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The contribution of tourism to municipal solid waste generation: A mixed demand-supply approach on the island of Tenerife

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ABSTRACT

Tourism contributes substantially to municipal solid waste generation, yet the waste from tourism systematically remains hidden behind residential waste flows. As a result, municipal fees are set without precise information about waste producers' contributions, causing budget imbalances and cross-subsidies between residential and economic activities. To estimate tourism's contribution to mixed waste generation in an island destination, socio-demographic, economic and disposal-related factors are modelled using municipal panel data from 2004 to 2015 for Tenerife (Spain). In contrast to previous studies, a mixed demand-supply approach is adopted to estimate the contribution of main tourism activities to mixed waste generation, thus, differentiating between tourists and residents' contributions. An auxiliary model is used to isolate employment levels in tourism activities attributable to residents' consumption and to capture tourists' and residents' mobility on the island. Estimates show that main tourism activities generate 0.40 kg of mixed waste per tourist daily, while residential and economic sectors account for 1.19 kg per resident daily. This tourism contribution is significantly lower compared to other studies, as it captures tourism's contribution to mixed waste generation, attributable only to tourists, following a mixed demand-supply approach. These results shift impacts from tourists to main tourism activities, which highlights the choices made by producers rather than the final customers and reinforces the producers extended responsibility principle. The implementation of a Pay-As-You-Throw tariff for mixed waste is discussed as a way of promoting waste prevention and recycling, as well as avoiding cross-subsidies among waste producers and, as a result, imbalances in municipal budgets.

1. Introduction

The impact of tourism on Municipal Solid Waste (MSW) generation is large and increasing (Murava and Korobeinykova, 2016; Matai, 2015; Pirani and Arafat, 2014; Mateu-Sbert et al., 2013). In some regions, MSW generation by a tourist can double that of a resident (Shamshiry et al., 2011). In addition, tourism seasonality leads to over-capacity in MSW treatment facilities, causing high operational costs (Arbulú et al., 2016). Specifically, tourism pressure on waste management in island destinations is a major concern, as they are isolated from mainland recycling networks and facilities and landfilling prevails over other waste management techniques (Mohee et al., 2015).

Indeed, islands all over the world exhibit the highest per capita waste indicators, not only because they keep a more complete account of waste generation but also because of their intensive tourism industries (Hoornweg and Bhada-Tata, 2012). Ezeah et al. (2015) and Eckelman et al. (2014) highlight a number of common waste management problems in tourism islands: reduced number of treatment and disposal facilities, high population densities, limited land mass to establish more landfills and other treatment facilities, difficulties to achieve economies of scale and significant seasonality in waste generation due to tourism. Thus, as an island's landfills become a cul-de-sac for waste produced by tourism and residential consumption, improving MSW management becomes a priority for sustainable strategies (Estay-Ossandon and Mena-Nieto, 2018). Indeed, islands may serve as a natural laboratory to study tourism's impacts on waste generation (Michael Hall, 2010).

Not surprisingly, most tourism waste is generated by hotels and restaurants, i.e. the hospitality industry (Pirani and Arafat, 2014; Sealey and Smith, 2014), with almost half of it being food waste (Pirani and Arafat, 2014). Since tourism waste is mainly characterized as MSW, its collection, transport and treatment are generally

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carried out within residential waste facilities and networks. Therefore, tourism waste figures are statistically hidden within residential waste indicators. Consequently, main tourism activities lack specific waste indicators and proper incentives to reduce waste generation or to sort waste. The latter results in significantly lower recycling rates (Styles et al., 2013; Williams et al., 2011).

Waste amounts and composition by producer comprise the basic and essential information for appropriate planning, operation and optimization of any waste management system (Beigl et al., 2008). Moreover, waste indicators by producer are key to designing adequate incentives to minimize waste generation and increase recycling rates, such as Pay-As-You-Throw (PAYT) fees (Elia et al., 2015; Karagiannidis et al., 2008; Puig-Ventosa, 2008; Reichenbach, 2008; Sakai et al., 2008; Skumatz, 2008). As Arbulú et al., (2016) point out, without adequate information, waste charges may create municipal budget imbalances and, more importantly, cross-subsidies among residential, tourism and other economic sectors. However, waste generation measurement on a detailed basis is not always possible, as door-to-door services are not extensively provided.

Reliable information on waste amounts and detailed composition is difficult to gather at a disaggregated level (Thanh et al., 2010). As an alternative, modelling waste generation can help determine the contribution of waste producers to MSW generation. Indeed, there is a long and interesting history of studies using different approaches. Traditionally, modelling waste generation has led to evaluations of disposal habits, changes and trends (Beigl et al., 2008). In addition, identifying and quantifying the relevant influencing factors are crucial for waste sector planning, leading to studies concerning changes in general conditions (e.g. economic system or demography), impact studies of policy measures, waste management measures (e.g. increasing waste recycling rates) on future waste quantities (Lebersorger and Beigl, 2011) and making projections under different scenarios (Estay-Ossandon and Mena-Nieto, 2018).

Modelling waste generation also involves testing many factors and quantifying their impact on MSW generation. The population has been considered as one of the most important variables affecting total waste generated since Hockett et al. (1995). For example, differences in consumption patterns, resulting from varying income levels, impact on waste generation levels (Dangi et al., 2011; Johnstone and Labonne, 2004; Wang and Nie, 2001; Buenrostro et al, 2001; Hockett et al., 1995). Other social and demographic factors have been widely tested in the literature, such as population size (Estay-ossandon and Mena-nieto, 2018; Ghinea et al., 2016; Mateu-Sbert et al., 2013; Chung, 2010; Hockett et al., 1995) and structure (Ghinea et al., 2016; Talalaj and Walery, 2015; Beigl et al., 2004; Kinnaman and Fullerton, 2000), average age of population (Callan and Thomas, 2006), education level (Keser et al., 2012; Miller et al., 2009; Callan and Thomas, 2006; Kinnaman and Fullerton, 2000), household size (Bureecam and Chaisomphob, 2015; Lebersorger and Beigl, 2011; Callan and Thomas, 2006; Beigl et al., 2004; Kinnaman and Fullerton, 2000) and climate (Keser et al., 2012; Miller et al., 2009). However, data at appropriate levels on potentially valid explanatory variables are hard to collect (Hockett et al., 1995; Jenkins, 1993), especially over a long period.

Other authors have modelled the impact of some economic activities on MSW generation. Keser et al., (2012) used the agricultural production value. Bach et al. (2004) used the number of agricultural firms and the percentage of employees in tertiary and secondary sectors. However, little attention has been paid in the literature to analysing tourism's contribution to MSW generation. Especially as tourism is a multidimensional, multifaceted sector that touches many different economic activities and aspects of individuals' lives. Thus, there is a significant challenge when attempting to measure tourism's direct impacts from either a demand-side (visitors consumption only) or a supply-side (tourism activities only) approach (United Nations, 2010). Indeed, not only are significant differences found when measuring, for example, the economic impacts of tourism in a specific territory, but also a completely different perspective of its environmental impacts and policies may arise. The confrontation and reconciliation between tourism supply of tourism products and services, and tourism consumption is shown in Fig. 1. The shadowed area shows the intersection of visitors (demand-side) and tourism activities (supply-side), which should provide a correct measure of tourism impacts.

