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The Impact of Tourism on Solid Waste Generation and Management Cost in Madeira Island for the Period 1996–2018

António Miguel Martins [1,*] and Susana Cró [2]

[1] CEEAplA (Center of Applied Economic Studies of the Atlantic) and University of Madeira, 9020-105 Funchal, Portugal
[2] CEFAGE and University of Évora, 7004-516 Évora, Portugal; srgcro@uevora.pt
* Correspondence: antonio.martins@staff.uma.pt

Abstract: The tourism sector in Madeira represents 26.6% of the regional GDP and 16.7% of employment in the region. However, the sector is a source of adverse environmental impacts. One of the environmental repercussions of tourism, regarded as an externality, is the generation of solid waste. This paper aims to estimate the impact of tourist activities on solid waste generation in Madeira for the period 1996–2018. We used a fully modified ordinary least squares (FMOLS) model, including annual tourism inflows data. The results show that tourist activities are responsible for 41.9% to 46.6% of solid waste generation per resident in Madeira. The empirical results also support the hypothesis that there is a non-linear effect of tourism on the generation of solid waste. The importance of internalising this negative externality caused by tourism with the implementation of appropriate economic instruments and policies is the main policy implication of the study.

Keywords: solid waste generation; externalities; tourism activity; FMOLS model

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1. Introduction

Tourism has experienced rapid growth in recent decades. However, it seems clear that there are certain costs associated with this growth. The attention of economists is increasingly focused on the economic, cultural, social, and environmental repercussions of tourism, which are known as externalities. This study confirms the existence of external environmental costs and the need to internalise them through implementation of appropriate economic instruments and policies. In the particular case of this study, the impact of tourism on the generation of waste on the island of Madeira, Portugal will be analysed, as well as the institutional instruments that are being implemented for its control.

Tourism can sustain high levels of production, income, and employment in the economies of many regions. It is a source of government income and foreign exchange. Further, the repercussions on investment cannot be overlooked, that is, the supply of the necessary infrastructure to receive and accommodate seasonal workers and the tourists themselves (e.g., Palmer and Riera [1]; Mateu-Sbert et al. [2]. However, despite these beneficial effects, the tourism sector is a source of economic, social, and environmental impacts that lead to resource consumption with consequent public health problems. One of the most important environmental impacts of tourism is solid waste generation.

- Consequently, it is worth studying the relationship between tourist activity and solid waste generation for at least three reasons. First, the tourism sector is particularly intensive in solid waste generation. Second, international tourist inflows are a special form of export, as consumption is made in the exporting country, so the entry of these tourists constitutes an additional source of solid waste in the tourist destination. Third, there may be negative impacts of improper solid waste management on the image of the destination since environmental resources are inputs of production in the creation of the tourist experience.

- The main objective of this research is to analyse, from a regional insular point of view, the main determinants of solid waste generation, with a special focus on the tourism-related variables in a mature tourist destination, as is the case of Madeira Island. Madeira is a popular tourist destination in Portugal and was elected the "Best Island Destination in the World" in 2015, 2016, 2017, 2018, and 2019 by the World Travel Awards. According to the Regional Statistics Directorate (The statistics referred to can be obtained here: https://estatistica.madeira.gov.pt/en/ (accessed on 23 March 2020).), the tourism sector in Madeira represents 26.6% of the regional GDP and employs 20,000 people in the region (16.7% of employment in the region). This regional directorate also shows that in 2018, the number of guests lodged in tourist accommodation in Madeira was 1,607,899, more than six times the resident population (254,156). Recently, some municipalities in the region have approved a tourist tax (Details of the proposal can be found here: https://www.themayor.eu/en/funchal-sets-sights-on-introducing-tourist-tax (accessed on 23 March 2020)) that will be used for the development of the city in three main areas—infrastructural improvement of tourist areas, co-financing of city management activities, and financing of the so-called "social distortion program", but this has received harsh criticism from the tourism sector. This set of statistics and discussion of institutional instruments is the main reason why this island is an interesting location for the analysis of the potential impact of tourist arrivals on solid waste management.
- There are few studies that address the relationship between solid waste generation and tourism, and only three studies investigate this issue in insular regions heavily dependent on tourism. These include the studies by Mateu-Sbert et al. [2], Arbulu et al. [3], and Estay-Ossandon and Mena-Nieto [4], which investigate this relationship in Mallorca, Balearic Islands, and Menorca Island, respectively.

Our study differs from these three by virtue of the fact that we have used a fully modified ordinary least squares (FMOLS) model to study the relationship between solid waste generation and touristic activities, given the non-stationary nature of the variables and the existence of a stationary linear combination between the time series. Another difference is that we have considered the possibility of the existence of a non-linear effect between solid waste generation and tourist activity, which was not addressed in the studies mentioned. We test this hypothesis in the present study.

- The results show a positive and statistically significant effect of the variables associated with per capita income, employment rate, construction activity, gender, and age structure on solid waste generation in the long term. The empirical evidence also shows that tourism activities are responsible for 41.9% to 46.6% of solid waste generated per resident in Madeira. Furthermore, the results confirm a non-linear and significant effect of tourism inflows on solid waste generation. Tourism inflows exert significant upward pressure on solid waste generation up to a turning point where more tourist arrivals contribute to a reduction in solid waste generation.
- The structure of the remaining paper is as follows. Section 2 provides a review of previous studies. Data is presented in Section 3. The FMOLS empirical model is discussed in Section 4. Section 5 reports and discusses the results. Section 6 concludes the paper.

2. Literature Review

2.1. Solid Waste Generation as a Negative Externality of the Tourism Sector

The economic literature contains several references to the environmental repercussions of tourism and the implications for public policies. Briefly, economists highlight that the negative environmental repercussions of tourism are a negative externality (e.g., Palmer and Riera [1]; Gooroochurn and Sinclair [5]; Pintassilgo and Silva [6]; Gago et al. [1]). Palmer and Riera [7] noted that studies on the negative externalities associated with tourism essentially focus on the destructive effects of mass tourism on natural ecosystems, forgetting urban areas that may also suffer similar effects. In an extreme scenario where the number of tourists exceeds the physical absorption capacity of the place, the long-term negative external effects (i.e., pollution and congestion) can be unacceptable.

