher the production of daily waste (which is exactly the contrary to the findings expressed by Ichinose and Hosoda (2014)). With regard to the *FOREIGN* variable, it has a negative coefficient, i.e. the presence of a larger number of foreign inhabitants reduces the amount of waste (while Prades et al. (2015) illustrated an opposite scenario). *ACCOMODATION* is in accordance with the assumption of Arbulú et al. (2015), and shows a positive coefficient; therefore, tourism is confirmed as having a positive impact on waste creation.

In order to test the robustness of our main result, additional analyses were run.[2] All these analyses confirm previous results concerning the WKC hypothesis. Firstly, the regressions presented so far were replicated by using log-level regression analyses and log-log analyses. Secondly, given that the Lombardy region is divided into 12 provinces (Milan, Bergamo, Brescia, Como, Cremona, Lecco, Lodi, Mantova, Monza, Pavia, Sondrio and Varese) which are quite heterogeneous in terms of size, geographic features (for instance altitude, morphology and degree of rurality), political culture (Consonni and Tonon, 2001) and in terms of the number and size of the municipalities forming them, we ran some analyses by adding to specification 3 in Table 2 a set of dummies that identify the province where the municipalities are located. The use of provincial dummies is also relevant because in Italy MW management is managed mostly on a provincial basis, with MW districts that in most cases are designed on the provincial perimeter. Since this information is time invariant, models were estimated through RE. Again, these results, omitted in order to save space, strongly confirm our main findings concerning the EKC.

Table 4 displays the results obtained for the main variables we are interested in through a dynamic OLS estimate and through the within-group estimate of equation (1) augmented by the inclusion of the lagged dependent variable. Estimates carried out through the Arellano-Bond two-step difference GMM are reported in column 3. The two-step robust estimator is applied in carrying out this estimate. Results obtained through the one-step estimator are not different from those reported here and are omitted in order to save space but available upon request. In these model, as discussed in Section 3, the lagged dependent variable is treated as endogenous; two lags of the endogenous variable were used as instruments for the level equation. All the models displayed in Table 4 include the control variables considered in Table 3; their results are not reported in order to save space but are available upon request to the authors.

Table 4 column (1) displays OLS estimate of the level equation; column (2) displays within-group estimates; column (3) displays Arellano- Bond two-step difference GMM estimates. Coefficients and robust standard errors in parentheses. The dependent variable is daily per capita waste generated expressed in kg(MSW). All the models include DENSITY, OLDSHARE, ACCOMODATION and FOREIGN among the covariates. The p-value of the serial correlation tests and the p-value of the Hansen test of overidentification are reported in square brackets. *Notes:* $^{***}p < 0.01$, $^{**}p < 0.05$.

	(1)	(2)	(3)

LAGGED MSW	0.5381***	0.3686***	0.5281***
	(0.0665)	(0.0100)	(0.1340)
ECONOMIC_DEV (x1000)	0.0546***	0.0393***	0.0333***
	(0.005)	(0.0059)	(0.01018)
ECONOMIC_DEV^2 (x1000)	−0.0011***	−0.0007***	−0.0006***
	(0.0000)	(0.0000)	(0.0002)
Year dummy	Yes	Yes	Yes
Arellano-Bond test for AR(1) in first differences z and p [in parentheses]			−5.28 [0.000]
Arellano-Bond test for AR(1) in first differences z and p [in parentheses]			0.71 [0.478]
Hansen test of overid. restrictions: chi2 and p [in parentheses]			7.96 [0.093]
Turning point	€24,818	€28,071	€27,750

Looking at the results for the main covariates we are interested in, they clearly highlight that the WKC is strongly confirmed. Indeed, statistically significant $\beta_1 > 0$ and $\beta_2 < 0$ are observed in all the models considered. This provides additional evidence that there is a non-linear inverted U-shaped relationship between waste generation and economic development. Coefficients estimated through the models (3).

As Baum (2002) highlights, the OLS and within-groups estimators are likely to be biased in opposite directions and a reliable estimator should lie between the two or should be not remarkably higher than OLS and remarkably lower than the within-groups. Indeed, this condition is observed when looking at the GMM estimates provided in column (3). Furthermore, the Hansen test reported at the bottom of the table suggests that the overidentification restriction is satisfied in model (3), and therefore the instruments used in the analysis are valid. According to these additional analyses, the turning point of the estimated Kuznets curve is slightly higher than the one calculated through the static panel investigation, since it is observed at €28,071. Fig. 1 provides a graphical representation of the estimated Kuznets curve.

