The Economic and Environmental Effects of Seasonality of Tourism: a loo k at Solid Waste

The Economic and Environmental Effects of Seasonality of Tourism: a Look at Solid Waste

Vincenzo Caponi, University of Sassari, CREST, IZA

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Abstract

Tourism brings great opportunities of growth with relatively small investments in physical and human capital, but it also comes with important negative externalities. This paper looks at the environmental cost of tourism in terms of solid waste produced in municipalities. Using the Data Envelopment Analysis developed by Charnes et al. (1978) and Banker et al. (1984), the paper estimates the efficiency of Tuscan municipalities in waste management and relates this measure to spatial and touristic variables. The scale of operations is also considered to see if tourism seasonality has an impact on the ability to operate at optimal scale. The empirical analysis suggests that seasonality has a negative effect on the efficiency of solid waste management and that this effect is primarily due to difficulties in operating at optimal scale. The seasonality of presences has a strongly negative impact on efficiency while tourists' average stay has a positive effect once scale effects are considered. The implications are that more effort should be made to flexibly manage waste collection in localities affected by seasonal tourism and reduce seasonality by incentivizing visitors to stay longer, for example by introducing a flexible tourist taxation as a function of presences and duration of stay.

Keywords: Sustainable tourism; Seasonality; Quantitative research; Indicators; Environmental impact assessments.

JEL codes: Q51; Q53; L83

1 Introduction

Tourism, unlike many traditional service sectors of the economy, relies heavily on public goods and/or produces a great deal of externalities.[1]

This paper looks at the effect that tourism has on the efficiency of solid waste management in the municipalities of the Italian region of Tuscany. The focus is on characteristics of tourism that might exacerbate the effect due to increased presences at certain times of the year (seasonality of tourism), and its impact on the ability of municipalities to manage the collection and recycling of solid waste. Seasonality in tourism is seen as a problematic feature for economic activities, and also for the communities of locations that are most affected by it. Businesses, such as hotels, restaurants, and others within the tourism sector, are unable to take full advantage of their investments for most of the year when presences are low, while communities might endure for a short period each year the negative effects of a highly concentrated flow of tourists, such as on traffic congestion, water supply, and waste management. Seasonality of tourism also requires extra effort by local administrations that need to provide for services including policing, traffic control, water management, and solid waste management.[2] The purpose of this paper is to look at this latter effect of tourism seasonality and how it affects the efficiency of waste collection and recycling. This is an important issue because decisions about waste management are often made following "best practices" that are not always efficiently applicable to all municipalities and do not take into account characteristics that may require different policies.

2 Literature Review

The relationship between tourism and the environment is subject to a large body of literature in a variety of disciplines. Within the economics of tourism, the environment is seen as a resource and, focussing on sustainable tourism, as a strategy for competitiveness (see for example Hunter (1997), Wunder (2000), Hassan (2000), and De Leaniz and del Bosque (2015) among others). In this way, the costs associated with pollution, the use of natural resources, and more generally the impact of these on the physical environment have also been studied and policies that address these issues have been

[1] See Briassoulis (2002) and Capo et al. (2007), among others, for the extensive use of natural resources and environmental externalities that can lead to over-tourism and hinder the potential of economic growth. See also Sheng and Tsui (2009) for a general equilibrium approach to evaluating the negative externalities implied by the massive and relatively sudden inflow of tourists in the area of Macao, China.

[2] For the impacts of seasonality of tourism see, among others, Butler (1998), Lee et al. (2008), Cannas (2012), and especially Commons and Page (2001), for congestion effects, under- and over-utilization of resources, and instability of returns to investments.

proposed.[3]

A recent trend in sustainable tourism has been to take into account an estimate of carbon emission to add, in negative terms, to the Tourism Satellite Accounts (TSA), which is the internationally agreed set of aggregate statistics that measure the added value of the tourism sector in national economies.[4] As an example, Pirani and Arafat (2016) quantified the waste produced at certain events in Abu Dhabi and their footprint in terms of water and kilogram of CO2 produced. In Table 4 of their work, they reported the calculated values that were only related to food waste, i.e., Post-Consumer Food Waste (PCFW). Undoubtedly estimates for this city are not representative for most of the tourism locations in Tuscany, however their exercise was very instructive and showed the important role of food waste in generating a large footprint. According to their calculations, the footprint/guest in terms of kg of CO2 varied from 0.25 for a breakfast buffet at less luxurious property to 9.38 for a lunch buffet at luxurious one. At the extreme, a wedding with 300 attendees would consume as much water as 17,000 people in a normal residential daily life situation.

The effect of tourism on the efficiency of waste management has been the object of other studies. Among many that report case studies of small localities, and often islands, one close to this work is the study conducted by Mateu-Sbert et al. (2013), which focused on the impact on waste production that touristic presences have compared to that of residents. The paper reported an interesting quantification of this impact from which it was also possible to derive the importance of seasonality, even though this was not directly measured. The study was limited to the Spanish island of Menorca but suggestive of a phenomenon that could be more general. The findings were that the impact of tourists on the production of solid waste was slightly lower than that of residents, but that tourists would recycle less (residents recycled 47.3% more than tourists). The latter provided an important indication of possible efficiency problems caused by touristic presences. The study did not address, however, the issue of efficiency in solid waste management, but only its production, and therefore did not consider the issue of seasonality on efficiency that can come as an additional effect of touristic presences unevenly spread over the year, due to difficulties in adjusting the scale of operations. Denafas et al. (2014)

[3] Gössling and Peeters (2015) presented a global assessment of the environmental impact of tourism, including on fresh water, land, and food use, including an evaluation of CO2 emissions. Filimonau et al. (2011) and Filimonau et al. (2014), reported a life-cycle assessment of carbon emissions directly or indirectly related to tourism activities. See also Lenzen et al. (2018) for a detailed global account of carbon emissions by the tourism sector between 2009 and 2013. As examples of mitigation policies to address the environmental cost of tourism Tol (2007) studied the effects of policies generally associated with climate change mitigation, on tourism, while Zhang and Zhang (2018) more recently provided an evaluation of carbon tax policy in the Chinese tourism sector using a Computable General Equilibrium approach.

[4] The TSA standard is a statistical framework developed by the World Tourism Organization (UNWTO), the Organization for Economic Cooperation and Development (OECD), the Office of the European Communities (Eurostat), and the United Nations Statistical Division. See Jones and Munday (2008) and Dwyer et al. (2010) on taking account of carbon footprint within the TSA.

looked at the production of solid waste in four cities in eastern Europe and found that in seasons with high touristic presences production increases significantly, posing the question of how to manage this important fluctuation. The focus of their paper was to find good models for forecasting production, that could also serve to better manage the flow. Greco et al. (2018) also analyzed the effect of tourism on solid waste management, this time on the unit cost per kilogram. They looked at several variables related to tourism and to the collection of solid waste, decomposing the latter variables in different recycling and non-recycling activities. They found a significant impact of tourism on increasing the cost of waste management per unit of waste collected. They looked closely at the relationship between tourism activities and the unit cost of waste management, an important indicator related to the efficiency of managing environmental resources. Their work, however, posed more questions than answers. In particular, why is it that tourism has such a negative impact on waste management efficiency? This is a very important question as it also relates to the possible negative effects that tourism might have on local communities that may have to pay the price of these inefficiencies. Another strand of the literature that focuses on the efficiency of solid waste management exists and is based on Data Envelopment Analysis (DEA).[5] The idea of applying DEA to look at the efficiency of different Solid Waste Management Units, also called Municipal Waste Management Systems (MWMS,) with Italian data was first proposed by Sarra et al. (2017). Using information from ISPRA[6], the same data used in this paper, they calculated scores for the municipalities of Abruzzo, Italy, namely the efficiency scores, and the Scale Efficiency Ratios (SERs) of those municipalities, and related those scores to exogenous variables to look at what could affect inefficiencies and in particular scale inefficiencies in waste management in Italy. Among their variables, geographical indicators such as altitude, population, and income per capita were used, together with tourism, measured as the number of tourist per person in a given year.

