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# Tourism and temperature effects on the electricity consumption of the hospitality sector

María del P. Pablo-Romero [a, *], Rafael Pozo-Barajas [b], Javier Sánchez-Rivas [a]

[a] Department of Economic Analysis and Political Economy, Faculty of Economics and Business Sciences, University of Seville, Ramon y Cajal 1, 41018, Seville, Spain

[b] Department of Financial Economy and Operations Management, Faculty of Economics and Business Sciences, University of Seville, Ramon y Cajal 1, 41018, Seville, Spain

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ABSTRACT

The European Union has recently presented a strategic long-term vision for a climate-neutral economy by 2050, considering that climate change is a serious concern for Europeans. A great socio-economic transformation is necessary, affecting all economic sectors. On the one hand, the European Union considers that it is necessary to achieve net zero greenhouse gas emissions by 2050; on the other hand, sectors need to adapt to a warming climate. Focusing on the tourism sector, and using panel data referring to 12 Spanish Mediterranean provinces and the 1999–2014 time period, this study tests the tourist stays and temperature effects on the electricity consumption of the hospitality sector by estimating extended Energy Environmental Kuznets curves for the sector. The results show that this curve is not supported. Instead, electricity consumption progressively increases as tourism grows. In addition, the results indicate that temperature variables have notable influence over electricity use, with a positive influence of global warming on electricity consumption. Finally, results also show positive relationships between overnight stays in hotels with higher star ratings and electricity use, while no significant price effects are observed. Electricity saving measures and renewable electricity generation promotion are recommended, especially in the highest energy consuming establishments.



## 1. Introduction

In 2015, 195 parties implemented the Paris Agreement (United Nations, 2015) to reinforce the response to the threat of climate change (CC) by creating objectives for the post-2020 period. Likewise, in December 2018, in order to implement the Paris Agreement, parties reached agreement in Poland through a *Rulebook*. In addition to defining and publishing their Intended Nationally Determined Contributions (INDCs), parties have to determine the domestic policies to achieve those INDCs targets, focusing on accelerating the effort toward more ambitious greenhouse gas emission (GGE) reduction targets in the coming years. These greater efforts are considered necessary as, according to the Intergovernmental Panel on Climate Change (IPCC) special report (IPCC, 2018), global warming has already exceeded pre-industrial levels by 1 °C and continues to rise by around 0.2 °C per decade. Therefore, if international climate actions are not stepped-up, at some time after 2060, the global increase in temperature could reach 2 °C.

The European Union (EU) is aware of the conclusions of the IPCC Special Report. Therefore, in addition to the adoption of the target of at least a 40% reduction in GGE by 2030 to meet the Paris Agreement commitments (European Commission, 2015), the EU has recently presented a strategic long-term vision for a climate-neutral economy by 2050 (European Commission, 2018). In this document, it is stated that CC is a severe concern for Europeans, and that in order to fight against CC, a greater economic and social transformation is necessary in Europe, affecting all economic sectors. This transformation must not only allow net zero GGE to be achieved by 2050, but also sectoral transformation to adapt to a

* Corresponding author.
*E-mail addresses:* mpablorom@us.es (M.P. Pablo-Romero), pozo@us.es (R. Pozo-Barajas), sanchezrivas@us.es (J. Sánchez-Rivas).

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warming climate.

In order to reduce emissions, the EU is already carrying out numerous sectoral energy measures, as around 80% of GGE in the EU is generated by energy production and consumption (European Environment Agency, 2015). Many of these measures are related to energy efficiency, the use of renewable energies and the trend to electrify production systems (EU, 2018). However, some forces may go against the control of energy use, such as the economic growth of the sector or the increase in energy needs, due to the global warming process. It is therefore interesting to know how countries can reach the energy use reduction targets (at least fossil fuel energy use reduction) in each economic sector, and in an economic growth and global warming context. Therefore, sectoral studies testing the relationships between energy use, economic growth and temperatures may be of interest.

This paper is focused on the relationships between energy use, tourism growth and temperature effects. Focusing on the tourism sector is relevant, as this sector has a notable effect on growth, also causing notable energy use and a notorious impact on sustainability development. As stated in the United Nations World Tourism Organization report (UNWTO, 2017), the tourism sector has a greater impact on society, the environment and the economy, as it represents 10% of global gross domestic product (GDP), 7% of total exports, and moves 1.2 billion tourists each year. Therefore, this sector is essential to achieving the objectives of the 2030 Agenda. In addition, testing the relationship between energy consumption and tourism growth may also be an interesting action to carry out. As stated in Daniarta and Farasi (2015), tourist destinations consume disproportionately more energy than other geographical areas of similar size, which may be due to the fact that tourism services tend to use energy-intensive technologies (Krstinić Nižić et al., 2016). Therefore, studying the relationships between energy consumption and tourism is especially relevant.

This study tests the effects of tourism and temperature on the electricity consumption of the hospitality service by using panel data referring to 12 Spanish Mediterranean provinces and the 1999–2014 time period. The relationships between these variables are analyzed by testing an extended energy-environmental Kuznets curve (EKC) for the electricity consumption in the hospitality sector. In order to measure the temperature effects, cooling degree days (CDD) and heating degree days (HDD) are used to measure the temperature effects. In the study, the effects of some tourism characteristics are also considered. Among them, the effect of the hospitality sector's electricity price, the percentage of total foreign tourist overnight stays, and total overnight stays in 4- and 5-star hotels.

Studying this relationship in the Spanish economy is pertinent, as Spain recorded the highest tourism gross value added (GVA) in the EU (€232,353 million in 2011), representing 58% of the tourism GVA of the 16 EU countries for which data was available (Eurostat, 2017). Likewise, focusing on the Mediterranean provinces is of special interest, as these 12 provinces are among the 15 with more tourist attractions, presenting similar characteristics. The provinces of the sample have a Mediterranean climate and their tourism is highly related to sun-and-beach tourism.

The paper is structured in five sections. After the Introduction, in Section 2, the literature review is presented. In Section 3, data are presented; while in Section 4, the methodology used is explained. The results and the discussion are presented in Section 5 and, finally, Section 6 offers the conclusions.

## 2. Literature review

Tourism is an important economic activity worldwide. However, the focus of attention has recently been on its negative impact on the environment and the global warming process (Scott et al., 2010).