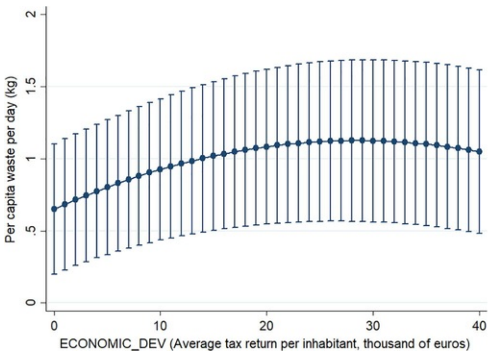

Fig. 1 Non-linear relation between economic development and waste production as resulting from the estimates provided by model (3) in Table 4. Vertical lines represent 95% confidence interval.

6 Conclusion

By using a novel database of municipal-level data from the Lombardy region, located in Northern Italy, this paper provided an empirical test of the hypothesis that there is an inverted U-shaped relationship between economic wealth and MSW generation (WKC hypothesis). The findings, which are robust to alternative specifications and estimators, provide support to such an hypothesis and reveal that after a certain point economic wealth exerts a "negative scale effect" on waste generation which might be due to a rising care for the non-materialistic goal of waste generation reduction.

Since in Italy, as well as in most of the European countries, the role of decentralized waste policies is structurally relevant (Mazzanti et al., 2008; Bertossi et al., 2000) our municipal-level analysis is particularly valuable.

On the one hand our results could support regional policy maker in fostering new accompanying measures aimed at reducing waste generation specifically designed for those municipality below the turning point estimated. On the other hand our results can contribute to better plan and size the set of policy instrument regarding the waste collection. In fact the reduction of the waste generation can low the costs of the waste treatments due to a demand effect.

Further research might inspect whether municipalities' MSW generation reveals any spatial dependence, which is certainly possible, given that the location of end-of-the-pipe disposal facilities (landfills and incinerators) could encourage some municipalities to reduce MW production and increase MW recycling.

Uncited reference

~~Apergis and Ozturk (2015).~~

References

Abrate, G., Ferraris, M., 2010. The environmental Kuznets curve in the municipal solid waste sector. HERMES Working Paper, 1.

Arbulú I., Lozano J. and Rey-Maquieira J., Tourism and solid waste generation in Europe: a panel data assessment of the Environmental Kuznets Curve, *Waste Manage. (Oxford)* **46**, 2015, 628–636.

Arellano M. and Bond S., Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations, *Rev. Econ. Stud.* **58** (2), 1991, 277–297.

Apergis N. and Ozturk I., Testing environmental Kuznets curve hypothesis in Asian countries, *Ecol. Ind.* **52**, 2015, 16–22.

Baum C.F., An Introduction to Modern Econometrics using Stata, 2006, Stata press.

Beigl P., Lebersorger S. and Salhofer S., Modelling municipal solid waste generation: a review, *Waste Manage. (Oxford)* **28**, 2008, 200–214.

Bertossi P., Kaulard A. and Massarutto A., Municipal waste management in Italy, In: Buclet N. and Godard O., (Eds.), *Municipal Waste Management in Europe* 2000, Kluwer Academic Publisher; London (UK), 121–169.

Bhattarai M. and Hammig M., Institutions and the environmental Kuznets curve for Deforestation: a crosscountry analysis for Latin America, Africa and Asia, *World Develop.* **29** (6), 2001, 995–1010.

Bond S.R., Dynamic panel data models: a guide to micro data methods and practice, *Portuguese Econ. J.* **1** (2), 2002, 141–162.

Cole M., Rayner A. and Bates J., The environmental Kuznets curve: an empirical analysis, *Environ. Dev. Econ.* **2**, 1997, 401–416.

Consonni G., Tonon G., 2001. La terra degli ossimori. Caratteri del territorio e del paesaggio della Lombardia contemporanea. In: Bigazz D., Meriggi M. (A cura di) (Eds.), Storia delle Regioni dall'Unità a oggi. La Lombardia, 53–187.

D'Amato A., Mazzanti M. and Nicolli F., Waste and organized crime in regional environments: how waste tariffs and the mafia affect waste management and disposal, *Resour. Energy Econ.* **41**, 2015, 185–201.

(Please, add the following reference: Eberhardt M. and Teal F.,Structural change and cross-country growth empirics, Policy Research Working Paper Series 6335, 2013, The World Bank.)European Environment Agency, Managing municipal solid waste – a review of achievements in 32 European countries, 2013, Publications Office of the European Union; Luxembourg.

Eurostat, 2014. GDP at regional level, available online at http://ec.europa.eu/eurostat/statistics-explained/index.php/GDP_at_regional_level [last access on 13/8/2017].