Most studies on tourism's waste contribution follow a demand-side approach using tourist flows to estimate their impact on MSW. Gidarakos et al. (2006) assumes an average MSW generation by tourists to calculate the total effect of tourism on MSW on the island of Crete. Mateu-Sbert et al. (2013) estimate the contribution of tourism on MSW generation on the island of Menorca (Balearic Islands) using a dynamic regression model including MSW monthly data collected from tourist and resident populations. However, they adopt the strong assumption that overall elasticity is equal to one, implying that MSW increases by the same factor as the total population: residents and tourists together. More recently, Estay-Ossandon and Mena-Nieto (2018) use the equivalent tourist population to forecast MSW generation on the Balearic Islands from 2015 to 2030 under different scenarios.

However, demand-side approaches can overestimate the direct contribution of tourism activities to MSW generation, since all sectors in the economy, and both direct and indirect impacts are being included. Moreover, attributing MSW to tourists overlooks the fact that their contribution to MSW generation is mainly determined by the waste management decisions taken by main tourism activities. As tourism activities face increasing responsibility for the amounts and streams of waste generated at tourism destinations (Guerrero et al., 2013), it seems essential to untie tourism's contribution to MSW generation from tourist numbers. Indeed, the amount and type of packaging waste generally depends on choices made by the producer rather than the final customer (EU, 2018), which can be extended to most waste stream management. Finally, municipal waste charges are generally defined by economic activities and not by individuals. Thus, in the context of incentive design, following a supply-side approach to estimate the impact of tourist activities on MSW generation seems to be a more appropriate approach.

Few studies have focused on a supply-side approach to measure the waste generated by main tourism activities. Saito (2013) conducted a survey of 50 hotel establishments to measure the waste produced per establishment, employees and visitors in five tourism activities on the main island of Hawaii. Abdulredha et al. (2018) also conducted a survey of 150 hotels during a major religious festival in the city of Kerbarla (Iraq) to estimate the impact of the hotel industry. Finally, Oribe-Garcia et al. (2015) estimated tourism's impact on urban waste generation in municipalities of Biscay using the ratio of hotel and catering establishments per resident, but they did not found a significant effect.

In these cases, supply-side approaches overestimate tourists' contribution to waste generation, since they do not consider the impact of residents' consumption in tourism activities. What is more important, some studies use supply capacity related variables without considering the level of demand for these activities, clearly a determining factor in tourism's waste contribution. Thus, a mixed demand-supply approach seems to be the most appropriate to obtain accurate estimates of tourism's contribution to MSW generation, using the proportion attributable to tourism from the main tourism activities that serve visitors.

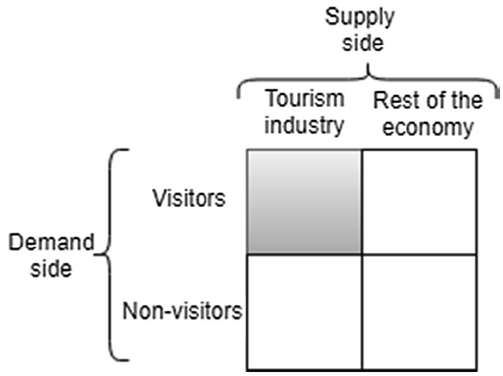

Fig. 1. Demand and supply-side approaches to estimate the tourist's contribution to waste generation through the main tourism activities. *Source:* Author prepared adapted from United Nations (2010, p. 60).

Thus, this paper adopts a mixed demand-supply approach to estimate tourists' contribution to MSW generation through the main tourism activities using municipal panel data for Tenerife, one of the Canary Islands. For this purpose, the number of jobs in the main tourism activities is used. Residents' contribution to waste generation through main tourism activities and other non-tourism activities is also analysed, as well as identifying and quantifying other socio-demographic and disposal related factors. Given the municipal level of this study, it is important to consider that both tourists and residents move around the island, influencing activity levels in other municipalities. To incorporate this aspect, an auxiliary model to capture the influence of mobility[1] on the activity level in the food & beverage sector is implemented. Indeed, the auxiliary model helps to differentiate employment levels in the food & beverage sector due to residents' consumption from that caused by tourists' consumption. The estimations are then used to evidence possible cross-subsidies among waste producers at the municipal level and to design a Pay-As-You-Throw (PAYT) tariff for mixed waste, targeting waste generation in order to increase recycling rates.

2. Material and methods

2.1. Case study: Tenerife, Canary Islands

With over 16 million tourist arrivals and 104.3 million overnight stays in 2017 distributed among seven islands (ISTAC, 2018), the Canary Islands have become the top tourism region (NUTS 2 level) in the EU (Eurostat, 2018). The contribution of the sector to the islands' regional GDP is 34.3% (EXCELTUR, 2017). However, overall waste generation is well above the 1.2 million tons reached in 2015, and mainly ends up in the islands' landfills (INE, 2017). Unlike the other Spanish archipelago, the Balearic Islands, in the Canary Islands, the main treatment facilities are landfills, since there is a strong social opposition to incineration. Thus, minimization of MSW generation and maximization of sorting waste have become priorities to comply with the European Directive, 2018/851/EC and Spanish National Waste Plan (2014–2020).[2] The per capita waste generation in the Canary Islands in 2015 was 594.1 kg per inhabitant, well above Spain's national average (466 kg per inhabitant). In fact, the Canary Islands have the second highest waste generation per capita indicator within Spain, just below the Balearic Islands (INE, 2017). In some tourist municipalities, waste generation per capita reached 964 kg per inhabitant (Adeje, Tenerife), 1,008 kg (Tías, Lanzarote) or even 1,172 kg (Yaiza, Lanzarote) for the same year (Cabildo Insular de Lanzarote, 2017; Cabildo Insular de Tenerife, 2017).

This study focuses on the island of Tenerife, the largest island of the archipelago with 933,419 inhabitants in 2018 and leader in the reception of tourists, with 5.7 million arrivals and more than 42 million overnight stays in 2017 (Turismo de Tenerife, 2018). Thus, the island of Tenerife is an ideal scenario to carry out this study, since tourism is stable throughout the year, and the island has a well-established waste network, which obliges all municipalities to operate under the same regulatory conditions.

According to current Spanish Law 22/2011 on Waste, municipalities are responsible for managing MSW collection and transport. MSW is considered the waste produced in the residential sector and similar waste produced at service establishments. There are 31 municipalities on the island of Tenerife, and 25 private, public or mixed companies running such municipal services. There are 9 municipalities that have joint MSW collection and transportation services arranged in 3 different municipal consortiums (Padron-Fumero et al., 2017). Regarding the municipal waste collection system, waste streams are distinguished between those collected separately (light packaging, paper-cardboard, glass, furniture, waste from road cleaning and public gardens) and those that are non-sorted (mixed waste). Both sorted and mixed waste streams are mainly collected in curb-side bins, while door-to-door services are reserved for big producers with waste storage facilities (Padron-Fumero et al., 2017). Citizens and small businesses also have eight waste collection points distributed throughout the island where they can deposit recyclable and other sorted municipal waste (PTEOR, 2009).