In the same vein, some studies have analyzed the relationships between tourism, emissions and energy consumption, with the aim of studying the negative impact of tourism on the environment. Most of these studies analyze the way in which tourism affects CO2 emissions, although most of them include energy consumption as an explanatory variable. Among them, the studies by Katircioglu (2014) and Katircioglu et al. (2014), analyzing the relationships between tourism, energy use and emissions in Turkey and Cyprus, respectively, may be highlighted. Likewise, the study by Zaman et al. (2016) may also be cited, as it investigates the relationship between economic growth, emissions, tourism development and other variables, testing the validity of tourism EKC in a variety of regions of the world, in the period from 2005 to 2013.

Other studies focused directly on the way in which tourism affects energy consumption. In this vein, the study by Qureshi et al. (2017) evaluates dynamic linkages between tourism and energy consumption in a panel of 37 tourism countries. Likewise, the study by Katircioglu et al. (2014) also estimates the long-term relationship between tourism and energy consumption in Cyprus. Following these studies, the studies by Pablo-Romero et al. (2017a, 2017b) also focus on the relationships between tourism and energy consumption in the EU and the Spanish provinces. Following this previous literature, our study focuses on the relationships between tourism and energy consumption in the hospitality sector, in the Mediterranean Spanish provinces.

In addition to this previous literature, some other studies have focused on the way in which the CC affects tourism. In this regard, the studies by Scott et al. (2016a, 2016b) analyze the situation of tourism in the face of the CC and global warming process, showing both the vulnerabilities of the sector to the process and its necessary adaptation to it. Some studies have started analyzing the temperature effects on tourism, such as, for example Grillakis et al. (2016), and Damm et al. (2017), which analyze the impacts of an increasing +2 °C on summer and winter tourism demand in Europe, respectively.

Following this latter aspect, some other recent papers (Pablo-Romero et al., 2017a, 2017b) have included the role of temperature in the analysis of tourism effects on energy consumption. The author analyzes how tourism induces energy use by controlling the temperature variable. Although the results indicate that its impact is not significant, the authors consider it may be due to the climate variable included in the model.

This current work goes beyond these previous papers and tests the interaction between tourism growth and electricity consumption in the hospitality sector. With this aim, the effect of temperature variables related to heating and cooling needs is taken into account in the study by introducing CDD and HDD.

As far as we know, these variables have not been previously used in tourism energy use studies. Nevertheless, there is a tendency to use these variables in energy use studies. They allow to take into account the non-linear effect of temperatures on energy use, distinguishing the effect of low and high temperatures on energy consumption (Fan and Hyndman, 2011; Blázquez et al., 2013; Mohammadi and Ram, 2017 and Serrano et al., 2017, for example).

However, our study goes beyond those mentioned, as it also analyses the non-linearity effects of the CDD and the HDD variables. The inclusion of these non-linearity effects is necessary, as the effect of temperature on electricity consumption has been observed to be non-linear. Thus, for example, Chang et al. (2016) have observed that an increase in temperature increases energy demand, but the increased amount depended on the initial temperature level, indicating, therefore, that it is not adequate to consider the CDD effects as linear. Therefore, our study analyzes the relationships between tourism and energy consumption in the hospitality sector, taking into account the non-linear effects of CDD and HDD. This is an advance in the previous literature.

This analysis is also carried out in a context of tourism economic growth. With this aim, the relationships between energy use (electricity consumption), the hospitality sector's economic growth and CDD-HDD are analyzed by testing an extended energy-EKC. The energy-EKC is a concept used by several researchers to analyze the non-linear relationships between income growth and energy consumption (Dong and Hao, 2018). Recently, some studies have tested the energy-EKC on several sectors, as notable sectoral heterogeneity in the elasticity of energy consumption had been previously highlighted (Burke and Csereklyei, 2016). Among these studies, it is relevant to point out those by Liu et al. (2016a), Pablo-Romero and Sánchez-Braza (2017) and Yin et al. (2015), related to the residential sector; those by Lin and Du (2015) and Pablo-Romero et al. (2017c) for the transport sector; and those related to the tourism sector by Pablo-Romero et al. (2017a; 2017b).

Fig. 1 shows the links between our study and the previous literature. On the one hand, our study is related to the tourism-energy use nexus literature; on the other hand, it is related to the temperature-energy use nexus, specifically to the CDD-HDD-energy use nexus literature. Thus, our study links tourism & temperature (CDD-HDD) to energy consumption. The estimate procedure is carried out by testing an extended EKC. Therefore, our study also refers to the previous literature regarding energy-EKC and the study of non-linearity effects on energy consumption. This study also includes other variables in the model to test for other effects. Among them, the income variable, the percentage value of total overnight stays in 4- and 5-star hotels, the percentage value of total inbound tourists and the electricity variable.

Therefore, this paper tests the energy-EKC in the Spanish Mediterranean provinces for the hospitality sector, being therefore in line with previous energy-EKC and those related to the hospitality sector. Nevertheless, this current work goes beyond previous papers, as it includes not only the CDD and HDD variables to take into account the different effect of cooling and heating needs in electricity use, but also analyzes the non-linearity of each one of these climate variables in the electricity consumption of the hospitality sector.

## 3. Data

The panel data used in this study refers to the 12 Spanish Mediterranean provinces during the 1999–2014 time period. The main databases and characteristics of the variables used are described below.

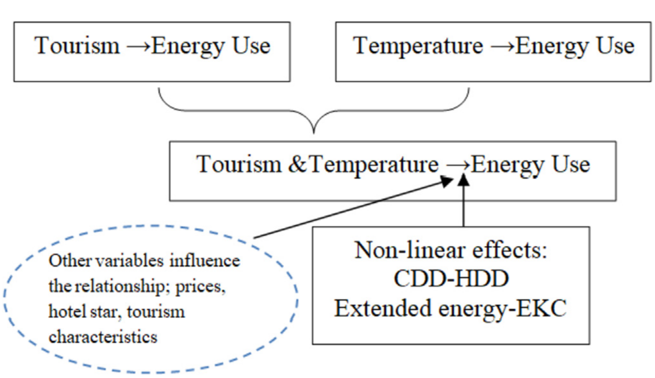


**Fig. 1.** Reference frame of the research.

### 3.1. Electricity consumption of the hospitality sector and the tourist overnight stay data

The electricity consumption data of the hospitality sector comes from the annual electricity consumption database by province offered by the Ministry for Ecological Transition (2019). The electrical consumption data for the hospitality sector includes the consumption of the accommodation and food services sectors (sectors 55 and 56 of the NACE statistical classification—*Nomenclature statistique des activités économiques dans la Communauté européenne*). In this study, the values of electricity consumption are expressed in Megawatt-hour (MWh) per thousand inhabitants, converted to logs. Provincial population data are obtained from the Instituto Nacional de Estadística (INE), (2019).

