Waste Management xxx (xxxx) xxx

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Waste generation in Spain. Do Spanish regions exhibit a similar behavior?

Alejandro Alcay, Antonio Montañés*, María-Blanca Simón-Fernández

University of Zaragoza, Spain

ARTICLE INFO

Article history:
Received 15 March 2020
Revised 19 May 2020
Accepted 20 May 2020
Available online xxxx

JEL Codes:
C33
R50
Q53
H50

Keywords:
Regional convergence
Waste generation
Waste prevention
Production efficiency
Regional disparities
Waste determinants

ABSTRACT

We analyze waste generation differences across Spanish regions by studying the evolution of two complementary indicators: municipal solid waste per unit of GDP as well as in per capita terms. To that end, we apply the recent statistic developed by Phillips and Sul (2007) which allows us to test for the null hypothesis of convergence. In the present case, this hypothesis is equivalent to admitting that the waste generation follows a similar path across the Spanish regions. Our results lead us to reject this hypothesis, which implies that Spanish regional waste generation is quite heterogenous and exhibits several patterns of behavior. We observe that the northern regions exhibit the lowest waste ratios while the insular and Mediterranean coast regions have the highest waste generation. This different behavior is also explained by some socioeconomic factors. Per capita income, environmental spending and education level are helpful in this regard. The population dispersion and the number of years that a region has been governed by a left-wing party are also associated with lower levels of waste generation. Finally, we can also observe that the regions with the highest levels of waste generation are greatly dependent on the tourism industry. Then, strategies targeting the transit towards a more sustainable economy in Spain should take into account this fact. In particular, the adoption of methods for the reduction of the waste levels generated by tourism activities in these areas can be very useful.

1. Introduction

The transition to the Circular Economy, from a European perspective, is based on the resource efficiency agenda set out in the framework of the "Europe 2020 strategy for smart, sustainable and inclusive growth", supported by the "Roadmap to a Resource-Efficient Europe" whose priority objective is to turn the European Union into a low-carbon, resource-efficient, green and competitive economy. Since the early 2000s, the European Commission has been promoting the creation of a circular economy associated with a 'zero waste' policy by combining policy actions and initiatives with a network of organizations. The Circular Economy concept can be closely related to the 3R Principles: Reduce, Reuse, and Recycle, as described in Tisserant et al (2017), Ghisellini et al (2016) and Lieder and Rashid (2016). One of the pillars of the circular economy is "closing the loop" to generate an integrated waste management system by recovering materials, but also by using the energy derived from the waste. Thus, organic waste can be reused for various purposes, such as reducing energy or raw material dependency. Tomić and Schneider (2018) summarize the alternatives for converting such waste into energy. Sharma et al (2020) propose hydrogen obtained through certain innovative biochemical processes as an energy source while D'Adamo et al. (2019) present the case of bio-methane as an important energy source in the transport sector in Italy.

The importance of waste management analysis can be understood if we consider the large amount of literature that has recently been generated in this area. Without being exhaustive, we can cite the works of Kashwan (2017) where the relationship between waste production and inequality is analyzed; and Corsini et al (2018), which focuses on awareness of the environmental impact and the willingness to assume that personal actions are decisive for reducing waste generation. Lieder and Rashid (2016) conclude that the joint support of all stakeholders is necessary to successfully implement the Circular Economy concept at large scale and Tamayo-Orbegozo et al. (2017) find that economic incentives are useful for reducing waste and promoting recycling. Other works such as Lavee and Khatib (2010) and Lavee and Nardiya (2013) create a model that estimates the expected costs

* Corresponding author.
E-mail addresses: alcay@unizar.es (A. Alcay), amontane@unizar.es (A. Montañés), bsimon@unizar.es (M.-B. Simón-Fernández).

https://doi.org/10.1016/j.wasman.2020.05.029
0956-053X/

Please cite this article as: A. Alcay, A. Montañés and M. B. Simón-Fernández, Waste generation in Spain. Do Spanish regions exhibit a similar behavior?, Waste Management, https://doi.org/10.1016/j.wasman.2020.05.029

of making a transition to recycling in Israel, so that the government has a decision-making tool to award grants efficiently. All of them coincide on the need for measures to be taken by policy makers to reduce the volume of solid waste, as a crucial point for moving towards more sustainable economies.

The works of Castillo-Giménez et al. (2019a,2019b) indicate how much progress has been made in this respect and how the approval of the European guidelines on waste generation has achieved, first, a substantial fall in waste generation and, above all, a reduction in the differences between European Union countries, especially between some Central and Northern European countries such as Denmark, Austria and Germany, and Eastern European countries that joined the European Union in the 2000s, whose performance is poor. This is the case in Croatia, as can be seen in Luttenberger (2020), which faces several problems in the implementation of the waste treatment and recycling system. Di Maria et al (2020) point to the targets set by the EU as an effective way of reducing waste and increasing recycling in Europe. They also consider the opportunity for Europe to set up a new line of economic activity that will reduce emissions of polluting gases, improve health and create jobs. In spite of the fact that the enactment of the current Waste Framework Directive in 2008 has clearly favored convergence among the EU-27, the differences are still significant.

The results of these papers are to some extent expected given the heterogeneity that exists between the considered countries. The question that remains is what can happen when an environment is analyzed that in principle should present greater similarities, as is the case of regions within the same country. The case of Spain is of great interest in this regard, given the economic, fiscal and cultural differences between the Spanish regions, as well as the high degree of disaggregation of political decision-making. In this regard, we should consider that the Spanish territorial implementation of waste treatment is diverse owing to the autonomous nature of regions which enjoy key competences in multiple areas. Following the Spanish legislation on waste, Law 22/2011, which transposes the European Directive 2008/98/EC, Spain has the power to set targets for waste reduction, based on European criteria, and to develop an annual strategy to achieve them. Regional governments can establish their own waste prevention plans, develop their own waste legislation and have the powers to monitor, inspect and sanction production and waste generation activities. Municipalities regulate the management of waste collection and treatment services, as it is their obligation to guarantee such services. Therefore, if the objective is to reduce the generation of waste at a national level, there needs to be a common approach in all Spanish regions, something that does not seem to be occurring at this time.

