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Analysis of electricity consumption in the tourism sector. A decomposition approach

Vincenzo Bianco

University of Genoa - DIME/TEC, Division of Thermal Energy and Environmental Conditioning, Via All'Opera Pia 15/A, 16145, Genova, Italy

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ABSTRACT

Index decomposition analysis (IDA) has become a common tool for studying the evolution of energy consumption. In its initial form it comprises three contributions, namely activity, structure and intensity effects. Various sectors of activities were studied in the literature by employing IDA approach and the present work proposes its application to the electricity consumption in the tourism sector. The proposed decomposition analysis is developed on the basis of seven indexes grouped in three macro contributions, namely energy intensity, economic structure and industrial structure. The decomposition is performed in the period 1995–2017 and Italy was used as test case for the methodology. The analysis highlights that, overall, the changes in electricity intensity and in the industrial structure were responsible for an increase of the electricity consumption of 5.581 GWh, whereas the economic structure was responsible for a decrease of 1.337 GWh. Their contemporary effect determined a total variation of electricity consumption between 1995 and 2017 of 4.244 GWh. Results demonstrated that the proposed IDA equation specifically tailored for the tourism sector allows to provide a detailed analytical explanation of the factors affecting electricity consumption in the Italian tourism sector. The same framework can be applied to any other country and source of energy.

1. Introduction

Italy is one of the top destinations in the world for both tourism and business motivations. The management of such a large flow of travelers requires the utilization of a substantial amount of resources, including electricity. For this reason it is of fundamental importance to understand the factors which determine the consumption, in order to define efficiency measures to reduce the sectoral energy intensity and to increase its sustainability.

The importance of the environmental impact of the tourism sector is demonstrated by the attention devoted to this issue in previously published analyses. In fact, Robaina-Alves et al. (2016) analyzed energy related carbon emissions in the Portuguese tourism sector, in order to understand which effects contributed more to the emissions, as well as in which tourism subsectors emissions are more relevant. They employed a decomposition analysis based on the Logarithmic Mean Divisia Index (LMDI). Also Moutinho et al. (2015) focused on the tourism sector in Portugal. They performed a decomposition analysis of the carbon emissions in the period 2000–2012 by taking into account five effects which provoke the changes. The paper demonstrates that the main changes are due to change in energy and economic efficiency in the different touristic subsectors taken into account.

Similarly, Tang et al. (2014) investigated on the carbon emissions of the Chinese tourism sector due to its quick development of the recent years. They developed a set of indicators to analyze the relationship between carbon emissions and economic development of the sector. Likewise, Meng et al. (2016) estimated the global, i.e. direct and indirect, carbon emissions of the tourism sector by using an input-output approach. The study determined that carbon emissions of the tourism sector represent ~2.5% of the emissions of all the industrial sectors and it was highlighted that tourism industry has low carbon and energy intensities with respect to the other Chinese industrial sectors.

In the same way, Tang et al. (2018) developed a computational model to estimate direct and indirect carbon emissions and energy consumption in the Wulingyuan area in China. They estimated the efficiency of the tourism sector in the period 1979–2015. They found that among all the industrial sectors of the area, the tourism is the most efficient one. On the other hand electricity represents the first form of energy for the sector, thus if the power sector has a

E-mail addresses: vincenzo.bianco@unige.it, vbianco@libero.it.

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low environmental footprint this is also reflected in the tourism sector.

In the same geographic area, specifically in Taiwan, Tsai et al. (2014) analyzed carbon emissions from four different typologies of hotels, namely international tourist hotels, standard tourist hotels, general hotels, and homestay facilities. According to their analysis, international hotels show the highest carbon footprint, therefore the study concludes that a re-thinking of the accommodation business model and implementation of massive energy efficiency policies are necessary.

The study of Taiwan also attracted the attention of Sun (2014), who developed a framework for allocating carbon emissions between national and foreign tourist flows in Taiwan. The analytical model employed for the analysis is represented by an extended input-output model. The analysis demonstrated that Taiwanese tourism sector performs worse than the average economy and this can be attributed to the fact that the tourism sector largely relies on a high volume of airplane transportation. In another study, Sun (2016) developed a calculation model for the decomposition of carbon footprint and economic growth in the tourism sector, in order to identify the links among economic growth, technological development and environmental externalities. A classical input-output framework was considered for the analysis. It was found that carbon emissions are linked to the economic development of the sector, therefore technological development is still far from determining the de-coupling.

By employing a comparable approach, Perch-Nielsen et al. (2010) developed a top down analysis on the carbon intensity of the tourism sector in Switzerland. They developed a set of five indexes to estimate the contributions to the carbon intensity and they found that the largest contributor is represented by the air transport. Furthermore, according to their analysis, the tourism sector results to be four times more carbon intensive with respect to the average of the Swiss economy.

The case of Turkey attracted the attention of Katircioglu (2014), who performed an econometric investigation to assess the long run equilibrium among tourism, energy consumption and environmental degradation, approximated with carbon emissions. The investigation highlights that tourism and energy consumption are in equilibrium with carbon emissions, therefore the tourism development determines not only an increase of energy consumption, but also of carbon emissions. To break this trend it is necessary to implement adequate environmental policies which determine an increase of the efficiency of the tourism industry in Turkey.

The Spanish case with specific reference to the Balearic Islands was investigated by Bakhat and Rosselló (2011), who estimated the contribution of the touristic flow to the increase of the electricity demand. They demonstrated that, in their case study, the contribution of tourism to the increase of electricity demand is modest.

Other authors, such as Pulido-Fernández et al. (2019), developed multi countries studies. They investigated the relationship between tourism activity and environmental sustainability by employing a structural equation model. Their results show a direct relationship between the tourism activity and the environmental impact on the specific destination. They conclude that environmental policies are strictly necessary to regulate the phenomenon and to mitigate its impact.

Despite its importance as one of the world leading destination, quantitative studies focusing on energy consumption in the Italian tourism sector are scarce. In particular, Bianco et al. (2017b) developed a bottom up model for the estimation of energy consumption, namely electricity and natural gas, in the Italian hotel sector. Whereas Cucculelli and Goffi (2016) analyzed the relationship between sustainability and competitiveness of a set of Italian destinations of excellence. On the basis of the results of a quantitative analysis developed by employing regressions models and principal components analysis, they concluded that sustainability contributes to the enhancement of the competitiveness. Other available studies focus on more specific issues or sub-sectors related to tourism. Therefore the literature shows a lack of studies related to the analysis of the overall energy performance of the tourism sector in Italy and, due to its relevance at international level, it appears fundamental to cover this knowledge gap.

The present paper aims to bridge this gap by analyzing the evolution of electricity consumption in the Italian tourism sector.

From the technical and managerial point of view, the understanding of the evolution of electricity consumption in the Italian tourism sector is important for electricity suppliers, policy makers and companies working in the tourism sector, since, within the service sector, tourism has a relevant impact both in terms of electricity consumption and GDP contribution. To comprehend the drivers determining the electricity demand supports electricity suppliers in estimating their expected volumes, helps policy makers in defining the optimal interventions to promote energy efficiency and assists tourism companies in the identification of possible areas of interventions for reducing their consumption.

