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A participatory waste policy reform for the hotel sector: evidence of a progressive Pay-As-You-Throw tariff

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Abstract

The hotel industry is increasingly developing voluntary measures to tackle waste generation, but they fall short of the problems faced by municipal waste services in many tourist destinations. This paper exemplifies how a collaboratively designed waste tariff reform for hotels in a tourism-intensive municipality can achieve a sustainable waste management system through stronger collective action, involving not only the hotel sector but also the city council and waste management companies. The co-created Pay-As-You-Throw tariff meets the demands of the stakeholders by establishing a progressive waste charge that penalizes hotels based on their waste generation intensity, defined as the ratio between waste flows and size. In addition, a competition system is introduced by imposing penalties (or rewards) according to whether the waste generation intensity is above (or below) the sector average during the settlement period, incentivizing waste prevention, recycling and encouraging long-term investment in sustainable waste management. The tariff is consistent with the principles of the EU's Circular Economy Package and offers hotels a competitive advantage, while ensuring a progressive waste charging system and waste management cost recovery. Empirical results of the co-created tariff show a reduction in waste generation intensity and signs of increased recycling rates.

Keywords: tourism, hotel, waste management, PAYT, sustainability, participatory approach

1. Introduction

Tourism has been shown to have a significant and increasing impact on waste generation in tourist destinations, particularly seasonal and/or island destinations (Ezeah et al., 2015). The rising pressure on destinations can be explained by the increased consumption of goods and services and the associated waste production as a result of tourism activities such as catering, accommodation and transportation (Gössling et al., 2012). The hotel sector is one of the largest generators of municipal waste through tourism activities, due to daily operations such as food and beverage service, room cleaning, and maintenance (Pirani & Arafat, 2014). Furthermore, waste produced by tourism, especially in the hotel sector, contributes to environmental degradation and overloads local waste management systems (WMS) (Arbulú et al., 2016).

The hotel industry is taking steps to reduce waste generation and improve waste management. According to Pirani and Arafat (2014), sorting and recycling are the most widely adopted waste management strategies in the hospitality sector. Other measures include compaction to reduce waste volume, the use of reusable items, the donation of old furniture, reduced use of office paper, bulk purchasing, and the elimination of single-use plastics (Pirani & Arafat, 2014). However, these measures are closely linked to the net operating income of each establishment and consist only of local environmental interventions and simple voluntary actions, mainly intended to improve resource efficiency, enhance reputation, increase value or address changes in demand (Graci & Dodds, 2008; Inoue & Lee, 2011; Khatter et al., 2021).

The lack of partnership development and the absence of effective local waste policies can damage the competitiveness of the local tourism industry, tarnishing the overall image and reputation of the destination (Koliotasi et al., 2023). To mitigate these effects, local governments and the tourism industry need to work together to implement effective waste management and reduction strategies (Martin-Rios et al., 2022), such as recycling programs, composting, and reduction of single-use plastics (Filimonau, 2021). A greater focus on waste prevention, particularly food waste, is needed, reflecting its position as the most favored option in the waste management hierarchy (Messner et al., 2020).

Policymakers play a critical role in designing effective waste management systems specifically for the hospitality industry, in particular the municipal authorities responsible for waste management services (Diaz-Farina et al., 2023). However, developing a sustainable waste management system (SWMS) requires a holistic strategy that integrates waste mitigation measures with extensive participation from all stakeholders to create synergies (Martin-Rios et al., 2022). The inclusion of stakeholders in the environmental policy process fosters greater comprehension of and support for the measures implemented, raising the probability of successful policy outcomes (Newig & Fritsch, 2009).

The increasing demand for SWMS collides with a lack of evidence on the development of successful policies. In this paper, we illustrate how an evidence-based and participatory process improves the design of economic instruments to ensure a SWMS in a tourist destination. In particular, we demonstrate the effectiveness of a novel Pay-As-You-Throw (PAYT) tariff for the hotel sector that incentivizes waste prevention and recycling (providing empirical evidence of 35% mixed waste reduction). A PAYT scheme is an economic tool that embraces the concept of the *polluter pays principle*, wherein individuals are billed according to the real volume of waste they generate. The co-created PAYT tariff had a high degree of acceptance due to the participation of all the agents involved in the WMS: the local policymaker, the hotel sector and the integrated waste management systems (IWMS). The process was led by our research team, which provided rigorous analysis to facilitate evidence-based policymaking.

The co-created PAYT tariff is aligned with the updated European waste framework (Directive (EU) 2018/851), of which the circular economy is an essential pillar. In fact, the European waste framework clearly establishes that Member States must transpose PAYT and landfill or incineration taxes into their national waste legislation to provide incentives according to the waste hierarchy.

This case study also contributes to the literature by providing an example of the design of a progressive waste charging policy (Bilitewski, 2008) and improving standard PAYT tariffs. In particular, the co-created PAYT tariff focuses not on the volume of waste generated but on the generation intensity, considering waste generated relative to establishment size or number of guests. This is compatible with the highly variable nature of hotel waste generation and ensures that the largest polluters (establishments with the most intensive waste-generating behavior) pay more. In addition, the tariff incorporates a system of penalties and rewards that are applied depending on whether the waste generation intensity (WGI) is above or below a reference value, incentivizing long-term investment in sustainable waste management. When the average WGI of the sector is used as a reference value, a dynamic competition system is introduced. In each settlement period, hotels risk being penalized if their WGI exceeds the sector average, and higher waste bills can ultimately affect their overall competitiveness.

The remainder of this paper is structured as follows. Section 2 presents the related literature on the impact of tourism and, more specifically, the hotel sector on waste generation and the literature on PAYT tariffs. Section 3 describes the methodology, focusing on the general context of waste policy reform and the specific participatory policy-making process carried out in our case study. Section 4 presents a summary and discussion of the results of the waste tariff reform. Section 5 presents the conclusions.

2. Literature review

The contribution of hotels to waste generation

Tourism presents a significant opportunity for the growth of many economies, particularly those of small areas like island territories (Cannonier & Burke, 2019; Fayissa et al., 2009; Schubert et al., 2011). However, the pressure that tourism places on the environment and local communities, including those of small islands, can become unsustainable (Wang et al., 2021). Waste production is one of the most obvious negative environmental impacts of the industry (Dolnicar et al., 2020), yet it remains one of the least studied (Arbulú et al., 2015). This is due in no small part to the lack of accountability for waste generation, which has no specific measurement system, unlike water and energy consumption (Diaz-Farina et al., 2023).

It is challenging to accurately determine the contribution of tourism services to municipal solid waste generation due to the way in which commercial waste is defined in most regulatory frameworks and local waste management networks, which typically treat waste generated by the *HoReCa* (Hotels, Restaurants and Catering) channel as household waste managed by local authorities (Diaz-Farina et al., 2020; Murava & Korobeinykova, 2016). The situation is further complicated by the limited availability of door-to-door waste collection services that could provide a more accurate picture of the tourism sector's waste generation if properly implemented (Arbulú et al., 2016).

The hotel sector is one of the areas of tourism activity with the highest generation of municipal waste (Diaz-Farina et al., 2020; Pirani & Arafat, 2014). Increasing pressure on the sector to remedy this situation has led to an understanding that long-term sustainability and growth are contingent on the adoption of suitable environmental practices (Cingoski & Petrevska, 2018; Erdogan & Baris, 2007; Mensah, 2014). However, the sustainability measures the hotel industry applies rely on corporate voluntarism and have failed to promote the wide adoption of sustainable waste management practices for a number of reasons (Chan, 2008). On the one hand, there is a lack of proper incentives for hotels to adopt sustainable waste management practices. Indeed, the voluntary actions implemented by the hotel sector are mainly intended to improve resource efficiency to save costs, and to enhance reputation, increase value or address changes in demand to raise revenues (Graci & Dodds, 2008; Inoue & Lee, 2011; Khatter et al., 2021). In addition, hotel firms often lack the knowledge and expertise to properly assess the sustainability of waste management practices. Hotels do not necessarily have access to the information needed to understand the environmental impact of their waste and to implement sustainable waste management practices effectively (Gössling et al., 2015). Ultimately, corporate voluntarism is more accessible to large hotel firms due to the scale of resources and knowledge needed to implement sustainable waste management, creating a gap between large and small-medium establishments (Radwan et al., 2012).

Instruments for a sustainable waste management system: relevance of PAYT tariffs

The existing culture of corporate voluntarism can be harnessed by policymakers to promote instruments that achieve collective action to reduce waste generation and the associated environmental impacts, thereby establishing a SWMS. To do so, it is essential to be able to identify the contribution of each economic activity to municipal waste generation, whether this information is obtained through audits, accounting records or estimates (Beigl et al., 2008).

The success of a SWMS depends on its capacity to promote behavioral change among waste producers implementing different policies, which can be categorized as regulatory, informational and economic (see Finnveden et al., 2013 for a detailed review of available waste policy instruments). The EU waste management framework focuses on economic instruments, which are intended to persuade waste producers to divert waste from landfill or incineration sites to material recovery and processing facilities, thus optimizing resource use while also contributing to the reduction of waste management costs (Oosterhuis et al., 2009).

The updated European framework acknowledges that economic instruments, such as PAYT tariffs and landfill and incineration taxes, are crucial in establishing an incentive scheme that ensures effective waste prevention and recycling. In applying the *polluter pays* principle, such instruments are consistent with the structure of co-responsibility models (Batllevell & Hanf, 2008). PAYT tariffs are an effective tool for internalizing the private and externality costs of waste management, as they reflect the marginal costs and therefore reveal the true relationship between the cost and the benefit of waste-generating activities (Choe & Fraser, 1998). Note, however, that in order to set PAYT tariffs, prior information is needed about the quantity and quality of waste generated by producers (Bilitewski, 2008; Elia et al., 2015; Karagiannidis et al., 2008; Puig-Ventosa, 2008; Reichenbach, 2008; Sakai et al., 2008; Skumatz, 2008), to prevent municipal budget imbalances and, more importantly, cross-subsidies among the residential, tourism and other economic sectors (Arbulú et al., 2016).

Furthermore, PAYT tariffs modify the behavior of waste producers by changing the cost-benefit ratio and therefore optimize decision-making when intrinsic motivation proves ineffective (Baumol et al., 1988; Heller & Vatn, 2017). PAYT tariffs have been shown to produce economic, environmental and social benefits (Elia et al., 2015; Slavík et al., 2020; Slavik & Pavel, 2013), to reduce the unfairness of an equal cost for all (Batllevell & Hanf, 2008; Bilitewski, 2008), and to have positive impacts on municipal budget balances (Slavík et al., 2020). In this sense, PAYT tariffs can be considered a cost-effective means of preventing waste and diverting disposal (Van Beukering et al., 2009).

However, PAYT systems also have some disadvantages. A review of PAYT systems applied to households in Europe (European Commission, 2003) reports the main strengths and weaknesses, which are summarized in Table 1. For example, the implementation of PAYT requires significant investment and has high operational costs, which may account for its low level of penetration worldwide.

Table 1. Pros and cons of a PAYT system applied in households in Europe.

Pros	Cons
• Good acceptance by householders • Fair allocation of costs to users • Reduction of waste in bins and bags (15–90% reduction reported) • Guaranteed transparency of waste management costs • Increased sorting of recyclables • Incentivization of home composting	• Increased costs (investment and operational) • Incentivization of *waste tourism* (i.e., waste moved to neighboring areas) • Incentivization of illegal waste dumping • Increased amounts of contaminants in recyclables

Source: adaption from Dahlén and Lagerkvist (2010).

