Investigation of efficiency in the UK hotel industry: A Network Data Envelopment analysis approach

Abstract

Purpose-We aim to investigate efficiency in the UK hotel industry and further evaluate the impacts of hotel characteristics and industry environment on efficiency.

Design/methodology/approach-The Network Data Envelopment (DEA) weak link approach is used for the efficiency analysis, while the determinants of efficiency are evaluated by Bootstrapped truncated regression.

Findings-The findings show that the UK hotel industry is very inefficient. The results of overall efficiency deconstruction show that the second-stage production process experiences an even lower level of efficiency than that of the first stage. The second-phase analysis shows that both the hotel-specific characteristics and the industry-specific characteristics are significantly related to UK hotel efficiency.

Research limitations/implications- robustness of the results is affected because a single set of input-intermediate product-outputs and a single DEA method were used. Therefore, further studies can use alternative inputs, intermediate measures and outputs in the efficiency analysis. In addition, robustness of the efficiency score can be checked using alternative parametric or non-parametric methods.

Practical implications- Hotels in the UK should focus on cost reduction, business diversification, improvement in capital level and labour productivity, while at an industry and macroeconomic level, discounts are recommended to be provided to international tourism and the tourism industry should be further opened.

Originality-The weak-link approach has been applied to estimate the efficiency level, as this provides more robust and accurate results compared to other non-parametric methods in the existing empirical studies and unique hotel-specific and industry-specific determinants of efficiency are considered in the second-stage analysis.

Keywords: Network DEA, Weak-link approach, UK hotel industry, Bootstrapped truncated regression

Introduction

The analysis of performance, in particular, the evaluation of efficiency in the UK hotel sector becomes of particular importance due to the fact that the assessment of efficiency is able to not only detect the situation of hotel operation in terms of allocation of resources, but also to generate important policy implications to optimize the hotel operation and reduce hotel costs. In general, the performance in the hotel industry has been comprehensively investigated by the empirical literature. The methods used for the performance evaluation mainly cross through different subject areas, such as accounting (Sainaghi, 2011); finance (Kim and Jang, 2012); operational research method (Assaf and Agbola, 2014), as well as management (Chen and Chang, 2012).

The empirical studies have not only focused on the performance evaluation, but a growing effort has also been made to examine the determinants of hotel performance. There are many types of independent variables included from different perspective of hotel operations and they can be classified into different subject areas including strategy (Sharma and Christie, 2010; Abrate and Viglia, 2016; Pereira-Moliner *et al*., 2015; Sainaghi and Baggio; 2017); Marketing (Mohsin and Lengler, 2015; Bore *et al*., 2017); Management (Giritlioglu *et al*., 2014; Zhu et al., 2014; Wang and Chung, 2015; Lee *et al*., 2015); and economics (Dewally *et al*., 2013).

The investigation using operational research methods in hotel efficiency did not only apply the parametric stochastic frontier analysis (Arbelo-Perez *et al*., 2017), but the non-parametric data envelopment analysis was also widely employed in the hotel sector (Manasakis *et al*., 2013). In particular, a number of attempts have been made to advance the traditional DEA model by developing network DEA model in the hotel efficiency analysis besides a number of other various developments on the non-parametric methods' application to the hotel sector (Hsieh and Lin, 2010; Zhang and Ma, 2011). Although, compared to the traditional DEA model, the network model can breakdown the production process into different stages, most of the network models presented in the DEA literature still suffer from the issue of lack of accuracy in identifying the source of inefficiency in the operational process.

In addition, although there is a growing interest in examining the determinant of hotel performance and the empirical studies have done this from different perspectives, in particular, as discussed previously, studies have investigated the determinants from a finance perspective, no attempt has been given to think about the role of internal characteristics in related to the performance improvement of the hotel sector. For example, the size of operation, the capital position and the staff productivity are all related to internal operation and management within the hotels themselves. The investigation of these will be very important for policy making purposes. In addition, although as discussed previously, empirical literature has addressed the impact of the macroeconomic environment on hotel performance, no attention has yet been paid to look at the influence of the industry environment. Hotel occupancy will not only be affected by the domestic travellers between different areas, but the international travellers also play an important role in promoting and increasing the occupancy of domestic hotels. What would be the impact of international tourism market environment on hotel performance is worthy of being investigated and will give policy to the government to improve hotel performance by formulating regulations on the tourism industry.

This paper assesses hotel efficiency in the UK and contributes to the existing empirical studies mainly in two ways. First, the hotel operation is viewed as a process consisting of two stages (sub-processes) in series, namely the asset generation stage and the revenue generation stage. Then, we use the weak-link approach of Network DEA (Despotis *et al*., 2016b) to assess efficiency in the UK hotel industry. In comparison to the standard DEA and other network DEA methods, the weak-link approach possesses several nice properties and locates more accurately potential inefficiencies in the hotel operation process. Secondly, we discriminate the efficiency related contextual variables in two groups, namely hotel-specific characteristics (size, capitalization and labour productivity), and industry-specific characteristics (the number of arrivals in international tourism, number of departures in international tourism, international tourism receipt and international tourism expenditure).

Literature Review

The investigation of hotel efficiency has been one of the research topics that has gained in popularity from the researchers over the past three decades (1989-2018) and the topic of hotel efficiency during the most recent decade (2009-2018) has been one of the research areas which attracted greatest attention from academic researchers (Ali *et al*., 2019). The traditional method first used to measure hotel efficiency is the non-parametric data envelopment analysis (Barros, 2005; Barros and Mascarenhas, 2005; Sanjeev, 2007; Barros and Dieke, 2008; Chen, 2009; Neves and Lourenco, 2009; Assaf *et al*., 2012; Manasakis *et al*., 2013; Luo *et al*., 2014; Ramanathan *et al*., 2016). However, Data Envelopment Analysis suffers from several limitations (Pestana and Peypoch, 2010): 1) the effect of exogenous variables on the operation is ignored; 2) statistical errors are ignored; 3) statistical test with the results are difficult to perform; 4) it cannot clearly indicate the way to improve efficiency. The second stream of method is the parametric stochastic frontier analysis (Chen, 2007; Anderson *et al*., 1999; Arbelo-Perez *et al*., 2017). The main weakness of stochastic frontier analysis is that it needs a particular parametric function form to represent the underlying technology and distributional assumption for the efficiency terms (Hossain *et al*., 2012).

Building on the above two traditional efficiency estimation methods, the DEA meta-frontier analysis was applied by Assaf *et al*. (2010). This method benefits from the advantage of being able to compare the performance between different groups without any ignorance of heterogeneity between them (Medal-Bartual *et al*., 2012); however, it suffers from the drawbacks of being unable to integrate the meta-frontier and undesirable output together. Another extension of the traditional DEA is the DEA window analysis (Pulina *et al*., 2010; Huang *et al*., 2012). This method has the advantage of making it feasible to evaluate and compare the performance of Decision Making Units in different periods by regarding them as separate entities in different periods (Yang and Chang, 2009); however, it suffers from the limitations that this technique was designed for a short period of time and the random error in the variables was not considered and the dependence structure to estimate the efficiencies was not used (Sanchez, 2018).

