Investigating the Effects of IT Capability on Hotel Performance Based on DEA Approach: An Empirical Example of International Hotels in Hong Kong

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Received: 8 July 2020; Accepted: 17 August 2020; Published: 19 August 2020

Abstract: IT capability improves organization resilience in uncertain social environments (such as the outbreak of COVID-19) and, thus, becomes a key factor in the organization of sustainable development. However, studies have rarely quantitatively examined the efficiency of IT capability and its effects on hotel performance. This study aims to investigate how and to what extent IT capability facilitates hotel operations. Context-dependent and measure-specific data envelopment analysis (DEA) models were employed to assess hotel performance and IT capability. The data from international hotels in Hong Kong were collected for an empirical analysis. The results indicated that the hotels in Hong Kong are classified as market leaders, challenges, followers, and nichers based on the efficiency scores. This study then analyzed the differences and relationship between hotel IT capability and hotel performance. The improvement targets of each input and output variable were also provided for further decision-making. Both theoretical and practical implications for hotel management are discussed.

Keywords: hotel performance; IT capability; context-dependent DEA model; measure-specific DEA model; efficiency evaluation

1. Introduction

The hotel industry has become one of the rapid development industries due to the boosting of the global economy in recent years. Scholars have demonstrated a significantly positive relationship between IT adoption and a higher level of competitive advantage, which is closely related to the social and economic benefits of hotel management [1–3]. Practitioners are also interested in ways to improve IT capability to further increase profit margins in the hotel industry. After the impact of COVID-19 on traditional industries especially, practitioners have to pay more attention to the development of IT capability. It is, thus, important to examine how and to what extent the current IT capability affects hotel operation.

Extensive literature has explored the relationship between IT and hotel management. Specifically, scholars have examined the direct impact of IT on hotels’ internal operation processes, such as the effects on hotel employees’ productivity, performance, and job satisfaction [4,5] and on the strategic management, service management, and transaction costs [6]. In addition, recent research has also studied the indirect effects of IT on the hotel external market competition environment, customer–service relationships, and collaboration in the hotel chain [3,7].
Prior studies have examined the role of IT for supporting hotel development by answering the why and what questions, and have done so using empirical research methods (e.g., survey, interview) [8–10]. However, the quantitative measurement of the effects of IT on hotel performance has been ignored in prior studies. This shortcoming makes it hard for managers to determine effective improvement policies. Furthermore, rare studies have been conducted to explore the relationship between hotel IT capability and hotel operation performance.

To fill the above-mentioned research gap, this study aims to quantitatively analyze the impact of IT capability on hotel performance. In order to achieve this objective, this study focuses on unveiling the following two research questions: (1) what is the relationship between the hotel’s IT capability and the hotel’s performance? and (2) how do managers improve the hotel’s overall performance by re-allocating their resources?

This study employed the non-parametric approach of the data envelopment analysis (DEA), which is frequently used for hotel performance evaluation to measure the current efficiency of hotels in Hong Kong and the degree of IT capability of these hotels. Specifically, this study conducted a three-step empirical analysis. Firstly, the context-dependent DEA model was used to classify the hotels into different efficient frontier levels. The operation differences and relationship between hotel performance and IT capabilities were then analyzed. Thirdly, this study used the measure-specific DEA model to analyze the improvement targets of hotels and to investigate how hotels could become efficient in each resource-based frontier. This study contributes to the existing hotel literature by providing a quantitative approach to analyze the effects of IT capability on hotel performance. In addition, the results of this study also suggested improvement strategies for hotel practitioners.

The rest of the paper is organized as follows. In Section 2, the research background of this study is reviewed. The research methodology details are presented in Section 3, followed by the analysis of empirical results. We then conclude the paper with a discussion of limitations and future research directions.

2. Theoretical Background

2.1. The Role of IT in Hotel Industry

IT has become an important part of hotel infrastructure that promotes hotel performance [11]. Typically, IT capability has become increasingly important to improve organization resilience under uncertainty. Existing studies have mainly investigated the impact of IT investment on hotel performance using empirical research methods [12,13]. For example, Melián-González and Bulchand-Gidumal [14] proposed a comprehensive empirical model that explained the influence of IT applications on improving hotel performance. Cohen and Olsen [3] built an empirical model to investigate the relationships among IT resources, employee performance, customer service outcomes, and hotel competitive performance from a resource-based view. Based on the studies in this stream, IT applications are related to every aspect of hotel operation.

Another stream of studies explores the effect of IT in a more comprehensive way using quantitative research methods. In these studies, the operation level of IT and organization performance are measured by comprehensive efficiency indexes using a DEA approach [15]. However, this stream of research focused on investigating how to measure the overall efficiency of hotel IT components. Rarely have studies been conducted to explore how and to what extent IT capability influences hotel operation performance.

Furthermore, the measurement of IT capability is grounded on prior studies of organizational capabilities. Based on the resource-based view of organization, capabilities refer to the efficiency of a firm that transfers a given set of input resources to obtain certain outputs [16]. According to this description of capabilities, Ayabakan et al. [17] reconceptualized and measured the IT-enabled process capability using a DEA theoretical approach. Therefore, consistent with prior research on measuring capabilities, this study employed the DEA method to evaluate the relative IT capability of hotels.
2.2. Hotel Performance Evaluation

Hotel performance evaluation has been an important process for operational management for decades. It provides managers with necessary information for making decisions, and is also needed to bring competitive advantages for sustainable development [1]. Hotel performance evaluation has aroused increasing attention among academics.