Eurostat, 2016. Waste database municipal waste.

Eurostat, 2016. Waste database generation of waste.

Fischer-Kowalski M. and Amann C., Beyond IPAT and Kuznets curves: globalization as a vital factor in analysing the environmental impact of socio-economic metabolism, *Popul. Environ.* **23** (1), 2001, 7–47.

Gaeta G.L., Ghinoi S. and Silvestri F., Municipal performance in waste recycling: an empirical analysis based on data from the Lombardy Region (Italy), *Lett. Spatial Resour. Sci.* **10** (3), 2017, 337–352.

Grossman, G., Krueger, A., 1991. Environmental impacts of a North American free trade agreement. National Bureau of Economic, NBER. Research Working Paper no. 3914, Cambridge.

Hage O., Sandberg K., Söderholm P. and Berglund C., Household plastic waste collection in Swedish municipalities: a spatial-econometric approach, In: *European Association of Environmental and Resource Economists Annual*

Conference. 25/06/2008-28/06/2008 2008.

Hansen L.P., Large sample properties of generalized method of moments estimators, *J. Econometric Soc.* 1982, 1029–1054.

Hettige H., Mani M. and Wheeler D., Industrial pollution in economic development: the environmental Kuznets curve revisited, *J. Dev. Econ.* **62**, 2000, 445–476.

Holtz-Eakin D. and Selden T.M., Stoking the fires? CO2 emissions and economic growth, 1992, National Bureau of Economic Research; Cambridge, Massachusetts, NBER working papers 4248.

Ichinose D. and Hosoda E.B., Double asymmetry of information in a waste treatment contract, In: Kinnaman T.C. and Takeuchi K., (Eds.), *Handbook on Waste Management* 2014, Handbook on Waste Management; Edward Elgar, Cheltenham, 394–415.

Ichinose D., Yamamoto M. and Yoshida Y., The decoupling of affluence and waste discharge under spatial correlation: do richer communities discharge more waste?, *Environ. Dev. Econ.* **20** (2), 2015, 161–184.

Ichinose D., Yamamoto M. and Yoshida Y., Reexamining the waste-income relationship, 2011, National Graduate Institute for Policy Studies; Tokyo: Japan, GRIPS Discussion Paper No. 10-31.

ISPRA, 2013. Rapporto Rifiuti Urbani. Edizione 2013. ISPRA, Rapporto n.176/2013.

Johnstone N. and Labonne J., Generation of household solid waste in OECD countries: an empirical analysis using macroeconomic data, *Land Econ.* **80** (4), 2004, 529–538.

Judson R.A. and Owen A.L., Estimating dynamic panel data models: a guide for macroeconomists, *Econ. Lett.* **65** (1), 1999, 9–15.

Karousakis K., The drivers of MSW generation, disposal and recycling: examining OECD inter-country differences, In: Mazzanti M. and Montini A., (Eds.), *Waste and Environmental Policy* 2009, Taylor & Francis Group; Routledge.

Lee S., Kim J. and Chong W.K.O., The causes of the municipal solid waste and the greenhouse gas emissions from the waste sector in the United States, *Waste Manage. (Oxford)* **56**, 2016, 593–599.

Lee K., Pesaran M.H. and Smith R., Growth and convergence in a multi-country empirical stochastic Solow model, *J. Appl. Econometrics* 1997, 357–392.

Lim J., The effects of economic growth on environmental quality: some empirical investigation for the case of South Korea, *Seoul J. Econ.* **10**, 1997, 272–293.

Managi S. and Kaneko S., Environmental performance and returns to pollution abatement in China, *Ecol. Econ.* **68** (6), 2009, 1643–1651.

Mazzanti M. and Zoboli R., Municipal waste Kuznets curves: evidence on socio-economic drivers and policy effectiveness from the EU, *Environ. Resour. Econ.* **44** (2), 2009, 203–230.

Mazzanti M. and Zoboli R., Delinking and environmental Kuznets curves for waste indicators in Europe, *Environ. Sci.* **2** (4), 2005, 409–425.

Mazzanti M., Montini A. and Nicolli F., Embedding landfill diversion in economic, geographical and policy settings, *Appl. Econ.* **43** (24), 2011, 3299–3311.

Mazzanti M., Montini A. and Nicolli F., Waste dynamics in economic and policy transitions: decoupling, convergence and spatial effects, *J. Environ. Plan. Manage.* **55** (5), 2012, 563–581.

Mazzanti M., Montini A. and Zoboli R., Municipal waste generation and socioeconomic drivers: evidence from comparing Northern and Southern Italy, *J. Environ. Develop.* **17** (1), 2008, 51–69.