Besides these two methods, the triangular DEA model was proposed by Keh *et al*. (2006). This specific method has the advantage of considering efficiency and effectiveness in the hotel production process at the same time under a model (Klassen, and Rohleder, 2001); however, as argued by the authors themselves, DEA is not suitable for small hotel chains. The slack-based DEA model was proposed by Ashrafi *et al*. (2013) and Cheng *et al*. (2010). This method benefits from the advantages of providing more discriminatory power and more sources of inefficiency can be detected (Rashidi and Cullinane, 2019); however, it failed to identify and consider the internal sub-production process (i.e., divide the production process into several stages). The super-efficiency DEA and grey entropy was proposed and applied by Shuai and Wu (2011). As argued by the authors, this is a better method in efficiency measurement in practice, grey entropy benefitting from the advantage of being able to compute the weight without any rigorous statistical requirement and assumptions; however, super-efficiency DEA suffers from the issue of infeasibility (Zhang, 2017).

Hsieh and Lin (2010) and Zhang and Ma (2011) proposed a network DEA model for hotel efficiency analysis. This method supplements the previous slacks-based model by dividing the production into stages and is able to identify the source of inefficiencies for each of the stages (Fukuyama and Weber, 2015); however, only information on frontier projection is provided, while the information on divisional efficiency is not available under the assumption of variable return-to-scale (Chen *et al*., 2013). A hyperbolic network DEA model was proposed by Yu and Lee (2009) and, as argued by the authors, this method benefits from the advantages of being able to consider the shared inputs in the model. However, there is a non-linear programming problem that needs to be solved (Zhao *et al*., 2011). The extension of the traditional DEA model was also seen by Yin *et al*. (2015) through proposing a two-layer bootstrapped DEA model. As argued by the authors, this method uses an independent and repeated sampling process, through which the errors could be reduced. However, it has unreasonable weights assigned for inputs and outputs, which would affect the robustness of the results (Cheng *et al*., 2016). Finally, the stochastic DEA model was proposed by Shang *et al*. (2010) and Sellers-Rubio and Casado-Diaz, (2018). As argued by Shang *et al*. (2010), this method benefits from providing a higher ability to measure efficiency in the environment with uncertainty. while the drawback lies in the fact that stochastic variables are imposed limitations (El-Demerdash *et al*., 2013). Related to the extension of the parametric stochastic frontier analysis, we saw that Bayesian stochastic frontier analysis was proposed and used by Assaf and Magnini (2012) and Assaf and Cvelbar (2011). Table 1 summarizes the input and output measures selected in different studies reported in the literature, as well as the main results obtained.

<<Table 1---about here>>

Data and methodology

The data set consists of 179 UK hotels over the 9-year period 2010-2018. Initially there were 240 hotels (records), from which 54 were omitted because of the unavailability of data for all the 9 years. From the remaining, 7 more were excluded because of missing data. In our study, we focus on measuring the generation of income through the assets. In view of this, hotel operation is modelled as a two-stage process, which is described in figure 1 as below.

<<Figure 1---about here>>

The first stage uses as inputs the cost of goods sold (x1), the fixed assets (x2) and the number of employees (x3) to generate current assets (total assets-fixed assets) within the year (z). The selection of cost of goods sold and the fixed assets is in line with Neves and Lourenco (2009), while the cost of goods sold includes the cost of labour. We include the number of employees as a third input, in line with Barros (2005), who used labour cost and employees number at the same time. We argue that the labour input in the hotel efficiency analysis should focus on two different perspectives, namely the labour cost in monetary terms and the number of employees. Total assets are used as the input variable in the hotel efficiency analysis by Neves and Lourenco (2009) to generate revenue. We follow it in a similar way by designing our production process in the second stage, our difference lying in that the total assets can be broken down into current assets and fixed assets as they play different roles in the production process. More specifically, fixed assets (such as computers, buildings, printers, tables, chairs, TVs, etc) should be used in the first stage production. They would be used to provide the services to the customers to generate the current assets, including cash and accounts receivables (such as debit and credit cards payments), while these assets would be further used for the daily operations in the production process to generate revenue. For example, the hotels will use the current assets to do some decoration, repairs for the hotel and/or to replenish the inventory for continuous hotel service provision. The current assets do not only generate revenue, but also capital (y2). We consider capital as output mainly for the following two reasons: the generation of capital through hotel operation provides more funds and greater ability for hotels to update capital items, such as furniture, televisions, telephones, kitchens and cleaning machines (Ramanathan *et al*., 2016). On the other hand, the generation of capital is very important for providing stability for hotel operation (Vivel-Bua *et al*., 2018). The contextual variables used for the second phase analysis can be further divided into two sub-groups, namely hotel-specific variables (hotel size, capitalization and labour productivity), and industry-specific variables the number of arrivals (international tourism), the number of departures (international tourism), international tourism receipts and expenditure. The input and output variables are collected from FAME database, while the industry-specific contextual variables, are collected from the world bank database.

Network DEA methodology

Given the two-stage representation of the hotel production process (Fig.1), we resort to the network DEA paradigm to assess hotel efficiency. Unlike the standard DEA proposed by Charnes *et al*. (1978), where the decision-making units (DMUs) are considered as "black-boxes", network DEA considers their internal structure. The DMU is treated in a framework which includes sub-processes that are connected to each other so as to map the flow of intermediate measures under the network DEA context. The classification scheme provided in Sotiros et. al (2019) for network DEA approaches is summarized and depicted in Figure 2. According to the independent assessments approach, standard DEA is applied to assess the efficiency of the stages and the system separately, neglecting the connection between the stages (Seiford and Zhu, 1999). On the other side, the holistic approach comprises the non-cooperative and the cooperative paradigms, where the efficiency of the whole system and the efficiencies of its sub-process are estimated jointly. The non-cooperative paradigm is a lexicographic approach. The efficiency of the stage characterized as leader is assessed in priority and then, the efficiency of the follower is assessed by keeping unchanged the optimal efficiency of the leader. In contrast, the cooperative approach comprises the methods where the overall efficiency and efficiencies of various stages can be estimated at the same time. The relational method (Kao & Hwang, 2008) and the additive method (Chen *et al*., 2009) are representative methods of the so called "top-down" approach, where the system's efficiency is assessed, and the efficiencies of the individual stages are estimated afterwards. Despotis *et al*. (2016a), employing an inverse "bottom-up" approach, developed the composition paradigm by introducing a multi-objective programming formulation, where instead the drivers of the assessment are the stages of the system.

<<Figure 2---about here>>

The weak-link method (Despotis *et al*., 2016b), which is used in this paper to assess the efficiency of companies in the hotel industry, falls into the bottom-up approach. This method is selected because of its conceptual soundness and its ability to provide unique and unbiased efficiency scores (see Sotiros et. al, 2019 for the relative argumentation). To outline the weak-link approach used in this paper, consider the case where each DMU_j , $j \in J = \{1, \dots, \mathrm{n}\}$ of *n* DMUs transforms some *m* external inputs $\left(x_{ij}, i = 1, \dots, m\right)$, to *s* final outputs $\left(y_{rj}, r = 1, \dots, s\right)$ via *q* intermediate measures $\left(z_{pj}, p = 1, \dots, q\right)$ under a two-stage process, as in the figure below (figure 3).

<<Figure 3---about here>>

The efficiency scores of stage-1 and stage 2 for a unit $j \in J$ are as follows:

$$e_j^1 = \frac{\sum_{p=1}^{q} \varphi_p z_{pj}}{\sum_{i=1}^{m} \eta_i x_{ij}}, \; e_j^2 = \frac{\sum_{r=1}^{s} \omega_r y_{rj}}{\sum_{p=1}^{q} \varphi_p z_{pj}} \qquad (1)$$

where $(\eta_1, \dots, \eta_m)$, $(\varphi_1, \dots, \varphi_q)$ and $(\omega_1, \dots, \omega_s)$ are the weights for the external inputs, the intermediate measures, and the final outputs, respectively.