Destinations that see an excessive growth in the number of tourists tend to suffer destruction of their heritage and the quality of life of their residents, becoming slowly uninhabitable places, not only for those who live there but also for those who visit them (Palmer and Riera [7]). Pintassilgo and Silva [6] shared the same opinion. In their study, they revealed that open access to the tourism accommodation industry generally leads to both economic and environmental overexploitation. According to the authors, environmental resources typically present common pool resource characteristics, where the exploitation of the resource by one agent reduces the availability of resources for the others and where the exclusion of the other agents is especially difficult and expensive. In this way, a capture process of the users of these natural resources that destroys resources on which they depend tends to occur; this phenomenon was termed "the tragedy of the commons" by Hardin [8].

- To achieve an efficient social solution, governmental management is required to drive the industry to the social optimum, in which the divergence between private and social costs must be eliminated. A variety of policy instruments can be implemented in the tourism sector to internalise the external costs (e.g., Palmer and Riera [7]; Gooroochurn and Sinclair [5]; Pintassilgo and Silva [6]; Gago et al. [1]; Logar [9]).

Logar [9] mentioned the existence of three types of policy instruments for tourism management: economic, regulatory, and institutional instruments. The economic (or market-based) instruments comprise eco-taxes, user fees, financial incentives, and tradable building permits. The regulatory instruments include quotas and zoning. The institutional instruments refer to eco-labels and changes in property rights.

Gooroochurn and Sinclair [5] highlighted that in the presence of negative consumption externalities, the market does not provide the optimum quantity, given that the social cost is greater than the private cost. Bhagwati [10] argued that consumption taxes are the ideal policy for correcting a consumption externality at the source. The basic method is to use a Pigouvian tax to ensure that the market reaches an efficient outcome, given that the tax rate bridges the gap between marginal social costs and marginal private costs. This rate should be applied to all agents that cause negative externalities and directed at goods and services that cause adverse effects without price (e.g., Palmer and Riera, [7]; Gooroochurn and Sinclair [5]).

2.2. Determinants of Solid Waste Generation

2.2.1. Dependent Variable: Solid Waste Generation

The majority of models based on collection-stream data use total solid waste generation as the only dependent variable (Beigl et al. [11]). This variable includes solid waste, mainly from residential, commercial, and institutional sources, but also some construction and industrial waste. Solid waste includes putrescible waste, paper, metals, glass, and plastic (e.g., Gidarakos et al. [12]). Given the inexistence in Madeira of a long series with the composition of solid waste produced, the total amount of waste produced is used as a dependent variable, encompassing all those categories of waste.

2.2.2. Independent Variables

Based on the model proposed by Beigl et al. [11], the independent variables used to estimate the models in most studies are the following:

- Population

Daskalopoulos et al. [13] argued that population is the main parameter that determines the total waste produced in a country, given that solid waste generation arises as a direct consequence of human activities. Therefore, the greater the number of people living in a country, the more waste produced. However, Hockett et al. [14] noted that when the quantity of waste produced is presented on a per capita basis, there is no relationship between population and waste generation. More populous municipalities simply do not produce more waste per person than less populated municipalities (Hockett et al. [14], p. 208).

- Mean Living Standard of the Population

According to Daskalopoulos et al. [13], p. 156, "the mean living standard of the population of a country is the second major parameter that can be related to the rate of the solid waste generation". This variable indicates the capacity of the population to consume goods and services, which in turn generates waste. The GDP has been used as a widely available parameter to capture the mean living standard and economic prosperity of a country. According to Daskalopoulos et al. [13], there is a strong correlation between GDP and total consumer expenditure. Finally, Namlis and Komilis [15] reported that most empirical studies show that GDP positively affects the generation of solid waste.

- Socioeconomic Variables

Arbulú et al. [16] and Oribe-Garcia et al. [17] employed a set of socioeconomic variables, such as employment status (level of unemployment), level of education (population with at least upper secondary school and university education), and urban morphology (e.g., the percentage of the total population living in rural areas), to explain solid waste generation.

- The empirical studies carried out by Arbulú et al. [16] and Oribe-Garcia et al. [17] revealed that a higher unemployment rate and education level generate a better environmental outcome. A better education level contributes positively to environmental quality by imparting a culture of "greener" behaviour or commitment (which is related to the technological effect). Oribe-Garcia et al. [17] stated that higher levels of education are related to high levels of awareness on environmental issues. Concerning the unemployment rate, the results showed a positive effect on the environmental outcome through a reduction in consumption capacity (impact on the scale effect). The purchasing power of households with unemployed members is undermined, and thus their consumption.
- Some studies consider the urban population as an independent variable because of their lifestyle, which is different from that of people living in the countryside. The occurrence of commercial activities that generate waste tends to be higher among people living in large cities (e.g., Dahlén et al. [18]). Further, the population that lives in urban areas "*is believed to rely heavily on standard municipal solid waste pickup versus alternative methods of disposal such as backyard disposal or burning*" (Hockett et al. [14], p. 211). However, the variable was not statistically significant in the empirical study conducted by Hockett et al. [14].
- Gender and Age Structure

The impact of gender and age structure of the population on solid waste generation was studied by Beigl et al. [19] and Talalaj and Walery [20]. Beigl et al. [19] found a positive relationship between the percentage of the medium age group (population aged 15 to 59 years) and solid waste generation. According to Daskalopoulos et al. [13], women play an important role in the consumer market, and a good example of this is the more frequent purchase of products through catalogue shopping or home delivery services by the woman population. Therefore, the higher the proportion of goods purchased by women, the higher their rate of waste generation. Finally, Talalaj and Walery [20] showed that a greater number of women in society contribute to greater waste production. Among the women, the greatest waste quantity is generated by the working-age group (women aged 14 to 64 years).