Among the approaches for performance evaluation, data envelopment analysis (DEA), proposed by Charnes et al. [18], is one of the most useful methodologies. DEA is a non-parametric technique to calculate the relative efficiency of a group of homogenous decision-making units (DMUs) with multiple inputs and outputs. The DMUs that have maximum efficiency scores are treated as benchmarks for the other DMUs. Thus, the efficiency scores of each inefficient DMU are determined by comparison with DMUs on the efficient frontier.

In their study, Yin et al. [19] summarized six kinds of DEA models that are prevalently used in the hotel performance evaluation literature: conventional DEA models, DEA Malmquist model, stochastic methods, network DEA model, window DEA model, and slack-based DEA model. However, these methods benchmark the DMUs by constructing one efficient frontier. Thus, given the limited production resources, it may be hard for some inefficient DMUs to become efficient based on the suggested improvement strategies. In addition, it is also hard for the inefficient DMUs to determine which DMUs on the efficient frontier should be benchmarked. Therefore, it is worth investigating a more feasible improvement strategy for these DMUs. The context-dependent DEA model was proposed to solve this problem.

The context-dependent DEA model was first proposed by Seiford and Zhu [20]. This approach classifies the DMUs into several efficiency levels. Correspondingly, different efficiency levels refer to different reference sets of DMUs. Each efficient frontier indicates a specific performance level. DMUs are ranked according to the efficient frontier they are on, but it is also possible to differentiate them if they are on the same efficiency level using efficiency scores. The comparison results can be determined by the attractiveness and progress scores at each efficient frontier. The attractiveness score quantifies how much better a DMU is than another DMU that is relatively less efficient, and the progress score reflects the improvement space available for a DMU with relatively poorer efficiency [20].

Furthermore, the attractiveness and progress scores provide decision makers with a detailed perspective to compare DMUs with each other—that is, the DMUs that, on the same efficient frontier level, can be ranked according to their attractiveness or progress scores differently. In other words, two DMUs that are on the same efficient frontier may be different benchmarking for DMUs on different efficient frontier levels. Therefore, the DMUs with the same efficiency scores can be differentiated in this way.

The current hotel performance evaluation literature contains few studies that have investigated hotel industry operation efficiency using the context-dependent DEA model. Cheng et al. [21] built an assurance region context-dependent DEA model, and applied the restricted weights derived by an analytic hierarchy process to evaluate the efficiency of 34 international tourist hotels in Taiwan. Cheng et al. [22] proposed an improved slack-based context-dependent DEA model and applied it to measure the efficiency of 34 Taiwanese hotels. The application of the context-dependent DEA model is still rare in the hotel performance evaluation field.

Nevertheless, the above-mentioned DEA methods can be radial or non-radial assumptions [23]. The radial assumption refers to the fact that all the inputs or outputs can be improved or decreased with the same ratio at the same time to become efficient for a DMU. The non-radial assumption refers to the fact that all the inputs or outputs of a DMU can be adjusted at the same time but with different ratios: that is, both the radial and non-radial assumptions request the adjustability of all inputs or outputs. However, in practice, some of the input or output resources may be nonadjustable. For example, an organization cannot flexibly adjust the fixed assets during a short time period. In addition, practitioners may have a preference of the adjustments of inputs or outputs for inefficient DMUs [24]. In these cases, neither the radial nor non-radial assumption is unsuitable. The measure-specific DEA model is suitable in these cases [25]. When only one or some of the input resources or
outputs can be adjusted, the measure-specific DEA approach can provide more reliable improvement strategies for managers. This study thus used the measure-specific DEA model to calculate the improvement targets for inefficient DMUs.

In addition, existing studies have investigated hotel performance in several countries and regions, including: the U.S. [26,27]; Portugal [28]; Spain [29]; Vietnam [30]; Algarve [31]; mainland China [32]; Taiwan [33,34], and so on. However, management practice has been rarely explored in other regions, such as Southeast Asia. Therefore, to enrich the findings in hotel performance evaluation, hotels in Hong Kong were selected as the research sample in this study. The corresponding overall hotel performance and IT capability were analyzed. In the following section, we illustrate the methodology used in this study.

3. Methodology

According to the research objectives, the context-dependent DEA model was adopted to cluster the hotels into several operational levels in this study. By doing so, we aimed to provide more feasible improvement strategies for the hotels at various efficiency levels. The measure-specific DEA model was employed to improve some of the inputs and outputs that can be managed. This section introduced these two models in detail.

3.1. Context-dependent DEA Model

Assuming that there are n DMUs, and each DMU produces s outputs using m inputs, the set of all DMUs is represented as O, and the set of efficient DMUs in O is represented as E. Then, the sequences of O and E are defined as O = O − E. The set E is the set of DMUs with optimal value ∅ equal to 1 for the following model (1):

\[
\phi_i = \max \phi \\
\text{s.t. } \sum_{j \in J} \lambda_j x_{ij} \leq x_{io}, \quad i = 1, \ldots, m, \\
\sum_{j \in J} \lambda_j y_{ij} \geq \phi y_{io}, \quad r = 1, \ldots, s, \\
\lambda_j \geq 0, \quad j \in J',
\]

where, \(x_{ij}\) represents the \(i\)th input variable of DMU \(j\), and \(y_{ij}\) indicates the \(r\)th output variable of DMU \(j\). When \(l\) equals 1, model (1) is the output-oriented CCR model. The set \(E - \text{i.e., the first level efficient frontier} - \text{consists of all the efficient DMUs. When } l = 2, \text{ we get the second level efficient frontier, excluding the DMUs from the first level efficient frontier. Thus, we have several levels of efficient frontier } E. \text{ The following algorithm indicates the process of calculating different levels of efficient frontier [35].}

Step 1: set \(l = 1\). Calculate all the efficiencies of DMUs \(O\) using model (1), and the set of efficient DMUs consists of the first level efficient frontier \(E\).