According to the weak-link method, the efficiency of the less efficient sub-process (the weak link) determines the efficiency of the overall system, i.e., $e^o = min\{e^1, e^2\}$ and is derived by solving the following weighted max-min model for each evaluated unit $j_0 \in J$.

$$e_{j_o}^o = max_{v,w,u}[min\{q_1 e_{j_o}^1, q_2 e_{j_o}^2\}] \qquad (2)$$

where $q_1 = 1/E_{j_0}^1$ and $q_2 = 1/E_{j_0}^2$, we estimate the efficiency scores of two different stages in a separate manner, which are represented by $E_{j_0}^1$ and $E_{j_0}^2$ The proportional relationship between the stage efficiency scores and $E_{j_0}^1 E_{j_0}^2$ is the basis of the parameters selection (c.f. Despotis *et. al*., 2016a for the complete development of the method). The latter are obtained by the following pair of standard DEA models:

$$\begin{aligned} E_{j_0}^1 &= max \frac{\sum_{p=1}^{q} \varphi_p z_{pj_o}}{\sum_{i=1}^{m} \eta_i x_{ij_o}} \\ s.t.& \\ \sum_{p=1}^{q} \varphi_p z_{pj} &- \sum_{i=1}^{m} \eta_i x_{ij} \leq 0, \forall j \in J \\ \eta_i \geq 0&, \varphi_p \geq 0, \forall i, p \end{aligned} \qquad (3)$$

$$\begin{aligned} E_{j_0}^2 &= max \frac{\sum_{r=1}^{s} \omega_r y_{rj_o}}{\sum_{p=1}^{q} \varphi_p z_{pj_o}} \\ s.t.& \\ \sum_{r=1}^{s} \omega_r y_{rj} &- \sum_{p=1}^{q} \varphi_p z_{pj} \leq 0, \forall j \in J \\ \varphi_p \geq 0&, \omega_r \geq 0, \forall p, r \end{aligned} \qquad (4)$$

The canonical form of model (2) derives from the following bi-objective program:

$$\begin{aligned} &max\, e^1 = \frac{\sum_{p=1}^{q} \varphi_p z_{pj_o}}{\sum_{i=1}^{m} \eta_i x_{ij_o}} \\ &max\, e^2 = \frac{\sum_{r=1}^{s} \omega_r y_{rj_o}}{\sum_{p=1}^{q} \varphi_p z_{pj_o}} \\ &s.t. \\ &\sum_{p=1}^{q} \varphi_p z_{pj} - \sum_{i=1}^{m} \eta_i x_{ij} \leq 0, \forall j \in J \\ &\sum_{r=1}^{s} \omega_r y_{rj} - \sum_{p=1}^{q} \varphi_p z_{pj} \leq 0, \forall j \in J \\ &\eta_i \geq 0, \varphi_p \geq 0, \omega_r \geq 0, \forall i, p, r \end{aligned} \qquad (5)$$

or its equivalent derived by transformation of Charnes and Cooper (1962):

$$
\begin{aligned}
&max\ e^1 = \sum_{p=1}^{q} w_p z_{pj_o} \\
&max\ e^2 = \frac{\sum_{r=1}^{s} u_r y_{rj_o}}{\sum_{p=1}^{q} w_p z_{pj_o}} \\
&s.t. \\
&\sum_{i=1}^{m} v_i x_{ij_o} = 1 \\
&\sum_{p=1}^{q} w_p z_{pj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0, \forall j \in J \\
&\sum_{r=1}^{s} u_r y_{rj} - \sum_{p=1}^{q} w_p z_{pj} \leq 0, \forall j \in J \\
&v_i \geq 0, w_p \geq 0, u_r \geq 0, \forall i, p, r
\end{aligned}
\tag{6}
$$

Where $(v_1, \ldots, v_m)$, $(w_1, \ldots, w_q)$ and $(u_1, \ldots, u_s)$ are the transformed weights for the external inputs, the intermediate measures, and the final outputs, respectively.

Model (6) is solved in two phases: Firstly, the model (7) provides a weak Pareto point in the objective functions space of (6) by minimizing its weighted Tchebycheff distance from $E_{j_0}^1$ and $E_{j_0}^2$. Then the model (8) estimates the final Pareto optimal solution (c.f. Despotis *et al*., 2016b, for the technicalities of the solution process).

Phase I:

$$
\begin{aligned}
&max\ \theta \\
&s.t. \\
&\sum_{p=1}^{q} w_p z_{pj_o} \geq \theta E_{j_0}^1 \\
&\frac{\sum_{r=1}^{s} u_r y_{rj_o}}{\sum_{p=1}^{q} w_p z_{pj_o}} \geq \theta E_{j_0}^2 \\
&\sum_{i=1}^{m} v_i x_{ij_o} = 1 \\
&\sum_{p=1}^{q} w_p z_{pj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0, \forall j \in J \\
&\sum_{r=1}^{s} u_r y_{rj} - \sum_{p=1}^{q} w_p z_{pj} \leq 0, \forall j \in J \\
&v_i \geq 0, w_p \geq 0, u_r \geq 0, \forall i, p, r; \ \ \theta \geq 0
\end{aligned}
\tag{7}
$$

Phase II:

$$
\begin{aligned}
& max\, s_1 + s_2 \\
& s.t. \\
& \sum_{p=1}^{q} w_p z_{pj_o} - s_1 = e_{j_0}^{1*} \\
& \sum_{r=1}^{s} u_r y_{rj_o} - s_2 \sum_{p=1}^{q} w_p z_{pj_o} - e_{j_0}^{2*} \sum_{p=1}^{q} w_p z_{pj_o} = 0 \\
& \sum_{i=1}^{m} v_i x_{ij_o} = 1 \\
& \sum_{p=1}^{q} w_p z_{pj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0, \forall j \in J \\
& \sum_{r=1}^{s} u_r y_{rj} - \sum_{p=1}^{q} w_p z_{pj} \leq 0, \forall j \in J \\
& v_i \geq 0, w_p \geq 0, u_r \geq 0, \forall i, p, r \\
& 0 \leq s_1 \leq E_{j_0}^{1}, 0 \leq s_2 \leq E_{j_0}^{2}
\end{aligned}
\tag{8}
$$

Given the optimal solution $(\hat{v}_1, \dots, \hat{v}_m)$, $(\hat{w}_1, \dots, \hat{w}_q)$, $(\hat{u}_1, \dots, \hat{u}_s)$ of model (8), the efficiency scores of the sub-stages as well as the overall level can be expressed as:

$$\hat{e}_{j_0}^{1} = \frac{\sum_{p=1}^{q} \hat{w}_p z_{pj_o}}{\sum_{i=1}^{m} \hat{v}_i x_{ij_o}}, \hat{e}_{j_0}^{2} = \frac{\sum_{r=1}^{s} \hat{u}_r y_{rj_o}}{\sum_{p=1}^{q} \hat{w}_p z_{pj_o}}, \hat{e}_{j_0}^{o} = min\{\hat{e}_{j_0}^{1}, \hat{e}_{j_0}^{2}\}$$

Simar and Wilson (2007) Bootstrapped Truncated Method

The following model is needed to start the estimation procedure

$$\hat{\delta}_i = Z_i \beta + \varepsilon_i$$

where Z_i in our study stands for the hotel characteristics and industry environment that are supposed to affect efficiency level, a vector of parameters is represented by β and the statistical noise is denoted by ε_i . This specific method benefits from the advantages of being able to produce not only the bias corrected estimates of δ, but also valid estimates of the parameters.

