

# 1    **Kuznets curve in municipal solid waste production: an empirical analysis based on** 2    **municipal-level panel data from the Lombardy region (Italy)**

## 5    **Abstract**

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

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

## 16    **1. Introduction**

17    Over the last decade (2001-2010), the European Union has observed a consistent increase in  
18    municipal waste (MW) per capita in 18 out of its 28 members (**European Environment**  
19    **Agency, 2013**). Even if MW only accounts for approximately 10% of total waste generated in  
20    the EU, it has a relevant socio-environmental impact (**Eurostat, 2016a, 2016b**); as a  
21    consequence, MW management is nowadays considered one of the main challenges for  
22    European countries (**D’Alisa et al., 2010**).

23    In order to be effective, MW management strategies should not be exclusively focused on  
24    waste collection, treatment, and recycling; instead, they should also involve monitoring  
25    households’ solid waste generation and incentivizing its reduction (**Beigl et al., 2008**).

26    This paper aims to contribute to the literature by empirically addressing a highly debated issue,  
27    namely the existence of a link between economic wealth and waste production as modeled by  
28    the Waste Kuznets Curve (WKC). In fact, despite the number of contributions on this topic,  
29    the empirical evidence concerning the WKC hypothesis is controversial. The results provided  
30    so far are heterogeneous among the contexts analyzed and upon the aggregation level of the  
31    analysis. Moreover, unicipal-level analyses, meanwhile, are much rarer, although those recently  
32    published seem to support the WKC hypothesis (**Ichinose et al., 2015**).

33    Our paper aims to add to this latter group of contributions by proposing an econometric  
34    analysis based on a large and newly constructed municipal-level dataset that considers  
35    municipalities from the Lombardy region of Northern Italy (n=1,497), which were  
36    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**), appear to be appropriate for our empirical investigation since this region is an appealing case study for inspecting waste production and waste management (**Gaeta et al., 2017**), which seems to be particularly helpful for testing the WKC hypothesis. Indeed, Lombardy is. In addition, it reports the highest total production of urban waste in Italy (**ISPRA, 2013**).

The paper is articulated as follows: section two provides a review of the empirical literature concerning the WKC. Section three presents the data used in the analysis, and section four discusses the methodological issues of the analysis. The results and their discussion are reported in section four. Finally, section five 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-intensive 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

1 explanation of the EKC shape might depend upon the fact that public opinion interest for  
2 “environmental goods” only emerges once their scarcity is perceived (**Unruh and Moomaw,**  
3 **1998; Torras and Boyce, 1998**).

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

11 As in the case of studies focused on the EKC, most tests of the WKC hypothesis are carried  
12 out through cross-national empirical investigations. By analyzing cross-national solid waste  
13 generation data from 1960-1990 provided by the Organisation for Economic Co-operation and  
14 Development (OECD) for 39 countries, **Shafik (1994)** finds a monotonic and direct  
15 relationship between waste production and income. According to his interpretation, this is  
16 because thanks to landfills “solid waste disposal can be transformed into a localized and  
17 potentially harmless problem” (p. 767). The same result, i.e. waste generation monotonically  
18 increasing throughout the income range examined, is found by **Cole et al. (1997)**, who focus  
19 on cross-national municipal waste data collected in 13 OECD countries over the period 1975-  
20 1990. Following a perspective similar to **Shafik (1994)**, these authors suggest that an increase  
21 of income determines an increase of waste generation. The idea that waste generation  
22 monotonically increases with income is also supported by **Johnston and Labonne (2004)** and  
23 **Karousakis (2009)**, who both analyze cross-national OECD data on municipal solid waste  
24 from 1980-2000. Based on 1995-2005 data from 25 European countries, **Mazzanti and Zoboli**  
25 **(2009)** reach the same conclusion, even if the elasticity of municipal solid waste production to  
26 income drivers found by their analysis is lower than that observed by previous contributions.  
27 While all the contributions just mentioned suggest a rejection of the WKC hypothesis, this  
28 result is not univocal, and is contested, for example, by **Raymond (2004)**. His analysis focuses  
29 on data from 142 countries and finds that the waste/consumption stress indicator<sup>1</sup> exhibits an  
30 inverted U-shape relation with income.

31 More generally, it is worth noting that while all the cited WKC studies have their merits, cross-  
32 national empirical investigations also have notable limits. Firstly, they estimate “average”  
33 international curves (**Mazzanti and Zoboli, 2009**), which might not hold when the analysis is  
34 addressed to sub-national administrative units that might reveal high heterogeneity in waste  
35 generation (**Ichinose et al., 2015**). This is a crucial limitation since, in EU countries, as well as  
36 in the USA and Japan, local authorities are mainly responsible for the implementation of waste

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<sup>1</sup> 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.

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, although they do not identify any turning point in the relationship between these variables. **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, which has already been indicated as an interesting case study for the analysis of waste production determinants. Our data does not cover a set of

1 selected municipalities from the region, but almost all the existing ones, and this allows us to  
2 build a comprehensive and large ( $n=1,447$ ) dataset to be employed in our econometric  
3 investigations.