Step 2: exclude the efficient DMUs from the sample—that is, \(O = O - E\). If \(O = \emptyset\), then stop.

Step 3: evaluate the efficiency results for DMUs in \(O\). The efficient DMUs are the new level of efficient frontier, \(E\).

Step 4: Set \(l = l + 1\), and go to Step 2.

The algorithm will end when \(O = \emptyset\): that is, when all DMUs are in some level of efficient frontier.

According to the above algorithm, the value of \(l\) is from 1 to \(L\), where \(L\) represents the ending condition. We can also conclude that these sets of DMUs have the following properties [35]:

1. \(O = \bigcup_{l=1}^{L} E\) and \(E \cap E' = \emptyset, l \neq l'\).
2. If \(l' > l\), the DMUs in \(E\) are dominated by the DMUs in \(E\).
3. For all \(l' > l\), each DMU in set \(E\) is efficient with respect to the DMUs in set \(O\).
In a context-dependent DEA model, each efficient frontier $E^l$ can be treated as an evaluation context. For example, each DMU in the first level efficient frontier may represent a choice or a product. Decision makers would not only compare choices or products among DMUs on the same efficient frontier, but they would also compare options from DMUs on higher or lower level efficient frontiers. The attractiveness or progress degrees of DMUs in different contexts quantify the differences of these comparisons.

Based on [20], consider a specific $DMU_q = (x_q, y_q)$ on the efficient frontier level $E^{l_0}$, $l_0 \in \{1, \ldots, L - 1\}$; we have model 2 to measure its output-oriented attractiveness.

$$\max \theta_q(d)$$

$$\text{s.t.} \sum_{j \in F(E^{l_0})} \lambda_j y_{jq} \geq \theta_q(d) y_{iq}, \quad r = 1, \ldots, s,$$

$$\sum_{j \in F(E^{l_0})} \lambda_j x_{jq} \leq x_{iq}, \quad i = 1, \ldots, m,$$

$$\lambda_j \geq 0, \quad j \in F(E^{l_0}).$$

(2)

where $d = 1, \ldots, L - l_0$. The inverse of the optimal value of model (2)—i.e., $1/\theta_q(d)$—is called the (output-oriented) $d$-degree attractiveness of $DMU_q$ from a specific level $E^{l_0}$.

Note that a degree refers to the difference in levels between the level of the DMU being evaluated and the lower level of the DMUs used as context. For example, the degree 1 attractiveness scores of level 1 DMUs indicate the scores measured by taking the level 3 DMUs as the evaluation context. For example, the degree 1 attractiveness scores of level 1 DMUs are evaluated in the context of level 2 DMUs. Degree 2 attractiveness scores of level 1 DMUs indicate the scores measured by taking the level 3 DMUs as the evaluation context.

The larger the value of $1/\theta_q(d)$, the more attractive $DMU_q$ is—that is, the more difference there is between $DMU_q$ and the evaluation context. By ranking the DMUs on efficient frontier $E^{l_0}$ based on attractiveness, the decision maker is convenient in finding the best benchmarking DMU. Note that the attractiveness values of the DMUs from the same efficiency frontier are different under different evaluation contexts.

In addition, the progress of $DMU_q \in E^{l_0}, l_0 \in \{2, \ldots, L\}$ can be measured based on the following model (3):

$$\max \vartheta_q(g)$$

$$\text{s.t.} \sum_{j \in F(E^{l_0})} \lambda_j y_{jq} \geq \vartheta_q(g) y_{iq}, \quad r = 1, \ldots, s,$$

$$\sum_{j \in F(E^{l_0})} \lambda_j x_{jq} \leq x_{iq}, \quad i = 1, \ldots, m,$$

$$\lambda_j \geq 0, \quad j \in F(E^{l_0}).$$

(3)

where $g = 1, \ldots, l_0 - 1$. The optimal value of model (3) (i.e., $\vartheta_q^*(g)$) is the (output-oriented) $g$-degree progress of $DMU_q$ from a specific level $E^{l_0}$.

The bigger the value $\vartheta_q^*(g)$ is, the greater room for the progress of $DMU_q$. Therefore, given a $DMU_q$, the smaller score of $\vartheta_q^*(g)$ is preferred. Each specific $DMU_q$ on the frontier $E^{l_0}$ can find a target DMU on efficient frontier $E^{l_0-k}$ to improve its efficiency. It is worth noting that there may be several progress objectives when $g > 2$. Thus, the highest degree progress score could represent the long-term improvement objective of $DMU_q$. It is easy to achieve the lowest degree of progress score, and this could represent the short-term improvement objective for $DMU_q$. By stepping through successive short-term objectives, this DMU can maximize its own efficiency.