This lack of homogeneity in taking environmental decisions makes it very difficult to implement a single pattern of behavior for waste generation in the Spanish regions. The results of Expósito and Velasco (2018), who employ data for 2013, reveal important differences in the Spanish regional recycling market. Similar results are obtained in Pérez-López et al (2018) and Bel and Fageda (2010), who study the effects of economies of scale, intermunicipal cooperation and management issues on the costs of recycling services; and in Díaz-Villavicencio et al (2017), who analyze the implication of education and workers' training on recycling. This heterogeneity is also found in other regional analyses. For instance, de Jaeger et al (2011) analyze the differences in waste collection using data from 299 municipalities in Flanders, Belgium, for the year 2003. Similarly, Agovino et al (2019) find differences between waste collection policies in Italian municipalities for 2012. All of these studies coincide in revealing the presence of very heterogeneous regional behaviors regarding the generation and treatment of waste. Another vector that can generate heterogeneity between regions is the presence of tourist activities. Falcone (2019) points out that tourism represents an important determinant of waste generation, which in turn can diminish the tourist appeal of the area if the problem is not properly managed. However, we should note that the methods employed in these studies only consider one year or, at least, the time dimension is scarcely considered. Therefore, it seems appropriate to perform an analysis with the help offered by the temporal dimension, so that this dynamic component can be taken into account and the results can be interpreted from a long-run perspective.

Against this background, the aim of the paper is to determine whether there is a similar pattern of behavior in the recent development of waste generation across the Spanish regions or whether, by contrast, several patterns of behavior can be found. To that end, and following Castillo-Giménez et al. (2019a,2019b), we can apply the statistics proposed in Phillips and Sul (2007, 2009) to test the null hypothesis of convergence for a pool of data. If we are unable to reject the hypothesis, we can conclude in favor of the existence of a common behavior between all the Spanish regions in terms of waste generation. However, if we are able to reject the hypothesis, then we will be able to identify multiple patterns of behavior and, consequently, determine the regions associated to them and the forces that may drive them.

The rest of the paper is organized as follows. Section 2 describes the data and the methods. Section 3 discusses the results obtained. Section 4 concludes.

2. Data and methods

2.1. Database

The variable under analysis is municipal solid waste (MSW) collection. These data have been obtained from the Spanish Institute of Statistics (INE). The data covers the period 1998–2016 and we have considered the 17 Spanish regions. The data for the two autonomous cities (Ceuta and Melilla) are not available and, consequently, we have excluded them. The data are measured in tons of all the urban waste collected by authorized managers throughout the national territory. Gross domestic product (GDP) and population series have also been obtained from the Spanish Institute of Statistics (INE) database.

Using these three variables, we can elaborate two different indicators. On the one hand, we use an indicator to see the evolution from the point of view of the total production of the economy. This is defined as the ratio between MSW and GDP and reflects the productive efficiency of the regions with respect to waste generation, in the sense that the lower the waste generation per unit of GDP, the more environmentally efficient the region. On the other hand, we can analyze waste prevention from the perspective of household consumption. To that end, we will use the per capita generated waste (MSW/population), this indicator providing us with information on the consumption habits of the regions and their environmental impact.

The data of the explanatory variables that will be employed in Section 3 have also been obtained from the INE. More details of these variables are provided in the Appendix.

2.2. Convergence and Phillips-Sul methodology

Convergence has been defined in the economic literature as a process where the dispersion of a variable, usually per capita GDP, reduces for a group of countries or regions. At the limit, when the variance is 0, all the components of this group show the same value of the variable and, therefore, exhibit a similar per capita GDP. The interest in this type of analysis grew due to the seminal

Please cite this article as: A. Alcay, A. Montañés and M. B. Simón-Fernández, Waste generation in Spain. Do Spanish regions exhibit a similar behavior?, Waste Management, https://doi.org/10.1016/j.wasman.2020.05.029

paper by Barro and Sala-i-Martin (1992) which opened the door to a very large number of papers devoted to the analysis of convergence. In this regard, we should cite the papers of Carlino and Mills (1993, 1996) and Bernard and Durlauf (1995), where the concept of stochastic convergence is developed, and those of Payne et al (2017) and Solarin (2019), where this concept of convergence is analyzed.

However, none of these papers develop or use a statistic that focuses on testing the null hypothesis of convergence. This problem is considered in Phillips and Sul (2007, 2009), PS hereafter, who designed a very popular statistic that has been extensively employed to test for convergence. We can cite the papers of Camarero et al. (2013a, 2013b), Kounetas (2018) and Apergis and Payne (2020) in this regard. Finally, Castillo-Giménez et al. (2019a, 2019b) also employ this methodology to analyze the evolution of waste efficiency in EU countries.

Following PS, let us consider that X_{it} represents either of the two measures of waste generation, with i = 1, 2, …, 17 (the 17 Spanish regions) and t = 1998, …, 2016. This variable can be decomposed as $X_{it} = \delta_{it}\ \mu_t$, where μ_t is the single common component and δ_{it} is the time-varying factor loading coefficient that measures the idiosyncratic distance between the common trend components μ_t and X_{it}. PS suggest testing for convergence by analyzing whether δ_{it} converges towards δ. To do so, they first define the relative transition parameter, as follows:

$$h_{it} = \frac{X_{it}}{N^{-1}\sum_{i=1}^{N} X_{it}} = \frac{\delta_{it}}{N^{-1}\sum_{i=1}^{N}\delta_{it}} \quad (1)$$

This variable describes the transition path for the i-th region relative to the panel average. In the presence of convergence, δ_{it} converges towards δ and, therefore, h_{it} should converge towards 1, while its cross-sectional variation, H_{it}, which is defined as follows:

$$H_{it} = N^{-1}\sum_{i=1}^{N}(h_{it}-1)^2 \to 0, as T \to \infty \quad (2)$$

should go to 0 when T goes towards infinity. Then, PS test for convergence by estimating the following equation:

$$log\frac{H_1}{H_t} - 2log[\log(t)] = \alpha + \beta\log(t) + u_t, t = T_o, \cdots, T \quad (3)$$

$\log\frac{H_1}{H_t} - 2\log[\log(t)] = \alpha + \beta\log(t) + u_t, t = [rT]+1, \cdots, T$with $T_o = [rT]$, and r = 0.3. Eq. (3) is commonly known as the log-t regression. The null hypothesis of convergence is rejected whenever parameter β is lower than 0. PS suggest estimating model (3) by methods which correct for the presence of autocorrelation and heteroskedasticity and, later, employing the t-statistic to test the null hypothesis $\beta = 0$. The use of these robust methods ensures that this t-ratio converges towards a standard N(0,1) distribution and, therefore, we will reject the null hypothesis of convergence whenever this t-statistic takes values lower than −1.65.