2.1 Sources of Data

Data on Tuscan municipalities have been taken from various sources. For waste management, the data come from the Italian National Institute for Environmental Protection and Research (ISPRA), which provides very detailed data on quantities and costs of waste collection by municipalities for most of Italy. It also provides details on how much differentiated waste is collected. Information about municipalities such as population, size in square kilometers, and altitude has been collected from the Italian National Institute of Statistics (ISTAT). All data from ISPRA and ISTAT are annual

[5]See Charnes et al. (1978) and Banker et al. (1984) for an introduction to te DEA method, and Sarra et al. (2017) for an application to solid waste management.

[6]Italian National Institute for Environmental Protection and Research.

and available for recent years up to 2019. Data on tourism flows come from the database of the Region of Tuscany.This database provides data on the arrival and presence of tourists by quarter, which is information used to assess the seasonality of such flows. Since this database contains data on municipalities from 2005 to 2019, an average of the cycles throughout these years, or a shorter recent period where older data not available, used.

The data collected from the above sources are complemented with variables already constructed and available from the Ministry of Finance of Italy, and in particular from the Technical Committee for Standard Needs (CTFS) which has a series of variables on the infrastructure of the Waste Management Plan (WMP) of all Italian municipalities. Variables such as distance to plants (a weighted measure of the distance of a municipality from a series of plants to which waste is transported, as calculated by the CTFS of the Ministry of Finance) and other specific policies adopted by municipalities, such as having waste collection areas and/or door-to-door recycling collection (for Tuscan municipalities) have been used in this study.

In addition to these sources, dummy variables have been constructed that take a value of 1 for municipalities that belong to certain optimal areas as defined by the Regional WMP, the masterplan that provides the general rules that local authorities follow. Tuscany's WMP defines three optimal management areas (ATO in Italian) to which municipalities belong; these areas are the central, coastal and southern areas of Tuscany.[7] Within the ATOs, one or more management companies share infrastructure and are in charge of collecting and transporting differentiated and undifferentiated waste to treating plants. To take into account the possible effects of different business models on the relative efficiency of municipalities, dummies for ATOs are also included among the explanatory variables.

Finally, for the spatial models, a distance matrix used to take into account geographical proximity has been built using travel distances collected from the Google DistanceMatrix API by Google developers.

From the ISPRA dataset, the data collected are from the latest available (2019), however, not all Tuscan municipalities are present across all years, so to increase the sample observations, 2018 have also been collected, although some are still absent and are not included in the analysis. Earlier years are not used as efforts to improve recycling, and therefore efficiency in collecting solid waste, is ongoing, so comparing different municipalities at different points in time does not give a good picture of geographical differences, which is the source of variation exploited in this analysis. Moreover, as

[7] ATO Tuscany Center: includes the municipalities within the provinces of Prato, Pistoia and Florence; ATO Tuscany Coast: municipalities in the province of Pisa, Lucca, Massa Carrara e Livorno (excluding Piombino, Castagneto Carducci, San Vincenzo, Campiglia Marittima, Suvereto e Sassetta, which belong to ATO Tuscany South); ATO Tuscany South: municipalities of the provinces of Siena, Grosseto, Arezzo and the one above excluded from ATO Coastal.

the index of seasonality has been built using quarterly time series of tourist flows, the panel nature of the ISPRA data has not been exploited. Rather, the analysis assumes that the latest available year represents the best effort for making the waste collection process as efficient as possible.

3 Methodology

This section lays down the methodological steps to carry out the analysis of this study. The first step is the computation of the efficiency scores using Data Envelopment Analysis, then the indexes that measure tourism seasonality are explained, finally Ordinary Least Squares (OLS) and Spatial Autoregressive models are briefly introduced and their use justified.

3.1 Data Envelopment Analysis

Data Envelopment Analysis (DEA) is a powerful benchmarking tool that associates the values of arrays of inputs with arrays of outputs and calculates how different decision units compare to one another in terms of the ability to change the composition of inputs (outputs) to obtain the same outputs (inputs). In other words, it identifies the most efficient decision units out of many and scores the others in terms of how far they are from that efficiency. Efficiency is, however, always defined in terms of inputs or outputs and can never be an absolute measure. DEA is a non-parametric approach that is completely agnostic about the functional form of the production system. It is also possible to calculate efficiency by imposing the same scale to all units under investigation or leaving the units free to operate at different scales; those different measures give the idea of how far one unit can be from its optimal scale and how much that costs in terms of efficiency. In this sense, in the literature on DEA benchmarking, another index called Scale Efficiency Ratio (SER) is used and is computed as the ratio between the score of the overall efficiency of the Decision Management Unit (DMU) j and the score of the efficiency at the given scale of production of the same unit. The SER index isolates the scale effect of possible inefficiencies that in administrative divisions can be quite significant.

The efficiency evaluation of the DMUs has been done following Sarra et al. (2017) and using the models introduced by Charnes et al. (1978) and Banker et al. (1984) for computing constant returns to scale (CRS) and variable returns to scale (VRS) efficiency scores. Given that waste management has desirable and undesirable outputs, as in Sarra et al. (2017), undesirable variables have been included among the inputs in a input-oriented efficiency evaluation. The Matlab toolbox developed by Alvarez et al. (2016) has been used for computational purposes.[8]

[8] They also provide an algorithm to take into account undesirable outputs directly, using this algorithm, scores that are highly correlated (> 0.9) are obtained with scores simply including undesirable outputs as inputs.

Therefore, total expenditure on solid waste collection, measured in euros, is the input variable. The output variables are: total of recycling solid waste produced, which is the desirable one, and total of undifferentiated solid waste, undesirable, both totals are in tons.[9]

3.2 Measuring Seasonality

Seasonality can be measured in various ways, and the three most used indexes are presented for completeness. However, within the analysis presented in this study, only the peak presences will be used. The reason for this is mostly practical. While the peak measure has the average of presences (or arrivals) at the denominator, the other two measures have the lowest count. For some municipalities, this is zero, resulting in an undefined overall index. Besides, the peak index also has well-defined limits of 0.25 and 1, which are the minimum and maximum seasonality. The indexes are computed as follows:

$$
\begin{aligned}
\frac{1}{T}\sum_i peak(x_{ij}) &= \frac{4}{T}\sum_i \frac{\max_q x_{ij}}{\sum_q x_{ij}} \\
\frac{1}{T}\sum_i ratio(x_{ij}) &= \frac{1}{T}\sum_i (\frac{\max_q x_{ij}}{\min_q x_{ij}}) \\
\frac{1}{T}\sum_i int(x_{ij}) &= \frac{1}{T}\sum_i (\max_q x_{ij} - \min_q x_{ij})
\end{aligned}
$$

where the subscripts q, i and, j stand for quarter, year, and municipality. So that the peak is an average across years of the highest flow of tourists divided by the average flows of the year, the ratio is an average of the ratio between the highest and lowest flow within each year. Each index can be computed for both arrivals and presences, where arrivals are the head-counts of tourists arriving in a municipality and while presences are the product of arrivals with nights spent by each tourist.