Despite some disadvantages, PAYT programs are highly flexible and have been implemented in a variety of ways, all of them designed around the basic principle that generating less waste for collection should cost less (Skumatz, 2008). There are different mechanisms for establishing a PAYT tariff. According to Alzamora and Barros (2020), PAYT systems charge either by volume (bags/stickers and bins) or weight. The volume-based system is more common, but the weight-based system is more precise and more sensitive to variation in waste generation; however, it requires a specially equipped truck and the collection and transfer of data (Alzamora & Barros, 2020). It is worth noting that many towns and cities around the world have adopted *payment by generation* systems, particularly in the United States (more than 7,100), but also in Canada, China, Japan, Korea, Italy, Germany, the Netherlands, Belgium, and many Central European countries. In Spain, PAYT tariffs are very rare, with only eight municipalities applying them in 2017 (Puig-Ventosa & Sastre Sanz, 2017).

Pay-As-You-Throw tariff in tourism firms

The literature reviewed shows that most previous experiences with PAYT tariffs have been applied to households, with few studies reporting their application to tourism firms. We found only three papers analyzing the willingness of tourism firms to accept a PAYT, in which the tariff was described as an instrument that would contribute to cost recovery in the waste management system (Manomaivibool, 2015), reduce the waste generated by hotels (Radwan et al., 2010) and restaurants and canteens (Rodrigues et al., 2015), and achieve high acceptance among small and medium hotels (Radwan et al., 2010).

More closely related to our analysis, although lacking empirical evidence, is the work of Alves et al. (2020). These authors proposed a theoretical PAYT tariff for the hotel sector on the Portuguese island of Funchal. The tariff includes a fixed component related directly to the infrastructure and a variable component that charges according to the rate of recyclable waste separation, within a range of €82–160 per ton of undifferentiated (non-recyclable) waste. The higher the rate of separation, the lower the cost per ton. This theoretical exercise highlights the need to redesign hotel sector tariffs, not only to ensure cost recovery in the waste management service but also to incentivize greater recycling separation. However, the design of Alves et al. (2020) focuses on the management of waste once it has been generated, leading to a behavioral change in how waste is separated rather than promoting waste prevention.

The literature lacks any discussion of a specific PAYT tariff for the hotel sector that is well accepted, prioritizes waste prevention, recovers management costs and can include other costs (externalities or costs derived from information or awareness-raising policies), and that provides for progressive payment according to the amount of waste generated. Our objective here, therefore, is to present a PAYT tariff that closes this gap in the literature.

3 Participatory waste tariff reform for the hotel sector: case study of Puerto de la Cruz (Spain)

In this section, we describe each step in the implementation of a participatory waste tariff reform for the hotel sector in Puerto de la Cruz, located in a European popular tourist region, the Canary Islands. We first describe the main features of our case study destination, Puerto de la Cruz. Next, we describe the co-design, implementation and evaluation of the new waste tariff following the five stages in public policy design (Tamayo Sáez, 1997).

Our contributions as researchers were to carry out a preliminary diagnosis of the waste management problem, to design and analyze the alternative policy proposals, and to evaluate the effectiveness of the tariff following its implementation. More broadly, our role was to demonstrate to all stakeholders the importance of collaboration and partnership development in successfully implementing a SWMS.

3.1 The context: the transition of Puerto de la Cruz to become a sustainable destination

Puerto de la Cruz is a mature tourist destination located on the north coast of the island of Tenerife in the Canary Islands (Spain), where tourists have typically accounted for more than 50% of the total population over the last decade (ISTAC, 2020). In 2019, the year before the COVID-19 pandemic, the destination received 806,433 tourists, representing a total of 5,492,551 overnight stays. This equates to an average daily tourist pressure of 15,050 people, while the resident population was 30,468 for the same year. Puerto de la Cruz closed 2022 with a total of 4,352,393 overnight stays, 20.8% less than in 2019.

Puerto de la Cruz experienced a sharp decline in demand from the late 1990s but, following the severe Spanish economic crisis of 2008–2013, a rejuvenation plan was initiated with the creation of the Consortium for the Rehabilitation of Puerto de la Cruz

(Rodríguez González, 2015). This process has enabled the destination to benefit from considerable funding and to develop a large number of programs to improve municipal management, branding and promotion, securing significant public and private investment in tourism infrastructure (Simancas Cruz & Hernández Martín, 2015).

Puerto de la Cruz city council is committed to sustainable tourism development and has launched several plans to reduce the environmental impacts of tourism firms as well as residents. The need for this is clear: waste indicators in Puerto de la Cruz reveal poor waste management, with 749 kg of mixed waste generated per capita in 2016 (Cabildo Insular de Tenerife, 2020; Instituto Nacional de Estadística (INE), 2018b), far exceeding the corresponding values for the Canary Islands (512 kg) and Spain as a whole (382 kg) (INE, 2018a). In the case of recyclable and sorted waste, in 2016 only 7.9% of total municipal solid waste in Puerto de la Cruz was sorted, below the national average (11%) but slightly better than the regional average (7%) (Ecoembes, 2017; Ecovidrio, 2017). The comparatively poor sorting rate of recyclables reflects the barriers that have been systematically encountered by municipal waste services in the Canary Islands, denoting a lack of interest by IWMS for recyclable material due to the high reverse logistics costs given the distance from Peninsular Spain (Diaz-Farina, et al., 2020). Indeed, hotels are excluded from the agreement between Puerto de la Cruz city council and Ecoembes (a non-profit collective management system for packaging waste in Spain) for the collection of packaging waste for two main reasons: i) the municipality does not want to assume the additional cost of this waste stream when the municipal waste service is running at a deficit; ii) Ecoembes does not want to handle packaging waste from hotels, claiming that this waste stream does not contribute to the Green Dot system. As result, the hotel sector, in general, does not sort packaging waste and pays for the paper and cardboard waste stream through a voluntary initiative.

One of the plans designed by the city council as part of the wider effort to improve waste management was Puerto de la Cruz 70/20, launched in 2017 with the aim of achieving 70% of sorted recyclable waste by 2020. Prior to the introduction of this plan, in 2016, the city council commissioned an audit to analyze the contribution of the hotel sector to municipal waste generation and to assess internal waste management in hotel establishments. It was concluded that the hotel sector is responsible for a deficit in the municipal waste management service and that the vast majority of establishments do not implement any kind of policy on waste minimization or separation for subsequent recycling (Diaz-Farina et al., 2023). In addition, it was found that many hotels use bins for mixed waste or recyclables that are intended for households on the same street, which could lead to the disposal of hazardous waste for which an authorized waste manager should be contracted. In light of these findings, the city council prioritized the involvement of the hotel sector in the Plan 70/20, introducing a waste tariff reform to promote waste prevention and recycling and to correct the deficit of the municipal waste service.

The waste tariff reform proposed by Puerto de la Cruz city council offered two alternatives, depending on the availability of waste storage inside hotels. The first, *Tariff A*, consisted of a 300% increase in the flat fee, that is, a yearly *price per bed* of €55.60 compared to the initial price of €13.90. The second, *Tariff B*, consisted of a PAYT tariff based on a charge of €4.90 for each collected bin of mixed waste and €3 for each bin of packaging. The collection of paper and cardboard and glass was to be exempt from payment thanks to specific agreements for these fractions between the city council and the municipality's subcontracted waste managers. Only hotels with waste storage – essential to be able to offer a door-to-door collection service – could choose *Tariff B.*

The hotel sector largely rejected the new tariffs proposed by the city council. In the case of *Tariff A*, the 300% increase was considered to be disproportionate. With regard to *Tariff B*, the PAYT tariff, the sector did not understand why a charge was levied for packaging bins if the objective was to encourage recycling and questioned why the tariff did not take into account the heterogeneity of waste generation between establishments in the sector. The regional hotel association (ASHOTEL) contacted the university sector to obtain an impartial assessment, drawing on its expertise in municipal waste management in tourist destinations. The city council agreed that the waste tariff reform for the hotel sector would be university-led, in an effort to ensure the sustainability of municipal waste management.

3.2 The participatory process of the waste tariff reform

The methodology of this case study is based on the stages of the public policy life cycle. Tamayo Sáez (1997) explains that every public policy has a life cycle composed of five stages: i) identification and definition of the problem; ii) development of proposals for its resolution; iii) choice of a proposal; iv) implementation; and v) evaluation of the policy. This section is therefore structured in five subsections, each of which contains a description of the method, the data used and the outcome.

3.2.1 Redefining the waste management problem

Using data provided by the municipal waste collection contractor (Valoriza) for twelve weeks in 2018 encompassing Easter, we were able to calculate the contribution of the hotel sector to the total generation of mixed waste in the municipality. The data correspond to the collection of mixed waste bins from 60 accommodation establishments in Puerto de la Cruz, consisting of 42 hotels and 18 apartment complexes. From the figures provided, it is estimated that the hotel sector is responsible for 40% of the total mixed waste generated in the destination. However, as the sample period is short, we have calculated the contribution of the accommodation sector to total mixed waste generation for the period 2006–2015 using the estimate of 0.33 kg/day of mixed waste per tourist in the hotel sector in Tenerife obtained by Diaz-Farina et al. (2020). According to this calculation, the contribution of the accommodation sector to total mixed waste generation in Puerto de la Cruz is around 22%.

By comparing the sector's contribution to mixed waste generation with its contribution to municipal revenues through the payment of waste tariffs (data provided by the city council), we can estimate the deficit generated by hotel sector. From 2011 onwards, the deficit became accentuated, reaching a difference of 14 percentage points between the sector's contribution to municipal waste generation and revenues generated from the sector through the flat waste collection fee, as shown in Figure 1. This deficit is explained by several factors. First, Puerto de la Cruz has the lowest waste tariffs for hotels of any tourist municipality in Tenerife, with a range of €11.80−13.10 per bed per year, depending on the category of establishment. This contrasts sharply with the range of €30−73 (depending on the number of days of services and the location) in other tourist destinations on the island, such as Adeje and Arona (Padron-Fumero et al., 2017). Second, the municipality of Puerto de la Cruz does not pass on to hotels the increase in the municipal waste disposal fee per ton charged by the island government. Third, the increase in the deficit since 2012 was exacerbated by the failure of some hotels to pay the waste tariff while the sector's contribution to total mixed waste generation was increasing.

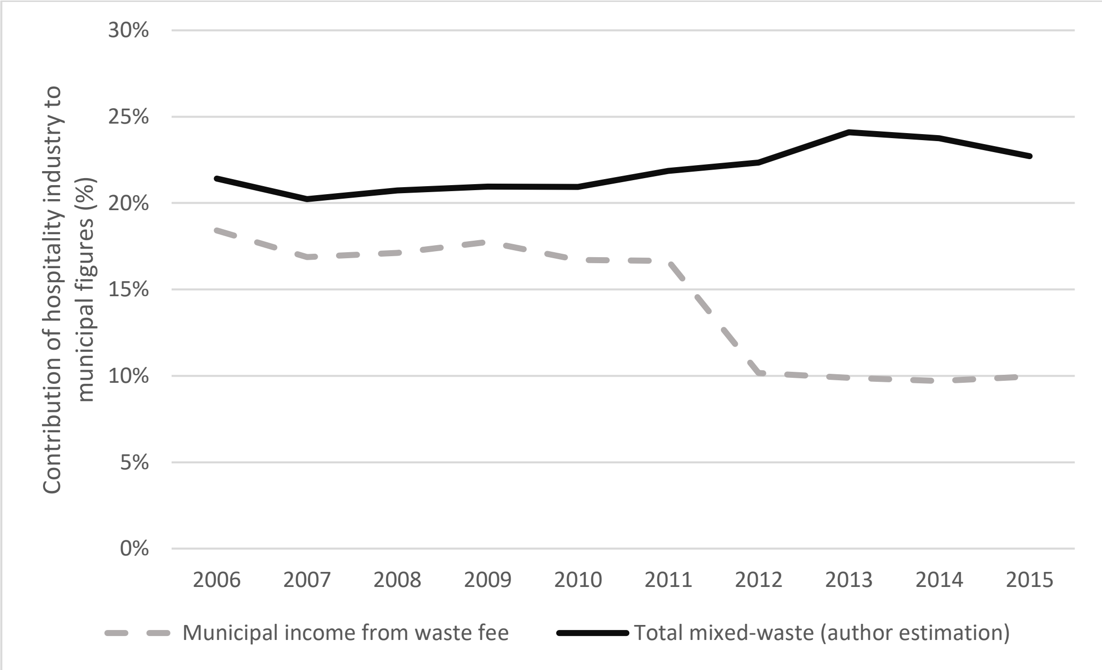

Figure 1. Contribution of the hotel industry in Puerto de la Cruz to total mixed waste generation and municipal income from the flat waste collection fee in the period 2006–2015 (%). Source: Diaz-Farina et al. (2023).