The investigation is developed by employing an index decomposition analysis (IDA) framework based on the Logarithmic Mean Divisia Index (LMDI) approach, as suggested by Ang (2005) and Ang (2015). The method is considered powerful, because, due to its relatively simple analytical framework, it allows to obtain relevant quantitative information. The proposed approach is general and applied to different sectors of the economy, as demonstrated by the relevant number of outstanding studies available in the literature. For example, Kwon (2005) studied the factors affecting carbon emissions from car travel in UK during the period 1970–2000, Moutinho et al. (2016) investigated on the factors provoking carbon emissions in EU 15, Moutinho et al. (2018) explored the drivers for carbon emissions in the top countries for RES development, Choi and Oh (2014) estimated the variations in energy intensity of the Korean manufacturing industry, Colinet Carmona and Roman Collado (2016) implemented a LMDI decomposition with reference to the energy consumption in Andalusia, Bianco (2018) identified the drivers for natural gas consumption in Italy, finally, very recently Xie and Lin (2019) and Xie et al. (2019) applied the decomposition framework to the Chinese food industry and power sector, respectively.

Therefore, it can be said that the proposed methodology is widely used and its results are considered robust and consistent, because of the absence of any residual (Ang et al., 2003).

The present study has a twofold focus, namely:

- the development of an innovative index decomposition approach, in order to understand which are the factors that affect electricity consumption in the tourism sector;
- to apply the proposed methodology for the analysis of the electricity consumption in the Italian tourism sector during the period 1995–2017.

In particular, seven different contributions have been identified and estimated in order to describe the economic structure, energy efficiency and industrial structure of the tourism sector. Then this framework is applied to the case of Italy in order to demonstrate its validity.

To the best of author's knowledge the present work represents the first attempt to introduce an index decomposition analysis specifically tailored for the tourism sector. The proposed equation can be applied to decompose energy consumption in the tourism sector in any country or region and it is based on data usually available in national/regional statistics. It can be considered a powerful tool due to its analytical simplicity and easiness in retrieving the data to develop the analysis.

It is believed that the present paper will be of interest for policy makers and energy managers dealing with the implementation and promotion of energy efficiency measures.

The paper is organized as follows. Section two describes the proposed index decomposition approach and the corresponding LMDI framework. Whereas section three elaborates on the historical data related to the Italian tourism sector, as well as section four shows the results deriving from the decomposition analysis. Finally, section five illustrates the conclusions and main findings of the investigation.

2. Methodology

The methodology considered for the development of the present work is the IDA jointly with the LMDI, that allows a perfect decomposition adequate for energy and emissions related studies (Madaleno and Moutinho, 2017).

It offers a unique and flexible structure for the quantitative estimation of the drivers determining energy consumption and/or carbon emissions in different sectors of activities.

The developed IDA-LMDI decomposition framework proposes seven factors to identify, quantify and explain the drivers which cause the variation in electricity consumption in the tourism sector.

The background idea is to provide a representation of the tourism sector by looking at its productive structure, which is divided in the three areas, namely energy intensity, economic structure and industrial structure.

The methodology is conceived and developed with reference to Italy, but it can be applied to other countries as well. Equation (1) represents the general form of the model:

$$E_{el} = Y_1 \cdot Y_2 \cdot Y_3 \cdot Y_4 \cdot Y_5 \cdot Y_6 \cdot Y_7 \quad (1)$$

Thus electricity consumption is given by the product of seven indexes related to three areas of analysis. In particular, Y_1 refers to the energy intensity of the sector, Y_2 and Y_3 are related to the economic structure of the sector and Y_4, Y_5, Y_6 and Y_7 regard the industrial structure of the sector.

The seven indexes included in the decomposition are named as energy intensity (EI), productivity (P), turnover (T), accommodation structure (AS), average hotel dimension (AHD), hotel share (HS) and total number of hospitality structures (N). Therefore, Eq. (1) can be rewritten as:

$$E_{el} = EI \cdot P \cdot T \cdot AS \cdot AHD \cdot HS \cdot N \quad (2)$$

The seven considered effects can be explained in the following way:

- EI: it represents the electricity intensity of the tourism sector and it is the ratio between electricity consumption and value added of the tourism sector. It indicates how many units of electricity (i.e. kWh) are necessary to generate value. It can be seen as a measure of energy efficiency for the sector.
- P: it is an index measuring the productivity of the sector. It indicates how much value is generated by each arrival. The higher is P and the higher is the value extracted by each arrival.
- T: it is a parameter measuring the turnover ratio of the sector by relating the number of arrivals to the available beds. The higher is the index and the more saturated are the hospitality structures, therefore a better utilization rate is achieved. It serves to characterize the degree of exploitation of the available hospitality structures.
- AS: it describes the typologies of accommodation structures. It is given by the ratio of the number of beds totally available and those available in hotels. The higher is the index and the lower is the impact of hotels.
- AHD: it defines the average dimension of hotels in terms of available beds per structures.
- HS: it indicates the share of hotels on the total available accommodation structures.
- N: it represents the total number of available accommodation structures.

On the basis of the definition of each index, it can be said that EI is representative of the electrical efficiency of the sector, P and T support the description of the economic performance of the sector, whereas AS, AHD, HS and N indicate the *industrial structure* of the tourism sector, with particular reference to the hospitality segment, which is the sub-sector of the tourism sector supposed to be more electricity intensive. It is important to highlight that the impact of the other sub-sectors (e.g. restaurant, bars, etc.) is accounted in the EI as well as in the P indexes, therefore Eq. (2) offers a complete representation of the tourism sector.

On the basis of the indexes definition, it is possible to rewrite Eq. (2) in the following form:

$$E_{el} = \frac{E_{El}}{V_{Add}} \cdot \frac{V_{Add}}{Arr} \cdot \frac{Arr}{N_{Beds}} \cdot \frac{N_{Beds}}{N_{HotelBeds}} \cdot \frac{N_{HotelBeds}}{N_{Hotel}} \cdot \frac{N_{Hotel}}{N_{Structures}} \cdot N_{Structures} \quad (3)$$

where E_{el} is the electricity consumption, V_{Add} is the value added, Arr are the arrivals, N_{Beds} is the number of beds, $N_{HotelBeds}$ is the number of beds in hotel, N_{Hotel} is the number of hotels and $N_{Structures}$ is the total number of accommodation structures (e.g. hotels + other structures).

It can be observed that Eq. (3) is an identity, therefore, from the mathematical point of view, the proposed decomposition is consistent.

According to the LMDI framework the changes in E_{el} referred to a specific period of time can be assessed by using an additive decomposition. Therefore Eq. (3) can be written as:

$$\Delta E_{El} = \Delta EI + \Delta P + \Delta T + \Delta AS + \Delta AHD + \Delta HS + \Delta N \quad (4)$$

The evaluation of each additive terms in Eq. (4) can be calculated according to the following equations:

$$\Delta EI = w \cdot \ln\left(\frac{EI_{\theta 1}}{EI_{\theta 0}}\right) \quad (5)$$

$$\Delta P = w \cdot \ln\left(\frac{P_{\theta 1}}{P_{\theta 0}}\right) \quad (6)$$

$$\Delta T = w \cdot \ln\left(\frac{T_{\theta 1}}{T_{\theta 0}}\right) \quad (7)$$

$$\Delta AS = w \cdot \ln\left(\frac{AS_{\theta 1}}{AS_{\theta 0}}\right) \quad (8)$$

$$\Delta AHD = w \cdot \ln\left(\frac{AHD_{\theta 1}}{AHD_{\theta 0}}\right) \quad (9)$$

$$\Delta HS = w \cdot \ln\left(\frac{HS_{\theta 1}}{HS_{\theta 0}}\right) \quad (10)$$

$$\Delta N = w \cdot \ln\left(\frac{N_{\theta 1}}{N_{\theta 0}}\right) \tag{11}$$

where w is a weighting coefficient determined as:

$$w = \frac{E_{el,\theta 1} - E_{el,\theta 0}}{\ln\left(\frac{E_{el,\theta 1}}{E_{el,\theta 0}}\right)} \tag{12}$$

The analysis is developed in annual terms and θ_1 and θ_0 represent two generic years for the calculation of the variation in electricity consumption and the consequent quantitative estimation of each of the effects (Eqs. (5–11)). It can be noticed that Eqs. (5–12) include some monetary quantities related to different periods of time. In order to take into account the "time value" of money, real monetary values are considered. In the present paper the year 2010 is taken as reference year for money value.