All municipal waste streams collected are transported to one of four transfer stations located on the island or directly to the island's waste treatment facilities (PTEOR, 2009). In the case of paper-cardboard and glass waste streams, they are transported to recycling facilities, where they are classified and prepared to be sent to the mainland to be recycled. In some municipalities, large producers may use the option of transporting their own waste to transfer stations, hiring transport services from specialized companies, with a discount in the municipal waste fee they pay in return (Padron-Fumero et al., 2017).

Municipal waste collection services deal municipalities with large differences in per capita waste generation on Tenerife (Cabildo Insular de Tenerife, 2017), as Fig. 2 shows. Indeed, in 2015, it ranged from 347 kg/inhabitant/year in rural municipalities (e.g. Fasnia) to 964 kg in tourist municipalities (e.g. Adeje). Urban municipalities on Tenerife are close to the average value on the island, at around 420 kg (e.g. La Laguna).

Fig. 3 shows the evolution of the proportion of recyclable waste streams and mixed waste collected in Tenerife. It was possible to obtain this information by using data from Cabildo Insular de Tenerife (2017), Ecoembes (2017) and Ecovidrio (2017). In 2015, mixed waste represented 90.7% of the total MSW generated on the island, glass 5%, paper and cardboard 2.1%, light packaging 1.3% and other sorted MSW 3.4%. These low amounts of recyclable waste collected show the gap to meet the European recycling targets of 50%[3] by 2020 and with other regions of Spain (INE, 2017).

[1] According to ISTAC (2018), each tourist spends, on average, on public transport and car rental a total of 10% of their expenses incurred in the Canary Islands, thus transport is as important as the expenditure on leisure. Based on FREDICA (Federación Regional Canaria de Empresarios Importadores y Concesionarios de Automóviles) data, the car rental industry in the archipelago represents 36% of total car sales, indicating the relevance of tourist mobility within the islands. See Table A1 in the Appendix A.

[2] Programa Estatal de Prevención de Residuos 2014–2020: https://www.miteco.gob.es/es/calidad-y-evaluacion-ambiental/planes-y-estrategias/Programa%20de%20prevencion%20aprobado%20actualizado%20ANFABRA%2011%2002%202014_tcm30-192127.pdf.

[3] Article 11.2 of the Directive 2008/98/EC on waste (Waste Framework Directive): "by 2020, preparation for re-use and recycling of waste materials such as paper, metal, plastic and glass from households and possibly from other origins to the extent these waste streams are similar to waste from households shall be increased to a minimum of 50% by weight".

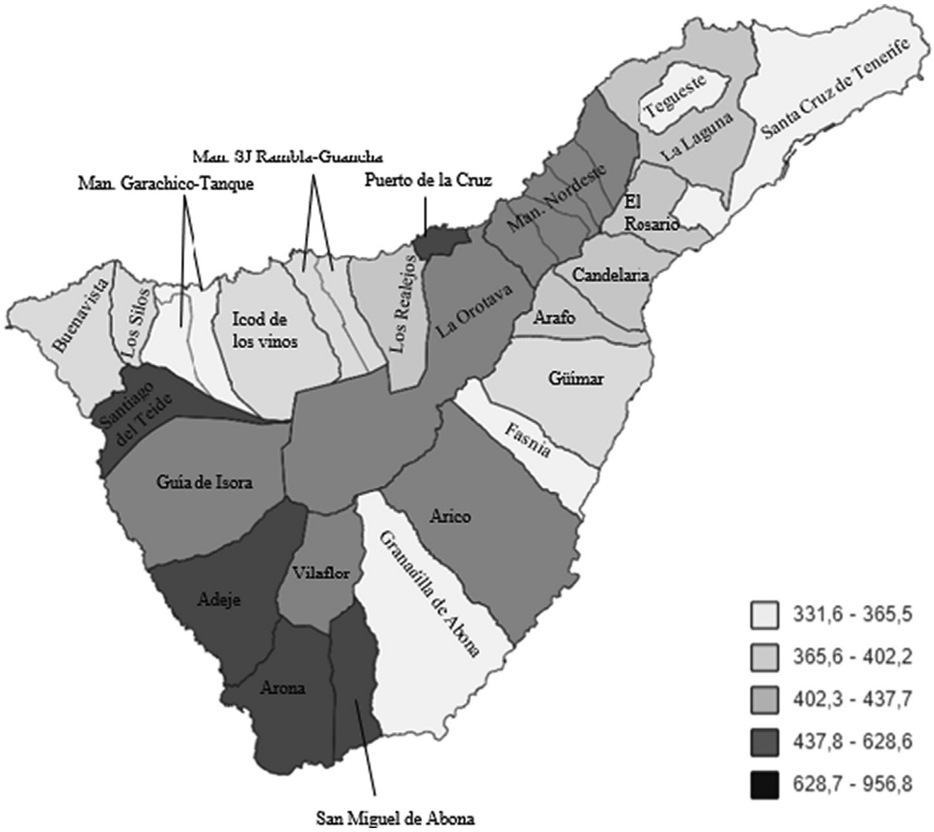

Fig. 2. Per capita MW collected by municipality on Tenerife in 2015 (kg/inhabitant). *Source:* Author prepared based on data from Cabildo Insular de Tenerife (2017).

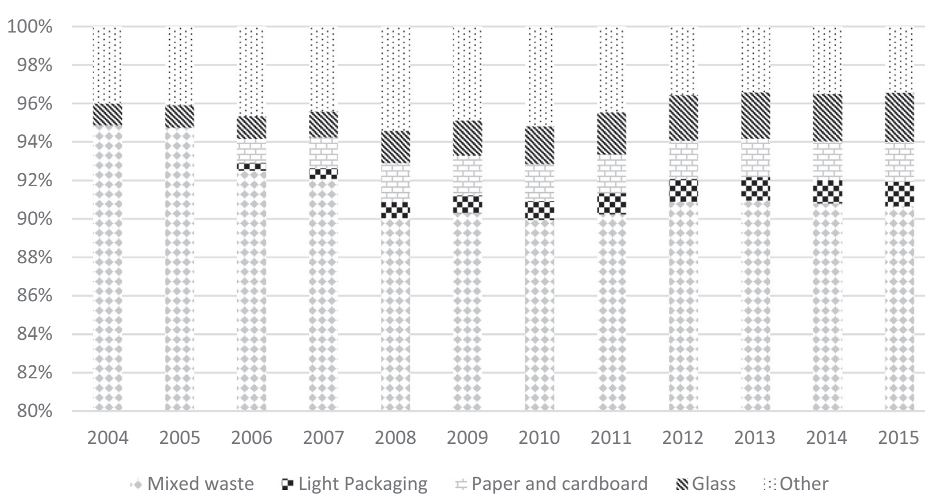

Fig. 3. Evolution of the proportion of recyclable waste streams and mixed waste collected in Tenerife. *Source:* Author prepared based on data from Cabildo Insular de Tenerife (2017), Ecoembes (2017) and Ecovidrio (2017).