Once the problem has been re-defined, it is important to understand the characteristics of the entities to which the public policy will apply. This ensures that the policy is adapted as closely as possible to the reality of the sector and increases the likelihood of effective implementation. This was one of the demands expressed by the hotel sector of Puerto de la Cruz after the analysis of the tariff reform proposed by the city council: that the sector's wide heterogeneity should be considered. Scientific evidence shows that the main causes of heterogeneity among hotel companies in terms of waste generation are establishment size and the food services offered (Abdulredha et al., 2018; Álvarez Gil et al., 2001; Filimonau & Tochukwu, 2020; Pirani & Arafat, 2014; Radwan et al., 2010).

A database was created to analyze the heterogeneity of the hotel sector. The database is a cross-section of 60 establishments (42 hotels and 18 apartment buildings) observed from March to May 2018 but using period-average data. The representativeness is around 74% of the hotels and 72% of the apartment buildings in the destination, according to data obtained from the regional statistics office ISTAC. In terms of beds, the representativeness rises to 92% for hotels and 80% for apartment buildings, according to the same source. To create our database, the following data were obtained directly from the sector: the number of beds (*Bed*) for each establishment and the availability (or otherwise) of waste storage (*WS*) inside the establishment. By combining this information with data for the number of bins of mixed waste collected, provided by the waste collection carrier – named *full equivalent bins* (*FEB*), since the data gathered describe the number of bins collected and the approximate percentage of filling (50%, 75%, 100% and 120%) – it was possible to create an indicator to capture the heterogeneity between establishments. This indicator is the *waste generation intensity per 100 beds* (*WGIB*), which measures the number of bins of mixed waste generated relative to the number of beds available in the hotel. The main descriptive statistics of this database are provided in Table 2.

Table 2. Descriptive statistics of variables used for the design of the PAYT tariff. Average weekly data from March to May 2018.

Variable	Label	Obs.	Mean	S.D.	Min	Max
FEB	Full Equivalent Bins	60	5.07	3.11	1	16.5
Bed	Beds	60	331.37	196.24	28	930
WS	Waste Storage	60	0.72	0.45	0	1
WGIB	Waste Generation Intensity per 100 beds	60	2.00	1.98	0.45	14.3

Source: Author prepared.

Figure 2 shows *WGIB* as a function of establishment size, revealing the negative correlation between the two variables: larger establishments tend to show lower mixed waste generation intensity. This suggests that large firms may be implementing more voluntary environmental actions, supporting the findings of Radwan et al. (2012). Therefore, WGI should be considered in the design of the waste tariff, to avoid penalizing larger establishments simply on the grounds of size, even if they implement measures to reduce their waste generation. Moreover, since most establishments without waste storage facilities have a WGI over the sector average, provision should be made to penalize them in the waste tariff reform.

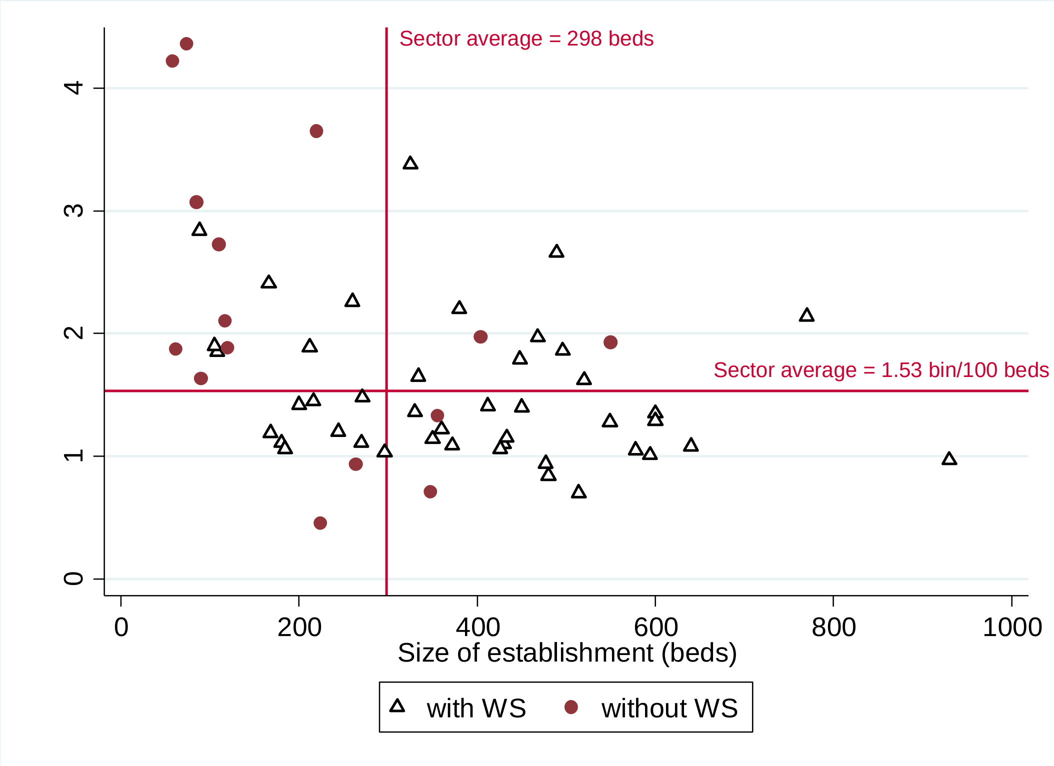

Figure 2. Mixed waste generation intensity by number of beds in the hotel industry in Puerto de la Cruz, 2018.

Source: Author prepared.

3.2.2 Co-design of policy proposal

A PAYT tariff with two parts was designed on the basis of an in-depth analysis of the alternatives proposed by the city council of Puerto de la Cruz and a detailed review of PAYT tariff applications worldwide, as covered in the literature. The PAYT tariff was co-designed considering the heterogeneity of the hotel sector and the objectives of the city council: to correct the deficit in the municipal waste service attributable to the hotel sector and to encourage the sector to reduce mixed waste and increase recycling rates, with the ultimate goal of improving the image and the sustainability of the destination.

The co-designed *Tariff C* is a two-part PAYT tariff based on a pay-per-bin mechanism (volume-based system) applicable to establishments with internal waste storage, which is essential for door-to-door waste collection services. Establishments without storage facilities will be charged *Tariff A* (a yearly fixed tariff equal to €55.60 per bed for the initial waste collection service), with the same waste collection system, street bin collection from Monday to Saturday. This is a means to penalize the higher WGI of hotels without storage, shown in Figure 2, and establishes the first incentive: establishments will try to avoid the 300% increase in the fixed tariff by building waste storage facilities, which should prevent further use of street bins for households.

Tariff C only charges for mixed waste, leaving recyclable waste free of charge. In order to secure this exemption, it was necessary to negotiate with Ecoembes, since most packaging waste from hotels does not contribute to the Green Dot scheme for, which 87% of the management cost of this waste is financed (see Rubio et al. (2019) for more details on how extended producer responsibility applies to packaging waste in Spain). However, a solid waste characterization carried out for Ecoembes by Eurocontrol S.A. revealed that 71% of hotel packaging waste contributed to the scheme and that this fraction should not be overcharged. In addition, reducing recycling costs further incentivizes recycling in hotels (Radwan et al., 2010, 2012).

The co-created PAYT tariff may allow the internalization of total costs (*TC*): *private costs* of the waste collection and disposal services, including PAYT implementation costs (administrative, technical and infrastructure), and the *externalities* associated with waste generation. However, in order to meet the demands of the city council, our PAYT tariff only considers private cost recovery. Thus, the municipal revenues are equal to the sum of the payments of all accommodation establishments in the municipality, ensuring total cost recovery. For simplicity, we will consider here that *TC* is a given value with the following form:

$$TC_t = \sum_{i=1}^{n} PAYT_{it}^{*} = \sum_{i=1}^{n}\sum_{s=1}^{S} PAYT_{is}^{*} \qquad (2)$$

where i is the establishment, t is the year and s is the settlement period. Thus, the annual payment for each establishment is equal to the sum of the payments in each settlement period (s). The TC is the result of the decisions made when implementing the municipal waste management service, such as weekly collection service frequency, among other variables pertaining to private costs. The proposed tariff could include externality costs in addition to private costs, which would ensure the financial sustainability of the service provider and the internalization of external costs, reaching a socially optimal solution.

To further develop the term *PAYT* introduced in (2), formula (3) shows a two-part PAYT tariff, with a fixed and a variable component. It contains two instruments, to ensure cost recovery and to incentivize waste prevention and recycling, respectively: *price per bed* and *price per bin* of mixed waste generated.

$$TC_t = \sum_{i=1}^{n} \left(\underbrace{\sum_{s=1}^{S} \frac{P_{Bed_t} * Bed_{it-1}}{S}}_{fixed\ part} + \underbrace{\sum_{s=1}^{S} \left(P_{Bin_t} * \left[\underbrace{(WGIB_{is} - \overline{WGIB_s})}_{heterogeneity} * Bed_{it-1} \right] \right)}_{variable\ part} \right) \quad (3)$$

The fixed part is strictly a collection mechanism that generates a stable source of revenue for the municipality to avoid the characteristic decapitalization of a unit-based pricing system, following Bilitewski (2008). The instrument for this part is the *price per bed*, which emulates flat tariffs. In the co-designed PAYT tariff, *price per bed* is applied to the total number of beds in the establishment for the previous year, as this is the number observed at the beginning of each period.

The variable part of the tariff contains the incentive mechanism for waste prevention and recycling (Yaobo et al., 2017) and also generates revenues, although to a lesser extent than the fixed part. The instrument considers the difference between the WGIB of establishment i and a reference value. This difference is multiplied by the number of beds in order to obtain the number of mixed waste bins generated or avoided relative to the reference value. If the value for establishment i is above the reference (the difference is positive), it will be charged for each excess bin generated; if the value is below the reference, the establishment will be rewarded for each bin avoided. This mechanism improves on classic unit-based pricing as it focuses on waste-generating behavior in relation to a reference value, rather than on the total volume of mixed waste generated. It is therefore possible to introduce a progressive waste charging policy (Bilitewski, 2008) under which larger polluters receive higher penalties but large establishments are not penalized simply for their size.

The higher the *price per bin*, the greater the reward or penalty, as applicable, and the greater the incentive for mixed waste prevention. However, the effectiveness of *price per bin* will depend on the distribution of WGI with respect to the reference value. In the unlikely event that all hotels had the same WGI, the effect of *price per bin* would be nullified. In fact, in the long term, a convergence on the reference value will occur due to the inertia of the incentive scheme. Note that this is a dynamic PAYT in which hotels will be charged according to their waste performance in each settlement period.

It is important to remember that the policymaker can define alternative benchmark values: either static or dynamic. Static benchmarks may be an *environmental target* or a *sectoral reference value* (for example, those extracted from Sectoral Reference Documents within EMAS). This decision is crucial as it can lead to three possible scenarios:

i) Total expenditure on rewards is equal to total income from penalties.

ii) Total expenditure on rewards is lower than total income from penalties.

iii) Total expenditure on rewards is higher than total income from penalties.

Setting a very strict reference value will result in many establishments having a higher WGI than the reference, leading to *scenario ii)*, in which additional revenues are generated that will help cover total costs and therefore allow a relaxation of the *price per bed* in the fixed part. If the reference value is very lax, the opposite will occur, leading to *scenario iii)*, in which the system of penalties and rewards entails a cost and the policymaker will have to raise the *price per bed* to cover total costs.