As highlighted by Eqs. (5–12), the application of the methodology is straightforward and it allows to obtain specific information on the drivers responsible for the variation of electricity consumption. The comprehension of such information consents to implement specific actions aiming at increasing the sustainability of the sector. As it can be noticed the proposed methodology is rather general and Eq. (4) can be applied to the tourism sector of different countries as is or with appropriate modifications to capture possible specific issues due to particular contexts. Furthermore, the LMDI method is a very powerful and robust methodology, since it allows the decomposition of energy consumption in a perfect way without the presence of any residual, as also noticed by Ang et al. (2003). This important property avoid the issues to find a criterion to distribute possible residuals among the different contributions. For such a reason the methodology became very popular, as highlighted by the vast literature available on the topic.

3. Data analysis

The analysis is developed by considering historical data over the period 1995–2017. Data are retrieved from official freely available databases, namely the European Union statistical database (Eurostat) and the Italian Institute of Statistics (ISTAT).

The considered period is long enough to highlight some interesting patterns characterizing the tourism sector and influencing the corresponding electricity consumption.

Fig. 1 reports the historical series of the raw data utilized to develop the analysis, namely the value added of the tourism sector, Fig. 1(a), electricity consumption in tourism sector, Fig. 1(b), amount of arrivals and total number of beds in Italian accommodation structures, Fig. 1(c), and the number of accommodation structures in Italy divided per categories, Fig. 1(d).

The value added shows an irregular behavior, in fact there is a stable growth till the year 2001, but afterward there is a decrease. This decrease could be ascribed to the international crisis of the tourism sector deriving by the terrorist attack of September 2001 in USA. After that period a reduction in international tourism flows, for both leisure and business, was recorded as also highlighted by Corbet et al. (2019) and Kester (2003), who studied the correlation between terrorist attacks and tourism flows. This determined a decrease in the value added for the following years and the level of 2001 was only reached six years later in 2007. In the period 2007–2015 the value added remains substantially stable, probably due to the global international crisis, whereas in years 2016–2017 a marked increase was registered.

The electricity consumption of the sector is reported in Fig. 1(b). The picture shows a clear trend, in fact a constant increase in consumption is highlighted in the period 1997–2011. This raising trend can be explained with the fact that there was an increase of the services offered by the touristic structures, which determined an increase of the electric load. As observed by Bianco et al. (2017b), the availability of air conditioning services is now a standard in all the accommodation structures, independently from their category, and this substantially contributes to the increase of electricity consumption. From 2011 onward a decrease of electricity consumption was observed and this can be explained with the implementation of energy efficiency measures, renewables generation (e.g. PV installations in many touristic structures with consumption of self-generated electricity) and the inclusion of sustainability issues in the business strategy of tourism activities, as highlighted by Iraldo et al. (2017) for the case of Italy and Metaxas et al. (2019) for the case of Greece. It is also important to notice that in 2017 at a substantial increase of the valued added corresponded an increase of electricity consumption, in particular at an increase of 3.6% of the value added corresponded an increase of 2.8% of the electricity consumption, therefore a certain degree of coupling exists between the value generated and the consumption of electricity.

Fig. 1(c) shows the historical trend of the arrivals and number of available beds in hospitality structures. As for the arrivals it can be noticed a steadily increasing trend with a slow down just after the year 2001 for the same reasons discussed in the case of the value added. It is interesting to notice that arrivals did not decrease in the years just after 2001, but there was a repositioning of the tourism flows, with a decrease of the international arrivals (i.e. extra EU) and an increase of the domestic arrivals (i.e. EU and national). On the other hand the spending capacity of domestic customers was lower with respect to extra EU ones (e.g. USA tourists), determining a reduction of the value added of all the sector. Overall, from 1995 to 2017 an increase of the arrivals of 45% was registered.

To accommodate the increasing number of tourists, the number of available beds in the different hospitality structures steadily increased as well. In particular, between the years 1999 and 2000 a marked increase of 7% was recorded. During all the period of analysis, i.e. 1995–2017, there was an increase of 34% of the available beds.

Finally, Fig. 1(d) shows the evolution of hospitality structures for total number and typology. The plot highlights a clear tendency, namely the relevant increase in number of alternative accommodations, such as bed and breakfast, room rentals, etc. Specifically, between the year 2000 and 1999 there was a boom of new structures, in fact the total number of structures passed from ~69.000 to ~117.000, totally due to B&B and similar structures.

This is confirmed by the fact that the ratio between the increase in beds and in structures is ~5, which means that the new structures, in average, have just 5 beds. Furthermore, in 2000 there was the approbation of a new law regulating the B&B sector, which contributed to determine this large expansion. After some years of fluctuations in the number of B&B structures, from 2007 onward a steadily increase can be observed and they represent the majority of the hospitality structures.

As for the hotels, their number remained substantially stable during the period of analysis with a slight decrease from 34.296 in 1995 to 32.988 in 2017.

Table 1 reports a comparison of the tourism sector with the whole service sector and with the commercial sector. The data show that the tourism sector in the last five years had a more sustained economic growth with an average pace of 2.6% versus 0.9% of the service sector and 1.9% of the commercial sector. It can be seen that this growth is decoupled by the increase in electricity consumption which had an average increase of 0.1% for the tourism