There are mainly four steps in the bootstrap algorithm, which are illustrated below:

1) Estimate the efficiency score $\hat{\delta}$ using the method described in the previous subsections

2) Estimate the truncated regression of $\hat{\delta}$ on Z_i based on the maximum likelihood method to get estimates $\hat{\beta}$of β and $\hat{\sigma}_\varepsilon$ of σ_ε

3) For each hotel $i = 1, \dots, I$, repeat the following three steps (a, b and c) L times, through which we obtain the bootstrap estimates, denoted by$A = \{(\hat{\beta}^*, \hat{\sigma}_\varepsilon^*)_b\}_{b=1}^{L}$

a. Draw ε_i from the $N(0, \hat{\sigma}_\varepsilon^2)$ distribution with left truncation at $(1 - \hat{\beta} Z_i)$.

b. Compute $\delta_i^* = \hat{\beta} Z_i + \varepsilon_i$

c. Estimate the truncated regression of δ_i^* on Z_i based on the maximum likelihood method, through which to get the estimates $(\hat{\beta}^*, \hat{\sigma}_\varepsilon^*)$.

4) Construct the confidence intervals based on the bootstrap results.

In the second-phased bootstrapped truncated regression analysis, we will investigate the determinants of UK hotel efficiency by dividing the variables interested into two groups: 1) hotel-specific characteristics; 2) industry-specific characteristics. More specifically, we control for three variables for the hotel-specific characteristics, including hotel size, measured by the natural logarithm of total assets (Chen, 2010); hotel capitalization, which is measured by the ratio of capital over total assets (Lehr, 2005), and labour productivity, which is measured by the ratio of operating revenue over the number of employees (Sanzo-Perez *et al*., 2017). Besides these three hotel-specific characteristics, we also control for four industry-specific characteristics, including the number of international arrivals, number of international departures, international tourism receipts and international tourism expenditure. The number of international arrivals is an important factor that will contribute to performance improvement in the hotel industry (Chen, 2011). In terms of the outbound international tourism because some flights will be in the morning time, this will make hotel accommodation a necessity for the domestic tourists, therefore, we argue that the international tourism departure will have a potential impact on hotel performance. International tourism expenditure is supposed to influence the hotel's cash flow generation potential because nearly half of tourism expenditure is related to accommodation and lodging (Wu *et al*., 2011). Peypoch (2007) uses tourism receipt as the output variable and two input variables (namely, the number of tourist bed-nights in hotels and the number of tourist bed-nights in campsites) to measure tourism productivity. This shows that there is a linkage between hotel accommodation and tourism receipts. In other words, tourism receipts will boost the hotel's cash flow potential. Table 2 presents the descriptive statistics of the variables in the first-phase efficiency analysis as well as the second-phase regression analysis. The data of inputs and outputs of the current study was deflated by the consumer price index to eliminate the price effect.

<<Table 2---about here>>

The figures in Table 2 show that UK hotels have smaller differences in the number of employees and cost of goods sold, as well as in the levels of capital, as reflected by the standard deviation. In comparison, all the other factors of production and outputs have a wider spread across the UK hotels in the sample, with the biggest difference observed in the volume of fixed assets. In terms of the contextual variables, the smallest difference is found for the level of capitalization, followed by hotel size, although bigger differences are observed in the amount of tourism receipt and tourism expenditure. We notice that the biggest difference lies in the areas of the number of international tourism arrivals and international tourism departures.

Analysis and discussion of results

An inter-temporal approach is followed to assess the efficiency of all the hotels in the sample per year. Then the average efficiency scores for each year are shown in Figures 3 and 4. The regional assessments, on the other hand, are made by taking the average performance of the hotels across the years. The average efficiency scores per region are shown in Figures 5 and 6.

The results from Figure 4 show that the efficiency level in the UK hotel industry over the examined period ranges from 0.144 to 0.168. This indicates that hotels in the UK can reduce their input investment by 83.2%-85.6% without any negative influence on the amounts of output generation. This figure further suggests that the UK hotels are very inefficient. A complete reform should be considered by the relevant regulatory authority to transform the whole industry to a new one with a completely different operating mechanism. Our results are in line with Ramanathan *et al*. (2016), where it is reported that the UK hotel industry has an average efficiency score of 0.07. Both our study and Ramanathan *et al*. (2016) report different results compared to most of the studies, which show that the hotel industry has an average efficiency score of over 0.6. One can observe that the standard DEA scores, which are obtained by considering the hotel operation as a black box, (i.e., by neglecting the intermediate measure), are much higher than those obtained by breaking down the hotel operation in two stages. This is as expected due to technical reasons. Indeed, the more the stages are considered, the lower will be the stage and the overall efficiencies, no matter how the latter is obtained from the stage efficiencies (bottom-up or top-down). However, the stage and the overall efficiencies are still relative measures and, thus, one should compare them against the highest scores assessed. Breaking down the hotel operation in successive stages, will provide a clearer picture regarding the operational performance in the hotel sector, i.e., the results will give the hotel managers a more objective view about their operations and over-optimism can be avoided. Therefore, the difference in the efficiency results from ours and the ones of other studies that report a relatively higher level of efficiency is mainly attributed to the different method adopted in the analysis. However, Ramanathan *et al*. (2016) use the traditional DEA model and report similar scores to us. This can be attributed to the different input and output variables used.

Figure 5 exhibits the efficiency scores of the two stages: stage1-assets generation and stage 2-income generation. The results show that the stage 1 efficiency scores range from 0.347 to 0.4, UK hotels can further reduce their investment in the inputs by 60%-65% without any reductions in output. In comparison the efficiency scores in stage 2 are lower on average, ranging from 0.245 to 0.3, which indicates that using the same level of the intermediate product (current assets), UK hotels can further increase the level of output by 70%-76%. The findings suggest that comparing between the two-stages, more effort should be given to optimize the resources in stage 2 although allocation of inputs and output is also needed for the production process in stage 1. This result provides interesting and important implications to the UK hotel industry: 1) with regard to stage 2, focus can be given to managing the current assets and relevant effort should be given to controlling costs in the hotel daily operation. For instance, as argued previously, in stage 2, current assets including cash and accounts receivables will be used to generate the final outputs, while in the production process, these intermediate products will be used for the hotel daily operations including decorations, repairs and inventory replenishment, while how to control the cost would be the key to reducing the hotel inputs and improving efficiency in stage 2; 2) in terms of stage 1, Cost of goods sold can also be optimized. This is mainly related to food and beverages, and it is recommended that UK hotels should find alternative outlets for purchasing food and beverages. It is further suggested that probably hotels can cooperate with each other when purchasing food and beverages, as bulk buying will not only increase their bargaining power but also reduce the cost from economies of scale.