In this study, provincial total overnight stays were used as an indicator of provincial tourism. The data was obtained from the occupancy rates offered by Turespaña (2019). Previous studies have used various indicators to measure tourism. Camuñez et al. (2018) indicate that some previous studies, such as Belloumi (2010) and Dritsakis (2004), have used international tourist income to measure tourism. Others, such as Massidda and Mattana (2013), have used the number of foreign tourists, while some others, such as Gómez-Calero et al. (2014) and Pablo-Romero et al. (2017a), used the number of overnight stays. Often, the first indicator is considered to be more appropriate for measuring tourism activity, although in provincial or regional studies, its use depends on data availability. In the case of the Spanish provinces, Turespaña (2019) offers information on the number of hotel overnight stays and number of travelers staying at hotels. In this study, overnight stays have been used, as this indicator is a good proxy for the income obtained from tourism, according to Gómez-Calero et al. (2014). The data used in this study are overnight stays per thousand inhabitants, which are subsequently transformed into logarithmic terms.

### 3.2. Temperature variables data

The use of temperatures as control variables in studies that estimate demand functions for energy consumption (and especially electricity), or that analyze their determinants, is common in previous literature. Some studies use average temperature, as do for example Lee and Chiu (2011), while others use temperature range, as in Gam and Ben Rejeb (2012). Nevertheless, recent studies have a tendency to use the HDD and CDD temperature variables, such as Fan and Hyndman (2011), Blázquez et al. (2013), Mohammadi and Ram (2017) and Serrano et al. (2017).

Following these last studies, in this paper, the HDD and CDD variables have been used. CDD indicates the number of days in a year that the average temperature (Ti) surpasses a value (Tb). It is considered that surpassing this value indicates that cooling is necessary. The CDD value for a day is calculated as $CDDi=(1-\gamma)(Ti-Tb)$. If the average temperature is higher than Tb, then $\gamma = 0$, and the CDD value is equal to (Ti−Tb). If the average temperature is below Tb, then $\gamma = 1$ and $CDD = 0$. The sum of the CDDi for a year gives the annual CDD value. Additionally, HDD indicates the number of days (and time) that it is necessary to use heat. The HDD value for a day is calculated as $HDDi=(1-\gamma)(Tb-Ti)$. If the average temperature is lower than Tb, then $\gamma = 0$, and the HDD value is equal to (Tb−Ti). In any other case, $\gamma = 1$ and $HDDi = 0$.

The Tb temperature chosen has been 18 °C, and alternatively 15 °C for heating and 22 °C for cooling, as in Blázquez et al. (2013), for the residential sector in Spain. In addition, it is worth noting that many previous studies have used similar temperatures. In this sense, a review of the temperature variables and the base temperatures, used for analyzing the relationships between residential energy use and income, can be found in Fazeli et al. (2016). All temperature data are calculated from the *Agencia Estatal de Meteorología* database (AEMET, 2019). This database offers daily data regarding maximum and minimum temperatures of several stations of all Spanish provinces. The data used to prepare average temperatures series have been those of the provincial capital station.

In addition, in order to evaluate the non-linearity of the climate variables, the squared values for the CDD and HDD have been considered. Boyd (2014) included these variables, considering that the heating or cooling needs are not to be lineal. Additionally, in this paper, the CDD variable for temperature values between 18 °C and 22 °C (CDD18-22), and an HDD variable for temperature values between 15 °C and 18 °C (HDD15-18), is also considered when Tb is 22 °C for CDD and 15 °C for HDD. In this case, this range of temperatures have been previously considered as limits, so studies of what happens in these ranges are of special interest.

Fig. 2 shows the Spanish Mediterranean provinces under study. The red color represents tourist overnight stays per inhabitant, being higher as the color becomes darker. The diameter of the pie chart included in each province represents the per capita electricity consumption in the hospitality sector, while each sector represents the proportion of hot and cool days of the year. Fig. 2 shows a clear relationship between tourists and electricity consumption, in per capita terms. In addition, it may also be observed that when there are similar tourist per inhabitant rates, consumption increases with extreme hot and cold days (i.e., when the higher sectors are CDD22 and HDD15).

### 3.3. Control variable data

Other variables have also been considered in this study to properly specify the estimated model.

Firstly, data on per capita provincial income are included to measure the possible effect of income on the electricity consumption of the hospitality sector. As an indicator of the level of provincial income, the per capita GDP level offered by the Spanish Regional Accounts (INE, 2019) has been used. In this study, data are measured in constant millions of Euros per thousand inhabitants, which are converted into logs.

Secondly, the effects of electricity prices on electricity consumption have also been taken into account. Including price variables on E-EKC is not usual, but some papers have previously introduced it to approximate an energy demand function. In this vein, it is worth noting the study by Pablo-Romero et al. (2017c), where an E-EKC is estimated for the transport sector. In order to calculate the electricity price related to the hospitality sector, the Blázquez et al. (2013) methodology has been used to calculate the price variable. Therefore, the indicator used is a weighted average of the companies' revenues from electricity consumed divided by the electricity supply in the free market (≥10 kW). It is measured as constant thousands of Euros to kilowatt hour (kWh), which have also been converted into logs.