### 4 **3. Data**

5 According to data availability, our analysis considers an unbalanced panel made up of 1,497  
6 municipalities from the Lombardy region of Northern Italy (out of a total of 1,527 existing  
7 municipalities) that were observed over a seven-year period from 2005 to 2011. Table 1  
8 presents the variables considered in the empirical study and shows for each of them the  
9 corresponding label, definition and data source.

10 Yearly municipal-level data concerning daily per capita waste generation (MWG) are provided  
11 by the Lombardy Regional Environmental Protection Agency (ARPA). MWG reveals a  
12 remarkable cross-municipality heterogeneity in the Lombardy region. The descriptive statistics  
13 displayed in Table 2 show that MWG varies from 0.352 kg per day (reported by the  
14 municipality of Dosso del Liro in 2010) to 7.223 kg per day (reported by Limone sul Garda in  
15 2011). The average value is 1.334 kg and it is in line with figures reported by **Abrate and**  
16 **Ferraris (2010)**, who investigated a small sample made up of the biggest Italian municipalities.  
17 MWG is used as the dependent variable in our regression analyses where a wide set of  
18 regressors is considered.

19 Given the objective of the paper, the covariate this study is mainly interested in is a municipal-  
20 level proxy of economic development. Due to data availability, measures of economic  
21 development adopted in WKC studies and in contributions on the determinants of municipal  
22 solid waste generation vary according to the territorial level investigated. The existing cross-  
23 national empirical literature on WKC measures economic development through variables such  
24 as final consumption expenditure of households or gross domestic product per capita  
25 (**Mazzanti and Zoboli, 2005 and 2009; Arbulú et al., 2015; Fischer-Kowalski and Amann,**  
26 **2001**). Meanwhile, within-country analyses focusing on the regional or provincial level use gross  
27 regional product (**Managi and Kaneko, 2009**) or per capita value added (VA) (**Mazzanti et**  
28 **al., 2008; Mazzanti et al., 2009; Mazzanti e Zoboli, 2009; Mazzanti et al., 2011; Mazzanti**  
29 **et al., 2012; D'Amato et al., 2015**).

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

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

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;  $\beta_1$  and  $\beta_2$  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  $\beta_k$  is the associated vector of coefficients while  $\zeta_t$  represents time fixed effects. Finally,  $u_i$  is the municipal (individual)-level effect and  $\varepsilon_{it}$  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  $\varepsilon_{it}$ . 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 ( $MWP_{it-1}$ ) should be/is included on the right hand of equation (1). This implies a reliance on an estimation strategy different from the one presented above. Indeed, with the inclusion of  $MWP_{it-1}$  among the explicative variables, the assumption of strict exogeneity of the regressors does not hold, and this leads to biased estimates. In order to face this issue, the difference 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 Blundell and Bond (1998) this approach is limited by the lack of power of the internal lagged levels of the endogenous variables as instruments. In order to overcome this issue, they propose a system GMM estimator which takes into account both the original equation in levels and the differenced one, and uses both lagged differences and lagged levels as instruments for the endogenous variables.

It is important to keep in mind that the GMM estimator has been developed specifically for microeconomic investigations. According to Eberhardt and Teal (2013), from a macroeconomic perspective, in a globalized world with interconnected economies, GMM models could be invalid in presence of heterogeneous equilibrium relationship (Lee, Pesaran,

and Smith, 1997). Moreover another limit of GMM estimator is linked with the type of dataset typical in microeconometrics, with a time dimension far smaller and an individual dimension far greater than macroeconomic panel. Nevertheless following Judson and Owen (1999) GMM procedure represents a second best solution when a corrected least squares dummy variable (LSDV) is not practical, with biased estimates lower than Anderson–Hsiao estimator.

## 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 1,000.

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.

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  $\beta_1$  and  $\beta_2$  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 € 23,830.60 and € 24,950.50. 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, and are reported by the following municipalities: Basiglio, Campione d'Italia, Cusago, and Galliate Lombardo. For the latter two, values higher than €25,000 (the turning point estimated by model 2, highest among those suggested by our estimates) 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.<sup>2</sup> 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 through the dynamic panel estimates. Estimates carried out through the Arellano-Bond two-step difference GMM are reported in column 1 while column 2 displays the two-step system GMM estimates. Both columns represent the results achieved by applying the two-step robust estimator. 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. As discussed in section 3, the lagged dependent variable is treated as

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

1 endogenous; two lags of the endogenous variable were used as instruments for the level  
2 equation in model 1 and for the transformed equation/level equation in model 2.

3 Looking at the results, they clearly highlight that the WKC is strongly confirmed. Indeed,  
4 statistically significant  $\beta_1 > 0$  and  $\beta_2 < 0$  are observed in both the models considered. This  
5 provides additional evidence that there is a non-linear inverted U-shaped relationship between  
6 waste generation and economic development.