Indeed, the current waste management system on the island does not provide sufficient incentives to maximize sorted waste and reduce landfill use. This could be due to the flat fees charged for municipal waste collection.

The treatment service of municipal waste on Tenerife is the responsibility of the Island Council after a transfer of powers by municipalities to the island government in 1983.[4] This treatment service also includes the transport of municipal waste from the four transfer stations to waste treatment facilities. In return, the Island Council charges municipalities a fee to finance this service. This fee follows a pay-as-you-throw (PAYT) system with a current fee per ton of 39.90€, and a per capita fixed fee of 2.75€/year to finance recycling operations (Cabildo Insular de Tenerife, 2016). The fixed part of the fee for each municipality is obtained considering both resident and tourist populations.

The municipal mixed waste sent to the waste treatment facilities passes through a mechanical biological treatment (MBT). The first phase of this treatment is the recovery of recyclable materials using mechanical processes. The second, and last phase, is the biological treatment of the fine fraction of municipal waste. In this

[4] Plan Insular de Residuos Sólidos Urbanos (PIRS), 28th January 1983.

phase, biogas is recovered, and compost is generated. The resulting waste is landfilled together with the bulky waste that could not be biologically treated due to its large dimensions.

2.2. Data

The data used in this paper consist of an unbalanced panel of municipal data from Tenerife. There is a total of 25 local entities (22 municipalities and 3 consortiums) observed in annual data from 2004 to 2015. Variables used are classified into waste stream, socio-demographic and economic data. A summary of descriptive statistics and the data sources of these variables are provided in Table 1.

To simplify terminology, all waste streams collected by municipal services, except for those comprising recyclable waste, will be referred to as mixed waste (MW). MW is composed of non-sorted waste, waste arising from public markets and road cleaning, waste from public gardens and parks and waste considered "bulky", such as furniture. Therefore, the MW to be modelled mainly consists of the waste streams that are sent to treatment facilities and are measured on an annual tonnage basis. As some large firms transport their own waste separately from municipal services, we decided to exclude this fraction, since it is quite volatile and impossible to identify either the firm or the sector that produces it. Additionally, only a few municipalities have a correct account of this waste.

The sorted waste collected from the different recycling containers, such as light packaging (*LPW*), paper and cardboard (*PCW*) and glass (*GW*) is added together under the *RW (recyclable waste)* variable. This *RW* variable is used as an explanatory variable of MW and the causal relationship is expected to be negative due to the predicted substitutability between disposable and recyclable waste, as Callan and Thomas (2006) and Chung (2010) found.

Regarding the socio-demographic variables, population and income data are used. *RP* refers to resident population in the municipality on January 1st each year, whilst *AA* measures their average age. *INC* refers to the aggregate disposal income in the municipality declared in the annual Personal Income Tax returns.

The production levels of economic activities are proxied by employment data, following Bach et al. (2004). Indeed, the number of jobs by sector instead of affiliations to social security is used. It is possible to read from the regional statistical office's (ISTAC) methodology that the number of jobs at the municipal level is the best available data to proxy the labour activity in the Canary Islands.[5] Another advantage of the number of jobs against affiliations is the availability of data displayed by two-digit disaggregation according to the European Classification of Economic Activities (NACE).

It is possible to identify the main economic activities producing MW within the service sector directly from a survey conducted by INE (2017).[6] These activities are wholesale, retail, health and hospitality[7] (split into accommodation and food & beverage (*F&B*)), which together represent more than 90% of total MW generated in the services sector.

2.3. Methodology

As there are data for 25 local entities observed in a 12-year period, a panel data model is implemented to measure the contributions to MW of main tourism activities, other economic activities (more linked to residents' consumption) and of the residential sector on Tenerife island at the municipal level. The random effects model is selected because there is interest in testing whether the type of municipality prevails (random effects) over the individual municipal characteristics (fixed effects) in mixed waste generation.

Random effects assume zero correlation between the observed explanatory variables and the error term (Wooldridge, 2015). The error term includes all possible potential explanatory variables that explain the dependent variable. In this case, according to the literature reviewed, potential municipal variables that can explain mixed waste generation are education level and climate variables. Indeed, these variables seem not to have a significant correlation with the explanatory variables included in the model, proxies of consumption and production levels. Thus, the random effects assumption of zero correlation is satisfied theoretically. Additionally, the Breusch-Pagan Lagrange Multiplier test is an objective proof that checks if the assumption of random effects is satisfied. Fig. G1, in Appendix G, confirms that the random effects model is valid in a statistical and objective way.

The dependent variable of the model is MW on a tonnage basis. The explanatory variables are recyclable waste (*RW*), resident population (*RP*) and its average age (*AA*), the *INC* and the number of jobs in accommodation (*JA*), food and beverage (*F&B*), wholesale (*JW*), retail (*JR*) and health sector (*JH*). All explanatory variables included have been tested before in the literature except for the number of jobs for some specific sectors. In addition, the correlation matrix (Table 2) shows a strong correlation between the explanatory variables and the dependent variable.

Additionally, a dummy variable, *mun_type*, is introduced to capture the unobserved heterogeneity derived from the nature of the municipality. The variable *mun_type* is the result of the implementation of a cluster in order to capture the unobserved heterogeneity caused by the nature of the municipality, which we suspect is affecting MSW generation. This clustering controls for municipal labour structure[8] and population size. As a result of this clustering, five groups are obtained as shown in Table 3.[9]

The contribution of tourism activities to MW is mainly captured by jobs in accommodation and F&B sectors, according to the list of tourism activities provided by UNWTO (2015).[10] It is assumed that the number of jobs in the accommodation sector in any municipality is explained by tourists in that municipality. However, consumption in the F&B sector in each municipality may be related to both residents and tourists. In addition, tourists and residents from other municipalities may also explain the jobs in F&B services in each municipality. Thus, it is important to differentiate the proportion of F&B jobs related to tourists (*JFBT*) and to residents' (*JFBRP*) consumption, whatever their municipality of origin, in the F&B sector. An auxiliary regression model is implemented for this purpose.[11] It is also assumed that wholesale, retail and health jobs are only related to residents' consumption. Fig. 4 shows the variables used to capture both the tourists' and residents' impacts on MW generation through tourism and non-tourism activities. Tourists' impact on MW generation is captured by *JA* and *JFBT*. Residents' impact on MW generation through tourism activities is captured by *JFBRP*, while *JW*, *JR* and *JH* captured the impact through non-tourism activities.

The auxiliary model considers that total jobs in F&B in each municipality are determined not only by residents and tourists from that municipality, but also from the surrounding municipali-

[5] http://www.gobiernodecanarias.org/istac/galerias/documentos/C00040A/Metodologia_EmpleoRegistrado_v_1_0.pdf.

[6] The main economic activities explaining the MSW generated in the private sector are obtained from a survey conducted by INE called "Contribution of specific economic sectors within the service industry to different waste streams". See the results of this survey in Table B1 in Appendix B.