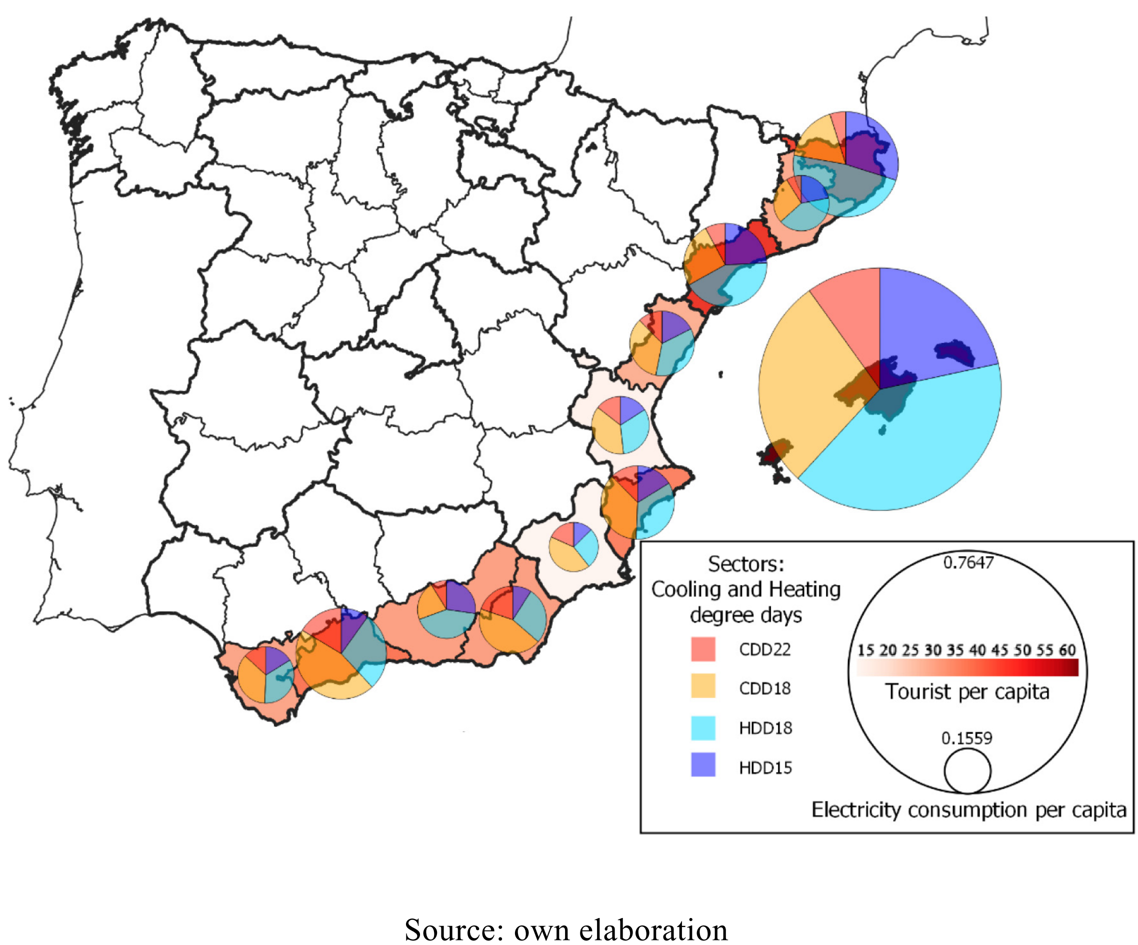


**Fig. 2.** Tourist overnight stays, hospitality electricity consumption and CDD-HDD in the Spanish Mediterranean provinces.

Finally, two other control variables were used in the study. The first one is the percentage value of total overnight stays in 4- and 5-star hotels. In this sense, previous studies, such as those by Tsai et al. (2014), Wang (2012) and Warnken et al. (2005), have highlighted that hotels which offer higher quality service use more energy. Therefore, it may be expected that higher-starred hotels, which offer higher quality service, cause energy consumption growth.

The second is the percentage value of total inbound tourists. In this regard, several previous studies have highlighted that different tourists have different energy use patterns, related mainly to their travel and accommodation choice (Becken et al., 2003). In this case, it could be expected that inbound and national tourists could have different tourism choices, and therefore, it could also affect their energy consumption. Both variables are measured in percentage terms and calculated from the INE database (INE, 2019).

### 3.4. *Descriptive statistics of research variables*

Table 1 shows the main descriptive statistics of the variables presented above. The *overall* statistics refer to the whole panel sample. The total number of observations of each variable is 192, referring to 12 provinces and a time period of 16 years (1999–2014). The *within* statistics refer to each considered Spanish Mediterranean province and to the variation from each province's average. The *between* statistics refer to the standard deviation, and the minimum and maximum of the averages for each considered Spanish Mediterranean province. It can be observed that the data typical standard deviation is higher across the 12 Spanish Mediterranean provinces than across time for all variables, except for the price variable.

## 4. Methodology

Following the previous study by Qureshi et al. (2017), energy consumption may be determined by tourism. However, some other variables may also influence this relationship. Firstly, as stated in Pablo-Romero et al. (2017a), energy consumption tends to vary when the tourism level changes, therefore there may be a non-linear relationship between the variables. This non-linear relationship is studied, as in previous studies by Pablo-Romero et al. (2017a, 2017b), by incorporating the squared value of the tourism variable. Secondly, as commented previously in the literature review section, temperature effects may also influence energy consumption, with these effects being non-linear. In this vein, previous studies, such as Blázquez et al. (2013) among others, have introduced the CDD and HDD variables to test for the non-linearity effects of temperatures on energy consumption. Thirdly, GDP has been also considered to influence the energy consumption in tourism studies. Along this line, many studies, such as Liu et al. (2016b) and Gokmenoglu and Eren (2019), incorporate this variable when analyzing the relationship between energy consumption and tourism. Fourthly, energy prices have been also considered to influence energy consumption when testing the EKCs hypothesis—for example, in Pablo-Romero et al. (2017c). Finally, as stated before, some authors (Tsai et al., 2014; Wang, 2012; and Warnken et al., 2005) have found that higher-quality service hotels use more energy, while different tourists have different energy use

**Table 1**
Descriptive statistics.

| Variable | | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Overnight stays per thousand inhabitants in logs | overall | 1.9425120 | 0.877850 | 0.271499 | 4.268882 |
| (T) | between | | 0.906295 | 0.677091 | 3.938549 |
| | within | | 0.116151 | 1.521012 | 2.272844 |
| Hospitality sector electricity consumption per thousand inhabitants in logs | overall | −1.159776 | 0.450882 | −1.967947 | 0.018109 |
| (E) | between | | 0.440346 | −1.626081 | −0.093007 |
| | within | | 0.156703 | −1.592707 | −0.824169 |
| Temperature variable: | overall | 6.775016 | 0.237826 | 6.004381 | 7.236483 |
| CDD18 | between | | 0.212216 | 6.361124 | 7.117664 |
| | within | | 0.122670 | 6.304075 | 7.111050 |
| Temperature variable: | overall | 5.751720 | 0.427467 | 4.160444 | 6.579113 |
| CDD22 | between | | 0.356895 | 5.045354 | 6.351144 |
| | within | | 0.255571 | 4.527984 | 6.572551 |
| Temperature variable: | overall | 6.219171 | 0.508600 | 4.948050 | 7.180222 |
| HDD15 | between | | 0.496845 | 5.387691 | 6.943137 |
| | within | | 0.176420 | 5.762925 | 6.706972 |
| Temperature variable: | overall | 6.930523 | 0.314700 | 6.338594 | 7.561225 |
| HDD18 | between | | 0.310313 | 6.478891 | 7.403578 |
| | within | | 0.101350 | 6.679371 | 7.256219 |
| Temperature variable: | overall | 1.023296 | 0.205683 | 0.657370 | 1.955227 |
| CDD18-22 | between | | 0.151031 | 0.766520 | 1.315770 |
| | within | | 0.145874 | 0.538499 | 1.776091 |
| Temperature variable: | overall | 0.711352 | 0.204725 | 0.381003 | 1.390543 |
| HDD15-18 | between | | 0.191293 | 0.460440 | 1.09120 |
| | within | | 0.090452 | 0.401386 | 1.010696 |
| GDP per thousand inhabitants in logs | overall | 2.977004 | 0.208705 | 2.595906 | 3.353623 |
| (Y) | between | | 0.212307 | 2.709223 | 3.289585 |
| | within | | 0.044821 | 2.853170 | 3.055025 |
| Electricity price in logs | overall | 0.121153 | 0.026430 | 0.076992 | 0.177288 |
| (p) | between | | 0.002439 | 0.118634 | 0.125861 |
| | within | | 0.026326 | 0.078847 | 0.179143 |
| Overnights in hotels with 4 and 5 stars as a percentage of the total | overall | 0.410279 | 0.161286 | 0.044256 | 0.658240 |
| (ST) | between | | 0.124830 | 0.189137 | 0.593590 |
| | within | | 0.107932 | 0.049820 | 0.667182 |
| Inbound tourists as a percentage of the total | overall | 0.482928 | 0.223436 | 0.133394 | 0.716990 |
| (ExtT) | between | | 0.227543 | 0.166686 | 0.686019 |
| | within | | 0.046873 | 0.319673 | 0.610022 |