7 Looking at the results for the other variables, the coefficients of the lagged dependent variable  
8 are positive and highly significant in both the models, and this confirms the intuition that waste  
9 generation shows serial correlation. Only the *FOREIGN* variable presents a reverse situation  
10 compared to the previous models: within the two-step system GMM estimates, its coefficient is  
11 non-negative, and this implies a positive relation between the number of foreign inhabitants  
12 and waste formation.

13 The Hansen test reported at the bottom of the table suggests that the overidentification  
14 restriction is satisfied, and the instruments used are valid.

15

## 6. Conclusion

The increase of municipal solid waste (MSW) generation in both developed and lesser-developed countries has recently prompted policymakers to reform waste management policies in order to improve recycling and separate collection (Sidique et al., 2010; Usui et al., 2015; Hoornweg and Bhada-Tata, 2012). For this reason, studies on the main socioeconomic drivers of MSW generation can be particularly useful for the design of policies aimed at reducing it. More specifically, the investigation of the link between MSW generation and economic development is particularly important, since it can reveal whether there is any “negative scale effect” of economic development on waste generation and whether economic development is linked with efficiency and care for the non-materialistic goal of waste generation reduction.

This paper try to address this issue by means of an econometric analysis based on a novel database of municipal level data from the Lombardy region. Results provide evidence in favor of an inverted U shaped relationship between economic development and MSW generation. This result confirms the WKC hypothesis, which is robust to alternative specifications, and is consistent across different estimation methods. These findings suggest that a waste sustainability gap exists and might increase over time between low- and high-income municipalities. The turning point of the WKC estimated by our analysis is placed approximately between €23,000 and €25,000, these values are included in the database scrutinized but are reported by a very limited number of observations, i.e. very few wealthier municipalities are on the descending curve tract.

These results allow us to shed light on the WKC hypothesis. 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 ì 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.

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Label	Description	Source
MWG	Per capita waste produced per day (kg)	ARPA Lombardy (Regional Environmental Protection Agency)
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).
DENSITY	Density of inhabitants (number of inhabitants per squared Km)	ISTAT (Italian National Institute of Statistics)
OLDSHARE	Share of people more than 65 years old (%)	ISTAT (National Institute of Statistics)
ACCOMODATION	Sleeping accomodation (per capita; number of sleeping accommodation facilities/total population)	Own elaboration on data from ISTAT (Italian National Institute of Statistics)
FOREIGN	Share of foreigners over population	Own elaboration on data provided by ISTAT (Italian National Institute of Statistics) and by the Lombardy Region

Tab. 1: Labels, description and data sources for variables used in the empirical 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

Tab. 2: Descriptive statistics of variables used in the analysis.



	(1)	(2)	(3)
ECONOMIC_DEV (x1000)	0.0424*** (0.0094)	0.0477*** (0.0121)	0.0489*** (0.0105)
ECONOMIC_DEV^2 (x1000)	-0.0009*** (0.0003)	-0.0010*** (0.0003)	-0.0010*** (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	€23,831	€24,950	€23,571

**Tab. 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 ( $\times 1000$ )	0.0424*** (0.0094)	0.0477*** (0.0121)	0.0489*** (0.0105)
ECONOMIC_DEV^2 ( $\times 1000$ )	-0.0009*** (0.0003)	-0.0010*** (0.0003)	-0.0010*** (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	€23,831	€24,950	€23,571

Tab. 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)
LAGGED MSW	0.5281*** (0.1340)	0.6641*** (0.0507)
ECONOMIC_DEV (x1000)	0.0333*** (0.01018)	0.0137*** (0.0041)
ECONOMIC_DEV^2 (x1000)	-0.0006*** (0.0002)	-0.0002** (0.0001)
DENSITY	-0.0003*** (0.0001)	-0.0000*** (0.0000)
OLDSHARE	0.5506 (0.4075)	0.5604*** (0.0923)
ACCOMODATION	0.2186 (0.1857)	0.4737*** (0.0812)
FOREIGN	-0.0676 (0.3468)	0.2476*** (0.0803)
Year dummy	Yes	Yes
Arellano-Bond test for AR(1) in first differences z and p [in parentheses]	-5.28 [0.000]	-6.50 [0.000]
Arellano-Bond test for AR(1) in first differences z and p [in parentheses]	0.71 [0.478]	0.89 [0.374]
Hansen test of overid. restrictions: chi2 and p [in parentheses]	7.96 [0.093]	8.40 [0.494]
Turning point	€28,520	€25,620

**Tab. 4:** column (1) displays Arellano- Bond two-step difference GMM estimates. Column (2) displays two-step system GMM estimates. Coefficients and robust standard errors in parentheses. The dependent variable is daily per capita waste generated expressed in kg(MSW). The p-value of the serial correlation tests and the p-value of the Hansen test of overidentification are reported in square brackets. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.