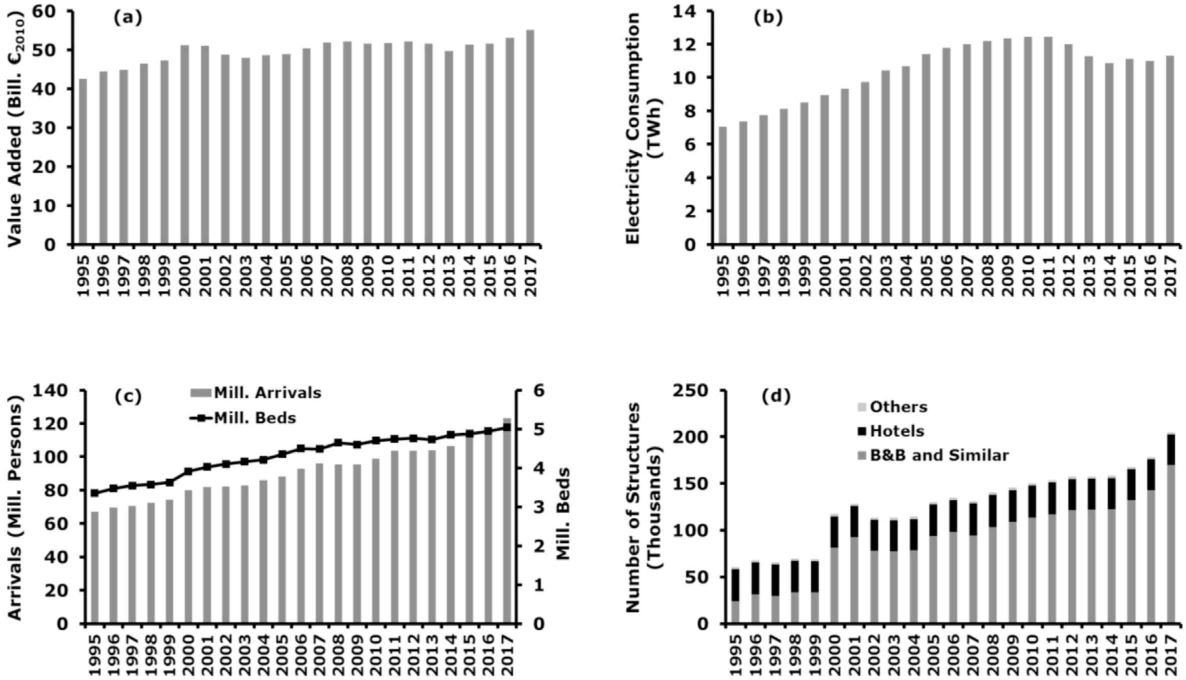

Fig. 1. Data used to develop the decomposition analysis: (a) value added of the tourism sector; (b) electricity consumption in the tourism sector; (c) arrivals and available beds; (d) number of structures.

Table 1
Comparison of the tourism sector indicators with the whole service sector and with the commercial sector.

Indicator	Sector	Units of Measure	2013	2014	2015	2016	2017	CAGR 2013−2017
Value Added	Service	Bill. $€_{2010}$	1038	1047	1055	1066	1078	0.9%
	Commercial	Bill. $€_{2010}$	339	344	351	358	365	1.9%
	Tourism	Bill. $€_{2010}$	50	51	52	53	55	2.6%
Electricity Consumption	Service	TWh	100	99	103	103	105	1.3%
	Commercial	TWh	80	79	83	83	85	1.6%
	Tourism	TWh	11	11	11	11	11	0.1%
Energy Intensity	Service	kWh/€	0.096	0.095	0.098	0.097	0.097	0.3%
	Commercial	kWh/€	0.235	0.231	0.236	0.232	0.233	−0.2%
	Tourism	kWh/€	0.227	0.212	0.216	0.207	0.205	−2.4%

sector, whereas service and commercial sectors highlight an average increase of electricity consumption of 1.3% and 1.6%. Therefore, an overall decrease of the energy intensity is obtained. On the basis of these data, it can be said that the tourism sector demonstrated better performances in terms of efficiency in electricity consumption with respect to the global trends in the service and commercial sectors.

The historical trend of the seven indexes used for the decomposition analysis is displayed in Fig. 2. These parameters are defined and estimated on the basis of the data shown in Fig. 1, according to the definitions given in Eq. (3).

The electricity intensity, Fig. 2(a), is defined as the ratio between the electricity consumption and the value added and it can be seen as a measure of the efficiency of the sector. Namely, the lower is the intensity and the lower is the electricity consumption for each unit of generated value. The trend highlights a substantially increasing tendency from 2000 till 2011 and then a constant reduction. As previously discussed, the increase of the electricity intensity can be ascribed to the increase of services in the different touristic structures, whereas in the last years an increased attention to sustainability issues determined a reduction.

The indexes describing the economic structure of the sector, namely the value creation and the turnover, are shown in Fig. 2(b). A reduction of the value created is observed and it can be attributed to the increase of low-cost travels (e.g. low cost accommodations, low cost trips, etc.) with a consequent reduction of the budget per trip (Eugenio-Martin and Inchausti-Sintes, 2016). As for the turnover, it can be observed a substantial steady value from 1995 up to 2010, whereas after 2010 increasing values are detected, therefore a better utilization rate of the available structures is pursued. This can be due to the implementation of specific strategies, such as the deseasoning of the tourism flows, in order to have a distribution of the demand during the whole year, rather than a concentration in specific periods of the years (Connell et al., 2015).

Fig. 2(c) and (d) describes the *industrial structure* of the hospitality sector. In particular, Fig. 2(c) illustrates the accommodation structure, namely the ratio between the total available beds and the beds available in hotels. It can be noticed an increasing trend of this index, which means that the amount of beds available in alternative structures with respect to hotels is increasing. The figure also highlights a constant increase of hotels dimensions from 1995 up to 2010, whereas from 2010 onward the dimension is quite stable and equal to ~70 beds per structure.

Finally, Fig. 2(d) reports the hotel share on the total of the accommodation structures and it can be seen a marked decreasing trend. This means that alternative structures are gaining market

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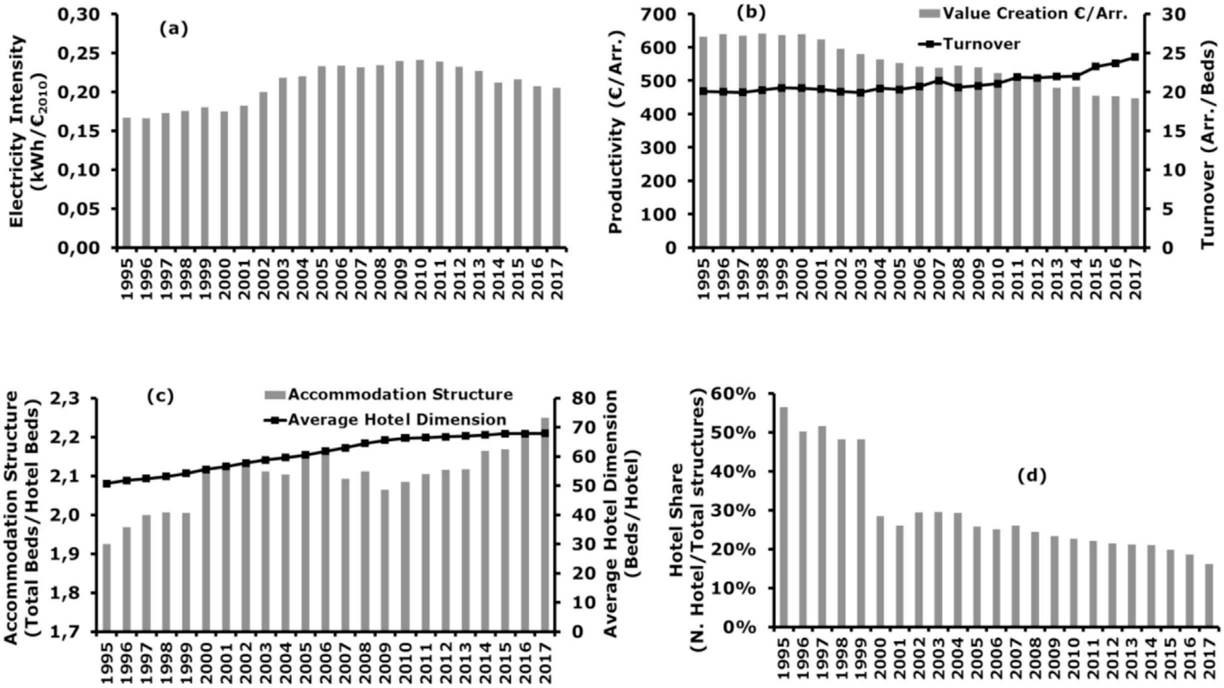

Fig. 2. Historical trend of the indexes considered in the decomposition analysis: (a) electricity intensity; (b) value creation & turnover; (c) accommodation structure and average hotel dimension; (d) hotel share.

shares with respect to traditional hotels, therefore the accommodation sector is in a transitional phase and moving toward a different business model (Zehrer and Möschl, 2008; Guttentag, 2015).