patterns (Becken et al., 2003).

Therefore, based on the previous academic models, the general function for testing tourism and temperature effects on the electricity consumption of the hospitality sector may be expressed as follows:

$$E_{it} = A_{it} + \beta_1 Y_{it} + \beta_2 T_{it} + \beta_3 T^2 it + \beta_4 CDD_{it} + \beta_5 HDD_{it} + \beta_6 ExtT_{it} + \beta_7 ST_{it} + \beta_8 P_{it} + e_{it} \quad (1)$$

where *E* is the hospitality sector's electricity consumption per inhabitants in logs, *Y* is the GDP per inhabitants in logs, *T* is the overnight stays per inhabitants in logs, *CDD* is the Cooling degree days in logs, *HDD* is the Heating degree days in logs, *ExtT* is the percentage value of total inbound tourists, *ST* is the percentage value of total overnight stays in 4- and 5-star hotels, *P* indicates electricity prices in logs, *A* indicates the sum of the *time* and *province effects, i* represents the Spanish Mediterranean provinces and *t* the years from 1999 to 2014. Finally, *e* is the random error term and *β* are the coefficients to be estimated.

In order to test if these additional variables contribute significantly enough to explain electricity consumption in the hospitality sector, the significance of each variable is tested by using the Akaike's Information Criterion (AIC). Table 2 shows the AIC statistic values when each variable is included in the base model (the model that only regresses electricity consumption in the considered sector with respect to the tourism variable). As Table 2 shows, the AIC statistic values decrease when the rest of the variables are included in the base model. Therefore, it can be considered that the variables have enough of a significant contribution to explain electricity consumption in the hospitality sector.

In addition to this specification, in order to evaluate the possible global warming effects reinforcing other variables, cross-products between ExtT and ST variables and CDD18 have also been tested in the model. These cross-product variables would measure the effects of the temperature on the effects of higher-star hotels and foreign tourism on the hospitality sector electricity consumption. In this case, the specification is as follows:

$$E_{it} = A_{it} + \beta_1 Y_{it} + \beta_2 T_{it} + \beta_3 T^2 it + \beta_4 CDD_{it} + \beta_5 HDD_{it} + \beta_6 ExtT_{it} + \beta_7 ST_{it} + + \beta_8 P_{it}\ \beta_0 CDD^* ST_{it} + \beta_{10} CDD^* ExtT_{it} + e_{it} \quad (2)$$

As shown in Table 2, the AIC values indicate that these variables contribute to explaining electricity consumption in the hospitality sector.

Likewise, in order to evaluate the non-linearity effect of global warming, squared values of CDD and HDD are considered, as in the study of Boyd (2014). In addition, the estimation procedure was also completed by considering the squared values of CDD22 and HDD15, and CDD18-22 and HDD15-18. These variables may allow for more flexibility, taking into account that the increased amount of energy consumption due to temperature increases may depend on the initial temperature level (Chang et al., 2016). Therefore, the third equation proposed is as follows:

$$E_{it} = A_{it} + \beta_1 Y_{it} + \beta_2 T_{it} + \beta_3 T^2 it + \beta_4 CDD_{it} + \beta_5 HDD_{it} + \beta_6 ExtT_{it} + \beta_7 ST_{it} + + \beta_8 P_{it}\ \beta_9 CDD^2 it + \beta_{10} HDD^2{}_{it} + \beta_{11}\,(\text{CDD18-22})_{it} + \beta_{12}\,(\text{HDD15-18})_{it} + e_{it} \quad (3)$$

Once again, the AIC values indicate that these variables contribute to explaining electricity consumption in the hospitality sector (see Table 2).

In order to properly estimate equations [1] to [3], multicollinearity and the stochastic nature of the variables were examined. The variance inflation factors (VIF) were performed for each variable in order to test for multicollinearity. As expected, multicollinearity is present, with some variables exceeding the value of 5. Therefore, all data were transformed into deviations from the geometric mean of the sample to rule out this problem, as previously performed in Pablo-Romero et al. (2017a).

Additionally, the Pesaran cross-sectional dependence (CD) test (2004), the Pesaran (2007) panel unit root tests (the cross-sectionally augmented Im, Pesaran and Shin tests-CIPS) and the Westerlund co-integration test (2007) were performed to study the stochastic nature of the series. As variables are I (1) (according to the CIPS test results), and the null hypothesis of no cointegration cannot be rejected for all the considered statistics (according to the Westerlund cointegration test results), the model was estimated in first differences. In addition, estimating by using first differences allows to eliminate constant or fixed effects that may condition electricity use in the Mediterranean provinces and which are not controlled by the model.