3.3 OLS and SAR Models

This paper proposes a possible explanation that is in line with textbook economic theory. Tourism, as well as other activities that are related to the exploitation of the "good season," can be a highly cyclical business, and such seasonality may well interfere with the predisposition of the proper scale of operation at any point in time as needed. Inefficiencies can therefore arise because of inappropriate seasonal scale that is too small during high season and too large during low season. The work of Sarra et al. (2017) has been followed closely, with some exceptions. First, more detailed data on tourism have

[9] A thorough explanation of the DEA method that is used here, along with an exhaustive review of the literature, was provided by Sarra et al. (2017). Their work is followed in much of the analysis, and the same data-sets are used for part of the results. Therefore, see their work for more details.

been used, and in particular indexes of seasonality of tourism; second, data have come from Tuscan municipalities since detailed data on tourism are available for this region, and also because Tuscany is one of the most visited regions of Italy and tourists are not concentrated in only a few locations; third, the paper follows a more traditional approach of looking at correlations by means of OLS regressions; however, to run OLS, the dependent variable is transformed using a -log transformation so that its domain goes from zero to plus infinity.[10] Finally, following Sarra et al. (2019), the analysis has been extended to include spatial effects within a SAR framework that relate efficiency measures to their possible determinants such that it is possible to capture spillover effects in terms of one variable in one municipality affecting the efficiency of another municipality.[11]

There are several reasons to think that observations are spatially correlated. First, because the observations are geographical entities, there may be present some degree of interdependence due to proximity correlated with the variables we are studying. Even more importantly, although municipalities are the management units for solid waste collection, they most often call on services that are supplied by one or a few entities covering an area of more municipalities. In this sense, the efficiency measures may be correlated spatially because of the common provider. Other issues may arise from competitive behavior, imitation, and other similar behaviors. The two models used are, therefore, the simple OLS model, as a benchmark,

$$Y = X\beta + \epsilon \tag{1}$$

where Y is one of the three indexes that proxy for efficiency and X is the matrix collecting the explanatory variables, and the Spatial Autoregressive (SAR) model, which is able to capture and distinguish the possible direct and indirect effects of the exogenous variables on the endogenous one, taking into account the feedback due to spatial autocovariance.

$$Y = \rho W X + X\gamma + \eta \tag{2}$$

where W is a weighing matrix that in this particular case is given by the distance of the municipalities in terms of kilometers of road between them. The data have been provided by ISTAT.

[10]The literature proposes a Tobit approach; however, Tobit models are valid for dependent variables that present a truncation and, as such, have a mass around the value of the truncation. The efficiency score is not truncated but simply built in such a way that limits its values between zero and one, and is unlikely to present masses at the boundary values. For this reason, it is preferred to use a transformation that allows the dependent variable to be in the same domain as the dependent ones.

[11]See LeSage (2008) for all the details of the SAR model.

Table 1: Summary of Variables		
Summary of Waste Variables		
Variable:	Mean	St. Dev.
Total Differentiated Solid Waste (tons)	5310	12125
Total Undifferentiated Solid Waste (tons)	8805	20606
Total Cost per Kg of Solid Waste	37.71	10.44
Percentage of Differentiated over total	0.36	0.09
Summary of Tourism Variables		
Total Presences	160784	563852
Peak of Presences	2.1758	0.5073
Presences per Resident	15.05	30.29
Total Arrivals	45260	209812
Peak of Arrivals	1.8897	0.4161
Arrivals per Resident	12.1419	54.1414
Summary of Other Variables		
Population	14386	31768
Area (kmsq)	81.40	66.67
Altitude (m)	255	206
Dist. Plant	29.3157	15.0356
Door to Door	0.8367	0.3696
Place of Collection	0.8980	0.3027

Analysis done by the Author with data from ISPRA, ISTAT, Region of Tuscany, Ministry of Finance of Italy. Units: municipalities of Tuscany.

4 Results and Discussion

Tables 1 and 2 give a summary of the data, with mean values and variation of the variables for the whole region in Table 1 and for the three ATOs in Table 2.

Cost figures are calculated in euros and refer to the cost of one kilogram of solid waste collected, while the amounts are in tons.

As the table suggests, there is considerable variation in all variables, both for the whole region and within the ATOs. Peak presences, for example, one of the most considered variables in tourist management studies, reveals an average of about 2 with a standard deviation of about 0.5. This means that there are municipalities where tourism is quite broadly spread over the year (1 would represent an acyclical presence), and others where the highest season collects most of the tourists (4 would represent all tourists staying for only one season). The other two indicators of interest also show quite significant variations: the cost of collecting solid waste, with a 40 euros average and a 10 euros standard deviation and the percentage of differentiated waste collection, with an interesting 50% average and 20% standard deviation. The next section goes deeper into the analysis of these data

Table 2: Summary of Variables

	ATO South		ATO Coast		ATO Center	
Summary of Waste Variables						
Variable:	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Total Differentiated Solid Waste (tons)	2510	3991	5178	9438	8833	19058
Total Undifferentiated Solid Waste (tons)	5599	9536	8136	14551	13569	32970
Total Cost per Kg of Solid Waste	38.34	10.42	41.47	10.38	31.64	7.35
Percentage of Differentiated over total	0.31	0.08	0.36	0.09	0.41	0.07
Summary of Tourism Variables						
Total Presences	140021	271663	126630	269432	233734	973449
Peak of Presences	2.2765	0.4497	2.2929	0.4945	1.8906	0.4779
Presences per Resident	17.45	27.10	16.05	36.54	10.78	22.77
Total Arrivals	36943	86464	35021	74523	69623	375547
Peak of Arrivals	1.8403	0.4443	1.8852	0.4104	1.9548	0.3790
Arrivals per Resident	11.9320	26.6733	16.3037	80.0131	6.5163	24.8875
Summary of Other Variables						
Population	8948	15190	12997	23179	22824	49937
Area (kmsq)	114.76	82.93	60.18	47.28	71.63	51.09
Altitude (m)	364	191	216	210	179	159
Dist. Plant	33.5742	14.9530	26.2178	15.9446	28.6167	12.3945
Door to Door	0.8025	0.3981	0.7917	0.4061	0.9412	0.2353
Place of Collection	0.8889	0.3143	0.8542	0.3529	0.9706	0.1690

Analysis done by the Author with data from ISPRA, ISTAT, Region of Tuscany, Ministry of Finance of Italy. Units: municipalities of Tuscany. Cost figures are in euros and per kilogram of solid waste collected, waste amounts are in tons.

by looking at some interesting correlations among those variables in a visual way with scatter plots. Then the results of the DEA analysis are presented, and those results are related to tourism variables in conclusion.