Table 2 offers a more quantitative view of the data by reporting the considered parameters and the corresponding indexes for some selected years. The table allows to understand the influence that parameters have on the indexes trend. It can be observed that electricity consumption and value added increase, as well as the electricity intensity. Therefore electricity consumption increases more than the value added. Also arrivals increase, but the value creation decreases, thus arrivals increase more than the value added. Similarly, the number of beds increases and the turnover grows as well, this means that arrivals increase more than the number of beds.

The accommodation structure shows an increasing trend due to the fact that the total number of beds grows more than the number of beds in hotels. Likewise, the average hotel dimension increases due to the increase of the hotel beds and the decrease in the number of hotels. Finally, hotel share decreases due to the relevant increase of the total number of structures and the decrease of the number of hotels.

4. Results and discussions

In this article the IDA-LMDI methodology is considered for the decomposition of electricity consumption in the Italia tourism sector. The decomposition is performed on the basis of seven indexes, namely electricity intensity (EI), productivity (P), turnover (T), accommodation structure (AS), average hotel dimension (AHD), hotel share (HS) and the total number of accommodation structures (N). In this regard, EI can be seen as a measure of the electrical efficiency of the sector, the product of P and T is representative of the economic structure of the sector, whereas the product of AS, AHD, HS and N indicates the industrial structure of the sector.

Electricity consumption between 2017 and 1995 showed an increase of 38%, namely 4.243 GWh, therefore an important growth is detected. In order to improve the efficiency and, thus, the

Table 2
Trend of the proposed seven indexes and of the parameters for their estimation.

Parameter	Units of measure	1995	2000	2005	2010	2015	2017
E_{El}	TWh	7.1	8.9	11.4	12.4	11.1	11.3
V_{Add}	Bill.$€_{2010}$	42.5	51.2	48.9	51.7	51.6	55.1
Arr	Mill. People	67.2	80.0	88.3	98.8	113.4	123.2
N_{Beds}	Mill. Beds	3.4	3.9	4.4	4.7	4.9	5.0
$N_{HotelBeds}$	Mill. Beds	1.7	1.9	2.0	2.3	2.3	2.2
N_{Hotel}	Thousands Hotels	34.3	33.4	33.5	34.0	33.2	33.0
$N_{Structures}$	Thousands Structures	60.7	117.2	130.0	150.3	167.7	205.0
E_{El}/V_{Add}	kWh/$€_{2010}$	0.166	0.175	0.233	0.241	0.216	0.205
V_{Add}/Arr	$€_{2010}$/People	632	640	553	523	455	447
Arr/N_{Beds}	People/Beds	20.1	20.5	20.3	21.0	23.2	24.5
$N_{Beds}/N_{HotelBeds}$	–	1.9	2.1	2.1	2.1	2.2	2.2
$N_{HotelBeds}/N_{Hotel}$	Beds/Hotels	50.7	55.6	60.5	66.3	67.8	67.9
$N_{Hotel}/N_{Structures}$	Hotels/Structures	0.56	0.28	0.26	0.23	0.20	0.16

sustainability of the sector it is fundamental to understand which are the causes determining the increase of the consumption.

Fig. 3 reports the results of the decomposition in the overall period, i.e. 1995–2017. In particular, Fig. 3(a) highlights the contribution of three macro effects, namely the change of the sectoral energy intensity, economic structure and industrial structure. The main contribution is represented by the changes in the industrial structure of the sector. As previously shown in Figs. 1 and 2, in the period 1995–2017 there were noticeably changes in the number and typology of hospitality structures, this caused an increase of 3.680 GWh of the electrical consumption. Furthermore, an increase of the electricity intensity also contributed to the rise of the consumption, namely 1.901 GWh. This can be due to the increasing amount of services based on electrical energy offered by the tourism sector. One main contribution can be represented by the introduction of air conditioning, which is now substantially offered in all the structures. Finally, the economic structure determined a decrease of the electricity consumption of 1.337 GWh, therefore it could be said that a more efficient business framework was implemented.

Fig. 3(b) adds a greater level of detail to the analysis, as the impact of each of the seven considered indexes is shown. As for the economic structure, it can be observed how the productivity determines a decrease of the consumption, conversely the turnover provokes an increase. This can be explained with the data shown in Fig. 2(b). Namely, the decrease of productivity is associated with a diminution of the consumption (e.g. low value generated and low consumption determined), whereas the increase of the turnover ratio (e.g. higher rate of occupancy) is responsible of more consumption.

The values of these two indexes reflect a structural change in act in the tourism sector. In fact, they show the impact of low cost travelling on energy consumption. Namely, lower productivity, which means less consumption per trip, but higher turnover, which indicates more trips.

A more detailed analysis of the industrial structure highlights the following contributions:

- AS provokes an increase of consumption due to a proliferation of beds in new typologies of accommodation structures (e.g. B&B). Alternative accommodation structures obtained a relevant success since the target for most of them is to satisfy the increased demand for budget accommodation, as direct consequence of the growth of low cost trips.
- AHD is responsible for a further rise in the consumption, because the new business model of the sector probably leaded to the closure (or transformation) of the smallest hotels due to the concurrency of other accommodations, mainly B&B, and to the increase of the average dimension of hotel, which is necessary to be competitive in the market. In particular, large hotels offer more services not available in B&B, therefore they target a different share of the market. On the other hand, the offering of more services determines an increase of electrical energy consumption.
- HS and N have two opposite contributions. Namely, the relevant reduction of the hotel share on the total of the accommodation structures caused a sharp decrease of the electricity consumption, correlated to the substantial decrease of the share, i.e. 56% in 1995 vs. 16% in 2017. Oppositely, the increase of the total number of structures, which can be completely ascribed to B&B and other structures (+144 k in total given by -1 k of hotels and +145 k of other structures), provoked a marked increase of the consumption, which almost balanced the decrease due to the reduction of HS.

To provide a more detailed understanding of the phenomenon, Fig. 4 reports the decomposition analysis for shorter period of time, namely 1995–1999, 1999–2005, 2005–2012 and 2012–2017.

Fig. 4(a) shows that in the period 1995–1999, all the macro-categories contributed to the increment of the consumption, with a more relevant contribution of EI and of the industrial structure, whereas the economic structure contributed to a less extent.

Table 3 provides the contributions determined by each index. In the period 1995–1999, it can be said that all the indexes were responsible for the increase of the electricity consumption, except for HS which is responsible of a decrease, in fact, as shown in Fig. 2(d) HS was reducing and, in particular, it passed from 56% in 1995 to 48% in 1999 indicating that the re-shaping of the accommodation sector already started during the first years of the proposed analysis.