If a dynamic reference value is set, such the *average waste generation intensity* of the destination, a competition system among hotels is created. The two-part tariff co-designed for the hotel sector in Puerto de la Cruz, shown in (3), considers this reference value in order to satisfy the sector's request that the wide heterogeneity in waste generation should be considered. The reference value is therefore adapted to the reality of the sector and the destination. This competition system bolsters the incentive for waste prevention and recycling: in each period, the threat of penalization under the new tariff will lower the average WGI in the destination. Further incentive is provided by the potential to gain a competitive advantage, since if an establishment records a value below the average, its costs under the new tariff will be lower than those of competitors with values over the average. The competition system also helps to combat two of the main disadvantages of the PAYT tariffs stated in Table 1: since the co-designed PAYT tariff charges waste-generating behavior in comparative terms between hotels, the hotels themselves are likely to monitor whether other establishments in the sector are carrying out *waste tourism* or illegal dumping.

If a dynamic benchmark is used, any of the three above scenarios can occur, depending on the heterogeneity of WGI between establishments. However, deviations from the reference value will in theory be smaller, since the incentive scheme should generate a convergence towards the average by all establishments in the destination. As such, *scenario i)*, in which total rewards are equal to total penalties, occurs only in very specific circumstances, which are described in Appendix A. This scenario will also arise in the long term, since the competition system reduces the sector's average WGI for each period due to the inertia of the incentive scheme. Thus, in the long term, all establishments will have a WGI very close to the sector average ($\lim_{it \to \infty} WGIB_{it} - \overline{WGIB_t} \approx 0$), so the *price per bin* will not have an effect ($P_{Bin} \approx 0$). Indeed, the tendency will be to generate "zero waste", reducing waste management costs. To avoid the application of a surplus tariff in the long term, the price per available bed can be relaxed as the total private costs decrease. However, in the short and medium term, *scenarios ii) or iii)* are more likely to occur. Depending on the situation after the initial prices have been set, the list of possible decisions the policymaker can make with regard to the two available tools, *price per bed* and *price per bin*, and the impact on cost recovery and waste prevention incentives can be seen in Table A.4 (Appendix A).

The policymaker also has to set the tariff settlement period (s). It may set more than one period within the calendar year; for example, s takes a value of 4 if the settlement period is quarterly. This decision is crucial for waste prevention incentives as the settlement period is the length of the 'game' in which accommodation establishments are competing to avoid a penalty or obtain a reward; its also serves to define the frequency of feedback. The settlement period can also be understood as the period in which firms optimize their waste management sorting and generation in order to compete with other firms, as they try to generate a volume of waste below the sector average or the environmental target.

3.2.3 Selecting the best evidence-based proposal

At this stage in the public policy development process, we conduct a comparative analysis of the two proposals made by the city council and the co-designed PAYT tariff, *Tariff C*. The objective of this stage is to provide the expected outcomes for each alternative tariff. We carry out an *ex-ante* evaluation using simulations with real data. The analysis follows two criteria: I, the recovery of municipal waste management costs for the service provided to the hotel establishments; II, the inclusion of economic incentives for waste prevention and to increase recycling rates.

It is important to note that the comparative analysis contains the PAYT tariff that was finally approved, *Tariff C'*. This is a derivative of *Tariff C* and is described in detail in the following subsection.

The simulations were carried out with the *price per bin* and *per available bed* for each tariff proposal shown in Table 3. For simplicity, we assume that the waste generation is constant for each establishment throughout the year and the settlement period is annual (s=1) for the PAYT tariff. Therefore, the impact of behavioral changes such as waste prevention is not considered. As a result, firms compete in a static game, which does not entirely resemble the dynamic game imposed by the co-designed tariff. Importantly, the data reveal that the tourist destination is in *scenario iii*, where the total rewards are greater than the total penalties, implying an additional cost.

Table 3. Price per bin and available bed, and revenues from establishments with and without waste storage, in euros, for the different waste tariff proposals.

Tariff	Tariff type	Price per bin	Price per available bed	Revenue from est. with waste storage	Revenue from est. without waste storage	Total revenue
Baseline	Flat	-	13.90	232,449.70	43,868.40	**276,318.10**
A	Flat	-	55.60	929,798.80	175,473.60	**1,105,272.40**
B	PAYT	4.90	-	368,061.43	175,473.60	**543,535.03**
C	two-part PAYT + penalty/reward	±7.28	23.60	368,061.43	175,473.60	**543,535.03**
C’	two-part PAYT + penalty	4.90	13.90	247,939.25	175,473.60	**423,412.85**

Source: Author prepared.

With regard to the cost recovery ability (criterion I) of each tariff proposal, we consider that the city council’s calculations for *Tariff A* are overestimated since we estimate that the municipal deficit attributable to the accommodation sector is around 14% and the increase in total revenue is 300% over the baseline. The city council made its own estimation of the cost of providing the service to the hotel sector as it is impossible to disaggregate the cost for this sector from that of the other waste producers covered by the municipal waste services. Furthermore, the revenue from the city council’s other proposal, *Tariff B*, is some distance from the supposed total cost of the service with *Tariff A*. Indeed, total revenue with *Tariff B* is 96% over the baseline. In any case, we assume that the revenue generated under *Tariff B* is that desired by the city council and, therefore, the expected revenue.

We set a price combination of ±€7.28 per *excess* or *deficit* mixed waste bin relative to the sector average and a *price per bed* of €23.60 per year to guarantee the expected revenue with *Tariff C*. In the case of the final PAYT tariff implemented, *Tariff C'*, and due to the restriction imposed by the city council to omit the reward component of the tariff, the revenue is 53% over the baseline, with a *price per bed* equal to the baseline (€13.90) and a *price per bin* above the sector average of €4.90 (the price proposed by the city council in *Tariff B*).

The incentives for mixed waste prevention (criterion II) in each of the proposals can be analyzed through the average cost per bin for establishments relative to mixed waste generation intensity, as in Bilitewski (2008). The average cost per bin is constant only for *Tariff B*, as shown in Figure 3, since this PAYT tariff only considers *price per bin* as a unit-based pricing. Therefore, *Tariff B* can be said to generate incentives, since it alters the cost-benefit ratio of waste generation (Baumol et al., 1988; Heller & Vatn, 2017), but these incentives are constant, independently of the level of WGI. This linear waste charging policy treats every waste producer and all excess waste generation in the same way, rather than penalizing larger polluters, as pointed out by Bilitewski (2008).

Tariff A and the *baseline* tariffs generate disincentives, i.e., the average cost decreases as WGI increases. This degressive waste charging policy is therefore more advantageous for larger waste producers (Bilitewski, 2008). The tariff that most strongly incentivizes waste prevention is *Tariff C*, as it introduces an average cost that increases with the level of WGI and penalizes excess waste generation more harshly as it is based on a progressive waste charging policy (Bilitewski, 2008). However, *Tariff C'* only incentivizes waste prevention for establishments with a WGI above the sector average, while those establishments below the reference value are disincentivized.

In summary, the best alternative in terms of compliance with the two criteria is *Tariff C*, since it covers the estimated private costs of the municipal waste service to hotels and generates strong incentives for waste prevention and recycling for all establishments, since it guarantees an increasing average cost per bin with the WGI. The second-best alternative is *Tariff C'*, which covers 78% of private costs and generates incentives at least for establishments that generate large amounts of waste (above the sector average). *Tariff B* fails to satisfy criterion II, since it does not generate strong incentives for waste reduction and does not penalize the largest polluters more harshly, while *Tariff A* generates perverse incentives.

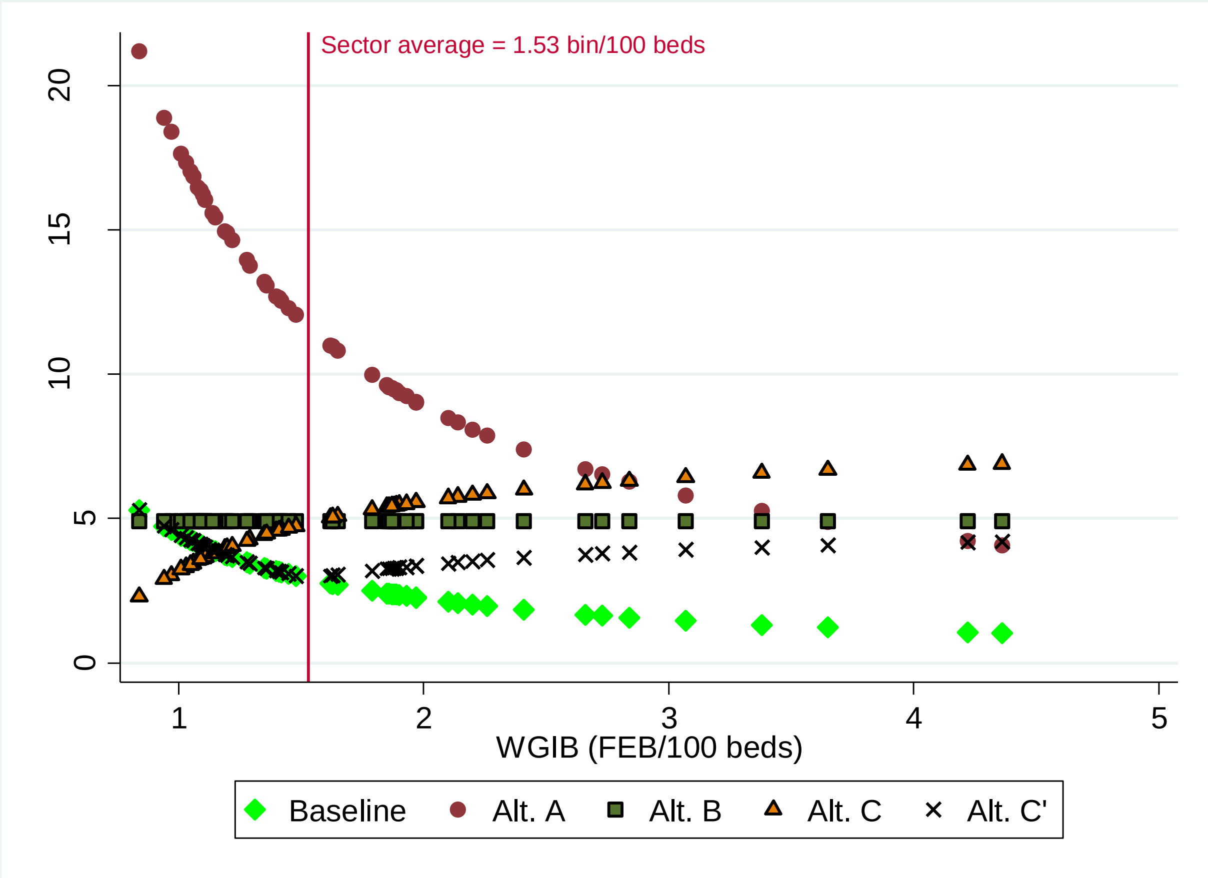

Figure 3. Average cost per bin according to mixed waste intensity under baseline waste fee and proposals for establishments with waste storage.

Source: Author prepared.

3.2.4 Implementation of the co-created PAYT tariff

The second-best option, *Tariff C'*, was adopted by the city council after demanding the omission of rewards for hotels with lower waste-generating behavior based on the simplicity of the revenue collection system. This means that establishments with a WGI below the sector average will only pay the fixed part of the PAYT tariff, as a kind of flat fee.