<<Figure 4---about here>>

<<Figure 5---about here>>

Besides looking at the whole sample on an annual basis, we also divide the whole sample into two groups: one is related to the hotels in London and the other group includes the hotels in the rest of the sample. Figure 6 reports the efficiency scores of these two groups over the period, including stage 1 efficiency, stage 2 efficiency as well as the overall efficiency. We can see from the figure that stage 1 has a higher level of efficiency compared to stage 2 for both of these two groups. This is in line with the results for the whole sample. We find that London has lower levels of efficiency in both stage 1 and stage 2 compared to the hotels in other areas, while the difference in the efficiency level is even bigger in stage 1, therefore, for the hotels in London, more focus should be given to optimising the resources in the production process of stage 1. The larger difference in the efficiency level in stage 1 can be explained from the perspective that hotels in London have substantially higher levels of cost compared to the hotels in other areas in the UK.

<<Figure 6---about here>>

Finally, we further divide our sample into 6 groups according to the location of the hotel. These 6 groups cover the following areas in the UK: Norther Ireland, Scotland, North England, South England, Midlands and Yorkshire, the overall efficiency scores from our network DEA weak link approach are reported in Figure 7. The findings show that, unlike the results reported on an annual basis for the whole sample, we have more optimistic results when dividing the sample into different areas. We can see that hotels located in different areas have a quite large difference in the level of efficiency. The hotels located in South England have the lowest level of efficiency, with an average efficiency score of 0.217, while the hotels in Northern Ireland have the highest level of efficiency with an average efficiency score of 0.734. All the rest of the areas also have average efficiency scores range from 0.416 to 0.665. The lowest level of efficiency score in South England, to a certain extent, can be attributed to the fact the hotels in London are included in this group.

<<Figure 7---about here>>

The second-phase regression analysis shows that larger hotels have higher efficiency. This can be explained by the fact that large hotels have lower costs derived from economies of scale. We further observe that hotel capitalization also positively and significantly affects the overall efficiency, and stage-1 efficiency but it is insignificant for stage-2 efficiency. We explain this finding by the fact that better capitalized hotels have lower borrowing costs. This leads to an efficiency improvement. Finally, labour productivity is related to the overall level of hotel efficiency, stage 1 efficiency as well as stage 2 efficiency in a significant and positive manner. This result confirms our recommendation earlier that UK hotels should optimize the resource in the production process by improving the productivity of labour. Regarding the impact of industry-specific characteristics, the findings suggest that the number of arrivals and departures in international tourism affects efficiency in a significant and positive way, the impact of arrivals being greater than that of departures. This finding suggests that the economies of scale effect from the tourism inflow to the UK is bigger than that of tourism outflow.

This generates important government policy recommendations related to international tourism. The UK government should encourage foreign tourists to travel to the UK by simplifying the visa application process or easing the visa application requirement and expanding the visa period. Finally, it is suggested that international tourism expenditure and international tourism receipts are significant and positively related to hotel efficiency in the UK. This finding suggests that spending from foreign tourists has a bigger impact on boosting hotel efficiency in the UK than the domestic UK tourists' expenditure abroad. This can be explained by the fact that the accommodation used by the domestic international tourists will be significantly less than the one used by the foreign international tourists in the UK. The period of stay in the UK hotels by the foreign international tourists is longer, which will increase the revenue of UK hotels. Table 3 shows the results from the Bootstrapped truncated regression and Table 4 reports the robustness check by using fractional logit regression analysis.

<<Table 3---about here>>
<<Table 4---about here>>

Conclusion

Conclusion

The findings of our study suggest that the efficiency scores in the UK hotel industry, using the weak-link approach of Network DEA, range from 0.139 to 0.168. This shows that the UK hotel industry is very inefficient. There would be a great potential to optimize the production process to further improve the level of hotel efficiency. We compared our results with the one generated from the traditional DEA model, which reported much higher efficiency scores. We argue that in the hotel efficiency analysis in the future, our approach is recommended because it can provide more objective results and over-optimism can be avoided. We examine hotel efficiency under a weak-link network DEA approach, which provides accurate and robust estimates.

Dividing the production process into two-stages, we further observe that the first-stage efficiency scores range from 0.347 to 0.4, whereas the second-stage production process have efficiency scores of 0.245 to 0.3. This shows although the production process in both of these two stages should be optimized, more effort should be given to the second stage. This is also a contribution that provides specific policy implications to the hotel operational process, which was not investigated by the previous studies.

The second phase bootstrapped truncated regression analysis shows both the hotel-specific characteristics and the industry-specific characteristics are significantly related to UK hotel efficiency

Theoretical implication

Unlike other empirical studies in relation to the estimation of hotel financial performance, economic performance (Alnawas and Hemsley-Brown, 2019; Sarwar and Muhammad, 2020), operating performance (Hua *et al*., 2019) and strategic performance (Majid *et al*., 2019), we use a sample of UK hotels to significantly contribute to the area of efficiency analysis by proposing a network DEA under the weak-link method. The weak-link approach possesses a number of nice properties and locates more accurately potential inefficiencies in the hotel operation process. Rather than focusing on the investigation of quality from the service perspective (Ranjbari *et al*., 2020) and the impact of human resource management on organizational performance in the hospitality sector (Kloutsiniotis and Mihail, 2020), we are also the first to estimate the influence of both hotel-specific characteristics (hotel size, hotel capitalization and hotel labour productivity) and industry-specific contextual variables (Number of Arrivals-International Tourism, Number of departure-International Tourism; International Tourism expenditure and International Tourism receipt) on hotel efficiency under a second-phased Bootstrapped truncated regression.

Practical implications

Our results generate interesting and important implications to the UK hotel industry to further improve their efficiency level: 1) regarding stage 2, focus can be given to manage the current assets and relevant effort should be given to control costs in the hotel daily operation. For instance, as argued previously, in stage 2, current assets (including cash and accounts receivables) will be used to generate the final outputs, while in the production process, these intermediate products will be used for the hotel daily operations, including decoration, repair and inventory replenishment, while how to control the cost would be the key to reducing the hotel inputs and improving efficiency in stage 2. 2) in terms of stage 1, Cost of goods sold can also be optimized. This is mainly related to food and beverages, and it is recommended that UK hotels should find alternative outlets for purchasing food and beverages. It is further suggested that probably hotels can cooperate with each other when purchasing food and beverages, as bulk buying will not only increase their bargaining power, but also facilitate the achievement of economic scale, through which to reduce hotel costs;3) the UK hotels are encouraged to increase the volume of business and types of businesses engaged in, and the resultant increase in the cost reduction derived from economies of scale and scope would improve hotel efficiency; 4) the UK hotel industry is encouraged to further increase the capital level; the resultant reduction in the cost of borrowing will improve the efficiency; 4) relevant policies should be established and implemented to reward the staff with higher levels of productivity, which will motivate the staff's working efforts and further improve hotel efficiency; 5) relevant policies should be established by the government to further open up the tourism industry and welcome tourists from all over the world to travel to the UK; 6) relevant goods or services tailored specifically to international tourists in the UK should be designed and discounts can be offered to increase tourist spending. This will be helpful to further improve the hotel efficiency in the UK.

Limitations and future research

The current study suffers from a number of limitations: 1) we focus on a single set of input-intermediate product-output variables; no other alternatives were used, which affects the robustness of the results; 2) in terms of the methodology, although we are the first to use the network DEA model with weak link approach in the hotel industry, we did not use any alternative efficiency analysis methods, which also affects the robustness of the results. Future research could use alternative advanced DEA methods to evaluate the efficiency in the UK hotel industry or use the advanced SFA to check and compare the robustness of our results. Also, the robustness of the results can be further checked by using different sets of variables in the efficiency analysis.