- Typology of Economic Activity

Hockett et al. [14] investigated the contribution of economic activity typology to the production of solid waste. Economic activity is measured through the inclusion of variables that measure retail sales, construction activity, and manufacturing. Hockett et al. [14] emphasised that retail sales are also a measure of tourism. Oribe-Garcia et al. [17] used the density of retail outlets and occasional goods outlets (‰ inhabitants) as proxies for commercial activity. To measure the general industrial activity, which contributes with packaging or scrap to waste generation, Hockett et al. [14] used the added value of goods manufactured by companies in a given region. Construction costs are included in the equation estimated by the authors in order to account for construction and demolition debris deposited in the landfill. According to a recent study by the European Commission, construction and demolition waste is the largest stream of all solid waste generated in the EU (European Commission [21]).

- Economic Crisis

Namlis and Komilis [15] studied the impact of the economic crisis on solid waste generation in Europe. According to the authors, a negative impact of the economic crisis on waste production was expected, given its impact on the deterioration of the standard of living. Their results showed that in most European countries in which there was a decrease in the GDP, there was a concurrent decrease in the generation of most waste streams. The exceptions are Portugal and Greece, where some waste streams have increased during the economic crisis.

- Tourism

A few empirical studies include a proxy for tourist activities in their estimation models of waste solid generation (exceptions are Hockett et al. [14]; Mateu-Sbert et al. [2]; Oribe-Garcia et al. [17]; Arbulu et al. [4,5]; Estay-Ossandon and Mena-Nieto [4]). In all these empirical studies, it is concluded that an increase in the flow of tourists causes an increase in the production of solid waste. As explained by Hockett et al. [14], p. 211, "*tourists spend considerable amounts of money on food, clothing, and merchandise which generate packaging, shipping, food, and other waste*". Thus, due to the scale effect, a greater flow of tourists implies the existence of a greater number of tourists per resident and, consequently, greater production of solid waste per resident. However, different proxies have been used to measure the impact of tourist activity on solid waste generation. These include retail sales (e.g., Hockett et al., 1995), tourist expenditure (e.g., Arbulu et al. [4,5]), inbound tourist arrivals (e.g., Mateu-Sbert et al. [2]; Arbulu et al. [16]; Estay-Ossandon and Mena-Nieto [4]), and spaces for tourist accommodation (‰ inhabitants) (e.g., Oribe-Garcia et al. [17]).

Filimonau and De Coteau [22]) reported that the EU hospitality sector is responsible for about 12% of the overall food waste (third largest figure) and is likely to be an underestimated indicator, since it does not include retail catering (e.g., coffee shops) and contract catering (e.g., work and hospital canteens). According to the authors, "*avoidable food waste in the UK hospitality sector occurs at the preparation (45%) and consumption (34%) stages but is also due to spoilage (which includes food that has passed its 'use by' date) in the process of handling (21%)*" (p. 237). Outside Europe, we find an identical picture, with Liu [23] and Papargyropoulou et al. [24] noting that the hospitality sectors in China and Malaysia produce more food waste than households.

- Finally, Arbulu et al. [16] demonstrated the existence of a non-linear and significant effect of tourist arrivals and expenditure per tourist on solid waste generation. In addition to the scale effect mentioned above, which explains the positive coefficient found for the linear term, the results revealed the existence of a negative coefficient associated with the quadratic term. This negative coefficient associated with the quadratic term is the result of the counterbalancing technological effect that may come from changes in the characteristics of tourism companies. This non-linear effect on solid waste generation was also observed by Mihalič [25], Mensah [26], and Han and Kim [27]. According to these authors, there is a tendency for internationalisation of tourism companies and tourism supply, which are dominated by chain hotels, as a result of the increase in the number of tourists in the destination, with the following positive consequences for environmental protection: (*i*) international and chain hotel managers tend to pay greater attention to environmental issues; (*ii*) international hotel chains can more readily implement environmental protection programmes than many small and independent hotels, even if there is great concern for environmental issues in these small hotels; and (*iii*) international hotel chains have a greater ability to replicate successful programmes of environmental protection implemented in other destinations.

3. Data

To study the impact of tourism on the production of solid waste in Madeira Island, we collected data on solid waste generation, tourist activities, and other control variables for Madeira Island between 1996 and 2018. The period considered in the analysis comprises the entire period of data available from the Regional Directorate of Statistics of Madeira on the production of solid waste, tourist activities and other control variables. Annual data are used in the analysis. Given the low levels of seasonality in Madeira (e.g., Almeida et al. [28]), such as in other essential beach destinations, the use of annual data for analysis is not a problematic issue. Currently, Madeira offers a wide range of events that take place throughout the year, such as Carnival, Flower Festival, and Atlantic Festival (e.g., Almeida et al. [29]). All variables used in the estimation of the model were obtained from the Regional Directorate of Statistics of Madeira (https://estatistica.madeira.gov.pt/en/ (accessed on 23 March 2020)). In the estimation model, a wide range of information on socioeconomic characteristics of Madeira Island and characteristics related to the tourism sector is used. The variables are shown in Table 1, where they are defined and explained.

Table 1. Data Description. This table present for the dependent variable (solid waste generation) and most representative groups of explanatory variables (socio-economic indicators), their definition/description and acronyms.