### 3.2. Measure-Specific DEA Model

In the traditional input-oriented or output-oriented DEA models, it is assumed that the inputs or outputs are proportionally improved. Therefore, to become efficient, a DMU must realize all target improvement values of inputs in the input-oriented model or outputs in the output-oriented model. However, in some cases, to improve all of the inputs or outputs at the same time may be hard or impossible for DMUs. Measure-specific DEA models are useful in these situations.
The measure-specific DEA model evaluates the target values only for specific inputs or outputs of interest. This model is also appropriate to use in situations where not all of the inputs or outputs can be adjusted. The input-oriented measure-specific model is shown as model (4).

\[
\min \theta \\
\text{s.t.} \quad \sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta x_{id}, \quad i \in I, \\
\sum_{j=1}^{n} \lambda_j x_{ij} \leq x_{id}, \quad i \notin I, \\
\sum_{j=1}^{n} \lambda_j y_{ij} \geq y_{id}, \quad r = 1, \ldots, s, \\
\lambda_j \geq 0, \quad j = 1, \ldots, n.
\]

where \( I \) represents the set of input variables of interest. Moreover, the output-oriented measure-specific model is shown as model (5), where \( G \) represents the set of output variables of interest.

\[
\max \varphi \\
\text{s.t.} \quad \sum_{j=1}^{n} \lambda_j x_{ij} \leq x_{id}, \quad i = 1, \ldots, m, \\
\sum_{j=1}^{n} \lambda_j y_{ij} \geq \varphi y_{id}, \quad r \in G, \\
\sum_{j=1}^{n} \lambda_j y_{ij} \geq y_{id}, \quad r \notin G, \\
\lambda_j \geq 0, \quad j = 1, \ldots, n.
\]

It is worth noting that this study employs the constant returns to scale (CRS) models because CRS assumption avoids the interference of increase/decrease returns to scale; we thus focused on exploring the relationship between IT capability and hotel performance. Furthermore, in the condition of CRS, the production processes are replicable. This enables us to more accurately generalize the results and findings of this study to similar situations. In the next section, the above models are used to empirically analyze the hotels’ IT capabilities and hotel performances.

4. Empirical Analysis

In this section, the empirical sample is firstly introduced. The results of hotels’ overall efficiencies and IT efficiencies based on context-dependent DEA models are presented. The impact of IT capability on hotel performance is discussed. Finally, the improvement spaces for each hotel are provided based on a measure-specific DEA approach.

4.1. Sample and Data

Hong Kong is an attractive travel destination in Asia. With the fast development of both the economy and technologies, the hotel industry in Hong Kong also has more IT investment than other Asian tourism destinations to facilitate hotel operation. This study thus selected hotels in Hong Kong as the research sample. It is worth noting that this study considered two kinds of hotel operation performances to examine the effects of IT capability. One was the hotel’s main business performance. Consistent with prior studies, the hotel’s main business refers to hotel accommodation and food and beverage sectors [19]. The other one was the hotel’s overall performance, which included the hotel’s main business and hotel IT operations in this study.

To calculate the hotel’s main business efficiency, two input variables were selected, including total wages and total fixed cost expenses, and the output variable was total revenue. These variables were selected based on the literature in the field of hotel performance evaluation: for example, total wage variables originated from Morey and Dittman [36] and Barros and Dieke [37]; total fixed cost expenses are used in Tsai et al. [38], Tsang and Chen [39], etc.; and the total revenue variable is seen
in Cheng et al. [22], Tsai et al. [38], Tsang and Chen [39], and others. As one of the important IT infrastructure investments, the telecom infrastructure was used to represent the IT capability related indicators. The two input variables were electricity and telecom salaries, and the output variable was telecommunication revenue. Furthermore, the hotel’s overall efficiency was calculated by treating total fixed cost expense and telecom salaries as inputs and total revenue as output in this study. The input and output data and corresponding descriptive statistical characteristics are shown in Tables A1 and A2 in Appendix A.

The dataset was collected by filtering the annual reports of Smith Travel Research Incorporated. For the Hong Kong region, we collected data for the 29 hotels that are referred to in the reports. However, some of the hotels were deleted due to the missing data for the primary variables in this study. Finally, the data of 10 hotels in the year 2014 were used to conduct the empirical analysis. It is worth noting that the sample size needed for a DEA model with outputs and inputs should satisfy the formula: \( N \geq \max\{s \times m, 3(s + m)\} \) [40]. Therefore, the sample size of this study was appropriate for the DEA model.

4.2. Operation Differences Analysis between Hotels’ Main Businesses and IT Capabilities

In this section, the differences of operation performance among hotels were analyzed according to the results of context-dependent DEA models. Specifically, this study mainly focused on two sectors of hotel operations, viz.: hotels’ main business performance and corresponding IT performance. Both the attractiveness and progress scores for each hotel were calculated and analyzed in detail.