If we reject convergence, PS propose the following robust clustering algorithm for identifying clubs in a panel:

i. Order the N states according to their final values
ii. Starting from the highest-order state, add adjacent states from our ordered list and estimate model (3). Then, select the core group by maximizing the value of the convergence t-statistic, subject to the restriction that it is greater than −1.65.
iii. Continue adding one state at a time of the remaining states to the core group, and re-estimate model (3) for each formation. Use the sign criterion (t-statistic > 0) to decide whether a state should join the core group.
iv. For the remaining states, repeat steps (ii)–(iii) iteratively and stop when clubs can no longer be formed. If the last group does not have a convergence pattern, conclude that its members diverge.

PS recommend performing club merging tests after running the algorithm using Eq. (3) in order to avoid an over-estimation of the number of clubs.

Finally, we have followed the suggestion of PS and extracted the trend components of the series by filtering them using the Hodrick and Prescott (1997) filter, applying the standard value λ = 400.

3. Results and discussion

3.1. Waste generation convergence

3.1.1. MSW/GDP ratio

The results of the application of the PS methodology are reflected in Table 1. The null hypothesis of convergence is clearly rejected when we analyze the MSW/GDP ratio. Then, there is no common pattern of behavior and several clubs exist, as the subsequent use of the PS cluster algorithm proves. We can observe the existence of 4 different clubs, whilst two regions (Madrid and Galicia) diverge. Club 1 is the group formed by Andalucía, Islas Baleares, Islas Canarias, Cantabria, Castilla-La Mancha and Extremadura. Asturias and Murcia belong to club 2. Cataluña, Castilla y León and the Comunidad Valenciana form Club 3. Finally, Aragón, Navarra, the País Vasco and La Rioja are included in club 4. Galicia and Madrid exhibit a different behavior and cannot be included in any of these clubs. Fig. 1 presents these results in a map.

In order to better understand the results obtained, the average values of the MSW/GDP ratio have been obtained for each one of the estimated clubs and are presented in Fig. 2 jointly with the values of Galicia and Madrid. Club 1 exhibits the greatest values of the ratio at the end of the sample. Therefore, we can consider this club to include the highest values of the MSW/GDP ratio. By contrast, the ratio of Madrid is the lowest, followed by that of club 4. Finally, we should comment on the case of Galicia. This was the region with the highest values of the MSW/GDP ratio at the beginning of the sample. However, its evolution has allowed it to remarkably reduce its waste generation and it is placed at the average at the end of the sample.

It is worth noting that there is a general decline for all the paths of the MSW/GDP ratio, showing the great effort made by all the regions to reduce their waste generation. Additionally, if we compare the range of variation of the MSW/GDP ratios, we can observe

Table 1
Testing for convergence.

	MSW/GDP	MSW/population
	Panel I. Testing for convergence	
$\hat{\beta}$	−1.97	−1.04
Log t-ratio	−32.43	−31.44
	Panel II. Estimated clubs	
	Regions	Regions
Club 1	AND, BAL, CAN, CAB, CLM, EXT	CAN, MUR
Club 2	AST, MUR	AND, CAB, CAT, CLM, CVA
Club 3	CAT, CYL, CVA	ARA, AST, CYL, EXT, GAL, MAD, NAV, PAV, LAR
Club 4	ARA, NAV, PAV, LAR	
Divergent	GAL, MAD	BAL

This table reflects the results of the use of the methodology proposed in Phillips and Sul (2007). Panel I presents the estimation of Eq. (3), whilst Panel II shows the results of the application of the cluster algorithm.