Mazzanti M., Montini A. and Zoboli R., Municipal waste generation and the EKC hypothesis new evidence exploiting province-based panel data, *Appl. Econ. Lett.* **16** (7), 2009, 719–725.

Prades M., Gallardo A. and Ibàñez M.V., Factors determining waste generation in Spanish towns and cities, *Environ. Monit. Assess.* **187** (1), 2015.

Raymond L., Economic growth as environmental policy? Reconsidering the environmental Kuznets Curve, *J. Public Pol.* **24** (3), 2004, 327–348.

Reggiani C. and Silvestri F., Municipal solid waste, market competition and the EU policy, *Environ. Resour. Econ.* **1–18**, 2017, https://doi.org/10.1007/s10640-017-0165-0, first online.

Roodman D., How to do xtabond2: an introduction to difference and system GMM in Stata, *Stata J.* **9** (1), 2009, 86–136.

Selden T.M., Forrest A.S. and Lockhart J.E., Analyzing the reductions in U.S. Air Pollution Emissions: 1970 to 1990, *Land Econ.* **75** (1), 1999, 1–21.

Shafik N., Economic development and environmental quality: an econometric analysis, *Oxford Econ. Papers* **46**, 1994, 757–773.

Sinha A. and Bhattacharya J., Estimation of environmental Kuznets curve for SO2 emission: a case of Indian cities, *Ecol. Ind.* **72**, 2017, 881–894.

Stern D., The rise and fall of the Environmental Kuznets curve, *World Dev.* **32** (8), 2004, 1419–1438.

Torras M. and Boyce J.K., Income, inequality and pollution: a reassessment of the environmental Kuznets curve, *Ecol. Econ.* **25**, 1998, 147–160.

Trujillo Lora J.C., Carrillo Bermúdez B., Charris Vizcaíno C.A. and Iglesias Pinedo W.J., The Environmental Kuznets Curve (EKC): an analysis landfilled solid waste in Colombia, *Revista Facultad de Ciencias Económicas: Investigación y Reflexión* **21** (2), 2013, 7–16.

Tsurumi T. and Managi S., Decomposition of the environmental Kuznets curve: scale, technique, and composition effects, *Environ. Econ. Policy Stud.* **11** (1–4), 2010, 19–36.

Unruh G.C. and Moomaw W.R., An alternative analysis of apparent EKC-type transitions, *Ecol. Econ.* **25**, 1998, 221–229.

Wang Z., Bao Y., Wen Z. and Tan Q., Analysis of relationship between Beijing's environment and development based on Environmental Kuznets Curve, *Ecol. Ind.* **67**, 2016, 474–483.

Wong Y.L. and Lewis L., The disappearing Environmental Kuznets Curve: a study of water quality in the Lower Mekong Basin (LMB), *J. Environ. Manage.* **131**, 2013, 415–425.

World Bank, World Development Report 1992: Development and the Environment, 1992, Oxford University Press; New York.

Footnotes

[1]The waste/consumption indicator used in this paper is one of the components of the Environmental Sustainability Index (ESI), developed by the Yale Center for Environmental Law and Policy, the Center for International Earth Science Information Network at Columbia University, and the World Economic Forum in order to rank countries according to their environmental sustainability.

[2]With the aim of saving space, the results achieved through these additional elaborations are not reported but are available upon request to the authors.

Highlights

- Municipal-level waste generation data from the Lombardy region Italy are inspected.
- The waste Kuznets curve (WKC) hypothesis is empirically tested.
- An inverted U-shaped link between waste and economic development is found.
- The estimated turning point of the WKC is approximately between €23,500 and €28,000.

Queries and Answers

Query: Your article is registered as a regular item and is being processed for inclusion in a regular issue of the journal. If this is NOT correct and your article belongs to a Special Issue/Collection please contact p.sivakumar@elsevier.com immediately prior to returning your corrections.
Answer: Yes

Query: The author names have been tagged as given names and surnames (surnames are highlighted in teal color). Please confirm if they have been identified correctly.
Answer: Yes

Query: Please check the address for the corresponding author that has been added here, and correct if necessary.
Answer: The address is correct

Query: References "Eberhardt and Teal (2013) and Baum (2002)" are cited in the text but not provided in the reference list. Please provide them in the reference list or delete these citations from the text.

Answer: The reference has been added in the reference list

Query: This section comprises references that occur in the reference list but not in the body of the text. Please position each reference in the text or, alternatively, delete it. Any reference not dealt with will be retained in this section.

Answer: The uncited reference can be deleted

Query: Please check the layout of Table 2, and correct if necessary.

Answer: the table is ok.