The total annual payment for each establishment with *Tariff C'* is calculated as follows:

$$PAYT_{it} = \frac{P_{Bed_t} * Bed_{it-1}}{S} + \begin{cases} \left(P_{Bin_t} * \sum_{s=1}^{S} (WGIB_{is} - \overline{WGIB_s}) * Bed_{it-1} \right) & if\ WGIB_{is} - \overline{WGIB_s} > 0 \\ 0 & if\ WGIB_{is} - \overline{WGIB_s} \leq 0 \end{cases} \quad (4)$$

Tariff C' was approved at the plenary session of the Puerto de la Cruz city council on 11 January 2019 and published in the Official Gazette of the Province of Santa Cruz de Tenerife on 21 January 2019, to come into effect on 1 April 2019.

3.2.5 Evaluation of the PAYT tariff implemented

This section only evaluates the effect of the PAYT tariff on mixed waste generation intensity since we do not have recycling data with which to estimate the possible deviation effect. Moreover, the impact on private cost recovery cannot be assessed because the tariff was revoked by the incoming government only a few months after it had come into effect. As a result, establishments never paid for the service under the PAYT tariff. However, during that period, hotels behaved in accordance with the PAYT tariff in force.

A second database was created for this evaluation. It is a balanced panel data with 18 establishments observed for 12 weeks, between March and May 2019. This period ensured that there were enough observations before (4) and after (8) the implementation of the PAYT tariff, which took effect on 1 April 2019. We also included the same period of the previous year as a control, yielding a total of 432 observations. The variables of this database and their descriptive statistics are shown in Table 4.

The mixed waste generation variable (*FEB*) and the number of beds (*Bed*) were constructed as in the first database. We estimated the overnight stays (*Ov*) for each establishment by multiplying the number of beds and the occupation rate by bed (*ORB*). These data were provided by ISTAC for the four micro-destinations in Puerto de la Cruz, differentiating the type of establishment (hotel or apartment) and the category. It was therefore assumed that within the same micro-destination, establishments of the same type and category have the same occupancy rate. Finally, as for the first database, we used an indicator to capture the heterogeneity of hotels, following previous studies of waste mitigation strategies (Ellison et al., 2019; Juvan et al., 2018; Painter et al., 2016). This variable is called '*Waste Generation Intensity per 100 Overnight stay*' (*WGIO*) and was constructed by dividing the number of *FEBs* by every 100 overnight stays.

Table 4. Descriptive statistics of variables used for the impact evaluation of the PAYT tariff. Weekly data from March–May 2018 and March–May 2019.

Variable	Label	Obs.	Mean	S.D.	Min	Max
FEB	Full Equivalent Bins	432	25.75	17.71	2	99
Bed	Beds	432	420.28	175.60	160	770
ORB	Occupancy rate by beds	432	66.59	10.79	32	100
Ov	Overnight stays	432	1,985.40	953.28	478	4,546

WGIO	Waste Generation Intensity by 100 overnight stays	432	1.29	0.56	0.06	3.77

Source: Author prepared.

A *panel data model* was implemented to estimate the causal impact on mixed waste generation intensity following the application of *Tariff C'*. The explained variable is the log of mixed waste generation intensity per overnight stay, *WGIO*. The model takes the following functional specification:

$$ln(WGIO)_{it} = \beta_0 + \beta_1 PAYT_t + \beta_2 Easter_{t+1} + \lambda_t + \gamma_t + u_i + \varepsilon_{it} \qquad (5)$$

where *i* denotes the establishment and *t* the weekly period. *PAYT* is a *period dummy variable*, taking a value of 1 after the 13th week of 2019 (1 April), common to all establishments. This variable captures the effect of the PAYT tariff implemented. As the dependent variable is in logarithms, the estimated coefficient can be interpreted directly as a percentage. *Easter* is another period dummy variable for controlling the effect of Easter in the following week. λ_t is a weekly fixed effect and γ_t is a yearly fixed effect, both common to all establishments. These time-fixed effects are introduced to control the weekly and yearly trends, respectively. Lastly, u_i is the unobserved *time-invariant* individual effect, and ε_{it} is the *idiosyncratic error term*, which follows a normal distribution with zero mean and constant variance (σ).

Model (5) has been estimated using *fixed effects*, where an individual fixed effect captures time-invariant unobservable heterogeneity to capture the causal effect of the tariff implementation. All pre- and post-estimation tests can be seen in Appendix B.

Table 5. Impact of PAYT tariff implementation on mixed waste generation intensity.

Regressor	Coefficient	St. error
PAYT	-0.3555**	(0.1537)
Easter	0.1764**	(0.0822)
Constant	-0.0865	(0.1244)
Week fixed effect	Yes	
Year fixed effect	Yes	
Obs.	432	
R-Squared	0.181	

Note: The dependent variable is the log of the weekly mixed waste generation intensity relative to 100 overnight stays (WGIO). Standard errors clustered at the establishment category and type level in parenthesis. Three stars indicate statistical significance at the 1 percent level, two stars at the 5 percent level, and one star at 10 percent. Source: Author prepared.

The results of the estimations are shown in Table 5. Thus, the introduction of the PAYT tariff in the accommodation sector in Puerto de la Cruz can be associated with an average short-term reduction in mixed waste generation intensity of 35%, controlling for the weekly and yearly trend and the *Easter* effect. Even though we expect the long-term results to hold, as shown by the Dijkgraaf and Gradus (2009) for households, these cannot be analyzed as the tariff was revoked by the incoming government. Mixed waste generation is reduced even though the PAYT tariff only considers penalization for hotels with a mixed waste generation intensity above the sector average. The *Easter* effect in the following week saw an increase in mixed waste generation intensity of around 17.6%. We lack data on recyclables collected individually, but the report by Padrón Fumero (2021) points to an increase in recycling rates in the hotel sector of Puerto de la Cruz after the introduction of the PAYT tariff.

The 35% reduction in mixed waste generation intensity following the implementation of the PAYT tariff must be interpreted cautiously. Although estimations confirm the existence of a notable reduction in mixed waste generation per overnight stay, the measurement of the explained variable, a volume-based system (*FEB*), may lead to an overestimated effect (Dijkgraaf & Gradus, 2009). Indeed, the waste collection company confirms that bins are denser or more compacted after the new tariff becomes effective. In other words, following the introduction of the new tariff, firms may separate recyclable waste such as packaging from the mixed waste bins, especially those of greater volume, and fill them with heavier waste. This idea is supported by the results of two characterizations of solid waste, the first carried out days prior to the introduction of the co-created PAYT tariff (March 29, 2019) and the second on 8 May 2019, both with mixed waste from four hotels. These characterizations show that the percentage of recyclable material in the mixed waste decreased by 5.2 p.p., while organic waste increased by almost 10 p.p.

Another contrasting dynamic may also be taking place. Dijkgraaf and Gradus (2009) state that environmental activism causes municipalities moving to a PAYT tariff to see a decrease in waste generation of around 6% before the tariff is actually introduced. Therefore, the real impact of the PAYT tariff may be underestimated. In our case study, it may have occurred during the participatory waste tariff reform process, which we could not observe due to a lack of data for this period (March 2018–March 2019).

Finally, we analyze whether the advantages and disadvantages of PAYT systems for households (shown in Table 1) hold for the co-created PAYT tariff for hotels in Puerto de la Cruz. Regarding the advantages, we can confirm that the hotel sector broadly accepts the tariff because it was made an active stakeholder in the participatory waste tariff reform process: there is a fair allocation of the management cost, compliant with the polluter pays principle, and there is evidence of reduced waste reduction and increased recycling rates (based on the results of two solid waste characterizations). However, we cannot confirm whether the transparency of waste management costs has improved because the city council did not offer more accurate data on the service provided to hotels. To our knowledge, hoteliers have not launched any composting initiatives.

With regard to the main disadvantages, in our PAYT system case study we found that implementing the new tariff increased management costs due to door-to-door collection, additional bins for hotels, and administrative expenses. However, the co-created tariff allowed the city council to recover total costs, including implementation costs, without additional expenses. Despite concerns about illegal dumping or waste tourism, no such incidents were reported during the tariff period. Even though no penalties were considered in the waste tariff reform for either illegal dumping or waste tourism, the competitive scenario created by our PAYT mechanism strengthens overall vigilance within the sector. We did not receive sufficient data on recyclables to corroborate a higher presence of contaminants in sorted waste.

4 Summary of results and discussion

In the previous section, we illustrated the different stages of a waste tariff reform for the hotel sector under a collaborative process between the city council, hotels and waste management firms. The main results can be summarized as follows. First, a PAYT tariff is designed on the basis of a comparative analysis and the use of simulations, under two criteria: cost recovery for the municipality and increasing marginal payment for hotels according to their WGI. Second, a tariff is developed that satisfies the requirements of the hotel sector and the municipality: hotels ensure that the heterogeneity of the sector is considered, to prevent the penalization of establishments that already promote sustainable waste management measures, and the city council improves budget deficits and waste recycling rates while reducing the overall mixed waste generated. Third, there is a high level of acceptance of the tariff because all the stakeholders in the waste management process have been included in its development. Fourth, empirical evidence indicates that the PAYT tariff has been effective, leading to a change in hotel behavior that has reduced mixed waste generation by 35%.

We believe that this evidence-based waste tariff reform, analyzed here as a case study of policy design and implementation, improves our understanding of key barriers to improving waste management in tourism destinations. Indeed, treating tourism as a commercial source of waste poses a series of challenges for municipal waste management in EU member states and other regions of the world. National legislation allows local authorities to either include commercial waste producers in their municipal waste management networks or to let these waste producers self-manage. However, the self-management of commercial waste may only be permitted when the waste producer complies with certain requirements that guarantee adequate management and reporting; where this cannot be assured, the local authority is obliged to assume responsibility and can charge the actual cost to the waste producer. In addition, the exclusion of commercial waste producers from the municipal waste network generates extra monitoring and tracking costs for private waste management. Depending on the size of the municipality and the relative number of commercial waste producers, the duplication of the local waste network may result in economic inefficiencies. Indeed, our case study of Puerto de la Cruz – a municipality of 8.73 km^2 with high population and tourist density – can be considered a good example of the need to avoid self-management of commercial waste.

This said, commercial waste producers could easily contribute to recycling targets – as provided for in the EU Waste Framework Directive – since a large fraction of their waste is recyclable material (EPA Ireland, 2018). Moreover, proper segregation of commercial waste could contribute to lowering unnecessarily high costs to businesses. PAYT tariffs could play a crucial role in achieving this. The progressive waste charge described in this paper illustrates the high degree of acceptance of a policy reform – by both the hotel sector and the local authority – when commercial waste producers are included in the WMS, thus avoiding the costs and inefficiencies derived from additional private waste management.

In line with Bramwell and Lane (2006), through their inclusion in the waste tariff reform process, hotel firms were obliged to challenge the waste management status quo and consider the social costs of waste management, ensuring broader acceptance of change. Partnership development creates a win-win situation: on the one hand, the hotel sector helps the municipality to achieve its objectives for sustainable waste management, which contributes directly to improving the destination's image; on the other, the local government adapts the policy to avoid penalizing hotels that already implement voluntary actions to reduce waste.

Another important contribution of the participatory waste tariff reform presented in this paper is the pressure to include packaging waste from hotels in municipal collection services, after negotiation with Ecoembes. The co-created PAYT tariff reduces the economic barriers to recycling commonly encountered by the hotel sector (Tansel et al., 2021) and maximizes incentives to divert recyclable waste from the mixed waste fraction (Radwan et al., 2010, 2012). We should recall that, in comparative terms, the tariff proposed by the municipality of Puerto de la Cruz (*Tariff B*) offered a differential of €1.90 per container for mixed waste and packaging. As a result of the participatory process, the co-created PAYT tariff maximizes the differential to €4.90, providing a greater incentive to separate recyclables.

With regard to the economic instrument, the co-designed two-part PAYT tariff contributes to the literature by offering a considerable improvement on standard PAYT tariffs (unit-based pricing). First, it is better adapted to the reality of the hotel sector, which is characterized by a high heterogeneity of services and infrastructure that influences waste generation and limits the opportunities to improve waste management. Heterogeneity between establishments is accounted using the WGI (waste per bed) indicator. In other words, the final amount payable by each establishment under the co-designed PAYT tariff will depend on waste generation proportional to size. Penalties are based on environmental performance, encouraging companies to develop a wider range of measures to prevent waste and improve waste management.