4.2.1. Results Analysis of Hotel’s Main Business Performance

Based on the context-dependent DEA model, the sample was classified into four categories on different efficiency levels. The results were shown in Table 1. Based on the market competitive structure theory, these four levels of DMUs can be labeled as market leaders (level 1 DMUs), market challengers (level 2 DMUs), market followers (level 3 DMUs), and market nichers (level 4 DMUs). The different degrees of attractiveness and progress scores for the DMUs were calculated using model (2) and model (3), respectively. The attractiveness results were summarized in Table 2.

| Frontier levels | DMUs                  |
|-----------------|-----------------------|
| Level 1         | DMU 8, DMU 9          |
| Level 2         | DMU 1, DMU 5, DMU 6   |
| Level 3         | DMU 2, DMU 4, DMU 10  |
| Level 4         | DMU 3, DMU 7          |

| Degree 1 | Degree 2 | Degree 3 |
|----------|----------|----------|
| Level 1  |          |          |
| DMU 8    | 3.1333   | 7.9130   | 48.8212  |
| DMU 9    | 1.2954   | 1.4059   | 1.4267   |
| Level 2  |          |          |
| DMU 1    | 2.5254   | 12.8316  |
| DMU 5    | 1.0719   | 1.1598   |
| DMU 6    | 1.0877   | 1.1485   |
| Level 3  |          |          |
| DMU 2    | 1.0606   |
| DMU 4    | 35.7622  |
| DMU 10   | 5.0784   |
Note that a bigger attractiveness score represented more competitive advantages. In addition, the industry attractiveness of each efficient DMU can also reflect its brand awareness degree as a market leader. Therefore, both the market acceptance and awareness of the DMUs were much higher for the DMUs with higher attractiveness scores. This means that these DMUs will be more likely to innovate in order to keep their competitive advantages and market share.

As shown in Table 2, for all degree 1, degree 2, and degree 3 results, the attractiveness ranking for level 1 DMUs was DMU 8 > DMU 9. This result indicated that DMU 8 had the biggest competitive advantage among the market leaders. On this efficient level, DMU 9 could treat DMU 8 as a benchmark (i.e., an improvement target) for further improving its operation efficiency.

The market challengers’ attractiveness scores regarding level 3 and level 4 DMUs are shown in lines 6–8 of Table 2. The DMUs on the level 2 efficient frontier can be ranked differently based on different degrees of attractiveness scores. For degree 1, we had DMU 1 > DMU 6 > DMU 5, and for degree 2, we had the ranking results DMU 1 > DMU 5 > DMU 6—that is, DMU 5 and DMU 6, which were on the level 2 efficiency frontier, had different attractiveness to level 3 and level 4 DMUs. This result was consistent with the characteristics of market challengers. This is because to survive amid the fierce competition in the market, market challengers are devoted to developing specific advantages, and the typical advantages can be identified differently by other market members.

As shown in lines 10–12 of Table 2, the attractiveness of DMU 4 was the highest, followed by DMU 10 and DMU 2. This result indicated that DMU 4 could be treated as a benchmark for market nichers. It also indicated that DMU 4 was the representative of hotels in the market follower segment. DMU 2 and DMU 10 could also further improve their market competitions by treating DMU 4 as a benchmark.

The progress scores of DMUs on levels 2, 3, and 4 efficient frontiers were also calculated, and the results are listed in Table 3. The progress score reflected the improvement space of the DMUs that were on the lower level efficient frontier relative to the upper level efficient frontier. A bigger progress score indicated that a DMU needs to improve more than other DMUs to reach the upper level efficient frontier. Therefore, the progress score of each DMU can also provide significant management implications for practitioners.

As shown in lines 3–5 of Table 3, the progress scores of level 2 DMUs were distributed densely between 1.0952 (DMU6) and 1.2081 (DMU 1)—that is, compared with level 1 DMUs, the operations of these DMUs were similar, which showed the fierce market competition among them. Therefore, as market challengers, these DMUs on the level 2 efficient frontier should adopt differentiation strategies to further expand their market share. Furthermore, DMU 6 was the closest to efficient frontier level 1. DMU 6 was, thus, the most likely to challenge the market leader role of the DMUs on the level 1 efficient frontier.

| Degree 1 | Degree 2 | Degree 3 |
|----------|----------|----------|
| **Level 2** | | |
| DMU 1 | 1.2081 | |
| DMU 5 | 1.1106 | |
| DMU 6 | 1.0952 | |
| **Level 3** | | |
| DMU 2 | 1.0608 | 1.1744 |
| DMU 4 | 1.0034 | 1.1607 |
| DMU 10 | 1.2507 | 1.4987 |
| **Level 4** | | |
| DMU 3 | 1.0163 | 1.1054 | 1.3630 |
| DMU 7 | 1.0599 | 1.1223 | 1.2441 |

Table 3. Hotels’ main business progress scores for level 2–4 decision-making units (DMUs).
The results in lines 7–9 of Table 3 indicated that DMU 2 and DMU 4 were very close to the level 2 efficient frontier: that is, in this market segment (i.e., market followers), DMU 2 and DMU 4 had more competitive advantages than DMU 10. In addition, for the DMUs on the level 3 efficient frontier, the level 2 efficient frontier can be treated as their short-term target, and the level 1 efficient frontier can be seen as the long-term target. Therefore, the decision makers of DMU 2 and DMU 4 should ensure the fulfillment of the short-term targets and should also start to set practical policies for long-term targets. Regarding DMU 10, the managers should focus on achieving the short-term objectives and improving competition advantages.

As for DMU 3 and DMU 7, they had three stage targets for them to become level 1 efficient. Decision makers thus can make a long-term improvement plan by learning from the management experiences of DMUs on other efficient frontiers. Furthermore, the progress scores of DMU 3 and DMU 7 were close. This means that this segment market was relatively stable.

To summarize, according to the results of the context-dependent DEA model, the main business performances of sample hotels in Hong Kong were clustered into four efficient levels, which have been labeled as market leader, market challenger, market follower, and market nicher. The market leaders had significant competitive advantages and brand awareness. Therefore, the managers of these hotels should pay more attention to sustainable development strategies. For the market challengers that are on the level 2 efficient frontier, the empirical results showed that there was fierce competition among them. Differentiation strategies are suggested to help them keep their market share and catch up with the target DMUs. The market followers and nichers should take a stepwise improvement strategy, where both short-term and long-term objectives are considered.