Using Δ to indicate first differences of the transformed variables, equations [1] to [3] may be rewritten as follows:

$$\Delta E_{it} = \Delta A_{it} + \beta_1 \Delta Y_{it} + \beta_2 \Delta T_{it} + \beta_3 \Delta T^2{}_{it} + \beta_4 \Delta CDD_{it} + \beta_5 \Delta HDD_{it} + \beta_6 \Delta ExtT_{it} + \beta_7 \Delta ST_{it} + \beta_8 \Delta P_{it} + e_{it} \quad (4)$$

$$\Delta E_{it} = \Delta A_{it} + \beta_1 \Delta Y_{it} + \beta_2 \Delta T_{it} + \beta_3 \Delta T^2{}_{it} + \beta_4 \Delta CDD_{it} + \beta_5 \Delta HDD_{it} + \beta_6 \Delta ExtT_{it} + \beta_7 \Delta ST_{it} + \beta_8 \Delta P_{it} + \beta_9 \Delta CDD^* ST_{it} + \beta_{10} \Delta CDD^* ExtT_{it} + e_{it} \quad (5)$$

$$\Delta E_{it} = \Delta A_{it} + \beta_1 \Delta Y_{it} + \beta_2 \Delta T_{it} + \beta_3 \Delta T^2{}_{it} + \beta_4 \Delta CDD_{it} + \beta_5 \Delta HDD_{it} + \beta_6 \Delta ExtT_{it} + \beta_7 \Delta ST_{it} + \beta_8 \Delta P_{it} + \beta_0 \Delta CDD^2 it + \beta_{10} \Delta HDD^2{}_{it} + \beta_{11} \Delta(\text{CDD18-22})_{it} + \beta_{12} \Delta(\text{HDD15-18})_{it} + e_{it} \quad (6)$$

where $\Delta \overline{A}_{it} = \delta_t$, and $\delta$ indicates a single time-period *dummy* coefficient for each year *t*.

Finally, in order to properly estimate previous equations, the estimated model has been chosen taking into account the Wooldridge test for autocorrelation (2002) and the Wald test for homoscedasticity (Greene, 2002) results. Accordingly, the feasible generalized least squares model (FGLS) was used to estimate equations [4] to [6].

**Table 2**
Significance test of each research variable.

| Function specification | AIC |
|---|---|
| base model: E = f(T) | −503.19 |
| E = f (T, T$^2$) | −518.67 |
| E = f (T, CDD18) | −549.57 |
| E = f (T, HDD18) | −505.33 |
| E = f (T, CDD22) | −533.30 |
| E = f (T, HDD15) | −507.86 |
| E = f (T, Y) | −514.18 |
| E = f (T, ST) | −504.29 |
| E = f (T, ExtT) | −507.30 |
| E = f (T, P) | −505.84 |
| E = f (T, Squared-CDD18) | −538.48 |
| E = f (T, Squared-HDD18) | −541.36 |
| E = f (T, Squared-CDD22) | −525.41 |
| E = f (T, Squared-HDD15) | −524.71 |
| E = f (T, CDD[a]ExtT) | −538.52 |
| E = f (T, CDD[a]ST) | −530.53 |
| E = f (T, CDD18-22) | −528.67 |
| E = f (T, HDD15-18) | −513.34 |

[a] In order to calculate the AIC values the iterated GLS estimator instead of two-step GLS estimator have been used.

## 5. Results and discussion

Table 3 shows the estimated results of [4] when using, alternatively, CDD18, HDD18 and CDD22, HDD15 temperature variables. Additionally, the last two columns include the estimated results

**Table 3**
Estimate results of [4].

| | FGLS [4] with CDD18&HDD18 | FGLS [4] with CDD22&HDD15 | FGLS [4] with CDD18&HDD18 and without P | FGLS [4] with CDD22&HDD15 and without P |
|---|---|---|---|---|
| T | 0.168*** | 0.140*** | 0.174*** | 0.130*** |
| | (0.047) | (0.049) | (0.049) | (0.046) |
| $T^2$ | 0.077*** | 0.074*** | 0.078*** | 0.076*** |
| | (0.021) | (0.022) | (0.022) | (0.020) |
| Y | 0.756*** | 0.504*** | 0.716*** | 0.548*** |
| | (0.159) | (0.174) | (0.169) | (0.166) |
| CDD18 | 0.063*** | | 0.077*** | |
| | (0.022) | | (0.021) | |
| HDD18 | 0.080** | | 0.104*** | |
| | (0.037) | | (0.033) | |
| CDD22 | | 0.024*** | | 0.021*** |
| | | (0.009) | | (0.009) |
| HDD15 | | 0.017 | | 0.017 |
| | | (0.020) | | (0.021) |
| ExtT | 0.228** | 0.214** | 0.301*** | 0.213** |
| | (0.108) | (0.087) | (0.110) | (0.110) |
| ST | 0.138** | 0.265** | 0.130* | 0.151** |
| | (0.062) | (0.121) | (0.083) | (0.062) |
| P | 0.002 | −0.028 | | |
| | (0.040) | (0.039) | | |

when eliminating the price variable due to its lack of significance.

The results indicate that the electricity E-EKC hypothesis for the hospitality sector is refused for the considered Spanish Mediterranean provinces, in the 1999–2014 period, as the T and $T^2$ coefficients are positive and significant in all the performed estimates. Instead, the estimated coefficient signs show that there is an increasing relationship between both variables. Therefore, as tourist overnight stays in the Spanish Mediterranean provinces increase, so does the electricity consumption in the hospitality sector, with the increases rising as tourism grows. Thus, the increase in overnight stays is generating a more than proportional increase in electricity consumption in the hospitality sector. This may be due to the need to open new establishments as the number of tourists' increases. These results are in line with those observed in Pablo-Romero et al. (2017a) for the Spanish provinces.

Regarding the temperature variables, estimated coefficients for the CDD and the HDD variables are positive in all estimates. The results indicate that the estimated values for the CDD variables are all positive, showing that an increase in temperature produces a greater demand for cooling energy. These results are in line with previous studies referring to Greece and Portugal. In the first case, Asimakopoulos et al. (2012) estimate that an increase of 24.8% in cooling demand is expected due to CC, while in the second case, Pinto et al. (2016) estimate a potential primary energy for a cooling increase of 25%.

In addition, the results also indicate that the estimated values for the HDD variables are positive, showing that a decrease in temperature produces a greater energy demand for heating in the hospitality sector, and therefore more electricity use in the sector. Nevertheless, it is worth noting that when HDD is calculated by using the base temperature of 15 °C, the variable becomes non-significant. The lack of significance could be related to the fact that if the temperature is too low, tourists would not come to these destinations, therefore less energy use is needed, and some hotels or restaurants close. Alternatively, it could also be explained by a fuel substitution between electricity and fuels. In this sense, it could be interesting, in future research, to analyze how changes in temperature may have effects on tourism arrivals, and indirectly on electricity use.