In the period 1999–2005, Fig. 4(b), the situation changed and some of the trends visualized in Fig. 3 appeared. First of all it is important to notice that the overall increase of electricity consumption was much more relevant, namely +2.872 GWh in

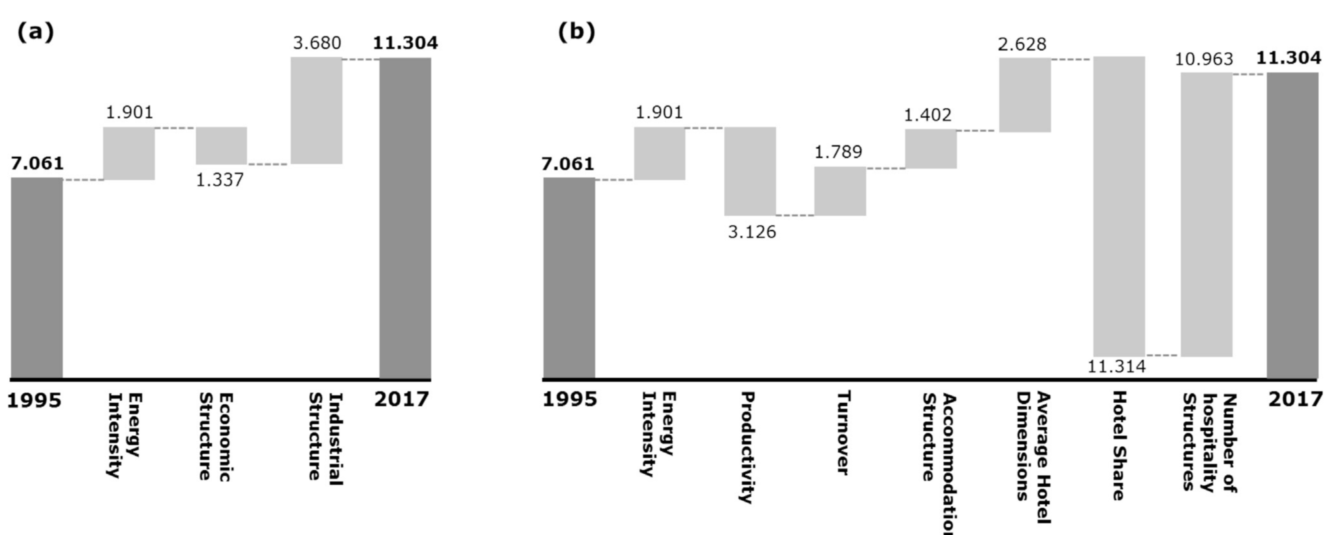

Fig. 3. Decomposition of the electricity consumption (GWh) in the period 1995–2017: (a) decomposition for the macro-categories; (b) indexes based decomposition.

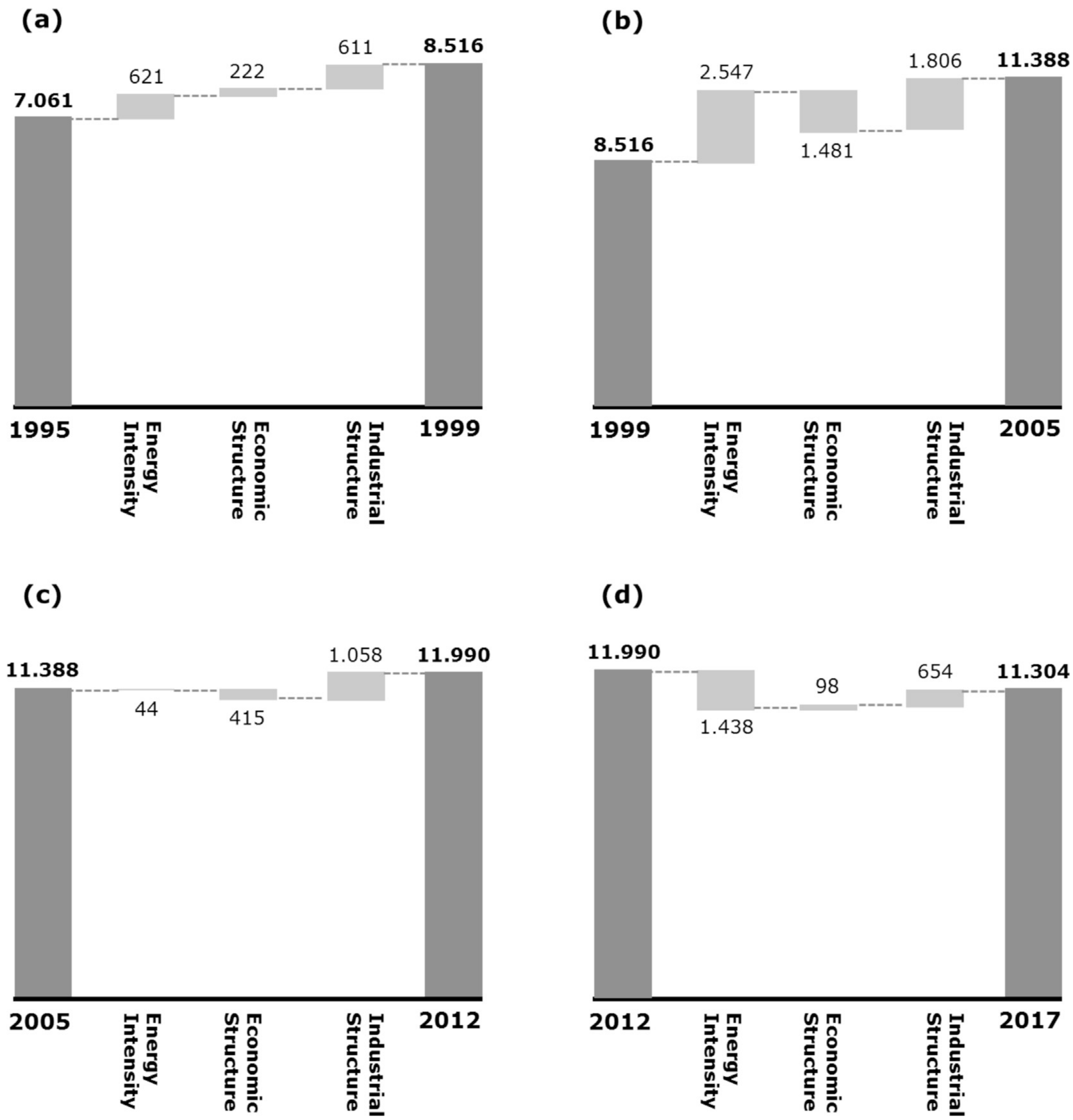

Fig. 4. Decomposition of the electricity consumption (GWh) for macro-categories in four sub-periods: (a) 1995–1999; (b) 1999–2005; (c) 2005–2012; (d) 2012–2017.

Table 3
Decomposition of the economic and industrial structures.

	1995–1999	1999–2005	2005–2012	2012–2017
Economic Structure	222	−1.481	−415	98
Productivity	*48*	*−1.375*	*−1.244*	*−1.250*
Turnover	*174*	*−106*	*829*	*1.348*
Industrial Structure	611	1.806	1.058	654
Accommodation Structure	*315*	*665*	*−157*	*712*
Average Hotel Dimension	*516*	*1.086*	*1.145*	*200*
Hotel Share	*−1.231*	*−6.172*	*−2.158*	*−3.342*
Number of Hospitality Structure	*1.012*	*6.227*	*2.228*	*3.084*

2005–1999 vs. +1.455 GWh in the period 1999–1995. A substantial contribution to the increase is given by the EI parameter, which determined an increment of 2.547 GWh, probably due to the massive increase of electricity based services, mainly air conditioning, in all the typologies of touristic structures.

The economic structure was responsible of a decrease in the consumption, given by the contemporary decrease of the productivity and turnover, as shown in Table 3. This decrease can be explained with the beginning of the low-cost tourism and with the crisis of the sector due to geo-political events (e.g. terrorism). Thus it can be said that the tourism sector is very vulnerable to geopolitical events, which are out of the control of the operators, therefore the connected business risk profile is relevant.