[7] Regarding number of jobs in the hospitality industry, it was considered as one code under NACE-93 but two different codes (55-accommodation; 56-food and beverage) from 2009 onwards. Thus, some adjustment was needed to recalculate the series.

[8] See Table C1 in the Appendix C to see the labour structure by cluster.

[9] More detailed explanation regarding the cluster analysis can be found in Appendix D.

[10] NACE codes considered as characteristic tourism activities are the following: 49, 50, 51, 55, 55, 68, 77, 79, 90, 91, 92 and 93.

[11] These proportions can be seen in Table E3 in Appendix E.

Table 1
Summary of descriptive statistic of main variables. *Source:* Author prepared.

Variable name	Variable Label	Obs.	Mean	Std. Dev.	Min	Max	Units	Source
MW	Mixed waste	292	18,650	22,999	674	102,429	Tons	Cabildo Insular de Tenerife
LPW*	Light packaging waste	236	194.4	289.4	1.5	1,377.8	Tons	Ecoembes
PCW*	Paper and cardboard waste	239	376.8	641.1	4.8	3,406.5	Tons	Ecoembes
GW	Glass waste	293	362.9	494.6	6.3	2,486.1	Tons	Ecovidrio
RW*	Recycling waste	293	826.9	1,251.4	8.5	6,130.5	Tons	Ecoembes, Ecovidrio
RP	Resident Population	299	34,775	46,476	1,671	206,965	Inhabitants	INE[a]
AA	Average Age	299	40.3	3.1	34.2	48.5	Years	INE[a]
INC	Municipal aggregate income	299	225	387	6.15	1,980	Million €	AEAT
ETP	Equivalent tourist population	299	3,520	8,340	3	39,196	Tourists	ISTAC, TURIDATA, Turismo de Tenerife
JA	Jobs in accommodation sector	299	761	1,700	0	8245	Jobs	ISTAC
JFB	Jobs in Food & Beverage sector	299	1,030	1,375	26	5,680	Jobs	ISTAC
JFBRP	Proportion of Jobs in Food & Beverage sector explained by resident population	299	885	1,200	26	4,800	Jobs	ISTAC
JFBT	Jobs in Food & Beverage sector explained by tourist population	299	148	213	0	945	Jobs	ISTAC
JW	Jobs in wholesale sector	299	637	1,186	1	6,739	Jobs	ISTAC
JR	Jobs in retail sector	299	1,666	3,044	24	15,621	Jobs	ISTAC
JH	Jobs in health sector	299	859	2,467	0	13,747	Jobs	ISTAC

Note:* available for the period 2006–2015, while the rest are available from 2004 to 2015.

Table 2
Correlation matrix between the dependent and the independent variables included in the regression model. *Source:* Author prepared.

Variable	MW	RW	RP	AA	INC	JA	JFB	JW	JR	JH
MW	1	0.84	0.95	−0.31	0.9	0.41	0.91	0.86	0.92	0.81

Table 3
Clustering results using labor structure and population size. *Source:* Author prepared.

Cluster (#municipalities)	Group number	Municipalities
Residential (10)	1	Los Realejos, Manc. Del Nordeste, Tegueste, Güímar, Manc. San Juan de la Rambla-La Guancha, Candelaria, El Rosario, Icod de los Vinos, La Orotava and Arafo
Urban (2)	2	La Laguna and Santa Cruz de Tenerife
Rural (5)	3	Fasnia, Manc. Garachico-El Tanque, Arico, Buenavista del Norte and Los Silos
Large tourist (4)	4	Adeje, Santiago del Teide, Arona and Puerto de la Cruz
Small tourist (4)	5	San Miguel, Vilaflor, Granadilla de Abona and Guía de Isora

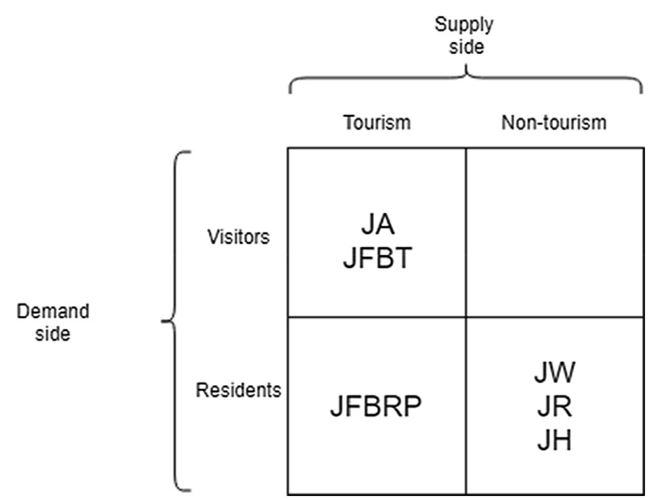

Fig. 4. Variables used to estimate both tourists' and residents' impact on MW generation through tourism and non-tourism activities. *Source:* Author prepared.

ties and the rest of the island. As shown in Fig. 5, the income level of the municipality, per capita income of surrounding municipalities and per capita income of the rest of municipalities of the island are considered as independent variables.

Surrounding municipalities have been defined according to the regional statistical office.[12] Defining surrounding municipalities captures the mobility of both tourists and residents on the island and their respective contributions to total jobs in the F&B sector. This results in an annual average contribution of tourism to jobs in the F&B sector of 12.5%. By clusters, tourism explains, on average, around 25% of total jobs in F&B in both small and large tourist municipalities, while this ratio falls to 7.9% in residential ones, 4.5% in rural ones and 4.25% in urban municipalities.[13] In terms of tourist and resident mobility, results from the auxiliary model show that the F&B sector within urban municipalities is the only one capable of attracting residents from any municipality on the island. Rural municipalities also attract residents, at least from their surrounding area. Regarding tourists, their mobility around the island in terms of F&B is limited to the municipality where they stay except for large tourist municipalities, whose F&B sectors are the only ones receiving tourists from other municipalities within the same surrounding area. There is no statistical evidence of larger tourist mobility.

[12] See Table E1 in Appendix E for surrounding areas.

[13] Mobility was also assessed in the rest of the economic activities contemplated, but there is no need to break down the number of jobs, as we only consider the distinction between residents and tourists. It means, for example, that the proportion of MW arising from resident population in the retail sector remains constant (100%), and the population from other municipalities explains some jobs in the municipality.

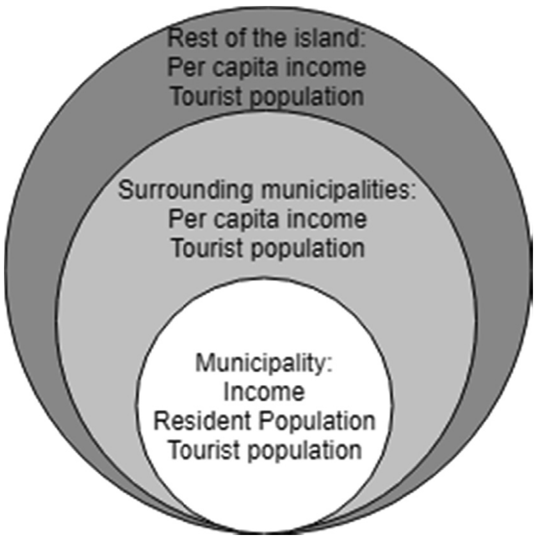

Fig. 5. Area of influence in each municipality and the explanatory variables used in the auxiliary model. *Source:* Author prepared.