Socio-Economic Indicators	Variable	Definition/Unit (according to Regional Directorate of Statistics of Madeira)	Acronym
		Dependent Variable	
	Waste Generation per capita	Overall solid Waste Production in Madeira Island (kg per capita * year)	SWG
		Explanatory Variables	
Economic Dynamism and Resources of Population	Real GDP per capita	Annual Gross Domestic Product per Inhabitant (thousand Euros)	GDP_PC
	GDP per capita in PPP	Annual Gross Domestic Product per Inhabitant in Purchasing Power Parity—EU28 (index)	GDP_PPP
	Available Personal Income	Annual Gross Disposable Income per Inhabitant (thousand Euros)	INC
	Employment Rate	Ratio between Employed Population and Working Age Population (%)	EMP
Economic Structure	GVA in Construction	Annual Gross Value Added in Construction Industry (thousand Euros)	GVA_CONS
	GVA in Trade, Transportation and Accommodation	Annual Gross Value Added in Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles; Transportation and Storages; Accommodation and Food Service Activities Industry (thousand Euros)	GVA_TTA
	Cement Sales	Cement Sales in Madeira (tonnes)	CEM
Tourist Activity	Guests Lodged	Guests Lodged in Tourism Accommodation (number)	T_GL
	Overnight Stays	Overnight Stays in Tourism Accommodation (number)	T_OS

Table 1. *Cont.*

Socio-Economic Indicators	Variable	Definition/Unit (according to Regional Directorate of Statistics of Madeira)	Acronym
Education, Gender and Age Structure	Population	Resident Population in Madeira (number)	POP
	Level of Education	Share of Resident Population that have completed at least upper secondary education (%)	EDUC
	Woman Population	Share of Resident Woman Population in Madeira (%)	WOM
	Working Age Group	Share of Resident Population Aged between 15 and 64 years (%)	W_AG
Urban Population	Funchal Population	Share of Resident Population Living in Funchal (%)	FUN
Economic Crisis	Economic Crisis Dummy	Economic Crisis Dummy	EC_D

* Per capita calculation is based on annual average population (Source: Regional Directorate of Statistics of Madeira).

In this study, we use three different proxies for income: real GDP per capita, GDP per capita based on PPP (purchasing power parity index), and disposable income. Instead of using the unemployment rate (a long series of these data is not provided by the Regional Directorate of Statistics of Madeira), the employment rate (the ratio of employed population to working-age population) is used in the estimation model.

As proxies for economic structure, we use the gross value added in the two main industries of Madeira Island: (*i*) construction and wholesale and retail trade, repair of motor vehicles and motorcycles, transportation, and storage, and (*ii*) accommodation and food service activities industry. We have seen in the literature review (under "Typology of Economic Activity" of Section 2.2.2) that construction waste is the largest stream of solid waste in the EU. Additionally, we use the quantity of cement sold on Madeira Island as a proxy for the civil construction activities carried out on the island.

Two different variables are used as proxies for tourist activities: guests lodged and overnight stays in tourism accommodation. To measure the impact of education level, gender, and age structure on the production of solid waste, the following three variables are included in the model: level of education, woman population, and "working-age" population. Finally, it is important to mention the potential impact of the financial crisis on waste production, as well as of population dynamics on the island of Madeira and its capital, Funchal. The latter variable aims to capture the contribution of the urban population to the production of solid waste, since having a different lifestyle from that of people living in the countryside, they are expected to produce a higher quantity of solid waste.

Table 2 presents the descriptive statistics for the variables used in the estimation model.

Table 2. Descriptive Statistics. This table shows the descriptive statistics—mean, standard deviation, minimum, maximum, skewness and kurtosis, of the variables used in the estimation model.

Acronym	Variable	Mean	Standard Deviation	Minimum	Maximum	Skewness	Kurtosis
SWG	Waste Generation per capita (kg)	641.27	57.69	547.35	743.82	0.451	2.616
GDP_PC	Real GDP per capita (thousand Euros)	14.48	2.15	11.15	17.21	−0.214	1.549
GDP_PPP	GDP per capita in PPP (index)	76.56	3.38	71.90	82.50	0.031	1.686

Table 2. *Cont.*

Acronym	Variable	Mean	Standard Deviation	Minimum	Maximum	Skewness	Kurtosis
INC	Available Personal Income (thousand Euros)	10.59	1.03	8.61	11.75	−0.513	1.944
EMP	Employment Rate (%)	69.88	6.03	59.37	76.89	−0.780	1.989
GVA_CONS	GVA in Construction (thousand Euros)	306.33	68.56	205.03	410.33	−0.043	2.000
GVA_TTA	GVA in Trade, Transportation and Accommodation (thousand Euros)	1066.30	163.35	812.38	1302.57	−0.130	1.845
CEM	Cement Sales (tonnes)	411,487.7	212,206.6	99,043.0	774,594.7	−0.065	2.257
T_GL	Guests Lodged (thousand)	1098.42	176.31	884.88	1487.49	1.261	3.477
T_OS	Overnight Stays (thousand)	5981.86	889.46	4993.56	7943.99	1.281	3.508
POP	Population (number)	254,410	6685	243,487	267,340	0.130	2.160
EDUC	Level of Education (%)	56.60	6.00	47.87	65.82	0.259	1.675
WOM	Woman Population (%)	52.95	0.22	52.71	53.35	0.845	2.318
W_AG	Working Age Group (%)	68.05	1.09	66.80	69.70	0.588	1.774
FUN	Funchal Population (%)	42.09	0.66	40.99	42.72	−0.910	2.194
EC_D	Economic Crisis Dummy	0.22	0.242	0	1	3.750	15.063

4. Fully Modified OLS Model

Navarro-Esbrí et al. [30] presented some forecasting techniques for solid waste management when time series are used in the analysis. The authors emphasised the importance of studying the stationarity of the time series used in the analysis. Despite that, the studies mentioned in the previous section used time series, which by their nature tend to be non-stationary, as is the case for the variables of personal income, tourist activity, and per capita production of solid waste, no stationarity test was performed for the time series used in the estimation.

- As explained by Engle and Granger [31], the results obtained by regression with non-stationary time series may be spurious and lead to poor understanding and forecasting. To obtain consistent and reliable results, non-stationary data must be transformed into stationary data. If a certain linear combination of these time series is stationary, the non-stationary time series is said to have a cointegration relationship. The stationary linear combination (cointegrating equation) may be interpreted as a long-run equilibrium relationship between time-series variables. If there is a stationary linear combination among the time series, the fully modified OLS (FMOLS) model proves to be a fully efficient method of estimation.