First of all, as we know from the previous study of Greco et al. (2018), albeit with slightly different data, tourism has an important effect on the efficiency of waste collection. In order to disentangle the effect of the seasonality of tourism and touristic presences per se, we need to be sure that the two variables are not too correlated, which would be the case if tourism were seasonal everywhere. Fortunately, in Tuscany there are various types of tourism, and these are normally classified into three main types: art-city tourism to Florence, Siena, and Arezzo and also to many smaller municipalities that enjoy this type of tourism; thermal (spa) tourism and coastal tourism. Each type may have some degree of seasonality, but without doubt, the first type presents the lowest degree of seasonality, as art cities are always available and Tuscany has a temperate climate throughout the year, while spa tourism shows a slightly higher but still moderate seasonality. Coastal tourism is the type that, for obvious reasons, has the highest degree of seasonality. Figure 1 shows the relationship between peak of presences and overall presences as a ratio of population we cannot spot any particular pattern from the scatter plot, which tells us that the two variables are likely uncorrelated, and therefore we can be confident that using peak presences as an explanatory variable for waste management efficiency enables us to identify the specific effect of seasonality independently on the overall tourism effect.

Figure 1: Relationship between Presences and Peak Presences

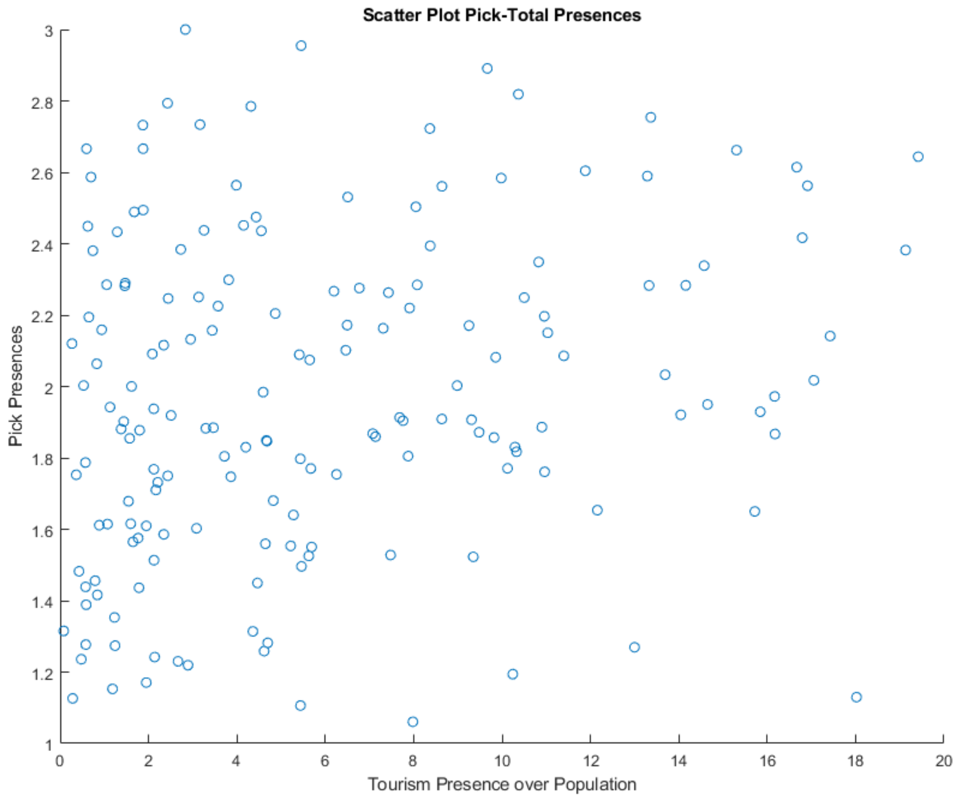
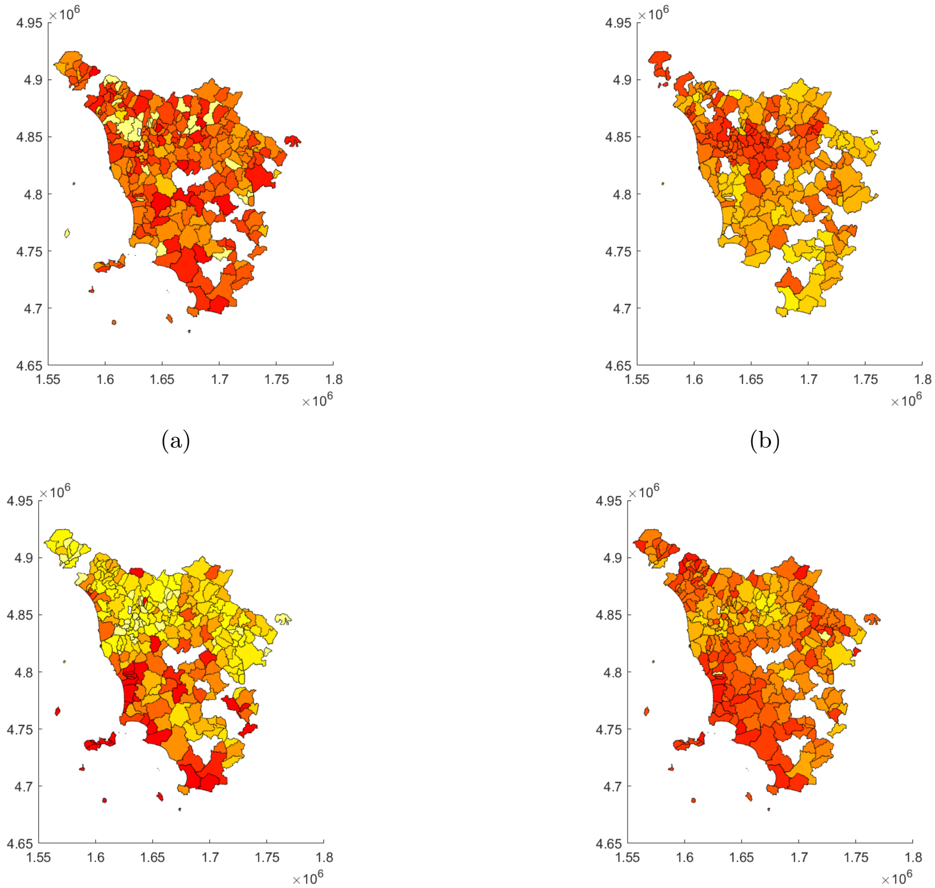


Figure 2 shows a second group of graphs whereby Tuscany is divided into municipalities. The colors from yellow to red indicate low to high values of several variables. Panel A shows the cost per kilogram of solid waste collected, Panel B shows the share of recycling done, Panel C shows the overall presence of tourists divided by the population, Panel D shows the peak presences.