The panel data model that explains MW generation takes the following functional specification:

$$lnMW_{it} = \beta_0 + \beta_1 lnRW_{it} + \beta_2 (lnRW_{it})^2 + \beta_3 lnINC_{it} + \beta_4 lnRP_{it} + \beta_5 (lnRP_{it})^2 + \beta_6 lnAA_{it} + \beta_7 lnJA_{it} + \beta_8 lnJFBRP_{it} + \beta_9 (lnJFBRP_{it})^2 + \beta_{10} (lnJFBT_{it})^2 + \beta_{11} (lnJW_{it})^2 + \beta_{12} lnJR_{it} + \beta_{13} lnJH_{it} + \delta_j Mun\_type_j + \mathrm{T} + u_{it} + \varepsilon_{it} \quad (1)$$

where i denotes the municipality and t the year. T captures the trend. $\delta_j$captures the unobserved heterogeneity derived from the municipality nature by type $j = 2, 3, 4, 5$. The residential cluster (group 1) is omitted to avoid perfect multicollinearity. u_{it} is an individual-specific effect. ε is the idiosyncratic error term, which follows a normal distribution with zero mean and constant variance (σ). Note that some variables, such as *RW*, are entered as second-degree polynomials, which is commonly done in the literature. Doing so allows the model to capture any nonlinearity in the effect of these variables on the explained one. This procedure is used with all variables, but for some of them, this generates parameters that were not significant thus giving overall weaker results.

3. Results

The model has been estimated[14] using a *Random effects* estimator, where it is assumed that the individual-specific effect is a random variable uncorrelated with the explanatory variables. Table 4 shows the coefficients for each explanatory variable, which should be interpreted as elasticities – for linear regressors – since the model is double-logarithmic. For the variables specified in a second-degree polynomial form (for example, *ln*RP and *ln*RP^2), the elasticity is obtained calculating the first derivative.[15] The model explains 98.3% of the MW variance. Armstrong's (2001) conditions regarding serial correlation, multicollinearity and possible outliers are met. Since the panel data show high dispersion, better conclusions can be drawn for the average municipality.

Results from estimating Eq. (1) show that recyclable waste collected is statistically significant, exhibiting a non-linear relationship. It shows an inverted U-shaped, which implies that as waste recycling increases, keeping the rest of variables constant, MW increases at a decreasing rate. This can be interpreted as a minimum amount of recyclable waste being needed in order to achieve a significant reduction in MW generation. This turning point[16] for the average Tenerife municipality is 305 tons and the elasticity value equal to −0.03. This elasticity can be interpreted by considering that if waste recycling increased by 1%, then MW would be reduced by 0.03%, keeping everything else constant. This negative relationship on a tonnage basis is consistent with Chung (2010).

The effect of resident population on MW generation within a household can be approximated using income elasticities and resident population, as waste produced in the residential sector depends on the number of people and the disposable income in households. The aggregate municipal income is statistically significant and has the expected positive sign, with elasticity equal to 0.4. Resident population exhibits a non-linear estimation. This non-linear relationship has an inverted U-shape implying that an increase in the number of residents will increase MW generation at a decreasing rate, with the turning point being at 361,068 inhabitants. Since all municipalities have a population well below this turning point, there is no chance for decreases in MW generation even if population increases in any municipality in Tenerife. The elasticity of population with MW taking the average values of all municipalities in Tenerife is 0.29. The other sociodemographic variable, average age of resident population, indicates that the older population tends to generate a lower amount of MW. This result is contrary to the one found by Callan and Thomas (2006) in the estimation of per capita waste disposal and recycling services in Massachusetts.

Regarding economic activities, results show a statistically significant estimator for the number of jobs in accommodation, food & beverage and wholesale sectors. While jobs in the accommodation sector show a linear relationship with MW generation, F&B and wholesale exhibit a non-linear relationship. In the case of the proportion of jobs in the F&B explained by tourists' consumption and in wholesale sector, only a quadratic term was included in the model showing a positive exponential relationship. By contrast, the proportion of jobs in the F&B sector explained by residents' consumption exhibits a U-shaped relationship. The elasticity between MW and jobs in the accommodation sector is 0.02. Using the average values for Tenerife, the elasticity for *JFBT* is 0.04, while the elasticity for *JFBRP* is 0.08. Finally, the wholesale sector's jobs show elasticity with MW equal to 0.05 for the average Tenerife municipality.

The type of municipality was also found to be relevant in the MW generation process. Indeed, only large tourist and rural municipalities show a higher MW generation than residential ones. In addition, there is no evidence that small tourist municipalities produce more MW than residential ones.

It is possible to convert these elasticities into marginal effects using the average values for all the municipalities in Tenerife. These marginal effects can be seen in Table 5. Column (1) indicates the marginal effects caused by an additional job, derived directly from the variable used in the model. Column (2) shows results in terms of tourists and residents in order to make comparisons possible with other studies found in the literature, which use tourist and resident numbers. The conversion from MW generated by jobs into MW generated by residents and tourists is possible using the ratio between: tourists and jobs for the accommodation sector,

[14] STATA software was used to run the model.

[15] Elasticity of RP, which is introduced as second degree polynomial, is obtained in the following way: $\beta_1 + 2 * \beta_2 * \mathrm{Ln(RP)}$, where β_1 is the coefficient of *ln*RP and β2 the coefficient of *ln*RP^2.

[16] The turning point is the minimum or maximum of a second-degree polynomial. It is directly obtained from the first derivation and equals zero. The variable RW is obtained from: exp (0.1618/(2 * −0.0141)) = 305. Note that the exponential is because the variable is in logarithmic form.

Table 4
Estimation results of regression model where the explained variable is the log of mixed waste. *Source:* Author prepared.

Variables	Coefficients
ln(RW)	0.1618**
ln(RW) ^{2}	−0.0141**
ln(INC)	0.4002***
ln(RP)	1.5875***
ln(RP) ^{2}	−0.0620**
ln(AA)	−0.6508*
ln(JA)	0.0239***
ln(JFBRP)	−0.3241**
ln(JFBRP)^2	0.0298**
ln(JFBT)^2	0.0039**
ln(JW) ^{2}	0.0039*
ln(JR)	0.0153
ln(JH)	0.0129
T	−0.0110***
Constant	−5.4931*
Mun_type	
Rural	0.2583***
Large tourist	0.5187***
Small tourist	0.0748
Urban	0.2531
R^2	**0.9826**
Wald chi^2	**2623.1**

Note: Three stars indicate statistical significance at the 1 percent level, two stars at the 5 percent level and one star at the 10 percent.

Table 5
Daily marginal effects of each variable for the average Tenerife municipality. *Source:* Author prepared.