4.1. Unit Root Tests

Testing stationarity is equivalent to examining whether there is a unit root in the time series. EViews, a statistical package for time-series-oriented analysis, provides six different tests for the presence of a unit root in time series: (*i*) Augmented Dickey–Fuller test (ADF) (Dickey and Fuller [32]); (*ii*) Phillips–Perron test (PP) (Phillips and Perron [33]); (*iii*) Dickey–Fuller test with GLS Detrending (DFGLS) (Elliot et al. [34]); (*iv*) Kwiatkowski, Phillips, Schmidt and Shin test (KPSS) (Kwiatkowski et al. [35]); (*v*) Elliot, Rothenberg and Stock Point Optimal test (ERS) (Elliot et al. [34]); and (*vi*) Ng and Perron test (NP) (Ng and Perron [36]).

- Table 3 presents the results of the unit root tests. The results show that solid waste generation and economic-related time series (personal income, economic structure, and tourist activity) have a non-stationary nature. They also show that the time series can be transformed into a stationary one after the first difference. The remaining time series, related to population, education, gender, and age structure, are stationary in level.

Table 3. Unit Root Tests Results. 1. Except for the KPSS unit root test, in all the other five unit root tests, the null hypothesis is that the time series is non-stationary (time series has a unit root), against the hypothesis H1 of (trend-)stationary series. The KPSS unit root test has as hypothesis H0 the (trend-)stationarity of time series, against the hypothesis H1 of non-stationary series. The values presented are those of the test statistic output and respective level of statistical significance. *** and ** denote statistical significance at 1% and 5%, respectively.

Acronym		ADF	PP	DFGLS	KPSS	ERS	NP
SWG	Level	−1.173	−1.145	−0.959	0.585 ***	15.298	12.361
	1st difference	−4.905 ***	−4.879 ***	−4.835 ***	0.900	2.075 **	2.121 **
GDP_PC	Level	−2.048	−1.862	−0.483	0.612 ***	197.147	12.566
	1st difference	−3.971 ***	−3.913 ***	−3.053 ***	0.839	2.540 **	2.761 **
GDP_PPP	Level	−2.017	−2.017	−1.432	0.232 ***	23.889	14.615
	1st difference	−3.488 **	−3.495 **	−3.572 ***	0.750	2.252 **	2.462 **
INC	Level	−2.456	−2.303	−0.659	0.548 ***	133.352	5.848
	1st difference	−9.287 ***	−3.475 **	−9.288 ***	0.759	2.109 **	2.726 **
EMP	Level	−0.371	−0.606	−1.566	0.562 ***	30.975	4.202
	1st difference	−2.914 **	−2.834 **	−2.847 ***	0.785	2.470 **	3.079 **
GVA_CONS	Level	−1.977	−1.467	−1.655	0.173 ***	6.452	5.208
	1st difference	−5.764 ***	−8.855 ***	−2.545 **	0.773	2.904 **	2.176 **
GVA_TTA	Level	−1.616	−1.651	−0.152	0.204 **	101.336	8.046
	1st difference	−5.003 ***	−4.991 ***	−5.126 **	0.761	2.315 **	2.462 **
CEM	Level	−1.415	−1.511	−1.160	0.233 ***	13.825	10.930
	1st difference	−5.824 ***	−5.824 ***	−5.814 ***	0.857	1.194 ***	1.207 ***
T_GL	Level	1.209	0.978	0.881	0.224 ***	138.415	31.187
	1st difference	−4.521 ***	−4.524 ***	−4.450 ***	0.819	1.588 ***	1.477 ***
T_OS	Level	0.834	0.735	1.753	0.176 ***	107.955	69.172
	1st difference	−5.126 ***	−5.092 ***	−4.695 ***	0.815	1.794 ***	1.418 ***
POP	Level	−5.436 ***	−3.779 ***	−4.212 ***	0.839	1.050 ***	0.793 ***
EDUC	Level	−3.413 **	−3.463 **	−3.393 ***	0.757	2.031 **	3.065 **
WOM	Level	−7.431 ***	−4.939 ***	−7.021 ***	0.649	0.608 ***	0.660 ***
W_AG	Level	−3.988 ***	−3.608 **	−2.362 **	0.694	1.526 ***	1.189 ***
FUN	Level	−2.825 **	−3.127 **	−2.619 **	0.702	1.532 ***	0.734 ***

4.2. Single-Equation Cointegration Tests

To test whether the model to be estimated, which includes non-stationary variables, presents a stationary linear combination (cointegration equation), we performed the Engle and Granger [31] and Phillips and Ouliaris [37] single-equation residual-based cointegration tests.

The results of the single-equation cointegration tests are shown in Table 4. Here, we see that both test results are broadly similar for the time series used, with the *tau*-statistic uniformly failing to reject the null of no cointegration at the conventional level for the Engle and Granger [31] and Phillips and Ouliaris [37] tests. The results for the *z*-statistics are mixed, with the residuals of three time series in both tests rejecting the unit root null at the 5% level. On balance, however, the test statistics suggest that we cannot reject the null hypothesis of no cointegration.

Table 4. Single-Equation Residual-Based Cointegration Tests. Table presents Engle and Granger [31] and Phillips and Ouliaris [37] residual-based cointegration tests. For both tests, we present *tau*-statistic (t-*statistic*) and normalized autocorrelation coefficient (which we term the *z*-statistic) for residuals obtained using each time series presented in Table 1 in the group as the dependent variable in a cointegration regression. Null hypothesis: the series are not cointegrated.