4.2.2. Results Analysis of Hotel’s IT Capability

In this section, the efficiency results of hotels’ IT capabilities are discussed. Table 4 lists the classification results of sample hotels’ IT capabilities. There were five efficient frontier levels of IT capabilities, where only DMU 1 was on the level 4 efficient frontier. Two of the DMUs were classified into the level 1 efficient frontier (DMU 7 and DMU 8). DMU 3 and DMU 5 were classified into level 2 efficient, and DMU 6 and DMU 9 were on the level 3 efficient frontier. The level 5 efficient frontier comprised the other three DMUs (DMU 2, DMU 4, and DMU 10). According to the above classification results, the corresponding attractiveness and progress scores of hotels’ IT capabilities were calculated, and the results are listed in Tables 5 and 6, respectively.

Based on the results in lines 3–4 of Table 5, the IT capabilities of level 1 DMUs had different degrees of attractiveness for the DMUs on lower level efficient frontiers. In addition, DMU 8 had higher attractiveness than DMU 9 for all DMUs on other efficient frontiers. DMU 8 could, thus, be the benchmark for all DMUs on level 2–4 efficient frontiers. For the level 2 DMUs, the rank based on attractiveness scores was DMU 5 > DMU 3. It was interesting to find that the ranks of degree 1 and degree 2 attractiveness for Level 3 DMUs were different: that is, the rank of degree 1 attractiveness was DMU 6 > DMU 9, while the rank of degree 2 attractiveness was DMU 9 > DMU 6. These results indicated that although DMU 6 and DMU 9 were on the same efficient frontier, they had different IT capabilities that were evaluated differently by different DMUs. In this way, DMU 6 and DMU 9 could have better market positions by fully understanding their advantages on different market segments.

Table 4. Frontier levels of IT capability for Hong Kong hotels.

| Frontier levels | DMUs          |
|-----------------|---------------|
| Level 1         | DMU 7, DMU 8  |
| Level 2         | DMU 3, DMU 5  |
| Level 3         | DMU 6, DMU 9  |
| Level 4         | DMU 1         |
| Level 5         | DMU 2, DMU 4, DMU 10 |
Table 5. Hotels’ IT capabilities attractiveness scores for level 1–4 DMUs.

| Level | Degree 1 | Degree 2 | Degree 3 | Degree 4 |
|-------|----------|----------|----------|----------|
| Level 1 |          |          |          |          |
| DMU 7  | 1.0293   | 1.5019   | 2.391    | 0.5651   |
| DMU 8  | 2.1614   | 2.3858   | 4.2022   | 5.7572   |
| Level 2 |          |          |          |          |
| DMU 3  | 1.1185   | 1.9701   | 2.6237   |          |
| DMU 5  | 1.4811   | 2.3579   | 5.4881   |          |
| Level 3 |          |          |          |          |
| DMU 6  | 1.7614   | 2.4709   |          |          |
| DMU 9  | 1.5918   | 3.7053   |          |          |
| Level 4 |          |          |          |          |
| DMU 1  | 2.3276   |          |          |          |

Table 6. Hotels’ IT capabilities progress scores for level 2–5 DMUs.

| Level | Degree 1 | Degree 2 | Degree 3 | Degree 4 |
|-------|----------|----------|----------|----------|
| Level 2 |          |          |          |          |
| DMU 3  | 2.1330   |          |          |          |
| DMU 5  | 1.0140   |          |          |          |
| Level 3 |          |          |          |          |
| DMU 6  | 1.0919   | 2.2796   |          |          |
| DMU 9  | 1.1275   | 1.4432   |          |          |
| Level 4 |          |          |          |          |
| DMU 1  | 2.6104   | 1.7288   | 2.2859   |          |
| Level 5 |          |          |          |          |
| DMU 2  | 1.0870   | 1.9146   | 2.1415   | 4.5678   |
| DMU 4  | 1.5531   | 2.5894   | 2.2236   | 5.1148   |
| DMU 10 | 1.5107   | 2.5512   | 2.2805   | 5.2239   |

Based on Table 6, the rank of degree 1 progress for level 2 DMUs was DMU 3 > DMU 5; that is, the IT capability of DMU 5 was relatively poor due to the bigger progress score, which means more room to improve. For level 3 DMUs, the degree 2 progress scores were higher than degree 1 progress scores. This result indicated that it was harder for level 3 DMUs to achieve to level 1 efficient frontier. Therefore, the decision makers of level 3 DMUs should aim for short-term targets, which focus on achieving to level 2 (i.e., degree 1) efficient frontier. Furthermore, the ranks of DMUs’ progress scores were different. For degree 1 progress, we had DMU 9 > DMU 6, and DMU 6 > DMU 9 for degree 2 progress. This result indicated that when Level 3 DMUs aim for a level 2 efficient frontier, DMU 6 could improving itself easier than DMU 9; when they aim for a level 1 efficient frontier, DMU 9 could achieve the objective easier than DMU 6. Practically speaking, given the different operation statuses of DMU 6 and DMU 9, decision makers of DMU 6 should firstly focus on short-term development, while DMU 9 should make a long-term development strategy. The level 5 DMUs can also be ranked on the basis of different progress degrees. For degree 1 and degree 2 progress, we had DMU 4 > DMU 10 > DMU 2. For degree 3 and degree 4 progress, the rank was DMU 10 > DMU 4 > DMU 2. Therefore, DMU 2 should take a sound improvement strategy that achieves a to level 1 efficient frontier step by step. However, for DMU 10, the results indicated that it should be easier to achieve level 3 and level 4 efficient frontiers than DMU 4 in the short-term. Although DMU 4 achieved level 1 and level 2 efficient frontiers easier than DMU 10, DMU 4 should also significantly improve its IT capability in the short-term to go one step further.