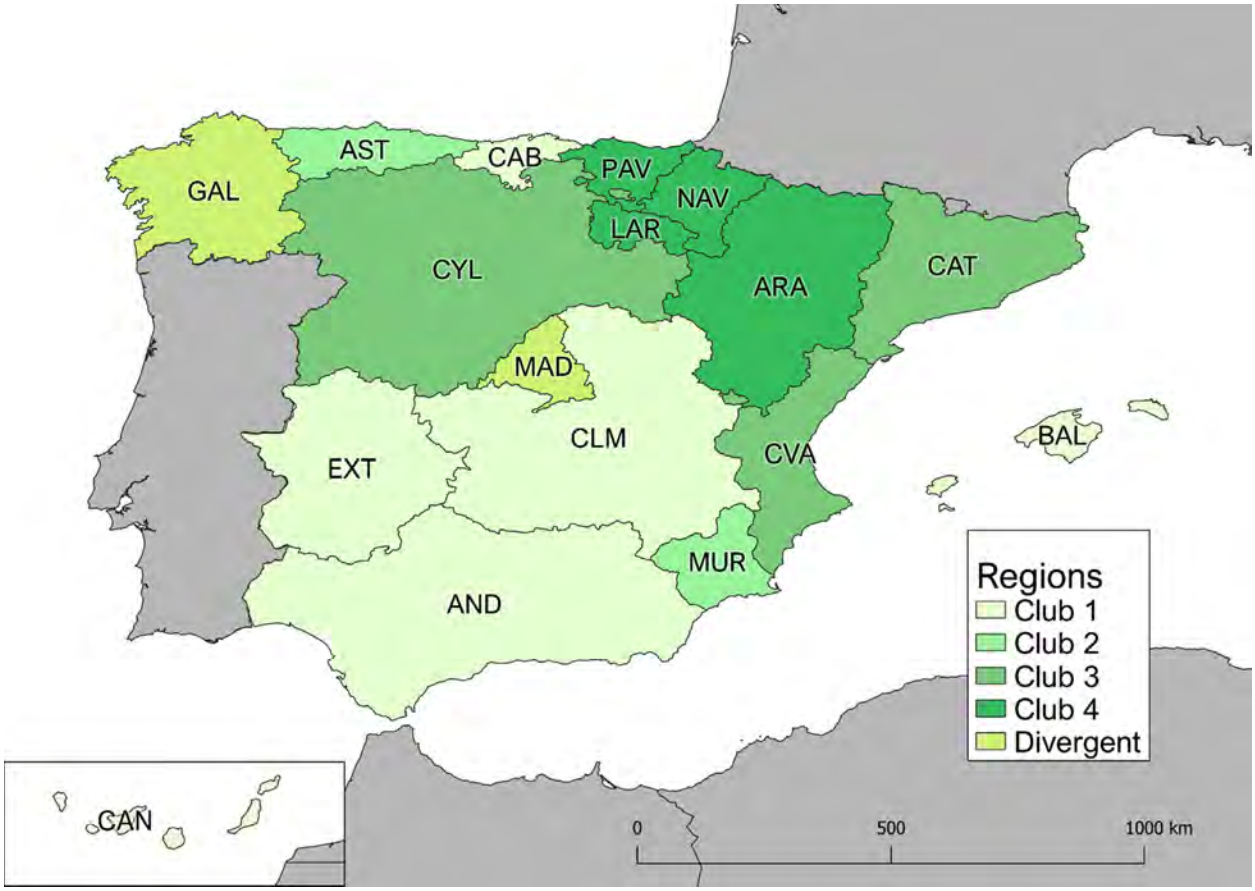

Fig. 1. Estimated clubs. MSW/GDP ratio.

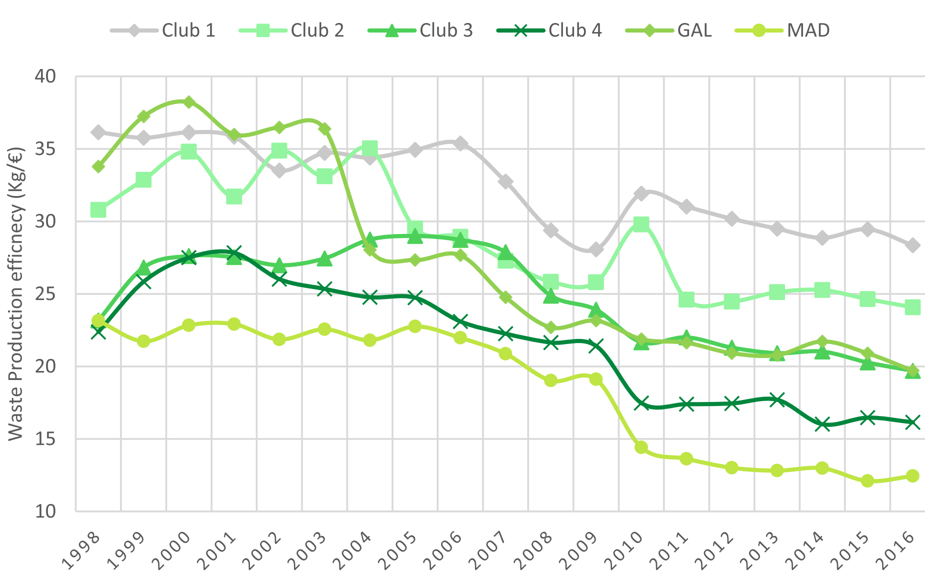

Fig. 2. MSW/GDP ratio evolution per club.

that the distance between the highest and the lowest value is greater at the end of the sample than at the beginning. This can be understood as additional evidence of the heterogeneity of the Spanish regions so far as waste generation is concerned.

3.1.2. Per capita MSW

When we consider the per capita waste generation ratio, we can also reject the null hypothesis of convergence, as can also be seen in Table 1. Then, we should again consider the presence of several

Please cite this article as: A. Alcay, A. Montañés and M. B. Simón-Fernández, Waste generation in Spain. Do Spanish regions exhibit a similar behavior?, Waste Management, https://doi.org/10.1016/j.wasman.2020.05.029

convergence clubs. The use of the PS algorithm provides somewhat different club estimations. We can observe that the Islas Baleares diverge. Club 1 is composed of the Islas Canarias and Murcia. Club 2 includes Andalucía, Cantabria, Cataluña, Castilla-La Mancha and Comunidad Valenciana. Aragón, Asturias, Castilla y León, Extremadura, Galicia, Madrid, Navarra, País Vasco and La Rioja make up Club 3. Fig. 3 reflects the club composition, whilst Fig. 4 presents the average values of the per capita MSW generation for each club.

If we focus on Fig. 4, we observe that per capita MSW does not exhibit a very clear downturn trend. Rather, it remains at around the initial levels, and a somewhat negative trend is only observed after the Great Recession. Additionally, we can appreciate that the values of the Islas Baleares are clearly greater than the rest, followed by those of club 1, which includes the Islas Canarias. Then, given that the economies of these two regions largely depend on tourism, this fact may play an important role in the per capita waste generation, as we will discuss below. Finally, we can also observe that there is no reduction in the differences between the average values of the clubs and, therefore, the degree of heterogeneity is greater than that of the MSW/GDP indicator. Even worse, there is no sign that these differences will disappear in the near future.

3.2. Forces that may drive the club creation

The results reported in the previous section have proved the heterogeneity of the evolution of waste generation management across the Spanish regions, reflected in the existence of several patterns of behavior. This section is devoted to an analysis of the forces that may drive the creation of these clubs. To that end, we have estimated the model

$$y_i = x_i{\prime}\beta + u_i (i = 1, 2, \ldots, 17) \quad (4)$$

where the dependent variable y_i may have various possible outcomes, each of them related to the number of clubs that the PS methodology has estimated. These different values imply a preference or an ordination of the clubs, which should be considered in the estimation. Therefore, ordered probit methods should be employed. The explanatory variables (x_i) have been selected from a set of general socioeconomic variables, such as per capita GDP, education level or public expenditure; other environmental variables, such as the number of recycling plants, landfills or homes that have reported environmental problems; and, finally, variables that reflect the institutional context such as the transparency of administrations or the crime rate. These variables are defined in the Appendix. The final specification has been selected by following a general-to-particular strategy, where the non-significant variables have been iteratively removed. Finally, we should note that the quality of the estimations is limited by the scant length of the sample, given that we have only 17 possible observations. This sample availability would be even shorter if we excluded the divergent regions. Then, in order to maximize the degrees of freedom of the estimation, we have preferred to retain the divergent regions in the estimation. They have been incorporated into the probit as a separate group. This means that we have 6 groups for the MSW/GDP ratio and 4 groups for the per capita MSW. In any event, we should note that the results presented here are robust to other allocations of the divergent regions.