Finally, the industrial structure provided a positive contribution to the increase of consumption. In particular, AS and AHD were both responsible for an increase of consumption due to two phenomena, whereas, HS and N almost balanced each other. The reasons of these trends are similar to those analyzed in Fig. 3(b).

The changes in AS and AHD reflect the reaction of the sector to the changes in the touristic demand. In fact, the increase of low cost trips required a new industrial organization for the sector, which determined the increase of bed places in alternative accommodation structure. Whereas, in the hotel sector, there was a consolidation of the offer, which determined an increase of the average dimension.

The period 2005–2012 is reported in Fig. 4(c) and it can be seen that the variation of the consumption during this time horizon is rather limited with an increase of only 602 GWh. This variation is due to the decrease of consumption due to the economic structure and to an increase due to the industrial structure, whereas the contribution of energy intensity is negligible. The total contribution of the economic structure is provoked by two opposite trends, namely the decrease of the productivity and the increase of turnover. Similarly for the industrial structure, where there was a negligible contribution of the AS parameter, a positive contribution of the AHD, while HS and N contributions approximately compensated each other. Finally, Fig. 4(d) shows the electricity consumption variation in the period 2012–2017. The change is limited and equal to 686 GWh, therefore the level of consumption in 2017 is comparable to that of 2005. It can be noticed a significant decrease of the energy intensity, which might be ascribed to the implementation of energy efficiency policies. Whereas the economic structure gave a negligible contribution provoked by two opposite trends in productivity and turnover, respectively determining a decrease and an increase of the consumption. Finally, the industrial structure was responsible of an increase in the consumption, substantially due to AS and AHD contributions, whereas HS and N had two opposite trends with the prevalence of the decrease in consumption due to the reduction of HS.

To increase the comprehension of the trends highlighted in Figs. 3–4, a chain linked decomposition is implemented. Namely, the decomposition is applied year over year in order to visualize the yearly contribution of the considered indexes to the variation in electricity consumption.

Fig. 5 shows the contributions provided by productivity,

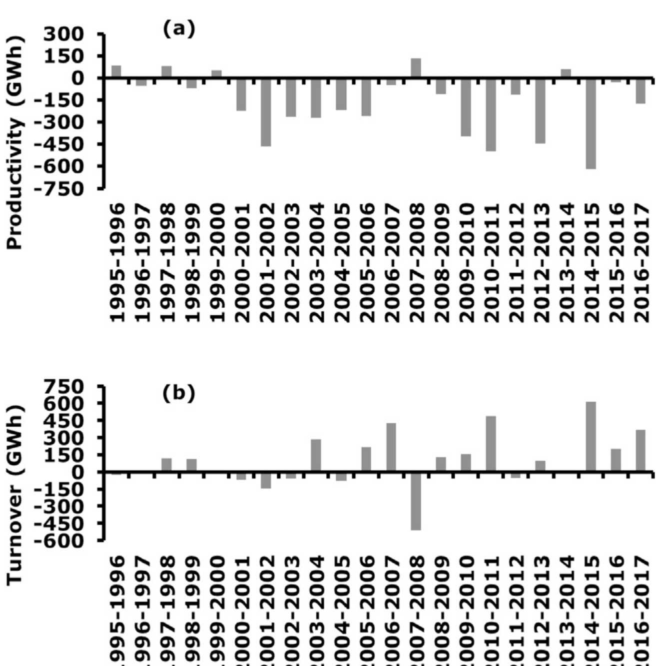

Fig. 5. Chain decomposition analysis of economic structure indexes: (a) productivity; (b) turnover.

Fig. 5(a), and turnover, Fig. 5(b). In the first years of the analysis productivity contribution is characterized by an oscillating behavior, but from 2000 to 2001 onward a marked decrease is observed. Therefore, it can be said that the phenomenon is structural and it seems to be still in progress. It is supposed to be connected with the reduced willingness to spend money during travels, which is associated with a growing number of low cost trips.

Turnover contribution, Fig. 5(b), also highlights a marked patterns, even though less strong with respect to productivity. In particular, in the first part of the considered period, i.e. 1995–2003, its contribution to variation of electricity consumption was quite modest, but from 2005 to 2006 onward a substantial increase is detected, even though with some oscillations. This can be explained by the enlargement of the touristic season to periods that some years before were characterized by a lower number of arrivals. The random oscillations of the contribution can be explained with specific events which affected people behavior in that specific year (e.g. climatic conditions, geopolitical instability, etc.).

The indexes related to the industrial structure are reported in Fig. 6. The accommodation structure, Fig. 6(a), contribution displays an increasing trend with some oscillation. The plot confirms the change in progress in the Italian accommodation sector. This change is determining an increase in electricity consumption. The variation of the structure of the accommodation sector can be visualized also in Fig. 6(b), where the average hotel dimension contributions is reported. In particular, the stable increase of hotel dimensions provoked a rise in electricity consumption. From 2010 to 2011 onward the phenomenon seems much smother, as hotel dimension is quite stable, Fig. 2(c), as, probably, most of the structures reached the optimal dimension to compete on the market.

Hotel share contribution, reported in Fig. 6(c), illustrates a decreasing contribution, very relevant in 1999–2000, when, due to regulatory change, there was a spike in the opening of other accommodation structures, Fig. 1(d). In the following years this trend persisted, even though with less intensity, because the share of hotels structures continued to reduce. Oppositely, the contribution of the total number of structures, Fig. 6(d), highlights an increasing trend thanks to the proliferation of other accommodation structures, which determined an increase of the electricity consumption. The highest variation is registered in the period 1999–2000 due to the aforementioned regulatory changes.

Finally, Fig. 7 reports the variations in electricity consumption due to energy intensity, Fig. 7(a), economic structure, Fig. 7(b), industrial structure, Fig. 7(c), and the total change, Fig. 7(d).

EI contribution depicts an increasing trend in the first period of the analysis, to be ascribed to the increase in electricity based activities. In the last period of the analysis, a decreasing trend is illustrated and it might be the consequence of the implementation of energy efficiency policies and regulations (e.g. installation of LED lamps). As demonstrated by previous studies, e.g. Bianco et al. (2017b), the potential to reduce energy consumption in the tourism sector are relevant, especially those referred to the accommodation sector. Various support mechanisms are now available to support the increase of energy efficiency in buildings, including those devoted to tourism services. It is believed that in the next years EI should decrease due to increased level of energy efficiency in buildings. On the other hand, an increase of the indicator could be registered due to the electrification of the consumption, which means the switching of consumption from one energy market to another (e.g. from natural gas to electricity), as illustrated by Bianco et al. (2017a).