The estimated results also show positive and significant values in all estimates for the ST and Ext coefficients, both of these variables therefore having positive effects on electricity consumption. The positive value of these coefficients could be related to the fact that hotels with more stars offer more services that, as well as the fact that foreign tourists demand more services. These services may mean an increase in electricity consumption. It could therefore be appropriate to reinforce the mentioned policies in higher-star hotels and in those spaces usually used by inbound tourists. Along this line, several studies indicate the possibility of saving energy use in these hotels. Thus, for example, the study by Alamri (2013) indicates how it was possible to save up to 15% of the total energy consumption in five-star hotels, every year, by introducing Wireless Energy Technology. Likewise, the study by Hotel Energy Solutions (2011) indicates that there is a potential for 25–30% energy savings in the highest annual energy consumption hotels in southern Europe.

Finally, regarding the price variable, it should be highlighted that in the performed estimates no significance is observed. Additionally, it is worth noting that excluding the price variable from the estimates does not notably change the estimated valued for the rest of the variables, as, for example, occurs in Pablo-Romero et al. (2017c) when estimating an E-EKC referring to the transportation sector. The lack of significance of the price variable may be in line with the results obtained by Labandeira et al. (2012), who find that companies and large consumers of electricity are hardly affected by the variations observed in prices. These results may indicate that energy policies focusing on price may not have effects on electricity consumption, at least in the current ranges.

Table 4 shows the estimated results of [5] when using, alternatively, CDD18, HDD18 and CDD22, HDD15 temperature variables. Additionally, Table 4 also shows the estimated values when eliminating the price variable, because, as before, it is not significant in any case.

Once again, the results indicate that the E-EKC hypothesis for the hospitality sector is not supported, with an increasing relationship between the studied variables. Likewise, as before, estimated coefficients for the CDD and the HDD variables are positive in all estimates, with the HDD variable becoming non-significant when using the base temperature of 15 °C. The estimated results also show positive and significant values in all estimates for the ST and Ext coefficients. Finally, it is also worth noting the positive and significant values for the cross-product between ST and the CDD variable. The results may indicate that these hotels may be offering more services, inducing more electricity use, and, as temperature

**Table 4**
Estimate results of [5].

| | FGLS [5] with CDD18&HDD18 | FGLS [5] with CDD18&HDD18 and without P | FGLS [5] with CDD22&HDD15 | FGLS [5] with CDD22&HDD15 and without P |
|---|---|---|---|---|
| T | 0.153*** (0 .049) | 0.140*** (0.045) | 0.100*** (0.045) | 0.166*** (0.051) |
| $T^2$ | 0.071*** (0.021) | 0.072*** (0.020) | 0.082*** (0.018) | 0.071*** (0.021) |
| Y | 0.731*** (0.173) | 0.794*** (0.151) | 0.878*** (0.181) | 0.686*** (0.183) |
| CDD18 | 0.095*** (0.026) | 0.109*** (0.024) | | |
| HDD18 | 0.103** (0.042) | 0.160** (0.038) | | |
| CDD22 | | | 0.045*** (0.011) | 0.032*** (0.011) |
| HDD15 | | | 0.047** (0.022) | 0.024 (0.024) |
| ExtT | 0.219* (0.116) | 0.212* (0.119) | 0.408*** (0.115) | 0.215* (0.126) |
| ST | 0.113*** (0.070) | 0.194*** (0.054) | 0.244*** (0.060) | 0.124* (0.071) |
| CDD*ExtT | 0.007 (0.116) | 0.029 (0.112) | −0.079 (0.124) | −0.011 (0.126) |
| CDD*ST | 0.209* (0.130) | 0.233** (0.112) | 0.212* (0.136) | 0.240** (0.136) |
| P | −0.004 (0.0467) | | −0.024 (0.034) | |

becomes higher, the electricity use in these hotels becomes higher than in others. This may also be related to the comfort conditions offered in these establishments. Therefore, focusing on these kinds of hotels could be convenient when applying energy policies related to energy efficiency and renewable energy use. In this sense, ecolabels could be appropriate.

Finally, Table 5 shows the estimated coefficient values when estimating [6]. The second and third columns show the estimates when the squared values of the HDD and CDD are included in the function, but not the variable referring to the ranges HDD15-22 and CDD18-22. The fourth column shows the estimated coefficient of [6], and finally, the fifth column shows the estimated coefficient of [6] when the price variable is not included, once again due to the lack of significance in the previous estimate.

**Table 5**
Estimate results of [6].

| | FGLS [6] with CDD18&HDD18 | FGLS [6] with CDD22&HDD15 and without CDD18-22&HDD15-18 | FGLS [6] with CDD22&HDD15, and CDD18-22&HDD15-18 with P | FGLS [6] with CDD22&HDD15, and CDD18-22&HDD15-18 without P |
|---|---|---|---|---|
| T | 0.133** (0.053) | 0.082*** (0.029) | 0.141*** (0.063) | 0.135** (0.063) |
| $T^2$ | 0.070*** (0.024) | 0.062*** (0.025) | 0.084*** (0.025) | 0.083*** (0.025) |
| Y | 0.779*** (0.183) | 0.732*** (0.201) | 0.518** (0.219) | 0.555*** (0.217) |
| CDD18 | 0.104*** (0.030) | | | |
| Squared-CDD18 | 0.086** (0.044) | | | |
| HDD18 | 0.081*** (0.041) | | | |
| Squared-HDD18 | −0.050 (0.046) | | | |
| CDD22 | | 0.068*** (0.016) | 0.155*** (0.051) | 0.158*** (0.051) |
| Squared-CDD22 | | 0.044*** (0.015) | 0.032** (0.014) | 0.034*** (0.012) |
| HDD15 | | 0.010 (0.028) | 0.168*** (0.060) | 0.134* (0.080) |
| Squared-HDD15 | | −0.004 (0.015) | −0.033*** (0.016) | −0.035** (0.015) |
| CDD18-22 | | | 0.133* (0.080) | 0.178*** (0.059) |
| HDD15-18 | | | 0.367*** (0.119) | 0.378*** (0.120) |
| ExtT | 0.351*** (0.118) | 0.287* (0.140) | 0.282** (0.144) | 0.308* (0.137) |
| ST | 0.181*** (0.061) | 0.130* (0.074) | 0.124* (0.077) | 0.134* (0.076) |
| P | 0.004 (0.047) | −0.062 (0.050) | −0.014 (0.039) | |