Second, the introduction of the dynamic benchmark reference waste per bed provides a strong incentive scheme to reduce mixed waste, encouraging long-term investment in waste prevention and recyclable waste separation. This incentive scheme is stronger when the industry average is used, ensuring that there will be hotels above and below this value, generating a competitive inertia towards zero waste due to the attractiveness of long-term investment in waste management measures and the possibility of building competitive advantage over rivals.

Third, the co-designed PAYT tariff is consistent with European regulations and the new Spanish Waste Law (7/2022), which require a differentiated non-deficit tariff that guarantees compliance with the polluter pays principle. The main advantage this offers over a standard PAYT tariff is that it reduces the uncertainty regarding the income required to maintain the current service (avoiding decapitalization) and promotes measures to improve the waste management system. Indeed, the tariff has two adjustable mechanisms (*price per bed* and *price per bin*) for generating additional revenue with which to finance other information policies. These mechanisms can be easily adjusted in the long term as collection costs are reduced at lower levels of waste generation. In terms of information measures, small and medium-sized establishments should be given the information and knowledge to promote voluntary pro-environment measures, overcoming the barriers of cost and trained personnel requirements that they face (Radwan et al., 2012). Other measures are consistent with the creation of a recognition system for firms with exemplary behavior who gain competitive advantage through signaling (King et al., 2005). Radwan et al. (2010) report that hoteliers in Wales consider that a simple distinction such as an award, certificate or sticker would help them to signal themselves.

Finally, it is important to highlight some of the obstacles to the successful implementation of the waste tariff reform reported in this case study. First, hotel establishments must adapt their infrastructure so that container storage is available for door-to-door collection, which is essential for a PAYT tariff. Second, all hotels must have their own containers. Third, given that there is scientific evidence that a PAYT tariff based on weight is more effective (Bel & Gradus, 2016), it is essential to have "modern technical solutions with the electronic identification and data transfer in a bin identification system (CWD-System)" (Bilitewski, 2008). Finally, increased vigilance is needed to avoid malpractice in hotel management (waste tourism, etc.), leading to increased costs.

5 Conclusions

Sustainable waste management practices targeting broad impact in tourism destinations must provide robust economic incentives for the hospitality sector and ensure full-cost recovery for waste managers. In this context, a transition from flat tariffs to waste-generated unit prices faces significant political, technical, and financial uncertainties. Our research is intended to show social scientists, authorities and tourism firms that more sustainable waste management systems can be achieved through evidence-based and collaborative design of PAYT tariffs. Specifically, we detail the co-design and implementation of a novel PAYT tariff for the hotel sector that introduces dynamic incentives to compete at the destination scale in mixed waste prevention and recycling rates. We provide evidence of significant short-term impacts in the form of induced behavioral changes that reduce mixed waste generation intensity by 35%, possibly by triggering recyclable waste collection.

The co-created PAYT tariff contributes to the literature by improving standard waste unit-prices in several ways. First, the tariff guarantees the full recovery of municipal mixed and sorted waste costs, including improved door-to-door collection and transport services, as well as additional implementation costs (such as administration, technology and infrastructure). Note that the tariff costs are directly internalized by private firms, according to the polluter pays principle. Second, by redefining the unit-based pricing reference from overall waste to WGI, the tariff progressively penalizes an establishment's failure to implement sustainable waste management measures. Third, it introduces a dynamic benchmarking mechanism that promotes competition among hotels to reduce waste and to invest in long-term waste management measures. Long-term incentives are particularly effective at increasing return on investment in structural facilities that improve waste management in hotels. Not only is this approach consistent with the principles of the EU Circular Economy Package, it also provides an opportunity to build competitive advantage in overall hotel operations.

The participatory waste tariff reform drew on the participation of all relevant stakeholders, including all national IWMS responsible for the collection of recyclable streams. In our case study, the municipal agreement with Ecoembes initially excluded packaging waste generated in hotel operations, owing to the over-cost of commercial waste within the municipal agreement. The same barrier has been systematically encountered in municipal waste services across the Canary Islands, indicating that there is no interest by IWMS for recyclable material due to the cost of reverse logistics given the distance to mainland Spain. This contrasts with the overall acceptance of the waste tariff reform by hotel managers and the induced behavioral changes observed.

Notwithstanding the evident advantages of waste tariff reform, our co-design process also has some limitations. In our case study, there was no mechanism to monitor and minimize perverse incentives such as illegal dumping, waste tourism or the presence of improper material in sorted waste to avoid penalties. While this type of incentive can be important in residential unit pricing, we believe that targeting large waste producers such as hotels and apartment complexes reduces the likelihood of such violations. Moreover, the competitive environment our PAYT mechanism creates should reinforce overall vigilance across the sector. Finally, there are key political issues that should be further addressed in local waste management reforms. Indeed, in our case study, the exclusion of political rivals and municipal finance officials from the co-design process was a major factor behind the abolition of the PAYT by the incoming administration.

Disclosure statement

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References

Abdulredha, M., Al, R., Jordan, D., Kot, P., Abdulridha, A., & Hashim, K. (2018). Estimating solid waste generation by hospitality industry during major festivals : A quantification model based on multiple regression. *Waste Management*. https://doi.org/10.1016/j.wasman.2018.04.025

Álvarez Gil, M. J., Burgos Jiménez, J., & Céspedes Lorente, J. J. (2001). An analysis of environmental management, organizational context and performance of Spanish hotels. *Omega*, *29*(6), 457–471. https://doi.org/https://doi.org/10.1016/S0305-0483(01)00033-0

Alves, L., Silva, S., & Soares, I. (2020). Waste management in insular areas: A Pay-As-You-Throw system in Funchal. *Energy Reports*, *6*, 31–36. https://doi.org/https://doi.org/10.1016/j.egyr.2020.10.024

Alzamora, B. R., & Barros, R. T. de V. (2020). Review of municipal waste management charging methods in different countries. *Waste Management*, *115*, 47–55. https://doi.org/https://doi.org/10.1016/j.wasman.2020.07.020

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 Management*, *46*, 628–636.

Arbulú, I., Lozano, J., & Rey-Maquieira, J. (2016). The challenges of municipal solid waste management systems provided by public-private partnerships in mature tourist destinations: the case of Mallorca. *Waste Management*, *51*, 252–258.

Batllevell, M., & Hanf, K. (2008). The fairness of PAYT systems: some guidelines for decision-makers. *Waste Management*, *28*(12), 2793–2800.

Baumol, W. J., Baumol, W. J., Oates, W. E., Baumol, W. J., Bawa, V. S., Bawa, W. S., & Bradford, D. F. (1988). *The theory of environmental policy*. Cambridge university press.

Beigl, P., Lebersorger, S., & Salhofer, S. (2008). Modelling municipal solid waste generation: a review. *Waste Management (New York, N.Y.)*, *28*(1), 200–214. https://doi.org/10.1016/j.wasman.2006.12.011

Bel, G., & Gradus, R. (2016). Effects of unit-based pricing on household waste collection demand: A meta-regression analysis. *Resource and Energy Economics*, *44*, 169–182.

Bilitewski, B. (2008). From traditional to modern fee systems. *Waste Management*, *28*(12), 2760–2766. https://doi.org/https://doi.org/10.1016/j.wasman.2008.03.032

Bramwell, B., & Lane, B. (2006). Editorial: Policy Relevance and Sustainable Tourism Research: Liberal, Radical and Post-structuralist Perspectives. *Journal of Sustainable Tourism*, *14*(1), 1–5. https://doi.org/10.1080/09669580608668587

Cabildo Insular de Tenerife. (2020). *Energía/Residuos [Database]*. http://www.tenerife.es/bancodatos/

Cannonier, C., & Burke, M. G. (2019). The economic growth impact of tourism in Small Island Developing States—evidence from the Caribbean. *Tourism Economics*, *25*(1), 85–108.

Chan, E. S. W. (2008). Barriers to EMS in the hotel industry. *International Journal of Hospitality Management*, *27*(2), 187–196. https://doi.org/https://doi.org/10.1016/j.ijhm.2007.07.011

Choe, C., & Fraser, I. (1998). The economics of household waste management: a review. *Australian Journal of Agricultural and Resource Economics*, *42*(3), 269–302.

Cingoski, V., & Petrevska, B. (2018). Making hotels more energy efficient: the managerial perception. *Economic Research-Ekonomska Istraživanja*, *31*(1), 87–101. https://doi.org/10.1080/1331677X.2017.1421994

Dahlén, L., & Lagerkvist, A. (2010). Pay as you throw. Strengths and weaknesses of weight-based billing in household waste collection systems in Sweden. *Waste Management*, *30*(1), 23–31. https://doi.org/10.1016/j.wasman.2009.09.022

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 Management*, *102*. https://doi.org/10.1016/j.wasman.2019.11.023

Diaz-Farina, E., Díaz-Hernández, J. J., & Padrón-Fumero, N. (2023). Analysis of hospitality waste generation: Impacts of services and mitigation strategies. *Annals* *of Tourism Research Empirical Insights*, *4*(1), 100083. https://doi.org/https://doi.org/10.1016/j.annale.2022.100083

Dijkgraaf, E., & Gradus, R. (2009). Environmental activism and dynamics of unit-based pricing systems. *Resource and Energy Economics*, *31*(1), 13–23. https://doi.org/https://doi.org/10.1016/j.reseneeco.2008.10.003

Dolnicar, S., Juvan, E., & Grün, B. (2020). Reducing the plate waste of families at hotel buffets – A quasi-experimental field study. *Tourism Management*, *80*, 104103. https://doi.org/https://doi.org/10.1016/j.tourman.2020.104103

Ecoembes. (2017). *Statistics database: Barómetro de recogida selectiva*. https://www.ecoembes.com/es/ciudadanos/envases-y-proceso-reciclaje/reciclaje-en-datos/barometro. (accessed 15.01.18).

Ecovidrio. (2017). *Statistics database: Datos de reciclado*. https://www.ecovidrio.es/reciclado/datos-de-reciclado/estadisticas. (accessed 15.01.18).

Elia, V., Gnoni, M. G., & Tornese, F. (2015). Designing Pay-As-You-Throw schemes in municipal waste management services: A holistic approach. *Waste Management*, *44*, 188–195.

Ellison, B., Savchenko, O., Nikolaus, C. J., & Duff, B. R. L. (2019). Every plate counts: Evaluation of a food waste reduction campaign in a university dining hall. *Resources, Conservation and Recycling*, *144*, 276–284. https://doi.org/https://doi.org/10.1016/j.resconrec.2019.01.046

Erdogan, N., & Baris, E. (2007). Environmental protection programs and conservation practices of hotels in Ankara, Turkey. *Tourism Management*, *28*(2), 604–614.

European Commission. (2003). *Variable Rate Pricing Based on Pay-As-You-Throw as a Tool of Urban Waste Management (PAYT), Literature Review WP1, EVK4-CT-2000-00021, under the Fifth Framework Programme Energy, Environment and Sustainable Development, Coordinated by Prof. Dr.-Ing. B. Bi.*

Ezeah, C., Fazakerley, J., & Byrne, T. (2015). Tourism waste management in the European Union: Lessons learned from four popular EU tourist destinations. *American Journal of Climate Change*, *4*(05), 431.

Fayissa, B., Nsiah, C., & Tadesse, B. (2009). Tourism and economic growth in Latin American countries (LAC): Further empirical evidence. *Department of Economics and Finance Working Paper Series, 1*, 26.