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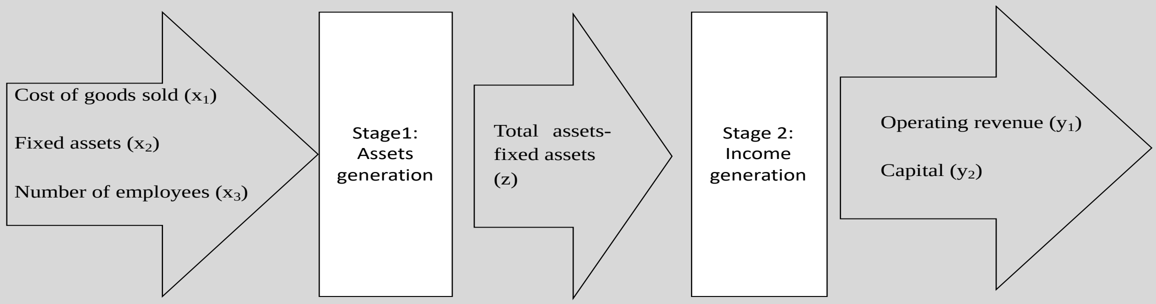

Fig.1: The hotel income generation as a two-stage process

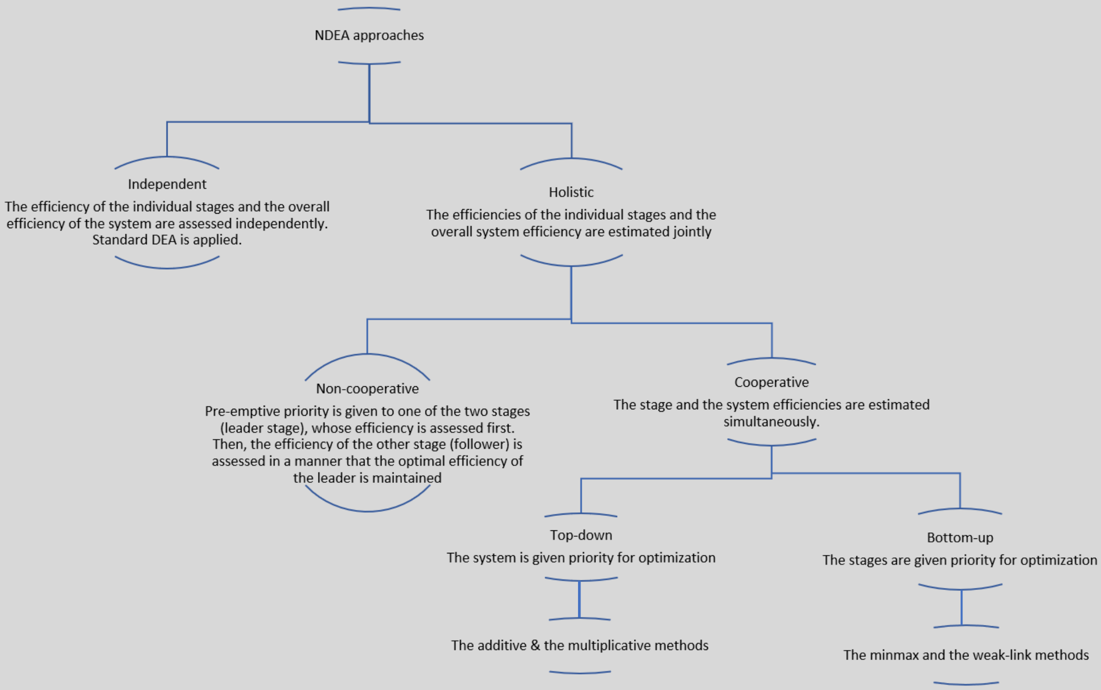

Fig. 2: A taxonomy of the network DEA approaches

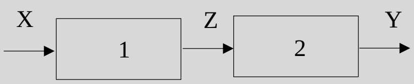

Fig. 3: A typical two-stage process

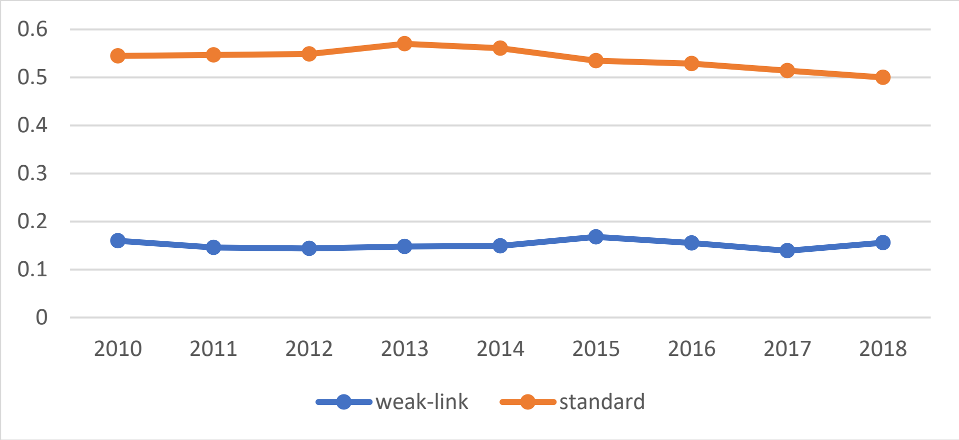

Figure 4. Average overall efficiency scores across the nine periods

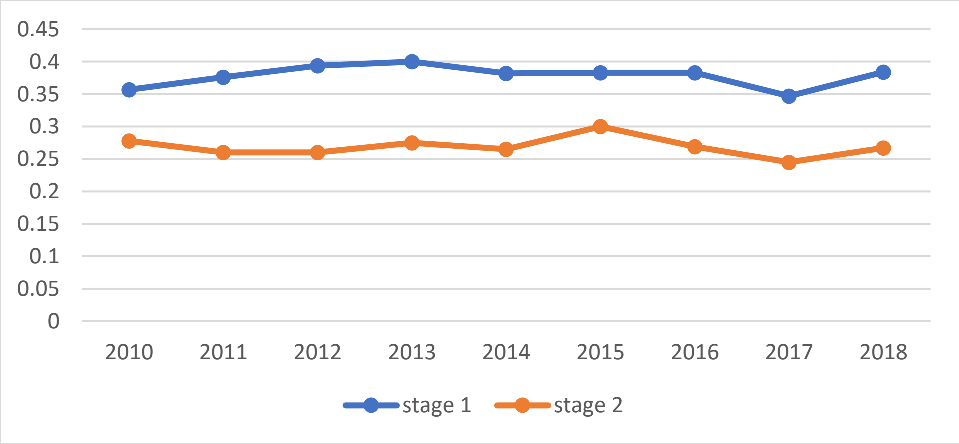

Figure 5. Average efficiency scores of the two stages across the nine periods

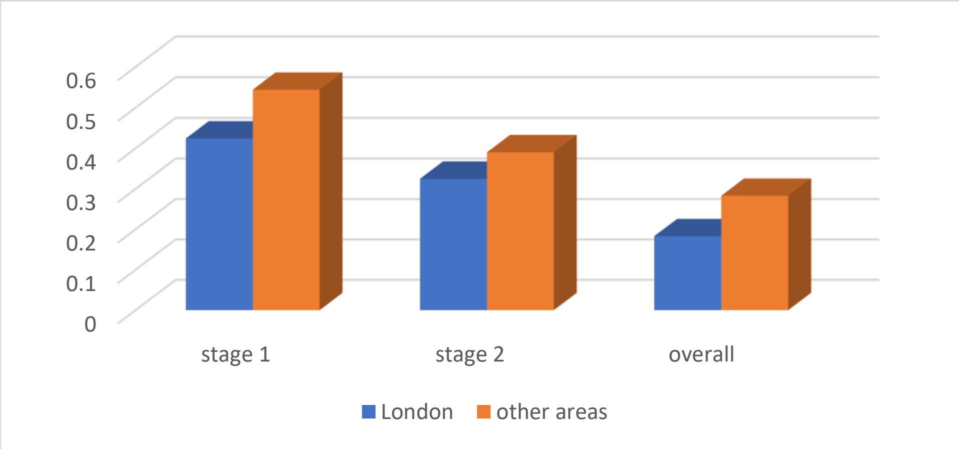

Figure 6. Efficiency of London hotels compared to other areas (average across the 9 periods)