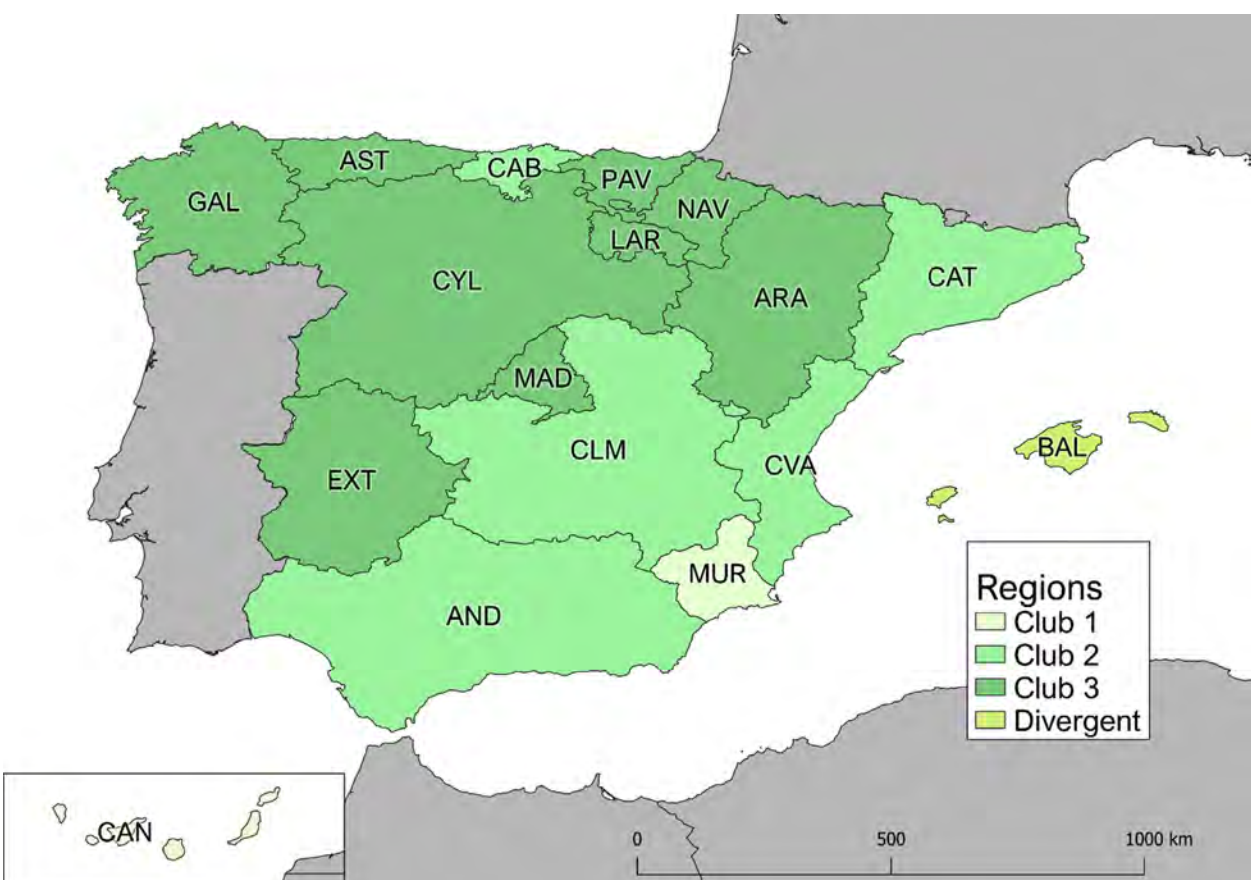

Fig. 3. Division by clubs. Per capita MSW.

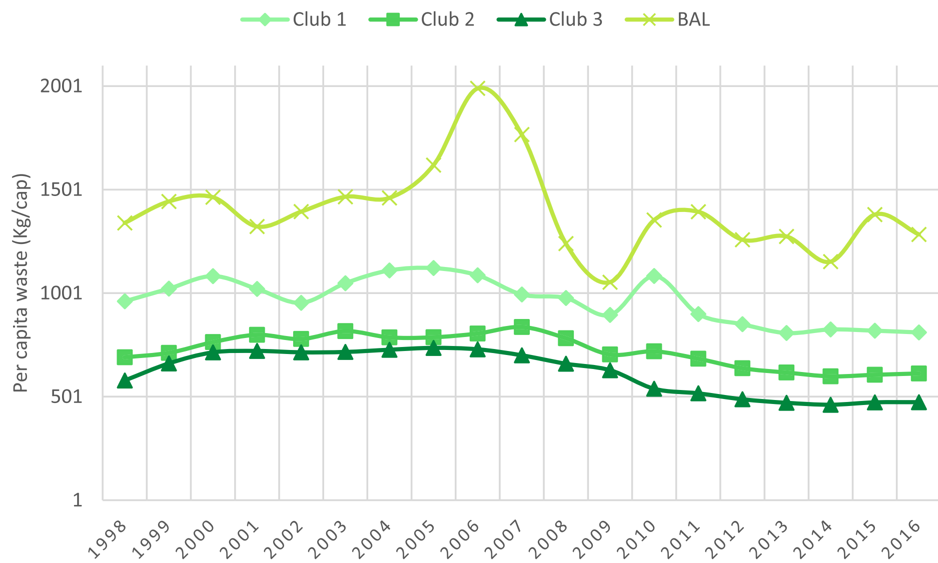

Fig. 4. Per capita MSW by clubs.