As we are interested in the efficiency of solid waste collection, we consider recycling to be a good outcome or output, undifferentiated waste a bad one, and the overall cost of operation as a summary value of the inputs. Panels A and B tell us something about efficiency in that they show cost per kilogram and percentage of recycling. From Panel A we see that the cost per kilogram is somewhat scattered around the region, but higher costs are consistently present in the Val D'Arno area (roughly around coordinates $(1.65,4.85)*10^6$), a highly industrialized area compared to the rest of Tuscany, and in coastal areas compared to mountainous inland areas. The white areas are municipalities for which we do not have complete data. Looking at Panel B, we see that the Val D'Arno area is also quite strong

Figure 2: Tuscany



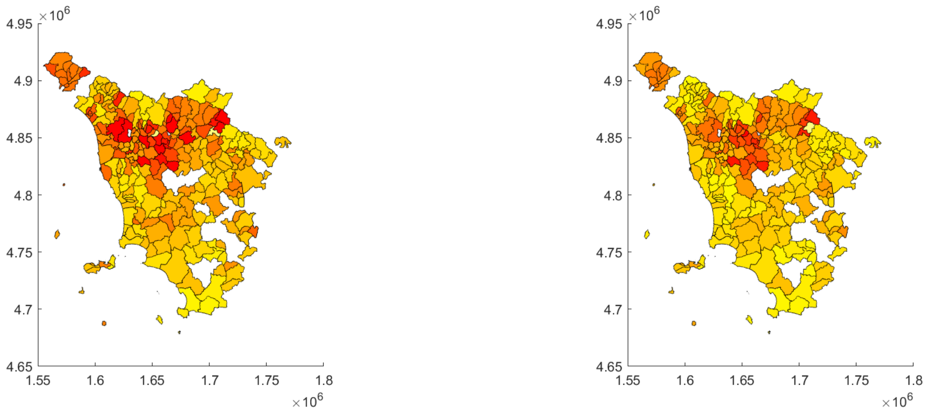
(a) (b) (c) (d)

in recycling, while costal areas are much weaker and particularly so the southern areas of Tuscany also known as Maremma. Panels C and D tell us about tourist presences. Panel C gives a measure of tourism compared to the resident population, and we can see here that the most affected areas in terms of this indicator are the coastal and southern areas. Locations such as Pisa, Livorno, and Florence do not appear particularly "hot" here because of their much larger populations compared to southern municipalities. Finally, Panel D gives an idea of seasonality as measured by peak presences across the year. Again the southern areas present a much higher seasonality than others, and even those that do not have high rates of presence overall, such as the more inland areas of the Maremma region. To put together the first two panels into a measure of efficiency, the next subsection shows a DEA analysis that uses solid waste collection data in a linear programming type of algorithm to benchmark municipalities from most to least efficient. Those benchmark scores will then be used to analyze the impact of tourism on the efficiency of this sector.

4.1 Data Envelope Analysis

This section presents the results of a Data Envelope Analysis (DEA) for most of the municipalities in Tuscany. Figure 3 shows the scores for each municipality in a geographic map; the scores are from 0 to 1 and from yellow to red, and therefore the red municipalities are the most efficient. Panel A reports CRS scores while Panel B reports VRS scores. Figure 4 reports the ratio of CRS/VRS, which is the Scale Effects (SE).

Figure 3: Data Envelopment Analysis - CRS and VRS

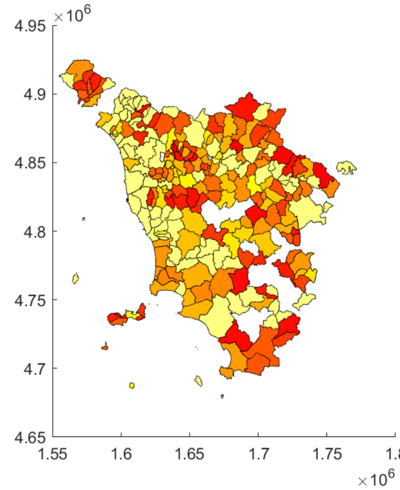


(a) (b)

Not surprisingly, having seen the evidence presented above, the lowest scores in terms of efficiency appear in the southern part of the region, the Maremma area in particular, and also in the coastal areas. This is true for both CRS and VRS scores. What is not evident from Figure 3 is the relationship between the CRS and VRS scores, which is also of interest to understand if inefficiencies are due to scale effects. To see this we can look at Figure 4, from which we can clearly see that the southern and coastal areas of the region also perform worse in terms of SER, while the area of Val D'Arno in particular seems to operate at an optimal scale, at least compared to other areas of Tuscany.

The next step is to see if tourism plays a role in explaining those differences. Tourism is a very large sector in Tuscany; in 2018 the number of presences was more than 47 million, which places Tuscany third in Italy after Veneto and Trentino-Alto Adige with more than one fifth of the entire tourist presence in the country. However, while Florence is certainly the main attraction within the region, contrary to Veneto and Lazio with Venice and Rome respectively, Tuscany enjoys a touristic presence that is much more widely spread over the region do to it also having some of the most popular coastal and thermal resorts that attract tourists from Italy and abroad. It is therefore extremely important to analyze the impact of tourism and the way it manifests itself on environmental resources.

Figure 4: Data Envelopment Analysis - Scale Effects



4.2 OLS and SAR Results

In Table 3, the efficiency scores considering constant returns, variable returns and scale efficiency have been regressed on peak presences, the variable of interest, and a set of control variables. These are presences per resident, population, population density, altitude, dummies for ATO Coast and ATO South, distance of the municipality from waste management plants, dummy for the adoption of door-to-door collection, and a dummy for the presence of a recycling center. All those variables can affect the efficiency of waste management and could also be correlated with our variable of interest. In particular, presences per resident, coastal area, and altitude are certainly correlated with seasonality and in principle could also autonomously affect the efficiency of waste management. In mountainous regions, for example, garbage collection could be more expensive given the morphology of the territory, and at the same time those areas may have seasonal tourism.

Coming to the variable of interest, seasonality, it appears to be sizeable and significant in terms of CRS and SER scores, but not significant for VRS, which suggests an effect on efficiency due to difficulties in reaching the right scale of production for those municipalities that see higher seasonality of presences. Tourist presences per resident appears instead to be negatively correlated with the CRS scores, although significant only at 10%, and strongly with VRS. Altitude, dummies for ATOs and door-to-door collection, and the presence of a recycling station appear to have a role in explanting efficiency scores, while the presence of recycling stations and the distance to plants are not generally significant.