To sum up, the competitions among Hong Kong hotels are fierce. The hotels have been categorized into four groups. Furthermore, the attractiveness and progress results also give detailed
information regarding the operation differences of hotels’ main businesses and IT capabilities. In the next section, the relationship between hotel performance and IT capability will be discussed.

4.3. The Relationship between Hotel IT Capability and Hotel Overall Performance

In this section, three steps of analysis are conducted to unveil the relationship between hotel IT capability and hotel performance. Firstly, based on the results of the context-dependent DEA model, we analyzed the relationship between the hotel’s main business performance and IT capability. Secondly, we calculated the hotel’s overall performance, and further quantitatively unveiled the relationship between the hotel’s overall performance and IT capability. Thirdly, we conducted a statistically robust testing using SPSS 26.0 to further verify the relationship between the hotel’s IT capability and hotel performance.

First, by comparing Tables 1 and 4, it can be seen that both the main business efficiency and IT efficiency results of DMU 8 were on the level 1 efficient frontier. As for DMU 9, its main business performance was in the level 1 groups, but its IT capability was on the level 3 efficient frontier. The relatively poor performance in IT capability did not decrease the main business performance of DMU 9. For market challengers, both the main business performance and IT capability of DMU 5 were on the level 2 efficient frontier. However, the IT capability of DMU 1 was on the level 4 efficient frontier and DMU 6’s IT capability was categorized into level 3. Therefore, only DMU 8 and DMU 5 had a relatively balanced operation level in terms of main business and IT capability. The IT capabilities of market followers were all on the level 5 efficient frontier. Interestingly, the market nichers had relatively high IT capabilities, whereas the IT capability of DMU 3 was on the level 2 efficient frontier and the IT capability of DMU 7 was on the level 1 efficient frontier. These qualitative analyses indicated that the hotel’s IT capabilities may not have a direct influence on the hotel’s main business performance.

Second, to quantitatively unveil the relationship between IT capability and hotel performance, we then evaluated the hotel’s main business efficiency, overall efficiency, and IT efficiency using model (1) by setting it based on the context-dependent DEA model (i.e., CCR model). As mentioned before, the hotel’s overall efficiency was calculated by treating the total fixed cost expense and telecom salaries as inputs and total revenue as output. The results were shown in Table 7. According to the efficiency results of Table 7, we visualized the change trends of these three efficiencies into Figure 1.

Table 7. Efficiency results of hotel’s main business, hotel’s IT capability, and hotel’s overall performance.

| DMUs | EMB   | ET    | EO   |
|------|-------|-------|------|
| 1    | 0.8277| 0.4375| 1.0000|
| 2    | 0.8515| 0.2189| 0.2398|
| 3    | 0.7337| 0.4688| 0.3233|
| 4    | 0.8616| 0.1955| 0.6901|
| 5    | 0.9004| 0.9862| 1.0000|
| 6    | 0.9131| 0.4387| 0.5390|
| 7    | 0.8038| 1.0000| 0.9224|
| 8    | 1.0000| 1.0000| 1.0000|
| 9    | 1.0000| 0.6929| 0.7661|
| 10   | 0.6673| 0.1914| 0.3644|

Note: EMB represents the efficiency scores of hotels’ main businesses; ET represents hotels’ IT efficiency scores; and EO represents hotels’ overall efficiency scores.
Sustainability results each input and output 4.4. businesses to treating IT as tools for long run. Therefore, business operation infrastructures) performance. Th there ET statistically valida there changes of hotels' dissemination in more efficient the hotel should be, because IT promotes both internal and external information efficiency performance of DMU 9. As an infrastructure system of hotel management, the more efficient the IT techniques are, the more efficient the hotel should be, because IT promotes both internal and external information dissemination in hotels that promote the efficient operation of hotels. As shown in Figure 1, the changes of hotels' overall efficiencies were consistent with that of hotels' IT capabilities. However, there were no identical relationships between IT capability and hotels' main business efficiency. To statistically validate this result, we ran the linear regression model in SPSS 26.0. The results showed that the ET was significantly and positively related to EO (β = 0.737, p < 0.05). However, there was a non-significant relationship between ET and EMB (β = 0.468, p > 0.1).

To sum up, IT capability was positively related to the hotel's overall performance. However, there was no significant relationship between hotel IT capability and hotel main business performance. These results indicate that, currently, the IT capabilities (especially the telecom infrastructures) are only treated as a source of revenue rather than a way to facilitate the hotel's main business operation. In these cases, it may be hard for IT capability to improve hotels' resilience in the long run. Therefore, the call for digital transformation in the hotel industry is urgent. Instead of treating IT as tools for obtaining revenue, it should also be deeply embedded in hotels' main businesses to achieve competitiveness by providing customized services.

4.4. Analysis of Hotels' Improvement Strategies

This section investigates how to improve the inefficient DMUs. The improvement targets for each input and output variable were calculated based on the measure-specific DEA model, and the results are listed in Table 8. Then, the suggested strategies were analyzed as follows.