Filimonau, V. (2021). The prospects of waste management in the hospitality sector post COVID-19. *Resources, Conservation and Recycling*, *168*, 105272. https://doi.org/https://doi.org/10.1016/j.resconrec.2020.105272

Filimonau, V., & Tochukwu, C. O. (2020). Exploring managerial approaches to mitigating solid waste in hotels of Lagos, Nigeria. *Journal of Cleaner Production*, *270*, 122410. https://doi.org/https://doi.org/10.1016/j.jclepro.2020.122410

Finnveden, G., Ekvall, T., Arushanyan, Y., Bisaillon, M., Henriksson, G., Gunnarsson Östling, U., Söderman, M. L., Sahlin, J., Stenmarck, Å., Sundberg, J., Sundqvist, J.-O., Svenfelt, Å., Söderholm, P., Björklund, A., Eriksson, O., Forsfält, T., & Guath, M. (2013). Policy Instruments towards a Sustainable Waste Management. *Sustainability*, *5*(3), 841–881. https://doi.org/10.3390/su5030841

Gössling, S., Hall, C. M., & Scott, D. (2015). *Tourism and water* (Vol. 2). Channel View Publications.

Gössling, S., Peeters, P., Hall, C. M., Ceron, J.-P., Dubois, G., & Scott, D. (2012). Tourism and water use: Supply, demand, and security. An international review. *Tourism Management*, *33*(1), 1–15.

Graci, S., & Dodds, R. (2008). Why go green? The business case for environmental commitment in the Canadian hotel industry. *Anatolia*, *19*(2), 251–270.

Heller, M. H., & Vatn, A. (2017). The divisive and disruptive effect of a weight-based waste fee. *Ecological Economics*, *131*, 275–285.

Inoue, Y., & Lee, S. (2011). Effects of different dimensions of corporate social responsibility on corporate financial performance in tourism-related industries. *Tourism Management*, *32*(4), 790–804.

Instituto Nacional de Estadística (INE). (2018a). *Estadística sobre recogida y tratamiento de residuos [Database]*. https://www.ine.es/dyngs/INEbase/es/operacion.htm?c=Estadistica_C&cid=1254736176844&menu=resultados&idp=1254735976612

Instituto Nacional de Estadística (INE). (2018b). *Statistics database: Demografía y población*. http://www.ine.es/dyngs/INEbase/es/categoria.htm?c=Estadistica_P&cid=1254735572981.

Juvan, E., Grün, B., & Dolnicar, S. (2018). Biting off more than they can chew: food waste at hotel breakfast buffets. *Journal of Travel Research*, *57*(2), 232–242.

Karagiannidis, A., Xirogiannopoulou, A., & Tchobanoglous, G. (2008). Full cost accounting as a tool for the financial assessment of Pay-As-You-Throw schemes: A case study for the Panorama municipality, Greece. *Waste Management*, *28*(12), 2801–2808.

Khatter, A., White, L., Pyke, J., & McGrath, M. (2021). Barriers and drivers of environmental sustainability: Australian hotels. *International Journal of Contemporary Hospitality Management*.

King, A. A., Lenox, M. J., & Terlaak, A. (2005). The Strategic Use of Decentralized Institutions: Exploring Certification With the ISO 14001 Management Standard. *Academy of Management Journal*, *48*(6), 1091–1106. https://doi.org/10.5465/amj.2005.19573111

Koliotasi, A.-S., Abeliotis, K., & Tsartas, P.-G. (2023). Understanding the Impact of Waste Management on a Destination′ s Image: A Stakeholders′ Perspective. *Tourism and Hospitality*, *4*(1), 38–50.

Manomaivibool, P. (2015). Wasteful tourism in developing economy? A present situation and sustainable scenarios. *Resources, Conservation and Recycling*, *103*, 69–76. https://doi.org/10.1016/j.resconrec.2015.07.020

Martin-Rios, C., Demen Meier, C., & Pasamar, S. (2022). Sustainable waste management solutions for the foodservice industry: A Delphi study. *Waste Management & Research*, *40*(9), 1412–1423. https://doi.org/10.1177/0734242X221079306

Mensah, I. (2014). Different shades of green: Environmental management in hotels in Accra. *International Journal of Tourism Research*, *16*(5), 450–461.

Messner, R., Richards, C., & Johnson, H. (2020). The “Prevention Paradox”: food waste prevention and the quandary of systemic surplus production. *Agriculture and Human Values*, *37*(3), 805–817. https://doi.org/10.1007/s10460-019-10014-7

Murava, I., & Korobeinykova, Y. (2016). The analysis of the waste problem in tourist destinations on the example of Carpathian region in Ukraine. *Journal of Ecological Engineering*, *17*(2).

Newig, J., & Fritsch, O. (2009). Environmental governance: participatory, multi-level – and effective? *Environmental Policy and Governance*, *19*(3), 197–214. https://doi.org/https://doi.org/10.1002/eet.509

Oosterhuis, F. H., Van Beukering, P. J. H., Bartelings, H., & Linderhof, V. G. M. (2009). *Economic instruments and waste policies in the Netherlands. Inventory and options for extended use*. Institute for Environmental Studies IVM.

Padrón Fumero, N. (2021). *Proyecto: Seguimiento de la Implantación de la Tasa por Generación (PAYT) a los Establecimientos Alojativos del Puerto de la Cruz. Informe de resultados*. http://riull.ull.es/xmlui/handle/915/32784

Padron-Fumero, N., Diaz-Farina, E., & Arroyo-Hernandez, N. (2017). *Análisis y evaluación del modelo de gestión de residuos domésticos en la isla de Tenerife*. https://riull.ull.es/xmlui/handle/915/14029

Painter, K., Thondhlana, G., & Kua, H. W. (2016). Food waste generation and potential interventions at Rhodes University, South Africa. *Waste Management*, *56*, 491–497. https://doi.org/https://doi.org/10.1016/j.wasman.2016.07.013

Pirani, S. I., & Arafat, H. A. (2014). Solid waste management in the hospitality industry: A review. *Journal of Environmental Management*, *146*, 320–336.

Puig-Ventosa, I. (2008). Charging systems and PAYT experiences for waste management in Spain. *Waste Management*, *28*(12), 2767–2771.

Puig-Ventosa, I., & Sastre Sanz, S. (2017). An exploration into municipal waste charges for environmental management at local level: The case of Spain. *Waste Management & Research*, *35*(11), 1159–1167.

Radwan, H. R. I., Jones, E., & Minoli, D. (2010). Managing solid waste in small hotels. *Journal of Sustainable Tourism*, *18*(2), 175–190.

Radwan, H. R. I., Jones, E., & Minoli, D. (2012). Solid waste management in small hotels: a comparison of green and non-green small hotels in Wales. *Journal of Sustainable Tourism*, *20*(4), 533–550. https://doi.org/10.1080/09669582.2011.621539

Reichenbach, J. (2008). Status and prospects of pay-as-you-throw in Europe - A review of pilot research and implementation studies. *Waste Management*, *28*(12), 2809–2814. https://doi.org/10.1016/j.wasman.2008.07.008

Rodrigues, J., Oliveira, V., Lopes, P., & Dias-Ferreira, C. (2015). Door-to-Door Collection of Food and Kitchen Waste in City Centers Under the Framework of Multimunicipal Waste Management Systems in Portugal: The Case Study of Aveiro. *Waste and Biomass Valorization*, *6*(5), 647–656. https://doi.org/10.1007/s12649-015-9366-3

Rodríguez González, P. (2015). Crisis y renovación en el ciclo de vida de los destinos turísticos. El caso de Puerto de la Cruz, Tenerife. *Atlántida*, *6*, 101–122.

Rubio, S., Ramos, T. R. P., Leitão, M. M. R., & Barbosa-Povoa, A. P. (2019). Effectiveness of extended producer responsibility policies implementation: The case of Portuguese and Spanish packaging waste systems. *Journal of Cleaner Production*, *210*, 217–230. https://doi.org/https://doi.org/10.1016/j.jclepro.2018.10.299

Sakai, S., Ikematsu, T., Hirai, Y., & Yoshida, H. (2008). Unit-charging programs for municipal solid waste in Japan. *Waste Management*, *28*(12), 2815–2825. https://doi.org/10.1016/j.wasman.2008.07.010

Schubert, S. F., Brida, J. G., & Risso, W. A. (2011). The impacts of international tourism demand on economic growth of small economies dependent on tourism. *Tourism Management*, *32*(2), 377–385. https://doi.org/https://doi.org/10.1016/j.tourman.2010.03.007

Simancas Cruz, M. R., & Hernández Martín, R. (2015). *Reinventando alojamientos turísticos: Casos de éxito y soluciones innovadoras*.

Skumatz, L. A. (2008). Pay as you throw in the US: Implementation, impacts, and experience. *Waste Management*, *12*(28), 2778–2785.

Slavik, J., & Pavel, J. (2013). Do the variable charges really increase the effectiveness and economy of waste management? A case study of the Czech Republic. *Resources, Conservation and Recycling*, *70*, 68–77.

Slavík, J., Pavel, J., & Arltová, M. (2020). Variable charges and municipal budget balance: Communicating vessels of the waste management. *Journal of*

Environmental Management, *257*(November 2019). https://doi.org/10.1016/j.jenvman.2019.109976

Tamayo Sáez, M. (1997). El análisis de las políticas públicas. *La Nueva Administración Pública*, 281–312.

Tansel, T., Yeshenkulova, G., & Nurmanova, U. (2021). Analysing Waste Management and Recycling Practices for the Hotel Industry. *Journal of Environmental Management & Tourism*, *12*(2), 382–391.

Van Beukering, P. J. H., Bartelings, H., Linderhof, V. G. M., & Oosterhuis, F. H. (2009). Effectiveness of unit-based pricing of waste in the Netherlands: Applying a general equilibrium model. *Waste Management*, *29*(11), 2892–2901.

Wang, K. C. M., Lee, K. E., & Mokhtar, M. (2021). Solid Waste Management in Small Tourism Islands: An Evolutionary Governance Approach. *Sustainability*, *13*(11). https://doi.org/10.3390/su13115896

Yaobo, S., Xinxin, Z., & Fuli, Z. (2017). Research on Estimates of Xi'an City Life Garbage Pay-As-You-Throw Based on Two-part Tariff method. *IOP Conference Series: Earth and Environmental Science*, *68*(1). https://doi.org/10.1088/1755-1315/68/1/012016

Appendix A. Developing the second part of the PAYT tariff (Alternative C)

In this appendix is developed the second part of the PAYT tariff (3) to prove that this part is usually different from zero unless in some circumstances.

The second part of (3) can be rewritten as:

$$\sum_{i=1}^{n}\sum_{s=1}^{S}\left(P_{Bin_t} * [(WGIB_{is} - \overline{WGIB_s}) * Bed_{it-1}]\right)$$
$$= \sum_{i=1}^{n}\sum_{s=1}^{S}\left(P_{Bin_t} * \left[\left(\frac{FEB_{is}}{Be_{it-1}} - \frac{\sum_{i=1}^{n} FEB_s}{\sum_{i=1}^{n} Be_{t-1}}\right) * Bed_{it-1}\right]\right)$$
$$= \sum_{i=1}^{n}\sum_{s=1}^{S}\left(P_{Bin_t} * \left(FEB_{is} - \frac{\sum_{i=1}^{n} FEB_s}{\sum_{i=1}^{n} Be_{t-1}} * Bed_{it-1}\right)\right) \neq 0 \qquad (A1)$$

where FEB_{is} is the number of bins generated by the establishment -*i* during the settlement period -*s*, and $\frac{\sum_{i=1}^{n} FEB_s}{\sum_{i=1}^{n} Bed_{t-1}} * Bed_{it-1}$ is the hypothetic number of bin of mixed-waste generated by the establishment -*i* with the same number of bed than the sector average. Indeed, the difference between this two terms will determine if the establishment -*i* will be penalized or rewarded.

In aggregated terms, (A1) will be equal to 0 only in the following situations for which have been developed an example setting a price per bin equal to 2 euros:

1. All establishments have the same number of available beds -which is impossible in a real case- even though they have a different mixed-waste generation intensity ($WGIB_{is}$),as Table A.1 shows.
2. All establishments have the same mixed-waste generation intensity ($WGIB_{is}$) even though they have a different number of available beds as Table A.2 shows.
3. Despite of having different number of available beds and same mixed-waste generation intensity ($WGIB_{is}$) the rewards are compensated by the penalties led by those bigger establishments (in terms of beds) as Table A.3 shows.