Table 4 reports the same set of regressions with one notable difference within the set of explanatory variables. An additional variable is included to measure the duration of stay. The literature on the

Table 3: OLS Models 1 - A to C

Dependent Variables:	CRS-Efficiency Scores	VRS-Efficiency Scores	SER-Efficiency Scores
Intercept	-0.42709	-0.50451	0.07742
	(0.17853)	(0.17154)	(0.14878)
Peak Presences	-0.20225	-0.01757	-0.18468
	(0.05954)	(0.05721)	(0.04962)
Presences per Resident	-0.00243	-0.00439	0.00196
	(0.00127)	(0.00122)	(0.00106)
Population	0.00007	0.00100	-0.00093
	(0.00124)	(0.00119)	(0.00104)
Density	-0.00021	-0.00008	-0.00012
	(0.00012)	(0.00011)	(0.00010)
Altitude	-0.00061	0.00033	-0.00094
	(0.00016)	(0.00015)	(0.00013)
Coast	-0.35414	-0.19486	-0.15928
	(0.06377)	(0.06128)	(0.05314)
South	-0.48046	-0.42100	-0.05947
	(0.06835)	(0.06567)	(0.05696)
Dist. Plant	-0.00265	-0.00188	-0.00077
	(0.00178)	(0.00171)	(0.00148)
Door to Door	0.39907	0.21879	0.18028
	(0.07146)	(0.06867)	(0.05955)
Reclying Station	0.10816	-0.14977	0.25793
	(0.08701)	(0.08360)	(0.07251)
R^2	0.52790	0.27094	0.48782
N.Obs:	246	246	246

Analysis done by the Author with data from ISPRA, ISTAT, Region of Tuscany, Ministry of Finance of Italy. Units: municipalities of Tuscany.

effect of tourism on the environment, and on solid waste management in particular, suggests that fewer tourists who stay longer have a lower negative impact, and this variable should be able to capture this possible effect given the already measured effect of seasonality. The OLS results are quite interesting and shed more light on the relationship between efficiency and duration of stay once seasonality of presences is taken into account. The first two columns show us that seasonality keeps its strong and significant role in diminishing CRS and SE scores while not significantly affecting VRS. Duration of stay is instead strongly and negatively correlated with VRS and positively correlated with scale scores. Moreover, presence also keeps its relationship with all three efficiency measure, becoming more significant for CRS. The fact that the duration of stay coefficient has a negative sign for VRS indicates that touristic presences have an overall strongly negative effect on the efficiency of waste management, even when controlling for arrivals. However, most interesting is that the coefficients for the same variables for CRS is not significantly different from zero, while it is strongly and significantly positive for scale efficiency. This indicates that increasing the duration of stay helps whith properly sizing the scale of operation and therefore gives margins for recovering efficiency.

As noted before, while OLS regressions are useful because they are easy to interpret and run and are clearly defined, there are reasons to believe that our data do not satisfy all the assumptions for

Table 4: OLS Models 2 - A to C

Dependent Variables:	CRS-Efficiency Scores	VRS-Efficiency Scores	SER-Efficiency Scores
Intercept	-0.40476	-0.33086	-0.07390
	(0.18215)	(0.16918)	(0.14668)
Peak Presences	-0.20667	-0.03569	-0.17098
	(0.05819)	(0.05405)	(0.04686)
Duration of Stay	-0.00122	-0.01987	0.01865
	(0.00549)	(0.00510)	(0.00442)
Pres. per Resident	-0.00002	-0.00002	0.00001
	(0.00001)	(0.00001)	(0.00001)
Population	0.00014	0.00217	-0.00203
	(0.00128)	(0.00119)	(0.00103)
Density	-0.00021	-0.00013	-0.00007
	(0.00012)	(0.00011)	(0.00009)
Altitude	-0.00061	0.00030	-0.00091
	(0.00016)	(0.00014)	(0.00013)
Coast	-0.35651	-0.21967	-0.13684
	(0.06407)	(0.05951)	(0.05160)
South	-0.47913	-0.43386	-0.04527
	(0.06850)	(0.06362)	(0.05516)
Dist. Plant	-0.00251	-0.00179	-0.00072
	(0.00178)	(0.00166)	(0.00143)
Door to Door	0.39394	0.19617	0.19777
	(0.07165)	(0.06655)	(0.05769)
Reclying Station	0.10829	-0.14470	0.25299
	(0.08694)	(0.08075)	(0.07001)
R^2	0.53036	0.32228	0.52422
N.Obs:	246	246	246

Analysis done by the Author with data from ISPRA, ISTAT, Region of Tuscany, Ministry of Finance of Italy. Units: municipalities of Tuscany.

carrying out correct inference. In particular, we should worry about geographically correlated errors arising from not taking into account possible relationships between close municipalities. The following set of estimations is based on the model presented in Equation 2, where the same variables are used as in Equation 3.

Tables 5 and 6 estimate the effect of the exogenous variables on CRS efficiency scores, Tables 7 and 8 estimate their effect on VRS efficiency scores, and finally Tables 9 and 10 on SER. Tables 5, 7, and 9 report the parameter estimation while Tables 6, 8, and 10 report the calculated direct, indirect, and total effects.

The results from the SAR models largely give the same insights as the OLS regressions, suggesting that the spatial autocorrelation of errors does not bias the estimates. It is however interesting to note that there is some feedback effect from one municipality to another. Given that we control for ATOs, the feedback effect is likely to come from a high degree of sharing practices within neighbouring municipalities.

First, we can see that the first two models show a significant and positive autocovariance signalled by the parameter ρ; this leads to significant spillover effects on waste management, measured by the

Table 5: SAR Model 1 - Estimation

Dependent Variable: CRS-Efficiency Scores			
Model			
Parameter	Coefficient	Std. Error	t-stat
Intercept	-0.23226	0.17978	-1.29191
Peak Presences	-0.18228	0.05494	-3.31763
Duration of Stay	0.00166	0.00519	0.31916
Pres. per Resident	-0.00002	0.00001	-1.94393
Population	-0.00016	0.00121	-0.13122
Density	-0.00018	0.00011	-1.62886
Altitude	-0.00057	0.00015	-3.90496
Coast	-0.27870	0.06493	-4.29260
South	-0.35611	0.07404	-4.80989
Dist. Plant	-0.00248	0.00168	-1.47802
Door to Door	0.38117	0.06763	5.63582
Reclying Station	0.07879	0.08238	0.95637
ρ	0.28599	0.07513	3.80682
R^2	0.52750		
N.Obs:	245		

Analysis done by the Author with data from ISPRA, ISTAT, Region of Tuscany, Ministry of Finance of Italy. Units: municipalities of Tuscany.

indirect effects in Tables 6 and 8. In Tabel 6, we see that peak presences have a negative and significant indirect effect on CRS; that is, the seasonality of tourism in neighbouring municipalities also has an impact. In Table 8, we see the same for the duration of stay and, although less significant, for overall presences.

Overall, the OLS and SAR results indicate that when we allow the scale of production to vary, the number of presences seem to be the driving force for negative efficiency, while if we keep the scale constant, seasonality has an important role in explaining the loss of efficiency. The duration of stay results show that increasing presences keeping the number of arrivals low helps in correctly sizing the scale of operation, an effect that may be driven by factors related to the attachment of tourists to a destination or the possibility of accurate forecasting of the number of presences to better adjust the scale of operations. Model 3 clarifies this point, with the peak presences clearly negatively and strongly significant, while the duration of stay is positive and also significant. Therefore, efficiency of scale is impacted negatively by seasonality and positively by the duration of stay.

Putting together the information that the set of three models brings us, it seems clear that seasonality has a negative effect on the efficiency of solid waste management, this effect is primarily due to difficulty in operating at an optimal scale, and that it is the seasonality of arrivals in particular that negatively impacts efficiency, while the average stay has an opposed positive effect once the scale effect is taken into account.