Table 5 again shows that the E-EKC hypothesis is not supported for the hospitality sector in the Spanish Mediterranean provinces and that an increasing relationship is observed. Therefore, taking into account the results shown in Tables 3–5, related to the tourism variable, it may be appropriate to implement some measures to compensate for the effect of tourism in increasing electricity consumption. Along this line, it could be appropriate to implement two main policies in order to avoid environmental damage linked to electricity consumption increases in the sector. Firstly, more energy efficiency measures need to be applied to compensate for the electricity consumption increase due to tourism growth. Nevertheless, authors such as Becken and Dolnicar (2016) found that companies perceive that these projects are not always well-matched with productivity, the financial cost being considered an important barrier. Secondly, renewable energies could be promoted in a double sense: On the one hand, the use of renewable technologies may be used in the hospitality buildings. Along this line, Chan et al. (2017) pointed out that hotel experts prefer solar systems. Thus, according to Gallo et al. (2014), these systems could supply up to 50% of hotels' energy use in Southern EU countries such as Spain. On the other hand, the use of renewable energies could be promoted for electricity generation, so that emissions related to this consumption increase would not provoke the generation of emissions. In this regard, the change in the energy mix could be appropriate. However, it is worth noting that a stronger growth in renewable energy could be expected due to the fact that solar and wind power are becoming more competitive, but there are some barriers that are still limiting the incorporation of renewable energy into power generation, such as surplus energy storage (European Union, 2018). Several studies, such as the report by Deloitte (2016), consider that self-generation and self-consumption may play a very important role, pointing out that it could be convenient to allow free access and to not impose penalties for this form of energy generation-consumption.

Regarding the estimated temperature coefficients, it is worth noting that Table 5 results indicate that the hypothesis of non-linearity effects of temperature variables on the electricity consumption is supported. The positive value of the squared variable indicates an increasing elasticity of electricity consumption in the sector when the CDD increases. This is also reinforced by the CDD18-22 estimate value, as this value is lower than that obtained for CDD22, also indicating that, when temperature increases, elasticity of electricity use will also increase for cooling spaces. Therefore, if global warming occurs, and the other variables remain constant, electricity consumption in the hospitality sector will tend to increase, with this increase being higher as the temperature increases. This effect may be due to the energy efficiency loss of the devices when they are used more forcefully, that is, when they require more effort in their use. These results are in line with those observed by Chang et al. (2016), who pointed out that the temperature increase would have more effect on energy use for higher temperature levels.

In the case of HDD coefficients values, the estimated values for HDD15 and HDD15-18 are positive, indicating that electricity consumption increases when temperatures become lower, so that more heating is necessary to warm spaces. Nevertheless, it is worth noting that the coefficient value is lower for the HDD15 than for the HDD15-18 variable, indicating that increasing the HDD for temperature ranges between 15 and 22 °C creates higher electricity needs than when increasing the HDD for temperatures below 15 °C. Likewise, this effect is also reinforced by the negative value for squared-HDD15, which indicates that the elasticity of electricity consumption, with respect to HDD15, is decreasing as temperature goes down, and heating is needed. It can be expected, then, that an increase of the temperatures that causes an increase of temperate days in which the use of the heating is needed (temperatures below 18 °C) is going to cause an increase in the use of electricity in the hospitality sector.

Finally, it should be highlighted that the estimates have been performed considering the average daily temperature, without taking into account the wide range between maximum and minimum temperatures, and without differentiating by months or seasonal characteristics. Therefore, when data permits, it would be interesting to undertake further research on these questions, which could improve the results, especially for HDDs.

## 6. Conclusions and policy implications

The EU has recently presented a strategic long-term vision for a climate-neutral economy by 2050. As the EU considers that CC is a serious concern for Europeans, a multi-sectoral socio-economic transformation is considered to be necessary. On the one hand, the EU considers it necessary to achieve a net zero GGE by 2050. On the other hand, the adaptation of the economic sectors to a warming climate is considered necessary. This study focuses on the tourism sector's adaptation to temperature changes by analyzing their effects on the hospitality sector's electricity consumption.

Specifically, and using panel data referring to 12 Spanish Mediterranean provinces and the 1999–2014 time period, this study tests the effects of tourist stays and temperature on the electricity consumption of the hospitality sector by estimating an extended E-EKC for the sector. In addition, in order to take into account the non-linearity temperature effects on electricity consumption, HDD and CDD are calculated for different temperature ranges and the squared values of variables are considered.

The results show that the E-EKC hypothesis is not supported, since it is observed that there is a growing relationship between the electricity consumption in the hospitality sector and the overnight stays. In addition, the results show that increased overnight stays in hotels with higher-star ratings, increased presence of foreign tourists and higher income levels tend to increase the electricity consumption in the hospitality sector. Likewise, the results show that electricity prices have no significant effects on the hospitality sector's electricity consumption.

Regarding the temperature effects, the results show a notable influence of temperature variables on electricity use, as increasing CDD and HDD cause electricity consumption to increase. The results indicate that these effects are not linear. In the case of CDD, the results indicate that the elasticity of the electricity consumption, with respect to CDD, is increasing. Therefore, global warming will induce not only increasing electricity use, but also that higher temperature increases will tend to strengthen these effects.

In the case of HDD, the results also indicate positive effects. Nevertheless, the elasticity value of the electricity use, with respect to the HDD, tends to be non-significant when the base temperature is lower. In addition, it is observed that although the elasticity is positive, it becomes lower as the variable grows, indicating that the effect is going to be lower as the temperatures become lower, or alternatively, that the effect will be greater when temperatures become higher.

The results indicate that tourism growth and global warming (increasing CDD and reducing HDD15 and increasing HDD, between 15 and 18 average temperature ranges) have a positive influence on hospitality electricity use. Therefore, it could be appropriate to implement some measures in order to control the increase in electricity use, at least the use of electricity from non-renewable sources. Along this line, it could be appropriate to implement energy saving measures, especially in those hotels with highest energy use, such as those with a high number of stars. Additionally, it could also be recommended to install renewable energy and electricity generation systems in hotels, especially if it is accompanied by state laws that do not punish electricity self-consumption. Finally, it is also considered appropriate to encourage the change in the electricity mix toward a more renewable generation.

Additionally, taking into account these non-linear results on temperature, it could be convenient to delve into these non-linearity effects in future research; for example, by differentiating the estimates by season. In addition, it could also be interesting to analyze how changes in temperature may have effects on tourism arrivals, and indirectly on electricity use. Likewise, it may also be interesting to analyze the effect of a rise in temperatures, for example of 1 °C, on the CDD and HDD variables and, in consonance, on the hospitality electricity consumption.

Finally, it is also worth noting the positive and significant values for the ST variable and also for the cross-product. In this regard, the results may indicate that these hotels may be offering more services, inducing more electricity use. In addition, as the temperature becomes higher, the electricity use in these hotels will become higher than in others.

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