Acronym	Engle and Granger [31] Test				Phillips and Ouliaris [37] Test			
	Tau-Statistic	Prob.	z-Statistic	Prob.	Tau-Statistic	Prob.	z-Statistic	Prob.
SWG	−4.745	0.7574	−15.438	0.2100	−4.370	0.8499	−13.607	0.9971
GDP_PC	−5.112	0.6538	−17.241	0.1982	−7.199	0.1551	−18.451	0.3063
GDP_PPP	−4.549	0.8066	−18.434	0.4731	−5.064	0.6612	−15.302	0.9830
INC	−5.037	0.6754	−15.188	0.2002	−5.267	0.5996	−15.055	0.9978
EMP	−4.454	0.8304	−17.917	0.2585	−4.879	0.7157	−15.158	0.9880
GVA_CONS	−5.055	0.6639	−19.949	0.2043	−5.811	0.4390	−16.855	0.9259
GVA_TTA	−5.009	0.6837	−55.460	0.0000	−4.223	0.8807	−12.887	0.0357
CEM	−3.362	0.9824	−13.483	0.1418	−3.455	0.9771	−12.635	0.0319
T_GL	−4.850	0.7290	−11.612	0.3205	−4.755	0.7508	−14.199	0.9980
T_OS	−4.900	0.7147	−52.451	0.0000	−4.724	0.7592	−14.114	0.0524
POP	−4.573	0.8003	−18.364	0.3329	−5.083	0.6557	−15.391	0.0762
EDUC	−3.513	0.9715	29.641	0.0000	−4.424	0.8375	−12.906	0.0358
WOM	−4.823	0.7319	−19.019	0.2917	−5.427	0.5506	−16.169	0.1306
W_AG	−5.042	0.6741	−13.018	0.3915	−3.846	0.9408	−12.297	0.9993
FUN	−4.777	0.7489	−19.704	0.1720	−5.103	0.6494	−15.021	0.0647
EC_D	−5.282	0.5952	−20.911	0.0797	−5.622	0.4934	−19.710	0.2332

4.3. Fully Modified OLS Model

Engle and Granger [31] noted that a linear combination of two or more non-stationary series may be stationary, or I(0), a situation where we can say that the time series are cointegrated. Such a linear combination defines a cointegrating equation, with the cointegrating vector of weights characterising the long-run relationship between the variables. Despite the existence of non-stationary series in the estimation model, the tests performed in the previous section confirm that the linear combination of these variables is stationary. The fully modified OLS (FMOLS) model is a fully efficient estimation method for estimating a single cointegrating vector (see Phillips and Hansen [38]).

Thus, we use the FMOLS estimator to estimate the determinants of solid waste production. For this purpose, the following single cointegration regression will be estimated as our baseline estimation:

$$SWG = \beta_1\, GDP + \beta_2\, EMP + \beta_3\, ES + \beta_4\, TA + \beta_4\, TA + \beta_5\, POP + \beta_6\, EDUC + \beta_7\, WOM + \beta_8\, W\_AG + \beta_9\, FUNC + \beta_{10}\, EC\_D + \varepsilon \quad (1)$$

where *SWG* is the solid waste generation per capita; *GDP* is any of the following variables related to economic dynamism: *GDP_PC*, *GDP_PPP* or *INC* (defined in Table 1); *EMP* is the employment rate; *ES* is any of the following variables related to economic structure: *GVA_CONS*, *GVA_TTA* or *CEM* (defined in Table 1); *TA* is any of the following variables related to tourist activity: *T_GL* or *T_OS* (defined in Table 1); *POP* is the resident population in Madeira; *EDUC* is the level of education; *WOM* is the percentage of woman population; *W_AG* is the percentage of working-age population; *FUNC* is the percentage of the population living in Funchal; *EC_D* is the economic crisis dummy; ε is a random error term; and β are parameters to be estimated. To test the robustness of the model, we use different proxies for economic dynamism, economic structure, and tourist activity.

Finally, we extend Equation (1) by regressing solid waste generation on *T_GL* (total guests lodged) and $(T\_GL)^2$ to test the existence of a non-linear effect on solid waste generation.

5. Empirical Results

The empirical results for linear single cointegration regression are reported in Table 5. The results are based on 23 annual observations (from 1996 to 2018). Eight specifications are presented. The real GDP per capita is used as a proxy for residents' income in the first four specifications. The GDP per capita based on purchasing power parity (PPP) is used as a proxy for residents' income in specifications V and VI. In the last two specifications, available personal income is used as a proxy for residents' income. To test the robustness of the results, different proxies of economic structure and tourist activities are used in the various specifications.

As expected, the results show a positive and statistically significant effect of the variables associated with per capita income, employment rate, and construction activity on solid waste generation. The higher the population's income and employment rate, the greater their capacity to consume goods and services and, in turn, to generate solid waste. Since the European Commission [21] has shown that construction and demolition waste is the largest stream of all solid waste generated in the EU, the results found for this variable can be explained based on this evidence.

Furthermore, a positive and statistically significant effect was found in most of the estimations for the variables associated with gender and age. It seems evident that there is a greater production of solid waste per capita as the percentage of women and middle-aged population increases in the resident population. Empirical evidence demonstrates that women play a more active role in the consumer market, making more frequent purchases of products through catalogue shopping or home delivery services. The positive impact of the working-age group on solid waste production is explained by their greater purchasing power. Similar results were obtained by Beigl et al. [19] and Talalaj and Walery [20].

However, for some variables, we found no evidence of a statistically significant impact on solid waste generation. This is the case for population (*POP*), education level (*EDUC*), percentage of the population living in the main city of Funchal (*FUN*), and economic crisis dummy (*EC_D*). Although several studies have shown a positive impact of population on solid waste generation, Hockett et al. [14] pointed out that when the quantity of waste generated is presented on a per capita basis, as is the case in the current study, there may be no relationship between population and waste solid generation. These authors also did not find empirical evidence that inhabitants of big cities (urban population) show a different lifestyle than those of the countryside. Regarding the level of education, we cannot conclude from the results that a higher education level leads to a better environmental outcome, for example through boosting "green" behaviour or commitment. In our view, an increase in education level puts two conflicting realities in confrontation: on the one hand, an increase in the number of residents concerned about their environment and willing to adopt or commit to a "green" behaviour, and on the other hand, given the increase in wages because of greater education, there is pressure for greater consumption, which leads to production of more solid waste. Lastly, it was expected that there would be a reduction in the production of solid waste due to the deterioration of the quality of life during the economic crisis, but this situation could not be confirmed. As explained by Namlis and Komilis [15], this may be because of the empirical evidence that in Portugal and Greece some waste streams have increased during the economic crisis.