Table A.4 lists the possible decisions that the policymaker can make - depending on the situation after the initial prices set - regarding the two available tools, *price per bed* and *price per bin*, and the consequences on cost recovery and waste prevention incentives. In *scenario ii)*, there is only one alternative that ensures a financial balance while keeping the incentives constant. In this alternative, the policymaker should reduce the *price per bed* significantly and keep the *price per bin* of mixed-waste collected constant compared to the initial prices set. The second-best alternative is to reduce the *price per bed* a little and also the *price per bin*, also lowering the incentives to waste prevention. In *scenario iii)*, the best alternative to guarantee the financial balance and the same incentive level is to increase the *price per bed* and keep the *price per bin* constant. It is important to highlight that the *price per bin* in *scenario ii)* is negatively related to total cost recovery and, therefore, increasing this price will generate a greater deficit than could be compensated by raising the *price per bed* sharply. In general terms, *price per bed* is the tool to correct the financial imbalances while *price per bin* of mixed-waste collected is more useful for correcting the level of incentive to waste prevention.

Table A.1. Second part of (3) equals to zero because all establishments have the same number of available beds despite of having different mixed-waste generation intensity.

Establishment	FEB_{is}	Be_{it-1}	$WGIB_{is}$	$\overline{\overline{WGIB}}_s$	$WGIB_{is} - \overline{WGIB}_s$	Municipal revenues
1	1,500	100	15.00	12.15	2.85	570.00
2	375	100	3.75	12.15	-8.40	-1,680.00
3	1,225	100	12.25	12.15	0.10	20.00
4	1,400	100	14.00	12.15	1.85	370.00
5	1,575	100	15.75	12.15	3.60	720.00
Total	6,075	500	-	-	0.00	0.00

Source: Author prepared

Table A.2. Second part of (3) equals to zero because all establishments have the same mixed-waste generation intensity despite of having different number of available beds.

Establishment	FEB_{is}	Be_{it-1}	$WGIB_{is}$	$\overline{\overline{WGIB}}_s$	$WGIB_{is} - \overline{WGIB}_s$	Municipal revenues
1	1,500	100	15.00	15.00	0.00	0.00
2	1,125	75	15.00	15.00	0.00	0.00
3	1,050	70	15.00	15.00	0.00	0.00
4	1,200	80	15.00	15.00	0.00	0.00
5	1,350	90	15.00	15.00	0.00	0.00
Total	6,225	415	-	-	0.00	0.00

Source: Author prepared

Table A.3. Second part of (3) equals to zero by compensation between rewards and penalties despite of establishments with different number of beds and mixed-waste generation intensity.

Establishment	FEB_{is}	Be_{it-1}	$WGIB_{is}$	$\overline{\overline{WGIB_s}}$	$WGIB_{is} - \overline{WGIB_s}$	Municipal revenues
1	1,500	100	15.00	14.64	0.36	72.29
2	375	75	5.00	14.64	-9.64	-1,445.78
3	1,225	70	17.50	14.64	2.86	400.60
4	1,400	80	17.50	14.64	2.86	457.83
5	1,575	90	17.50	14.64	2.86	515.06
Total	6,075	415	-	-	-0.69	0.00

Source: Author prepared

Table A.4. The decision over the initial *price per bed* and *price per bin* under the two-part PAYT tariff designed according to the objectives pursued.

Scenario		Decision over inital		Effect on	
		P_{Bed}	P_{Bin}	Budget	Incentives
ii)	Competition with surplus (rewards < penalties)	↓↓	=	Balance	Equal
		=	0	Balance	None
		=	=	Surplus	Equal
		↓	↓	Balance	Lower
iii)	Competition with losses (rewards > penalties)	↑↑	=	Balance	Equal
		=	↓	Deficit	Lower
		=	=	Deficit	Equal
		↑↑↑	↑	Balance	Higher

Source: Author prepared

Appendix B. Pre- and post-estimation tests

Pre-estimation tests:

- Hausman test: is one of the most extended tests to check whether using a random or fixed-effect model. The null hypothesis is that the preferred model is random effects vs. the alternative fixed effects. In other words, it tests whether the unique errors (u_i) are correlated with the regressors, the null hypothesis is they are not. In our case, the Hausman test suggests using the Fixed Effect estimator for the model (1) as we can reject the null hypothesis, as it can be seen in Figure B1.
- Outliers: they can be easily detected by representing each explanatory variable against the explained one in a scatter plot. Figure B2 shows that there are no problems with outliers in any of the two variables composing the dependent variable of the model (1).
- Serial correlation: this can be tested with Wooldridge test for autocorrelation in panel data, where the null hypothesis is no first-order autocorrelation. Then, we are interested in not rejecting the null. As we can see in Figure B3, the null cannot be rejected, at least at 5% significance level, indicating that there is no auto serial correlation.
- Model specification: a modified version of the link test for model specification is implemented to test if model (1) is correctly specified. As we are running a panel data, a modified version is needed because the link test is only available for single-equation estimation. Therefore, after regression our panel data model (1), we store the fitted values that are exclusively explained by the independent variables and we regress the our dependent variable against the fitted values and the square of these fitted values. As last step, we test is the square fitted value is statistically equal to zero. As we can see in Figure B4, we fail to reject the null, confirming that our regression model (1) does not support evidence of misspecification.

Post-estimation tests:

- Heteroscedasticity test for the original model evidences the presence of heteroskedasticity in the panel data, as shows Figure B5. Thus, we proceed using robust standard errors cluster at the individual level.

- Multicollinearity: the uncentered Variance Inflation Factor (VIF) has been implemented to check the multicollinearity. A value below 5 is usually set to discard the multicollinearity presence. Figure B6 confirms the no presence of multicollinearity.
- Correlation of residual: a simple way of checking that there is no correlation between the residuals is with a scatter plot. In Figure B7 we can see that residuals are randomly distributed.
- Normality of residuals: it is possible to see easily with a histogram of residuals of the model. Figure B8 shows clearly that the residual of the main regression model follows a normal distribution.

```
                      b = consistent under Ho and Ha; obtained from xtreg
        B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test:  Ho:  difference in coefficients not systematic

             chi2(13) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                      =      220.94
            Prob>chi2 =      0.0000
            (V_b-V_B is not positive definite)
```

Figure B1. Hausman test from model (1).

Source: Author prepared.

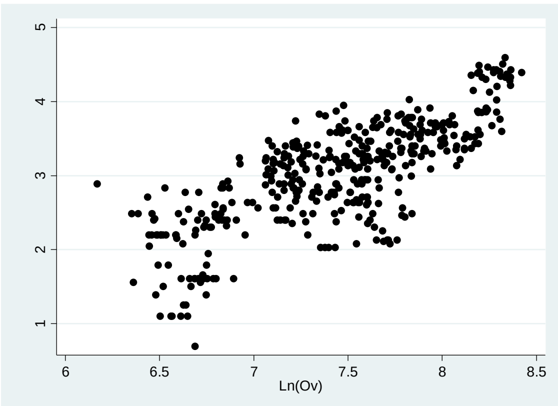

Figure B2. Scatter plot of the log of *FEB* and the log of *Ov*, the two variables composing the dependent variable of the model (1), *WGIO*.

Source: Author prepared.

```
Wooldridge test for autocorrelation in panel data
H0: no first-order autocorrelation
    F(  1,      17) =      4.042
           Prob > F =      0.0605
```

Figure B3. Test for serial correlation.

Source: Author prepared.

lninten_pe~t	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
fitted	.484195	4.380605	0.11	0.912	-8.126929	9.095319
sq_fitted	-.0582637	.4947423	-0.12	0.906	-1.030798	.9142703
_cons	-1.138568	9.674239	-0.12	0.906	-20.15559	17.87846
sigma_u	.33469292					
sigma_e	.36267389					
rho	.45994075	(fraction of variance due to u_i)				

```
F test that all u_i=0: F(17, 412) = 20.44                 Prob > F = 0.0000

.
. test sq_fitted=0

 ( 1)  sq_fitted = 0

       F(  1,   412) =    0.01
            Prob > F =    0.9063
```

Figure B4. Test for misspecification.

Source: Author prepared.

```
Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (18)  =      368.34
Prob>chi2 =       0.0000
```

Figure B5. Test for the heteroskedasticity.

Source: Author prepared.

Variable	VIF	1/VIF
period_payt	5.20	0.192308
wafter_eas~r	2.00	0.500000
year		
2019	4.80	0.208333
week		
11	1.20	0.833333
12	1.20	0.833333
13	1.20	0.833333
14	1.63	0.615385
15	1.13	0.888889
16	1.13	0.888889
17	1.63	0.615385
18	1.13	0.888889
19	1.13	0.888889
20	1.13	0.888889
21	1.13	0.888889
Mean VIF	1.83	

Figure B6. Variance Inflation Factor (VIF) of the model (1).

Source: Author prepared.

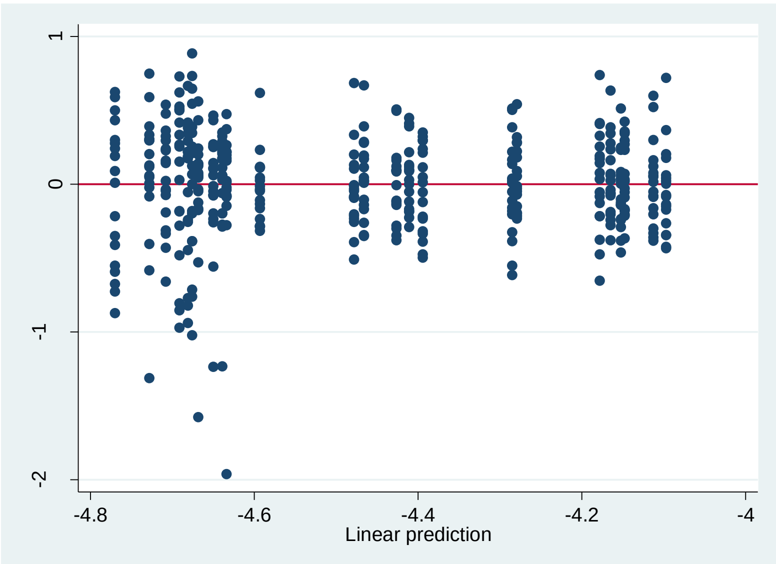

Figure B7. Residuals distribution of model (1).

Source: Author prepared.

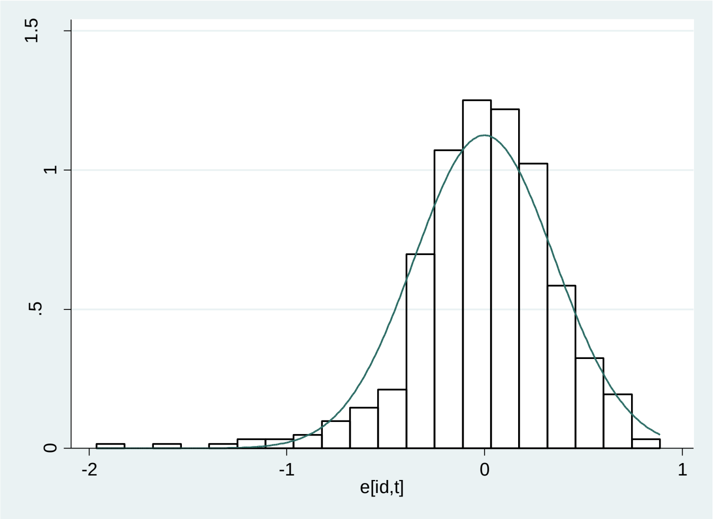

Figure B8. Normality of residuals of model (1).

Source: Author prepared.