Variable	Column (1)	Column (2)	Dimension
JA	1.53 (kg/job)	0.33 (kg/tour)	Tourism
JFBT	1.59 (kg/job)	0.07 (kg/tour)	Tourism
JFBRP	3.87 (kg/job)	0.10 (kg/res)	Residents
JW	3.95 (kg/job)	0.07 (kg/res)	Residents
JR	0.46 (kg/job)	0.02 (kg/res)	Residents
JH	0.72 (kg/job)	0.02 (kg/res)	Residents
RP	0.40 (kg/res)		Residents
INC	0.09 (kg/€1,000)		Residents
AA	−785.68 (kg/year)		Residents
RW	−1.67 (kg/Ton)		Common

Note: in column (1) the marginal effects of economic activities are calculated for an additional job, while in column (2) we use the ratio between tourists/jobs and residents/jobs in order to obtain the marginal effect for an additional tourist or resident.

tourists and the proportion of F&B jobs explained by tourists, and residents and jobs for the rest of economic activities considered.

Results in terms of marginal effects show that an additional tourist increases MW generation by 0.4 kg per day in the average Tenerife municipality, distributed between 0.33 kg in the accommodation sector and 0.07 kg in the F&B sector. By way of comparison, Abdulredha et al. (2018) found that a hotel in Kerbala during the major religious festival generated 0.89 kg of MSW per guest. Saito (2013) found that accommodation produced 5.9 kg of MSW per guest and restaurants generated 2 kg per guest on the largest island of Hawaii. The Rezidor Hotel Group (2014) reported that Park Inn hotels produced 2.87, 1.77 and 0.76 kg/guest of MSW per day in the United Kingdom, France and Germany, respectively.

In terms of jobs in main tourism activities, it is found that an additional job in accommodation causes an increase in MW generation of 1.53 kg/day and an additional job in F&B explained by tourists' consumption causes an increase in MW generation of 1.59 kg daily. Saito (2013) found -conducting a small survey- that the MSW generated in the accommodation sector was 2.4 kg per employee daily, while in F&B, the MSW generation per employee was 9.8 kg/day, considering that F&B sector is solely explained by tourists' consumption.

As can be seen, our results are significantly lower compared to previous results in the literature, since the net impact of tourists on MSW generation through tourism activities is estimated. In addition, our results refer to the average value for the whole island, which includes tourist and non-tourist municipalities and, more importantly, they reveal that the resident population is mainly responsible for employment levels in F&B sector and thus, its waste flows.

The contribution of the resident population to MW generation is attributable to consumption both in households and in economic activities. The MW produced in a household can be approximated using income and resident marginal effects. Therefore, an additional resident in the average Tenerife municipality with an average income of 6470€/year[17] causes an increase in MW generation of 0.98 kg per day in the municipality. The MW produced by economic activities (both tourism and non-tourism) as a result of an additional resident is 0.21 kg daily. This MW produced can be divided into 0.10 kg in F&B, 0.07 kg in wholesale and 0.02 kg for both retail and health sectors. Thus, the total contribution to MW generation attributable to an additional resident in the average Tenerife municipality is 1.19 kg per day, which almost triples that of the MW generated by an additional tourist on the island. This result is consistent with other authors in similar tourist regions. Estay-Ossandon and Mena-Nieto (2018) found that an additional resident generates 1.3 kg/day in the Balearic Islands and Mateu-Sbert et al. (2013) 1.48 kg/day in Menorca. Finally, Gidarakos et al. (2006) estimate a range between 0.8 and 1.2 kg/day per inhabitant in Crete according to population size of the municipality.

Total MW generated attributed to residents and to tourists in the average Tenerife municipality can be now computed using marginal effects.[18] Results show that residents within a household produce 79.7% of total MW collected, followed by MW production in the F&B (8%), in wholesale (5.9%), in retail (1.8%) and health sector (1.4%). The remaining 3.3% of mixed waste generated in the average municipality corresponds to main tourism activities - distributed in 2.7% in accommodation and 0.6% in the F&B sector.

If we followed only a supply-side approach, as Saito (2013), the global contribution of tourism activities to MW generated in the average municipality of Tenerife would be 11.3%, which is really close to the estimations in other tourist islands such as Hawaii (10.7%) and Menorca (12%) (Saito, 2013; Mateu-Sbert et al., 2013).

Finally, our results for the accommodation sector can be used to approximate the MW generated by type of establishment. To do this, the yearly ratios between jobs and beds and between jobs and overnight stays in hotels and apartments provided by the regional statistical office are used.[19] Table 6 summarizes the marginal effects of both accommodation establishments' related variables for the average Tenerife municipality. As expected, the type of establishment is determinant in MW generation. Indeed, an additional bed in a hotel increases MW generated by 0.28 kg daily, while an additional bed in an apartment produces less than half this amount of MW (0.12 kg/day). Regarding overnight stays, an increase by one unit causes an increase of 0.39 kg of MW generated per day in a hotel and 0.24 kg per day in an apartment. These results can be of particular importance, since very few municipalities in Tenerife dis-

[17] It is the average income per inhabitant on the island of Tenerife.

[18] Total MW is estimated by multiplying the marginal effect by the average values of each variable.

[19] See the ratios in Table F1 in Appendix F.

tinguish the type of accommodation establishment in their waste payment structures and if so, the fee set is only slightly differently.

4. Discussion and policiy implications

Economic instruments such as Pay-As-You-Throw (PAYT) for mixed waste may help to meet stringent MSW targets (Elia et al., 2015; Dahlén and Lagerkvist, 2010; Puig-Ventosa, 2008; Skumatz, 2008). However, there is a gap in the literature regarding the implementation of PAYT charges for the tourism sector. One possible reason is that waste meters are needed to identify the waste by producers in order to implement unit-price systems. Even though door-to-door collection is possible for bulky waste producers with waste storage, it is not sufficiently extended in residential and economic sectors in many regions (Puig-Ventosa, 2008). In any case, estimations of MSW amounts and proportions are needed to avoid cross-subsidies among waste producers, perceptions of unfair prices and budget imbalances in MSW services (Batllevell and Hanf, 2008; Le Bozec, 2008).

Currently, a few municipalities in Tenerife are considering switching from waste flat fees to PAYT (specifically a pay-per-bin) for mixed waste in order to increase recycling rates and promote waste prevention throughout the supply chains, especially from tourism activities such as accommodation and F&B. However, per-unit waste pricing may risk municipal budget balances, since no previous measures of the waste generated by residential, tourism and other sectors at the municipal level exist. Moreover, PAYT systems create high levels of uncertainty in municipal authorities regarding both operating costs once the incentives are in place and possible future revenues for MSW municipal services. For this reason, some authors propose a PAYT that combines an annual basic fee (mandatory) to finance fixed costs of municipal services and a variable cost for bins or waste bags to cover variable, social and environmental costs of mixed waste. According to previous experiences (Torrelles de Llobregat or Argentona, both in Catalonia), a two-part tariff scheme improves both recycling rates and waste prevention (Puig-Ventosa and Calaf-Forn, 2011; Puig-Ventosaa, 2002).