Results similar to those depicted in Fig. 7(a) are reported by Colinet Carmona and Roman Collado (2016) for the Andalusian

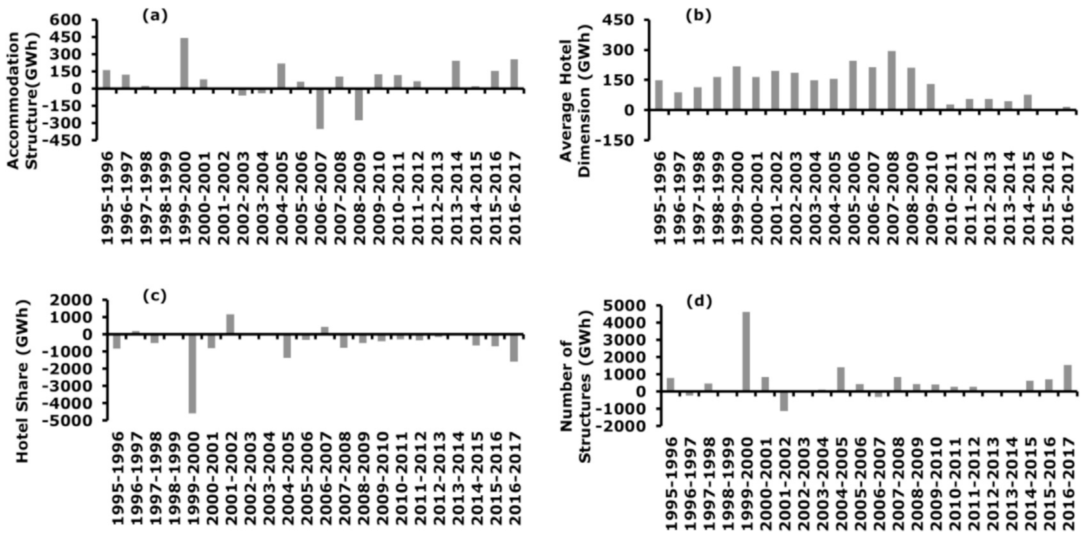

Fig. 6. Chain decomposition analysis of industrial structure indexes: (a) accommodation structure; (b) average hotel dimension; (c) hotel share; (d) number of structures.

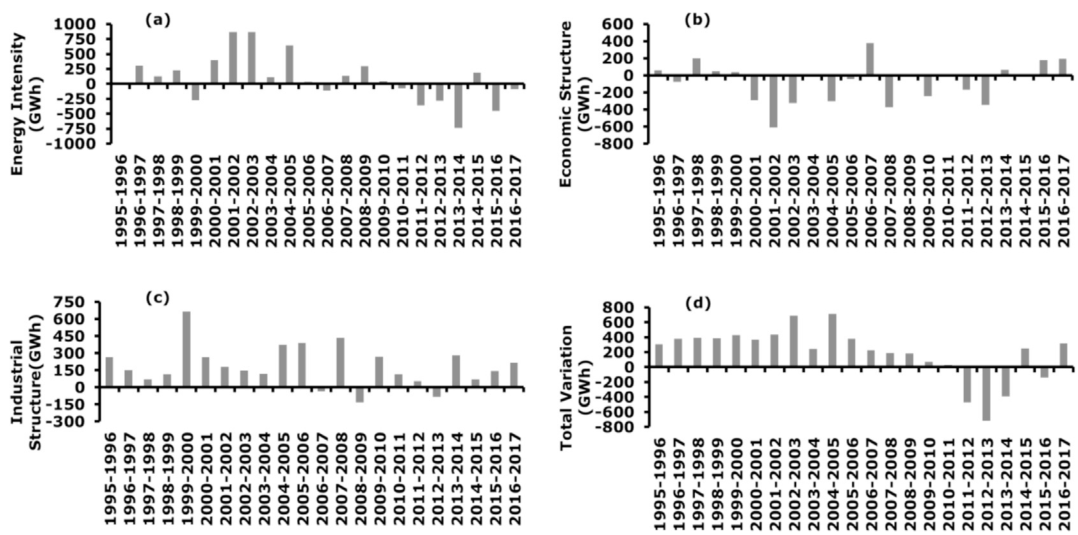

Fig. 7. Year over year variations of electricity consumption: (a) electricity intensity contribution; (b) economic structure contribution; (c) industrial structure contribution; (d) total variation.

service sector, which is largely influenced by the tourism segment. More in general, Madaleno and Moutinho (2017) illustrated that a decreasing trend of energy intensity can be detected in the last years if EU28, EU15 and EU13 countries are considered. However, the EU13 group shows the most continuous decrease in energy intensity.

The economic structures contribution is characterized by an oscillating trend, resulting by the opposite behavior of productivity and turnover. In the last years of analysis, the turnover contribution is the prevalent one.

The industrial structure contribution is definitely positive, therefore the new arrangement of the accommodation sector determined a positive variation of electricity consumption. The substitution of larger structures, i.e. hotels, with a larger number of smaller configurations, e.g. bed and breakfast, determined an increase in electricity consumption. It is likely that similar trends can be expected also for other sources of energy, such as natural gas.

The total variation of electricity consumption, Fig. 7(d), illustrates an increasing trend in consumption till the year 2008–2009. This behavior can be attributed to two principal factors, namely energy intensity and industrial structure. In the following years, a decrease of consumption is noticed and it can be again ascribed to two main factors, namely energy intensity and economic structures.

The main limitation to the validity of the proposed results is represented by the correct specification of the decomposition equation. If the variables considered in the equation are not representative of the analyzed sector, the mathematical procedure will provide quantitative data in any case, but they result completely disconnected from the considered industrial context. On the basis of this, it can be said that it is fundamental to be accurate during the data analysis phase.

The present research might be extended to other segments of the service sector, in order to offer a complete picture of the determinants of the electricity consumption. This would be fundamental to understand the origin of the consumption and, consequently, the area of action for increasing the efficiency level. In performing such analysis, an important challenge is the data

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mining, since, often, data are difficult to retrieve from official and reliable sources.

5. Conclusions

The aim of the present paper is to develop an innovative decomposition analysis of electricity consumption suitable for to the tourism sector. The methodology is applied to the case of Italy, but it can be extended to other countries as well.

The key conclusions obtained by the proposed research can be summarized as follows:

- Seven indexes are identified to describe energy consumption (electricity in the present case) in the tourism sector and their calculation is based on data easily available on country/regional statistics;
- The analysis highlighted the effect of a relevant change in the hospitality structures of the Italian tourism sector, namely the relevant increase of alternative hospitality structures from 2000 onward and their corresponding impact on electricity consumption. Namely, +11 TWh of electricity consumption in the period 1995–2017 due to the increase in the number of structures to be ascribed to other hospitality structures.
- It appears fundamental to regulate the sector of alternative hospitality structures from the energy point of view in order to increase the level of energy efficiency of the whole sector. The challenge is to monitor these structures due to their numerosity (e.g. ~170.000 other hospitality structures vs. ~33.000 hotels).

These detailed and complete decomposition results not only provide an improved insight about the evolution of electricity consumption in the Italian tourism sector, but also help to identify challenges and opportunities to take into account in the design of future energy policy measures. In terms of policy, the main indication that emerges is that the sector as a whole is progressing towards higher energy efficiency levels (e.g. reduction of energy intensity, namely from the peak value of 0.241 kWh/€ in 2010 to 0.205 kWh/€ in 2017) demonstrating a proactive approach towards the reduction of energy consumption. Therefore, it could be effective to provide some stimulus in terms of support measures to accelerate the progression towards higher levels of efficiency. At the same time a clear energy regulation is necessary for alternative hospitality structures, which have a relevant weight on the final electricity consumption.

The present research might also provide opportunities for future extensions, since more and complementing information regarding decomposition of energy consumption could be valuable for new policy design. In particular, other typologies of energy can be taken into account in future analysis as well as the decomposition could be extended to carbon emissions and even water consumption. The main issue for the possible extensions consists in data availability.

The results and comments proposed in this paper are supposed to be useful for policy makers and/or professionals engaged with the analysis of energy consumption in the tourism sector.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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