Table 6: SAR Model 1 - Average Marginal Effects

Dependent Variable: CRS-Efficiency Scores

Parameter	Coefficient	Std. Error	t-stat
Marginal Average Effects Model 1			
Direct Effects			
Peak Presences	-0.18447	0.05493	-3.35815
Duration of Stay	0.00167	0.00518	0.32329
Pres. per Resident	-0.00002	0.00001	-1.96668
Population	-0.00014	0.00124	-0.11165
Density	-0.00018	0.00011	-1.64420
Altitude	-0.00058	0.00015	-3.84314
Coast	-0.28385	0.06502	-4.36541
South	-0.36266	0.07521	-4.82195
Dist. Plant	-0.00250	0.00170	-1.46788
Door to Door	0.38361	0.06863	5.58982
Reclying Station	0.07828	0.08332	0.93953
Indirect Effects			
Peak Presences	-0.07364	0.03531	-2.08554
Duration of Stay	0.00074	0.00223	0.33033
Pres. per Resident	-0.00001	0.00000	-1.59263
Population	-0.00006	0.00053	-0.12157
Density	-0.00007	0.00005	-1.35062
Altitude	-0.00023	0.00010	-2.32071
Coast	-0.11008	0.03932	-2.79970
South	-0.14001	0.04579	-3.05758
Dist. Plant	-0.00101	0.00083	-1.21950
Door to Door	0.15304	0.06100	2.50904
Reclying Station	0.02985	0.03586	0.83253
Total Effects			
Peak Presences	-0.25811	0.08180	-3.15518
Duration of Stay	0.00241	0.00731	0.32982
Pres. per Resident	-0.00002	0.00001	-1.94561
Population	-0.00020	0.00176	-0.11608
Density	-0.00026	0.00016	-1.61194
Altitude	-0.00081	0.00022	-3.67688
Coast	-0.39394	0.08527	-4.61991
South	-0.50267	0.09379	-5.35969
Dist. Plant	-0.00352	0.00245	-1.43456
Door to Door	0.53665	0.10993	4.88158
Reclying Station	0.10814	0.11670	0.92658

Analysis done by the Author with data from ISPRA, ISTAT, Region of Tuscany, Ministry of Finance of Italy. Units: municipalities of Tuscany.

4.3 Discussion

The results reported above are novel in that there has never been a systematic study of the effect of seasonality of tourism on the efficiency of SWM; however, studies about the effect of tourism on SWM have been proposed in several forms, mostly as case studies. An example of such a study is the one

Table 7: SAR Model 2 - Estimation

Dependent Variable: VRS-Efficiency Scores			
Model			
Parameter	Coefficient	Std. Error	t-stat
Intercept	-0.17356	0.16398	-1.05845
Peak Presences	-0.00920	0.05033	-0.18281
Duration of Stay	-0.01590	0.00481	-3.30933
Pres. per Resident	-0.00002	0.00001	-2.68386
Population	0.00173	0.00111	1.55488
Density	-0.00009	0.00010	-0.91220
Altitude	0.00021	0.00014	1.52831
Coast	-0.15673	0.05766	-2.71795
South	-0.31629	0.06778	-4.66631
Dist. Plant	-0.00188	0.00154	-1.21929
Door to Door	0.17064	0.06203	2.75108
Reclying Station	-0.14737	0.07515	-1.96092
ρ	0.35797	0.08718	4.10595
R^2	0.33220		
N.Obs:	245		

Analysis done by the Author with data from ISPRA, ISTAT, Region of Tuscany, Ministry of Finance of Italy. Units: municipalities of Tuscany.

carried out by Arbulu et al. (2017), which estimated the increased generation of solid waste in the island of Mallorca. Interestingly, they estimated the elasticity of solid waste generation with respect to both tourist presence tourist expenditure, 1.25% and 0.51%, respectively. Their results would favor policies targeting wealthy tourists.

One interesting study is the one carried out by Rada et al. (2014), which reported no effects of tourism on "selective collection efficiency," which is a measure of recycling affecting the overall efficiency of SWM. Even more importantly, the study took into account somehow the seasonality of tourism looking at time series frequencies that were higher than annual within a province that has its touristic peak in summer and winter, and again they do not find any effects on recycling efficiency. One possible explanation for these results was reported in their paper and is related to tourists being for the most part returning ones, who might know the recycling system put in place in the province. This explanation is also consistent with the above results that see duration of stay, often correlated with the fidelity of tourists, having a positive effect on efficiency. Another possible explanation, which would need to be tested with further research, could be related to that of tourists and the recycling practices they have at "home." In fact, the province of the study was Trento, in the region of Trentino-Alto Adige, which is a popular destination for many German tourists, and Germany has recycling practises that are traditionally more enshrined in its society. It could then be the case that those tourists behave even better than locals, compensating for the possible difficulty of organizing scale in the presence of

Table 8: SAR Model 2 - Average Marginal Effects

Dependent Variable: VRS-Efficiency Scores

Parameter	Coefficient	Std. Error	t-stat
Marginal Average Effects Model 1			
Direct Effects			
Peak Presences	-0.00799	0.05036	-0.15863
Duration of Stay	-0.01610	0.00484	-3.32664
Pres. per Resident	-0.00002	0.00001	-2.70968
Population	0.00178	0.00114	1.56958
Density	-0.00009	0.00010	-0.92858
Altitude	0.00021	0.00014	1.52168
Coast	-0.16028	0.05913	-2.71058
South	-0.32284	0.06878	-4.69361
Dist. Plant	-0.00194	0.00157	-1.23428
Door to Door	0.17272	0.06303	2.74027
Reclying Station	-0.14826	0.07656	-1.93648
Indirect Effects			
Peak Presences	-0.00404	0.03014	-0.13415
Duration of Stay	-0.00886	0.00410	-2.15969
Pres. per Resident	-0.00001	0.00001	-1.91948
Population	0.00099	0.00076	1.30156
Density	-0.00005	0.00006	-0.82248
Altitude	0.00011	0.00009	1.28353
Coast	-0.08620	0.04168	-2.06796
South	-0.17404	0.06056	-2.87375
Dist. Plant	-0.00109	0.00105	-1.04471
Door to Door	0.09623	0.05212	1.84637
Reclying Station	-0.08319	0.05602	-1.48495
Total Effects			
Peak Presences	-0.01203	0.07927	-0.15178
Duration of Stay	-0.02496	0.00789	-3.16326
Pres. per Resident	-0.00003	0.00001	-2.60217
Population	0.00277	0.00181	1.53205
Density	-0.00015	0.00016	-0.91290
Altitude	0.00033	0.00022	1.49560
Coast	-0.24648	0.09009	-2.73604
South	-0.49688	0.09839	-5.05004
Dist. Plant	-0.00303	0.00253	-1.19968
Door to Door	0.26895	0.10526	2.55521
Reclying Station	-0.23145	0.12520	-1.84864

Analysis done by the Author with data from ISPRA - years 2018 and 2019, ISTAT, Region of Tuscany, Ministri of Finance of Italy year 2018. Units: municipalities of Tuscany - 2005-2020

large fluctuations of demand.

A case study that is also relevant, although different in many ways, is that of de Araújo and da Costa (2007). Their study reported the pollution of a tourist beach in Brasil during the highest tourist seasons. The relevance of this study is in that most highly seasonal tourist locations in Tuscany are also coastal areas and most probably also face pollution in terms of solid waste due to sea currents. To a large extent, this is an exogenous effect to the municipality as the sea currents can span much larger areas than the ones covered by municipal authorities, yet they do represent an additional cost as it is the municipality that has to clean up the beaches.