Previous estimations on waste contribution by sector or activity are used to determine the fixed part of the PAYT tariff. The annual basic fee for each waste producer covers mixed-waste management costs in the average municipality of Tenerife, assuming that street-bin collection and transport cost per ton of MW does not depend on the type of waste producer. This annual basic fee, which will reflect the implicit price per ton for each producer, is then compared to the current flat fee in the average municipality of Tenerife to find evidence of possible cross-subsidies among agents at the island level.

Currently, waste flat fees in Tenerife's municipalities discriminate waste producers by their nature.[20] However, fees have not historically been clearly referenced to the waste generated by each activity or to the collection and transport costs and have rarely been updated for increasing service costs.

The resulting basic fee for each economic sector is shown in Table 7. The average municipal cost of MSW management in 2015 was around €3.65 million[21], and it is distributed among producers proportionally to estimations of their contributions to mixed waste. The implicit unit price faced by each waste producer is the same and equal to 235.61€ per ton generated, where 39.90€ captures the island's landfill fee (17% of total cost) and 195.71€ covers the municipal waste collection costs (83%). It is important to note that although the analysis could only be done for residential, accommodation and F&B sector, their contribution to total mixed waste generated was calculated taking into account the contribution of all the sectors included in the estimates.[22]

Table 6
Marginal effects (kg/day) of MSW within accommodation sector by type of establishment in Tenerife. *Source:* Author prepared.

Variable	Hotel	Apartment	Total accommodation
Bed	0.28	0.12	0.22
Overnight	0.39	0.24	0.33

It can be also concluded from Table 7 that there may be possible cross-subsidies when comparing the current municipal flat fees and the basic annual fee.[23] Indeed, the contribution of the accommodation sector to municipal services is 148% higher than that proposed as the basic fee, possibly reflecting cross-subsidization of accommodation in favour of residential and F&B sectors. However, this may be explained by the fact that collection and transport costs are higher at hotel establishments, even though door-to-door services or single routes are an exception on the island.

Regarding the differences found in MW generated by accommodation type, our results support charging a higher annual basic fee for hotels, since their production of MW by bed and overnight stay is almost double that of apartments.

We do not enter into a discussion on the unit price for the variable, social or environmental costs such as landfill emissions. The experience in other municipalities in Spain shows a price per bag equal to 0.0382€/litre for mixed waste, 0.01€/litre for waste packaging from both residential and commercial and a range from 0.85€/litre up to 1.72€/litre for an extra bin for commercial organic waste (Puig-Ventosa and Calaf-Forn, 2011).

5. Conclusions

The main contribution of this paper is the adoption of a mixed demand-supply approach in order to estimate tourists' and residents' contributions to MSW generation produced by tourism and non-tourism activities. We used a municipal panel data for an island destination (Tenerife) using socio-demographic, employment levels and other economic factors. An auxiliary model was run to determine the proportion of tourism activities explained by tourists and residents, and to capture their mobility on the island. The application to an island destination offers an ideal scenario to study tourism's impacts, because islands exhibit the highest per capita waste indicators worldwide, and they have a more complete and homogeneous account of waste generation.

The estimates show that tourism activities in the average Tenerife municipality generate 0.4 kg of MW daily per tourist, divided into 0.33 kg for accommodation and 0.07 kg for the F&B sector, with about 6.4% of total MW produced in F&B directly related to tourists. In contrast, the contribution of an additional resident in the average Tenerife municipality to MW generation

[20] In general, municipal fees consider residential sector, accommodation, food and beverage and other economic activities depending on their business nature. For example, residential is taxed by household, sometimes depending on the location within the municipality; bars and restaurants and commercial establishments are taxed according to their size; and, finally, hotels, apartments and health care centres are generally taxed by the number of beds.

[21] Data available in Spanish Treasury portal: http://www.hacienda.gob.es/es-ES/Areas%20Tematicas/Administracion%20Electronica/OVEELL/Paginas/PublicacionPresupuestosEELL.aspx.

[22] Only conversion ratios between jobs and establishment was possible for F&B sector. Retail and wholesale sectors are charged by size of the establishment, but there is no information available. The same happens with health sector and its relationship with the number of beds.

[23] The current average flat fee is obtained from calculating the average price faced by each sector in the island of Tenerife using a weighted average of its price in each municipality by its share of the total in the island. For example, for the accommodation sector it was obtain as follows: $Average\ price_{accommodation} = \sum_{i=1}^{n} Price_i * \frac{Beds_i}{Totalbeds_{Tenerife}}$; i *denotes the municipality*.

Table 7
Minimum municipal fee to recover treatment costs. *Source:* Author prepared.

Variable	Accommodation	F&B	Households
MW generation	558.45 (kg/job/year)	1992.90* (kg/job/year)	357.7 (kg/res./year)
Conversion ratio	0.14 (jobs/bed)	3.08 (jobs/estab.)	2.65 (res./household)
MW generation (in units defined by municipal waste fee)	79.26 (kg/bed/year)	6138.13 (kg/estab./year)	947.91 (kg/household/year)
Fee to recover treatment costs	3.16 (€/bed/year)	244.91 (€/estab./year)	37.82 (€/household/year)
Fee to recover collection costs	18.48 (€/bed/year)	931.28 (€/estab./year)	200.65 (€/household/year)
Total municipal fee	21.64 (€/bed/year)	1176.19 (€/estab./year)	238.47 (€/household/year)
Observed average waste fee in Tenerife	53.72 (€/bed/year)	639.71 (€/estab./year)	85.44 (€/household/year)

*Note**: sum of JFBRP and JFBT.

is 1.19 kg daily. This amount is explained by the MW generated at household level and in both tourism and non-tourism activities. A substitution effect between recyclable waste and MW is also found, but in an inverted U-shaped relationship. The age effect was also tested, showing that older populations tend to generate a lower amount of MW. The type of municipality was also found to be relevant in the MW generation as rural and large tourist municipalities produce more MW than residential ones.

The total MW produced by sectors was calculated and altogether the accommodation and F&B sector linked to tourists' consumption are responsible for 3.3% of total MW collected, in the average municipality on Tenerife. If all the waste produced by main tourism activities was attributed to tourists, following only a supply-side approach, a contribution of 11.3% of MSW by tourists would be obtained.

Comparing our results with other studies following different approaches, we can conclude that: (1) tourism's waste contribution comes mainly from the hospitality industry – accommodation and F&B; (2) following a demand-side approach overestimates waste generated by tourism activities and unties waste production from waste management decisions of firms; (3) following a supply-side approach overestimates the contribution of tourism to MSW, since both tourists and residents consume tourism activities. Additionally, the municipal level of the analysis shows the importance of residents and tourists' mobility in the F&B sector, which can be of particular interest in tourist municipalities.

More precise estimates of waste producers' contribution to MSW generation is a necessary step to design economic incentives to promote recycling rates and prevent mixed waste. This analysis constitutes an initial effort to highlight the transversal nature of the tourism sector and, therefore, the difficulties to estimate its economic and environmental impacts. Finally, further research is needed to focus on tourist municipalities, as there is large variability in the panel data set, and on tourist expenditure in order to reflect better the tourists' consumption levels.

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.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.wasman.2019.11.023.

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