Table 5. Estimation Results by FMOLS. This table reports the estimation results by FMOLS for overall solid waste production per capita (SWG) in Madeira based on Equation (1). The definition and description of each explanatory variable used to estimate the model is presented in Table 1. ***, ** and * denote statistical significance at 1%, 5% and 10% levels, respectively.

Variables	I		II		III		IV		V		VI		VII		VIII	
	Coef.	T-Stat.	Coef.	T-Stat.	Coef.	T-Stat.	Coef.	t-Stat.	Coef.	t-stat.	Coef.	t-stat.	Coef.	T-Stat.	Coef.	T-Stat.
GDP_PC	7.949 ***	4.229	6.327 ***	3.687	13.091 ***	3.896	19.268 ***	4.187								
GDP_PPP									5.512 ***	2.828	6.560 ***	4.580				
INC													0.022 **	2.481	0.019 **	2.721
EMP	6.371 ***	5.344	3.159 **	2.448	2.372 ***	3.152	2.949 ***	2.887	4.932 ***	3.786	4.048 ***	3.834	1.508 **	2.447	1.618 **	2.575
GVA_CONS			0.200 *	1.859												
CEM	0.001 *	1.803			0.001 ***	2.731	0.001	2.893 ***	0.001 **	2.740	0.001 **	2.859	0.001 ***	3.277	0.001 ***	3.041
GVA_TTA							0.216	2.986 ***								
T_GL					0.245 ***	3.385					0.318 ***	7.611			0.372 ***	4.673
T_OS	0.053 ***	8.040	0.061 ***	6.502					0.068 ***	8.229			0.071 ***	4.630		
POP	0.004	0.655	0.002	0.325	0.001	1.560	0.001	1.123	0.002	0.426	0.004	1.176	0.001	0.148	0.001	0.261
EDUC	2.395	0.647	1.821	0.587	2.864	0.761	0.908	0.353	2.395	0.647	2.350	0.684	2.186	0.796	1.825	0.707
WOM	1.318 *	1.925	0.6261	0.826	1.427 *	1.890	1.233 *	2.118	1.382 *	1.925	1.361 *	2.051	1.542 **	2.454	1.144 *	2.049
W_AG	1.173 **	2.683	1.319 ***	3.219	1.354 **	2.662	1.304 **	2.930	1.173 **	2.683	1.249 **	2.764	1.290 ***	3.223	1.114 **	2.672
FUN	0.584	0.089	1.201	0.252	0.532	0.905	0.167	0.295	0.584	0.898	1.032	0.180	0.262	0.497	0.359	0.769
EC_D	−1.097	−0.460	0.609	1.609	0.230	1.175	0.341	1.521	1.097	0.460	0.790	0.338	0.499	1.544	0.353	1.642
#Observations	23		23		23		23		23		23		23		23	
Adj. R^2 (%)	83.40		84.47		84.68		81.81		84.76		84.72		83.38		83.80	

Finally, the results show a positive and statistically significant impact of tourist activities on solid waste generation. The three proxies used to measure tourist activities (*GVA_TTA*; *T_GL* and *T_OS*) have a level of statistical significance of 1%. The scale effect is observed in the present study, in which a greater flow of tourists implies the existence of a greater number of tourists per resident and, consequently, greater production of solid waste per resident. The results show that, for long-term equilibrium, there was an increase in solid waste generation of between 0.245 kg and 0.372 kg per capita for each increase of 1000 tourists (*T_GL*) in Madeira. In the analysed period, Madeira recorded an average tourist population of 1,098,420 (see Table 2). This means that their contribution to the generation of waste per capita was between 1098.42 × 0.245 = 269 kg and 1098.42 × 0.272 = 298.8 kg per year. Given that the average production of solid waste per resident in Madeira was 641.27 kg, tourist activities were responsible for 41.9% to 46.6% of overall solid waste produced per inhabitant. In 2018, EUR 17,659,000 were spent on solid waste management in Madeira, which means that tourists should have been charged between EUR 7399,121 (17,659,000 × 0.419) and EUR 8229,094 (17,659,000 × 0.466). The cost that tourists should have been charged per overnight stay in 2018 is between EUR 0.88 and EUR 0.98, since there were 8,382,384 overnight stays in that year.

We also tested the possibility of the existence of a non-linear effect on solid waste generation. The results confirm this non-linear behaviour. According to the empirical results presented in Table 6, tourism inflows cause a significant increase in the generation of solid waste until a turning point is reached, from when the increase in tourism inflows leads to a reduction in solid waste generation. The turning points were reached when there were between 2116.5 and 2323 thousand lodged guests. Given that in 2018 the number of guests lodged was 1,607,899, the increase in the number of tourists would continue to cause an increase in solid waste until the turning point is reached. This non-linear effect on solid waste generation may be the result of two factors: on the one hand, a scale effect that predicts that increases in tourism inflows will cause an increase in solid waste per resident and, on the other hand, a counterbalancing technological effect as a result of changes in the policies and conduct of tourism companies with increase in tourist arrivals to a destination. Similar results were obtained by Arbulu et al. [16], Mihalič [25], Mensah [26], and Han and Kim [27]. As described in the literature review section, the positive coefficient in the linear term is explained by the scale effect and the negative coefficient associated with the quadratic term is the result of the counterbalancing technological effect.

Table 6. Non-Linear Estimation on Solid Waste Generation. This table presents the estimation results by FMOLS of non-linear estimation on overall solid waste production per capita (SWG) in Madeira. The definition and description of each explanatory variable used to estimate the model is presented in Table 1. ***, ** and * denote statistical significance at 1%, 5% and 10% levels, respectively.