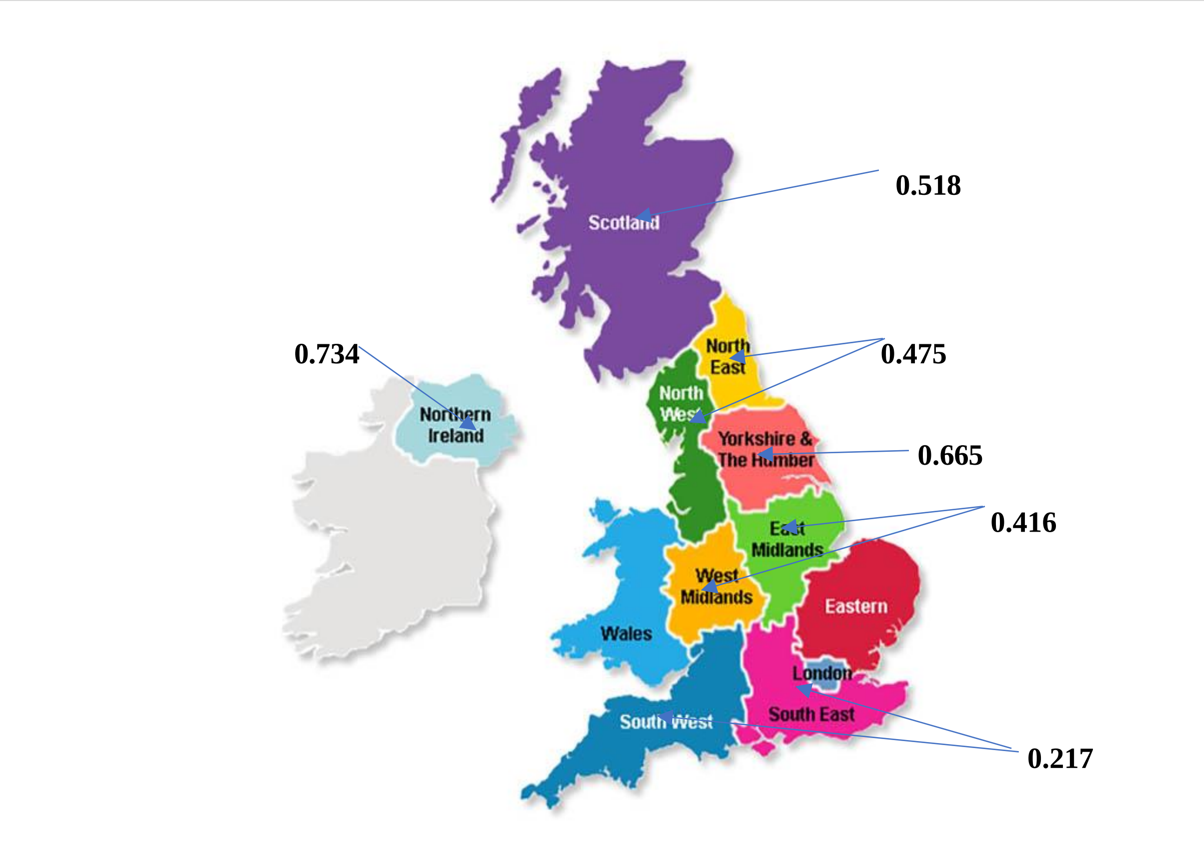

Figure 7. Hotel efficiency in different areas in the UK (average across the nine years)

Table 1 Summary of the empirical studies in evaluating hotel efficiency under data envelopment analysis

Authors and years	country	Inputs	Outputs	Second-stage analysis	Findings
Barros (2005)	Portugal	employees number labour cost number of rooms hotel surface area Property value operational and external cost	volumes of sales Number of nights spent by customers Amounts of guests	No	Scale economies and location are the main determinants of hotel efficiency
Barros and Mascarenhas (2005)	Portugal	Employees Physical capital Rooms	Sales Number of guests Nights spent	No	Hotel privatization enhances the level of hotel efficiency
Sanjeev (2007)	India	Capital employed Current and fixed assets Cost of operation	Operating income and profit before depreciation, interest and tax	No	The average efficiency score is 0.73, and size positively affects efficiency.
Barros and Dieke (2008)	Africa	Total costs Investment	Ratio between sales and number of rooms	Bootstrapped truncated regression	Efficiency increases over the examined period; market share and international strategy enhance efficiency
Chen (2009)	Taiwan	Number of employees Total surface areas of floors Guest rooms Operating expenses Depreciation expenses	Number of guests Occupancy rate Rate of guest satisfaction Room revenue Other revenue	No	the average efficiency score is above 0.7.
Assaf *et al*. (2012)	Slovenia	materials cost services cost employees number	sales from the room Sales from food and beverage	Bootstrapped truncated regression	More extensive reporting on environmental, social

		Rooms number			and financial issues lead to better hotel performance.
Manasakis *et al*. (2013)	Greece	Employees number, beds number and total operational cost	Total revenue Nights spent	No	Nationally branded hotels have the highest efficiency.
Luo *et al*. (2014)	China	hotels number employees number Fixed assets	Total revenue Total tax	Tobit regression	The inefficiency is derived from pure technical efficiency and the difference in efficiency level is attributed to the levels of tourism openness and dependence.
Ramanathan *et al*. (2016)	United Kingdom	Assets	Return on assets Return on capital employed	hierarchical linear regression	The UK hotel industry has an average efficiency score of 0.07
Neves and Lourenco (2009)	Worldwide	Current and fixed assets goods and services cost shareholders' equity	Revenue before Interest Taxes Depreciation and Amortization	No	Managers should focus on the inputs-outputs transformation process and reduce the hotel size.
Chen (2007)	Taiwan	Labour Food and beverages Materials	Total revenue	One-way ANOVA	Taiwan hotel has an average efficiency of more than 0.8
Anderson *et al*. (1999)	USA	Number of employees Number of rooms Total gaming related expenses Total food and beverages expenses Other expenses	Total revenue	No	The US hotel has an average efficiency of nearly 0.9