Table 2
Ordered probit estimation.

Variables	Estimations	Variables	Estimations
Panel I. MSW/GDP		Panel II. per capita MSW	
pcGDP	0.000853	HOUSEHOLD	−0.00278
	(2.64)		(-3.26)
EDU	1.48	GRADUATES	1.16
	(2.11)		(3.58)
SERV	− 0.23	LEFT-WING	0.11
	(-2.64)		(2.97)
ENVIRON	0.000015	ENVIRON	0.000012
	(2.05)		(2.17)
		DISPERSION	15.24
			(2.97)

This table reflects the results of the ordered probit estimation of equation (4). Panel I considers the MSW/GDP ratio, whilst Panel II analyzes the per capita waste generation. The dependent variable takes the value i when the region is included in club i, with i = 1, 2, . . ., M and M being 6 for Panel I and 5 for Panel II. The values in parenthesis are the robust t-statistics for testing the null hypothesis whose associated coefficient is 0.

3.2.1. MSW/GDP ratio

The results are presented in Panel I of Table 2. The explanatory variables included in the final specification are the per capita GDP (pcGDP), the percentage of people between the ages of 25 and 64 who participate in training activities (EDU), the percentage of the service sector over the total GDP (SERV) and the expenditure of local authorities in the Environment Spending Chapter (ENVIRON). Note that we can relate positive coefficients with lower waste generation, given that belonging to a higher group indicates less waste per unit of GDP.

Then, we can observe that the higher the per capita GDP, the lower the MSW/GDP ratio of the region. This relationship is also valid for the level of continuing education and the level of environmental spending. By contrast, the dimension of the service sector has an opposite effect. The greater the service sector, the greater the MSW/GDP ratio.

The analysis of the results leads us to observe the importance of the economic structure and the general level of economic activity in relation to waste generation, as has been analyzed in Arbulú et al (2015) or in Namlis and Komilis (2019). In the Spanish case, this factor is very relevant for those regions with significant tourist activity. The regions having the largest service sector exhibit the highest degrees of MSW/GDP ratio. This result can be easily understood if we take into account that the environmental regulation of the service sector is more relaxed.

Education and qualifications are also key in industrial sectors that use highly trained workers. Industrial regions with a higher level of education will, in turn, end up having more reduced levels of waste. These characteristics are shared by the regions that make up Club 4 (País Vasco, Navarra, Aragón and Rioja), added to which we could incorporate Madrid as the region with the lowest levels of waste generation. They stand out for their high per capita income and for an economic structure with a greater weight of industry, agri-food or highly specialized services such as logistics, the financial sector or research. Higher and continuous education and training is also a feature of these regions.

3.2.2. Per capita MSW

The results obtained from the estimation of model (4) are reflected in Panel II of Table 2. The explanatory variables included in the final specification are the average household expenditure in the region (HOUSE_EXP), the number of university graduates (GRADUATES), the years of government of left-wing parties in the region (LEFT_WING), the proportion of people living in settlements of less than 10,000 inhabitants (DISPERSION) and the expenditure of local authorities on environmental items (ENVIRON).

The analysis of the estimated model leads us to very interesting insights. Household income is directly related with the per capita MSW ratio. This result should be interpreted with some caution. It might show that an increase in household income would result in a greater environmental impact, which would contradict the results obtained for the MSW/GDP ratio. However, we should note that the Islas Baleares have the greatest per capita waste and, at the same time, one of the largest per capita GDP and household incomes. By contrast, the regions included in the estimated club 1 have the lowest values of these economic indicators, whilst those in estimated club 3 have the highest. Therefore, the relationship between income and per capita MSW is clearly altered by the behavior of the Islas Baleares.

The effect of the educational level and provision of higher education is again of considerable importance in determining the level of waste per capita. The higher the education level, the lower the per capita MSW.

Left-wing parties have traditionally been associated with the extension of civil rights, social protection or environmental sustainability as their priorities of government. The fact that the variable years of left-wing regional governance is significant would confirm that the ideology of the government matters so far as waste collection is concerned. In this regard, our results are consistent with the fact that left-wing governments are more aware of environmental concerns, as suggested by Harring et al. (2019).

The fact that territorial dispersion amounts to per capita waste generation implies that the territorial organization and spatial distribution of economic activity is not neutral with respect to waste generation. If the regions with the highest proportion of their population in nuclei with less than 10,000 inhabitants have a lower environmental impact measured in per capita waste generation, this implies that there are differences in rural and urban societies. It follows that the insular and urban grouping structure around the coast, in which various regions belonging to groups 1, 2 and 3 are grouped, is one of the explanations of the higher intensity of per capita waste generation.

In this regard, we should take into account the results of Kennedy et al (2007). These authors observe a trend in cities over the last few decades towards a greater use of materials, especially for the construction of new buildings. Given that building materials are difficult to recover and recycle, it is to be expected that they will end up being dumped. Thus, the amount of waste generated may be increasing even in cities that have implemented an efficient recycling system for urban waste.

Finally, the results also suggest a clearly differentiated behavior between the Northwestern and the Mediterranean regions of Spain, with the latter showing a lower per capita waste generation than the former.

3.3. Discussion of results and implications

Prevention in the generation of waste produces considerable environmental benefits and plays a key role in the roadmap to advance towards an Efficient Europe in the use of the resources within the 2020 Strategy of the European Union. Hence, all EU countries seek to design policies to reduce the generation of waste. In Spain, the political initiatives relating to the Circular Economy at national, regional and local level have also been notable in recent years.

It should be noted that the effort made in Spain to contain waste generation has been truly remarkable, going from a total of 0.70 tons of waste per inhabitant in 1995 to 0.58 in 2016, a reduction of almost 20%. However, this effort has not been homogeneous. Our results demonstrate, on the one hand, the existence of clearly different regional patterns of behavior and, on the other hand, they identify variables that can help explain these differences. This will facilitate the design of policies aimed at reducing waste generation even further.

Our results indicate that the regions with a greater dependence on the tourism sector show a significantly worse performance both in the MSW/GDP ratio and, especially, in the per capita MSW. If we focus on this last measure, it can be seen that Islas Canarias, Islas Baleares and Murcia, regions where the tourism sector is very important, have double the average generation of waste than the regions with the best performance.