In terms of carbon emission this study suggests that it is important to address the seasonality of

Table 9: SAR Model 3 - Estimation

Dependent Variable: SER-Efficiency Scores			
Model			
Parameter	Coefficient	Std. Error	t-stat
Intercept	-0.06769	0.14414	-0.46958
Peak Presences	-0.17055	0.04570	-3.73229
Duration of Stay	0.01861	0.00432	4.31106
Pres. per Resident	0.00001	0.00001	0.82124
Population	-0.00203	0.00101	-2.00946
Density	-0.00007	0.00009	-0.80564
Altitude	-0.00089	0.00013	-7.10974
Coast	-0.13319	0.05125	-2.59850
South	-0.04141	0.05460	-0.75844
Dist. Plant	-0.00071	0.00140	-0.50699
Door to Door	0.19878	0.05625	3.53411
Reclying Station	0.24936	0.06860	3.63488
ρ	0.03795	0.08881	0.42733
R^2	0.52408		
N.Obs:	245		

Analysis done by the Author with data from ISPRA, ISTAT, Region of Tuscany, Ministry of Finance of Italy. Units: municipalities of Tuscany.

tourism and the duration of stay of tourists to promote a more environmentally friendly economic sector and sustainable development. The carbon footprint of tourism is estimated to have grown substantially between 2009 and 2013 as reported by Lenzen et al. (2018), representing about 8% of total greenhouse gas emissions. The same study "projects that, due to its high carbon intensity and continuing growth, tourism will constitute a growing part of the world's greenhouse gas emissions." SWM, and its efficiency, particularly measured by the share of waste that is recycled, is directly related to gas emissions. Muehle et al. (2010) reported that German SWM produces five times less emissions than that of the U.K. because of its focus on recycling.

Table 10: SAR Model 3 - Average Marginal Effects

Dependent Variable: SER-Efficiency Scores

Parameter	Coefficient	Std. Error	t-stat
Marginal Average Effects Model 1			
Direct Effects			
Peak Presences	-0.17126	0.04687	-3.65348
Duration of Stay	0.01862	0.00430	4.32747
Pres. per Resident	0.00001	0.00001	0.83289
Population	-0.00204	0.00101	-2.02299
Density	-0.00007	0.00009	-0.79832
Altitude	-0.00089	0.00013	-6.96554
Coast	-0.13270	0.05186	-2.55907
South	-0.04067	0.05509	-0.73839
Dist. Plant	-0.00070	0.00142	-0.49536
Door to Door	0.19880	0.05609	3.54428
Reclying Station	0.25213	0.06928	3.63943
Indirect Effects			
Peak Presences	-0.00794	0.01765	-0.44999
Duration of Stay	0.00085	0.00188	0.45084
Pres. per Resident	0.00000	0.00000	0.31101
Population	-0.00009	0.00023	-0.41776
Density	-0.00000	0.00001	-0.30173
Altitude	-0.00004	0.00009	-0.44249
Coast	-0.00523	0.01355	-0.38568
South	-0.00096	0.00680	-0.14068
Dist. Plant	-0.00004	0.00017	-0.22362
Door to Door	0.00923	0.02035	0.45350
Reclying Station	0.01105	0.02560	0.43144
Total Effects			
Peak Presences	-0.17920	0.05199	-3.44691
Duration of Stay	0.01946	0.00479	4.06382
Pres. per Resident	0.00001	0.00001	0.82918
Population	-0.00213	0.00108	-1.97976
Density	-0.00008	0.00010	-0.79440
Altitude	-0.00093	0.00014	-6.59729
Coast	-0.13793	0.05362	-2.57252
South	-0.04163	0.05742	-0.72501
Dist. Plant	-0.00074	0.00150	-0.49489
Door to Door	0.20803	0.06198	3.35652
Reclying Station	0.26318	0.07459	3.52838

Analysis done by the Author with data from ISPRA, ISTAT, Region of Tuscany, Ministry of Finance of Italy. Units: municipalities of Tuscany.

5 Conclusions

Tourism is traditionally associated with excellent opportunities for growth with relatively small investments in physical and human capital, but also with high levels of negative externalities. The aim of this paper is to bring evidence of the environmental costs of tourism in terms of SWM efficiency in

Tuscan municipalities (Italy), with particular focus on the seasonality of tourism. This paper fills the gap in the literature that has not investigated so far how tourism typically manifests itself that is, with highly seasonal increases in presences. The results collected in the paper confirm previous studies that have been reported the important impact of tourism on the efficiency of SWM operations, also relating it to difficulty in reaching optimal scale. This paper shows in addition that the seasonality of tourism greatly amplifies the impact of tourism on waste management. It also shows that this additional impact comes through scale effects, with seasonality making it harder to manage solid waste at optimal scale. Finally, conditional to the size of touristic seasonal flow of presences, it notes a preference for a lower number of tourists who stay longer over a larger number of short stays. The paper adds to the literature on the environmental effects of tourism by shedding more light on the mechanism that relates tourist presences with solid waste management efficiency, identifying a strong negative effect of the seasonality of tourism and short stays. The implications of these results are clear, namely that more effort has to be made to flexibly manage solid waste collection. For example, the concept of ATO could be more extensively exploited , where possible, reallocating resources from municipalities of the same ATO that during peak seasons see their residents decrease to the ones where the net inflow of tourists is positive, typically from internal to coastal areas and vice versa. Efforts should also be made to increase the average stay of tourists and improve offseason attractiveness. A more punctual and immediately applicable policy to counter the seasonal effect could also be a flexible taxation on touristic presences in terms of a tax that could be thought as of a function of predicted congestion of presences to counter the negative externalities associated with it and reduce carbon emissions.

5.1 Future Research and Limitations

This work suggests that Tuscan municipalities that face highly seasonal tourism have more difficulty in adapting their scale of operations to changes in the production of solid waste. As stated above, the regional WMP states that differentiated collection and recycling should increase substantially and efforts should be made to reach the objective of 70% recovery of material. At ATO level, there seems to be no constraints towards reaching this goal in terms of infrastructure.[12] It is therefore at the level of municipalities that there are difficulties caused by the seasonality of the flow of touristic presences. It would be interesting to have a deeper look at the infrastructure of waste management such as the availability and capacity of plants for selecting and re-using waste, to understand how they interact with municipalities. In particular, if those plants have the necessary flexibility/capacity to adapt to seasonal flow and, if not, if their difficulty is reflected to municipalities. This work points out a

[12] See reports by APRR for more details: https://www.arrr.it/rapporto-annuale-rifiuti-urbani

potential future development to study, that flows could be compensated. Within an ATO, there could be municipalities that see opposite flows of residents/tourists, and it would be interesting to explore the possibility of synergies and compensations when these flows of opposite signs exist. Moreover, this could also be the ground for assessing the optimality of an ATO. Finally, the SAR results indicate that spillover effects exist between municipalities, which is an interesting management and policy issue as it raises questions on the cross-responsibilities of municipalities. Future research should investigate this important issue more deeply from a theoretical and applied point.

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