Arbelo-Perez *et al*. (2017)	Spain	Materials Employees Physical capital Other operating cost	Operating revenue Other operating revenue	No	The average efficiency score over the period is over 0.9. quality is a factor influencing efficiency level.
Assaf et al. (2010)	Taiwan	Number of rooms Number of full-time employees	Total revenue Market share for each hotel Employee performance	one-way ANOVA test	The lowest efficiency is nearly 0.7, while size, ownership and classification of a particular hotel influence efficiency
Pulina *et al*. (2010)	Italy	Labour cost	Sales revenue Value added generated	No	All the hotel achieve an efficiency score of nearly 0.7
Huang *et al*. (2012)	China	Number of employees Guest rooms Fixed assets	Total revenue Average occupancy rate	Dynamic Tobit regression	Chinese hotels are approaching the efficiency frontier and the efficiency is affected by international tourism attractiveness, education and payment levels of employees
Keh *et al*. (2006)	Asia	Rooms number Total expenditure INTERMEDIATE Expenditure on marketing	Rooms revenue F&B revenue	Stepwise regression	Increase in the volumes of marketing activities will increase the revenue of inefficient hotels
Ashrafi *et al*. (2013)	Singapore	Gross domestic product Average room price	Revenue from food, beverage and room Occupancy rate Gross lettings	No	All the hotels have an efficiency score of more than 0.75

		Volumes of international tourist arrivals			
Cheng *et al*. (2010)	Taiwan	room and employee numbers Catering department area Operating and catering expenses	Total operating revenues Average occupancy rate Average room rate Average production value per employee revenue from room and catering	No	Learning practice should be engaged in between hotels and the hotels in the leading levels can use lower progress to analyse potential competitors in the lagging levels
Shuai and Wu (2011)	Taiwan	Number of guest room Number of full-time employees Operating expenses	Total revenue generated from rooms Total revenue generated from food and beverages	one-way ANOVA test	Internet marketing affects hotel efficiency
Hsieh and Lin (2010)	Taiwan	Accommodation and catering costs Number of Employees in the accommodation and catering departments INTERMEDIATES number of rooms and catering floor	Revenue from room and catering	No	Stage 1 efficiency ranges from 0.1-0.4, while stage 2 efficiency ranges from 0.1-0.9
Zhang and Ma (2011)	China	Total assets Owner's equity Accrued wages Liquidity INTERMEDIATES	Profit Current liabilities Cash ratio	No	There is a large disparity on the efficiency level with lowest efficiency score of 0.2 and highest efficiency score of 1.

		Advocate business income Sales expenses Administrative expenses			
Yu and Lee (2009)	Taiwan	Employees number Rooms number Floor area Total expenditure INTERMEDIATES capacity of room, food and beverage	total revenue	The Kruskal–Wallis test and The Mann–Whitney test	Hyperbolic Network Data Envelopment Analysis generates efficiency score, which is lower than the one of one-stage DEA but higher than the one of two-stage DEA.
Yin *et al*. (2015)	Taiwan	Employee Total cost Area Guest rooms	Revenue Occupancy rate	No	All the hotels in the sample have an efficiency score of more than 0.6
Shang *et al*. (2010)	Taiwan	Employees and rooms number Catering department area Operating expenses	Total revenue	Tobit regression	The hotels in the sample have an average efficiency of over 0.8. location is a factor influencing efficiency
Sellers-Rubio and Casado-Diaz (2018)	Spain	Number of hotels Number of available hotel beds Number of full-time employee	Average daily rate Revenue per available room Average occupancy rate	Bootstrapped truncated regression	Hotel efficiency is affected by the number of international tourists, stay length and quality.
Assaf and Magnini, (2012)	United States	Fixed capital Number of employees Other operating costs	Total revenue Occupancy rates	No	All the hotels have an efficiency score of more than 0.7

Assaf and Cvelbar (2011)	Slovenia	Materials Fixed assets Number of employees	sales from room, food and beverage	posterior probability density function	Hotel efficiency is affected by privatisation, international attractiveness, and management tenure.

Table 2.

Descriptive statistics of the variables used in the dataset over the period 2010-2018

Variables	Mean	Maximum	Minimum	Standard deviation
inputs				
Number of employees	437.92	11602	2	1040.653
Fixed assets	6.01e+07	1.73e+09	14754	1.36e+08
Cost of goods sold	9604794	1.61e+08	191674	1.49e+07
Intermediate output				
Total assets-fixed assets	1.79e+07	1.20e+09	171345	5.49e+07
Final outputs				
Operating revenue	2.43e+07	3.29e+08	310532	3.68e+07
Capital	7386962	4.41e+08	570	2.51e+07
Contextual variables				
Hotel-specific variables				
size	7.54	9.261	6.268	0.525
capitalization	0.165	7.917	1.29e-06	0.54

Labour productivity	78296.55	6757289	80.519	176167
Industry-specific variables				
Number of arrivals (International Tourism)	31,816,324.42	37,814,000.00	28,199,000.00	3,566,900.57
Number of departures (International Tourism)	62,511,993.83	74,189,000.00	55,562,000.00	6,458,211.21
International tourism (expenditure)	81.61	94.96	71.67	7.40
International tourism (receipt)	52.58	65.45	39.04	8.69

Table 3. Determinants of efficiency in the UK hotel industry under bootstrapped truncated regression

	Hotel overall efficiency	Stage 1 efficiency: Asset generation	Stage 2 efficiency: Income generation
Hotel-specific characteristics			
Hotel size	0.28** (2.23)	0.19* (2.08)	0.13* (1.88)
Hotel capitalization	0.015*** (4.98)	0.018*** (4.83)	0.022 (0.09)
Hotel labour productivity	0.93*** (6.99)	0.77*** (7.18)	0.88*** (6.76)
Industry-specific characteristics			
Number of arrivals (International tourism)	0.22*** (8.18)	0.29*** (8.68)	0.11*** (7.91)
Number of departures (international tourism)	0.21*** (5.83)	0.33*** (5.17)	0.41*** (7.72)
International tourism (expenditure)	0.002*** (3.11)	0.008* (1.77)	0.005* (1.69)
International tourism (receipts)	0.011*** (3.96)	0.009* (1.77)	0.008* (1.63)
Constant	-0.22** (2.66)	-0.23* (-1.79)	0.83*** (8.99)
Wald Chi(2)	392.38***	6275.4***	492.71***
Log Likelihood	885.35	1018.47	1191.26

*, **, *** represent significant level of 1%, 5% and 10%, respectively

Table 4. Robustness check: determinants of efficiency in the UK hotel industry under fractional logic regression

	Hotel overall efficiency	Stage 1 efficiency: Asset generation	Stage 2 efficiency: Income generation
hotel-specific characteristics			
Hotel size	0.28** (2.73)	0.22* (1.79)	0.17* (1.78)
Hotel capitalization	0.09*** (4.11)	0.09*** (5.23)	0.09 (0.03)
Hotel labour productivity	0.66*** (8.38)	0.55*** (7.61)	0.39*** (5.35)
Industry-specific characteristics			
Number of arrivals (International tourism)	0.55*** (4.91)	0.28*** (6.99)	0.19*** (7.88)
Number of departures (international tourism)	0.31*** (5.13)	0.19*** (4.23)	0.12*** (6.91)
International tourism (expenditure)	0.011*** (7.73)	0.09* (1.88)	0.13* (1.88)
International tourism (receipts)	0.09*** (6.91)	0.09* (1.85)	0.05* (1.89)
Constant	-0.22*** (7.22)	-0.22*** (6.18)	-0.32*** (7.73)
Log Likelihood	-100.16	-86.13	-96.65

*, **, *** represent significant level of 1%, 5% and 10%, respectively