So, it seems appropriate to think about reducing the generation of waste in those regions with the worst performance in order to improve the global data for Spain. In this context, we should note that the works of Weber et al (2019) and Diaz-Farina et al (2020) study the effect of the implementation of unit-pricing schemes in waste management in Spanish tourist areas. These authors conclude that this type of economic stimulus makes it possible to decrease the generation of waste and, at the same time, to increase recycling levels. Similar conclusions are drawn from other studies not focused on the Spanish case, such as Sakai et al (2008) for Japan or Bueno and Valente (2019) who analyze the experience of Trento (Italy). The results of these works indicate that the reductions in waste generation are around 30% after applying these unit-pricing schemes. If we accept this figure as an achievable goal, the levels of waste generated from Islas Canarias and Murcia would decrease to around the average value of Spain. The case of Islas Baleares would improve, but the values would still be very high and the effort would have to be greater and more persistent over time. All in all, this strategy would help to reduce the distances between the Spanish regions and, as a result, to improve the levels of sustainability of the Spanish economy.

However, this should not be the only strategy to follow, but should be accompanied by others. The results discussed in the preceding sections indicate various key factors for improving the ratios of waste generation. These include public awareness, through the improvement of educational levels, a more rigorous regulation of waste generation in the services sector, and a clear commitment by regional and local administrations to an efficient consumption system.

4. Conclusions

Following the recent literature on the economics of waste, we have studied the evolution of municipal solid waste generation in the Spanish regions. To that end, we have focused on two different indicators: the MSW/GDP ratio and the per capita MSW generation. The use of the methodology proposed in Phillips and Sul (2007) leads us to conclude that there has not been a convergence process between the Spanish regions. Rather, we can observe the existence of several patterns of behavior, which implies the existence of a very heterogenous behavior so far as waste prevention is concerned. In this regard, we can see that Madrid, the País Vasco and the regions of the Ebro Valley present the lowest MSW/GDP ratios and that these regions plus Asturias, Castilla-León, Extremadura and Galicia have the lowest per capita MSW. By contrast, the regions situated along the Mediterranean coast and the Islas Canarias exhibit the greatest MSW ratios.

We have employed several socioeconomic variables to explain these different patterns of behavior. The estimation of two ordered probit models leads us to observe that the level of economic activity, the education level of the population, public environmental expenditure, the ideology of the government of the region, the degree of dispersion of the population and, especially, the economic structure are factors that can help us to explain the regional differences in waste prevention. In this regard, we should note that there is a clear relationship between the dependence of the regional economy on the tourism industry and waste generation. This fact must be considered to design strategies aimed at shifting the Spanish economy towards zero-waste, the adoption of unit-pricing schemes being an interesting option for achieving this goal, as analyzed in previous literature.

Finally, we should recognize that a more in-depth investigation into the temporal and regional evolution of MSW is required. Here we have focused on the generation and prevention of waste. However, we should be aware that recycling and energy recovery are two of the priorities of the circular economy in terms of waste management. Consequently, it is also very important to examine how technological progress and the evolution of social demands can help to adapt waste treatment capacity to the needs set by European Union objectives. The study of the long-term relationships between GDP (as a measure of the evolution of a society) and waste generation/recycling would be of great interest in this regard. Knowing the relationship between the production of goods

Please cite this article as: A. Alcay, A. Montañés and M. B. Simón-Fernández, Waste generation in Spain. Do Spanish regions exhibit a similar behavior?, Waste Management, https://doi.org/10.1016/j.wasman.2020.05.029

and services and the generation of waste is not only useful for better prediction, but also for evaluating to what degree the production and consumption system is more dependent on the incorporation of materials and the generation of waste. This dependence, studied in the literature as decoupling, has not been evaluated for waste generation and recycling in the EU. This remains for future research.

Funding sources

This work was supported by the "Fundación Caja Rural de Aragón" Chair of the University of Zaragoza, Spain.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The paper has benefited from the comments of two anonymous referees and those of an associate editor. The usual disclaimer applies. The authors gratefully acknowledge the financial support from the Gobierno de Aragn under grants LMP71_18 and LMP113_18.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.wasman.2020.05.029.