Variables	I		II		VI	
	Coef.	T-Stat.	Coef.	T-Stat.	Coef.	T-Stat.
GDP_PC	6.7643 **	2.474				
GDP_PPP			1.4214 **	2.485		
INC					0.0252 ***	3.215
EMP	2.5485 **	2.212	3.8819 ***	4.057	2.7624 **	2.318
CEM	0.0002 ***	3.511	0.0002 ***	4.054	0.0002 ***	3.644
T_GL	0.8466 ***	4.105	0.9292 ***	4.639	0.9094 ***	3.483
T_GL^2	−0.0002 ***	−3.209	−0.0002 ***	−3.056	−0.0002 **	−2.176
POP	0.0027	0.392	0.0052	1.552	0.0006	0.118
EDUC	3.3938	0.942	3.3252	0.854	1.1841	0.338
WOM	1.1929 *	1.955	1.2381 *	1.955	1.1372 *	1.921
W_AG	1.2195 **	2.460	1.2213 **	2.763	1.1723 **	2.621
FUN	0.5151	0.908	0.2755	0.484	0.4922	0.911
EC_D	0.3189	1.407	0.4055	0.713	0.4595	1.205
# Observations	23		23		23	
Adj. R^2 (%)	86.27		85.76		83.62	
Turning Point: Guests Lodged (thousand)	2116.5		2323.0		2273.5	

6. Conclusions

This study aims to investigate the impact of tourist activities on solid waste generation in Madeira for the period 1996–2018. A fully modified OLS (FMOLS) model has been applied to study the determinants of solid waste generation, given that most of the variables used in the estimation model are non-stationary but cointegrated in a single equation.

We conclude that solid waste generation is significantly and positively affected by variables associated with per capita income, employment rate, and construction activity. There is also a positive and statistically significant relationship between solid waste generation and the percentage of women and the middle-age population. However, for some variables, we found no evidence of a statistically significant impact on solid waste generation. This is the case for such variables as population, education level, percentage of the population living in the main city Funchal (proxy for urban population), and economic crisis dummy. A key finding of the study is the positive and statistically significant impact of tourist activity on solid waste generation. The results show that tourism activities are responsible for 41.9% to 46.6% of solid waste per resident in Madeira. It has been deduced from these results that tourists should be charged between EUR 0.88 and EUR 0.98 per overnight stay in Madeira. The empirical results also support the hypothesis that there is a non-linear effect of tourist activities on the generation of solid waste. This non-linear effect on solid waste generation may be the result of two factors: on the one hand a scale effect that predicts that increases in tourism inflows will cause an increase in solid waste generated per resident and, on the other hand, a counterbalancing technological effect as a result of changes in the policies and conduct of tourism companies with increase in tourist arrivals to a destination.

This study has various practical and political implications. First, it can help with the planning of waste collection services and waste infrastructure in tourist areas. Second, the results show that it is important to internalise the negative external environmental impacts caused by tourism by adopting appropriate economic instruments and policies. Limiting the number of permits to operate in the sector, Pigouvian taxes, and restrictions on land use are among the policy instruments mostly used by the authorities to achieve the social optimum, in the presence of negative externalities. In the present study, we conclude that tourists should be charged between EUR 0.88 and EUR 0.98 per overnight stay in Madeira, because of the extra cost of solid waste disposal accrued by residents due to these overstays. Third, the study shows the importance of designing sustainable tourism policies and marketing campaigns that encourage a more pro-environmental behaviour by tourists, which can be as effective as market-based policies such as environmental taxes (Araña and León [39]). Additionally, zero-waste (ZW) initiatives could reduce much of the waste produced (e.g., Pietzsch et al. [40]). According to the authors, there are critical success factors for an effective and efficient ZW implementation. The first is the substantial change in citizens' and tourist behaviour and consumption patterns. However, this can also be extended to managers, as was evident in a study by Filimonau and De Coteau [22]. Second, the authors referred to the need for correct regulation of rates and financial incentives.

Fourth, given the non-linear effect of tourist activities on solid waste generation and the counterbalancing technological effect that may be the result of changes in the characteristics of tourism companies, there should be lower environmental taxes for tourists staying in international and chain hotels and green hotels (eco-friendly lodging property), since in these hotels there is great concern for the environment.

Our investigation directly indicates some lines of interesting future research. Our results suggest that tourists should be charged between EUR 0.88 and EUR 0.98 per overnight stay in Madeira, because of the extra cost of solid waste disposal accrued by residents due to these overstays. However, as mentioned by Palmer and Riera [1], given the difficulty in calculating the private marginal benefits of tourist activities, we cannot conclude that these amounts are the values that tourists should be charged for the solid waste generated. An integrated view of these aspects could help to define the optimal Pigouvian rate to be implemented. In this paper, we have focused on solid waste costs. Another important issue to investigate in the future is the adequacy of environmental taxes imposed on tourists by municipalities in the Madeira region. Some municipalities in the region have approved a tourist tax of EUR 2 that will be used for the city's development in three main areas—infrastructural improvement of tourist areas, co-financing of city management activities, and financing of the so-called "social distortion program". We are currently analysing the impact of tourism on housing prices for a different study, so in the future, it will be possible to carry out an integrated analysis of the reasonableness of tourist tax charged. Studies on other negative externalities caused by tourism will make it possible to analyse the suitability of tourist rates. Even so, this analysis will be limited, given the difficulty in calculating the private marginal benefits of tourism activities.

Further research studies should also study the impact of the COVID-19 pandemic on solid waste generation. As explained by Lew et al. ([41] p. 456), "*travel and tourism may* *be the single most impacted sector of the global economy under the COVID-19 pandemic*". While many still hope to return to "business as usual" as soon as everything is over, others are seriously doubting that this will be possible. If tourism does not return to "business as usual", does it make sense to continue to charge the tourist rates previously determined, given the foreseeable reduction in waste produced by tourists?

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