References

Agovino, M., Cerciello, M., Musella, G., 2019. The good and the bad: identifying homogeneous groups of municipalities in terms of separate waste collection determinants in Italy. Ecol. Ind. 98, 297–309.
Apergis, N., Payne, J.E., 2020. NAFTA and the convergence of CO2 emissions intensity and its determinants. Int. Econ. 161, 1–9.
Arbulú, I., Lozano, J., Rey-Maquieira, J., 2015. Tourism and solid waste generation in Europe: a panel data assessment of the Environmental Kuznets Curve. Waste Manage. 46, 628–636.
Barro, R.J., Sala-i-Martin, X., 1992. Convergence. J. Polit. Econ. 100 (2), 223–251.
Bel, G., Fageda, X., 2010. Empirical analysis of solid management waste costs: Some evidence from Galicia, Spain. Resour. Conserv. Recycl. 54 (3), 187–193.
Bernard, A.B., Durlauf, S.N., 1995. Convergence in international output. J. Appl. Econ. 10 (2), 97–108.
Bueno, M., Valente, M., 2019. The effects of pricing waste generation: a synthetic control approach. J. Environ. Econ. Manage. 96, 274–285.
Camarero, M., Castillo, J., Picazo-Tadeo, A.J., Tamarit, C., 2013a. Eco-efficiency and convergence in OECD countries. Environ. Resour. Econ. 55 (1), 87–106.
Camarero, M., Picazo-Tadeo, A.J., Tamarit, C., 2013b. Are the determinants of CO2 emissions converging among OECD countries? Economics Lett. 118 (1), 159–162.
Carlino, G.A., Mills, L., 1993. Are US regional incomes converging? A time series analysis. J. Monetary Econ. 32 (2), 335–346.
Carlino, G.A., Mills, L., 1996. Testing neoclassical convergence in regional incomes and earnings. Reg. Sci. Urb. Econ. 26 (6), 565–590.
Castillo-Giménez, J., Montañés, A., Picazo-Tadeo, A.J., 2019a. Performance and convergence in municipal waste treatment in the European Union. Waste Manage. 85, 222–231.
Castillo-Giménez, J., Montañés, A., Picazo-Tadeo, A.J., 2019b. Performance in the treatment of municipal waste: are European Union member states so different? Sci. Total Environ. 687, 1305–1314.
Corsini, F., Gusmerotti, N.M., Testa, F., Iraldo, F., 2018. Exploring waste prevention behaviour through empirical research. Waste Manage. 79, 132–141.
D'Adamo, I., Falcone, P.M., Ferella, F., 2019. A socio-economic analysis of biomethane in the transport sector: The case of Italy. Waste Manage. 95, 102–115.
De Jaeger, S., Eyckmans, J., Rogge, N., Van Puyenbroeck, T., 2011. Wasteful waste-reducing policies? The impact of waste reduction policy instruments on collection and processing costs of municipal solid waste. Waste Manage. 31 (7), 1429–1440.
Di Maria, F., Sisani, F., Contini, S., Ghosh, S.K., Mersky, R.L., 2020. Is the policy of the European Union in waste management sustainable? An assessment of the Italian context. Waste Manage. 103, 437–448.
Diaz-Farina, E., Díaz-Hernández, J.J., Padrón-Fumero, N., 2020. The contribution of tourism to municipal solid waste generation: a mixed demand-supply approach on the island of Tenerife. Waste Manage. 102, 587–597.
Díaz-Villavicencio, G., Didonet, S.R., Dodd, A., 2017. Influencing factors of eco-efficient urban waste management: evidence from Spanish municipalities. J. Cleaner Prod. 164, 1486–1496.
Expósito, A., Velasco, F., 2018. Municipal solid-waste recycling market and the European 2020 Horizon Strategy: a regional efficiency analysis in Spain. J. Cleaner Prod. 172, 938–948.
Falcone, P.M., 2019. Tourism-based circular economy in Salento (South Italy): A SWOT-ANP analysis. Soc. Sci. 8 (7), 216.
Ghisellini, P., Cialani, C., Ulgiati, S., 2016. A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. J. Cleaner Prod. 114, 11–32.
Harring, N., Jagers, S.C., Matti, S., 2019. The significance of political culture, economic context and instrument type for climate policy support: a cross-national study. Climate Policy 19 (5), 636–650.
Hodrick, R.J., Prescott, E.C., 1997. Postwar US business cycles: an empirical investigation. J. Money Credit Bank., 1–16
Kashwan, P., 2017. Inequality, democracy, and the environment: a cross-national analysis. Ecol. Econ. 131, 139–151.
Kennedy, C., Cuddihy, J., Engel-Yan, J., 2007. The changing metabolism of cities. J. Ind. Ecol. 11 (2), 43–59.
Kounetas, K.E., 2018. Energy consumption and CO2 emissions convergence in European Union member countries. A tonneau des Danaides? Energy Econ. 69, 111–127.
Lavee, D., Khatib, M., 2010. Benchmarking in municipal solid waste recycling. Waste Manage. 30 (11), 2204–2208.
Lavee, D., Nardiya, S., 2013. A cost evaluation method for transferring municipalities to solid waste source-separated system. Waste Manage. 33 (5), 1064–1072.
Lieder, M., Rashid, A., 2016. Towards circular economy implementation: a comprehensive review in context of manufacturing industry. J. Cleaner Prod. 115, 36–51.
Luttenberger, L.R., 2020. Waste management challenges in transition to circular economy-case of Croatia. J. Cleaner Produ 120495.
Namlis, K.G., Komilis, D., 2019. Influence of four socioeconomic indices and the impact of economic crisis on solid waste generation in Europe. Waste Manage. 89, 190–200.
Payne, J.E., Vizek, M., Lee, J., 2017. Is there convergence in per capita renewable energy consumption across US States? Evidence from LM and RALS-LM unit root tests with breaks. Renew. Sustain. Energy Rev. 70, 715–728.
Pérez-López, G., Prior, D., Zafra-Gómez, J.L., 2018. Temporal scale efficiency in DEA panel data estimations. An application to the solid waste disposal service in Spain. Omega 76, 18–27.
Phillips, P.C., Sul, D., 2007. Transition modeling and econometric convergence tests. Econometrica 75 (6), 1771–1855.
Phillips, P.C., Sul, D., 2009. Economic transition and growth. J. Appl. Econ. 24 (7), 1153–1185.
Sakai, S., Ikematsu, T., Hirai, Y., Yoshida, H., 2008. Unit-charging programs for municipal solid waste in Japan: a tool for urban waste management. Waste Manage. 28 (12), 2815–2825.
Sharma, S., Basu, S., Shetti, N.P., Aminabhavi, T.M., 2020. Waste-to-energy nexus for circular economy and environmental protection: recent trends in hydrogen energy. Sci. Total Environ. 713, 136633.
Solarin, S.A., 2019. Convergence in CO 2 emissions, carbon footprint and ecological footprint: evidence from OECD countries. Environ. Sci. Pollut. Res. 26 (6), 6167–6181.
Tamayo-Orbegozo, U., Vicente-Molina, M.A., Villarreal-Larrinaga, O., 2017. Eco-innovation strategic model. A multiple-case study from a highly eco-innovative European region. J. Cleaner Prod. 142, 1347–1367.
Tisserant, A., Pauliuk, S., Merciai, S., Schmidt, J., Fry, J., Wood, R., Tukker, A., 2017. Solid waste and the circular economy: a global analysis of waste treatment and waste footprints. J. Ind. Ecol. 21 (3), 628–640.
Tomić, T., Schneider, D.R., 2018. The role of energy from waste in circular economy and closing the loop concept – energy analysis approach. Renew. Sustain. Energy Rev. 98, 268–287.
Weber, G., Cabras, I., Calaf-Forn, M., Puig-Ventosa, I., D'Alisa, G., 2019. Promoting waste Degrowth and environmental justice at a local level: the case of unit-pricing schemes in Spain. Ecol. Econ. 156, 306–317.