Table 8. Results of improvement targets based on measure-specific data envelopment analysis (DEA) model.

| DMUs | Main Business Improvement | IT Improvement |
|------|---------------------------|----------------|
|      | X_{1b} | X_{2b} | Y_{b} | X_{1t} | X_{2t} | Y_{t} |
| 1    | -17.32% | -68.08% | 20.81% | -76.20% | -57.58% | 129.36% |
| 2    | -15.94% | -97.42% | 17.44% | -78.11% | -87.08% | 356.78% |
| 3    | -29.84% | -98.52% | 36.30% | -53.12% | -59.09% | 113.30% |
| 4    | -14.35% | -94.95% | 16.07% | -84.68% | -82.03% | 412.05% |
| 5    | -10.65% | -96.02% | 11.06% | -10.42% | -1.38% | 1.40%  |
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|   | X6 | X7 | X8 | X9 | X10 |
|---|----|----|----|----|-----|
| 6 | −9.47% | −97.51% | 9.52% | −58.08% | −60.11% | 128.01% |
| 7 | −21.03% | −97.51% | 24.41% | 0.00% | 0.00% | 0.00% |
| 8 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| 9 | 0.00% | 0.00% | 0.00% | −63.71% | −33.42% | 44.85% |
| 10 | −33.64% | −87.36% | 49.87% | −84.25% | −82.48% | 422.84% |

Note: X6 represents total wages; X7 represents total fixed cost expenses; X8 represents total revenues. X9 represents electricity; X10 represents telecom salaries; Y1 represents telecommunication revenue.

As shown in Table 8, the DMUs that were evaluated as efficient in the prior DEA model were still efficient using the measure-specific DEA model. The improvement spaces for efficient DMUs were 0%. Taking DMU 1 as an example, to improve DMU 1’s main business performance, there are three alternatives for decision makers to do: that is, the managers of hotel 1 could reduce the total wages by 17.32%, reduce the total fixed cost expenses by 68.08%, or increase the total revenue by 20.81%. Therefore, if this hotel reduced the total wages by 17.32%, then DMU 1 would become efficient in the total wages-specific DEA model. Practically, this process may be achieved by examining the overall operation process of hotels to reduce the corresponding redundant human capital. Therefore, based on our empirical results, as a first step toward achieving further development, hotel managers should pay attention to reducing the waste of input resources during their production process. The manager of hotels could select one or more alternative plans to reduce the waste of specific controllable input resources and make more rational allocations of resources. In addition, hotels could be more focused on taking advantage of their existing resources to develop their competitive advantages.

Based on columns 2-4 in Table 8, decision makers could adjust their corresponding production resources to make the inefficient DMUs become efficient in view of the hotel’s main business performance. However, in practice, it may be hard for managers to adjust the input or output resources immediately. For example, we would expect it to be hard for DMU 10 to improve its total revenue by 49.87% and thereby become efficient in the total revenue-specific DEA model during a short time period. However, DMU 10 could be total wage-specific efficient if it decreases the total wages by 33.64% gradually. According to the results in Table 8, we can see that the phenomenon of resource wasting is significant in the Hong Kong hotel industry. Most of the DMUs should reduce their input resources to become efficient.

Columns 5–7 of Table 8 show the improvement targets for each input and output of the hotel’s IT capability. Corresponding strategies for decision makers to improve their IT capabilities are also provided. For example, three strategies can be drawn for the consideration of decision makers in DMU 5: that is, to decrease the electricity input by 10.42%; to reduce the salaries by 1.38%; and to improve the revenue by 39.12%. For instance, the decision makers may choose the strategy of reducing the salaries by 1.38%, so that DMU 5 can be efficient in the salaries’ specific efficient frontier. Only two of the 10 Hong Kong hotels’ IT capabilities in our research sample were efficient. More than half of the hotels needed to reduce their corresponding input resources to become efficient. Comparatively, the IT outputs of six hotels in the sample should be significantly improved. In other words, the large amount of investment in IT does not produce corresponding revenue for hotel operation. Managers in these inefficient hotels should thus enhance the awareness of IT requirements to reduce unnecessary inputs.

5. Conclusions

In modern hotel management, IT has become an important tool to support the normal operation of hotel businesses. This study explored the relationship between IT capability and the overall performance of Hong Kong hotels. Based on the results of the context-dependent DEA model, this study concluded that there were differences between the hotel’s main business performance and the hotel’s IT capabilities. There was no significant relationship between the hotel’s IT capability and the hotel’s main business performance. In addition, IT capability was significantly and positively related...
to the hotel’s overall performance. The results of the measure-specific model indicated that most of the hotels invested too much resources without producing more revenue.

Therefore, by dividing the hotels into different efficiency levels, the empirical results of this study provided hotel managers with more precise views of their current status in terms of main business operation performance and IT capabilities. Furthermore, the methods used here provided specific improvement targets for each input or output resource, as well as providing concisely practical management strategies for improving performance. Thus, this study has significant practical implications. We also contributed to the academic literature by investigating IT capability and its impact on overall performance in the hotel industry. Furthermore, we also enriched the literature by taking Hong Kong hotels as the empirical research sample and providing more information about management practices in Southeast Asia.

There are some limitations of this study. For example, only one type of IT (i.e., telecom infrastructures) was taken into consideration. Future studies can also be conducted to examine the operation efficiency of the overall IT infrastructure in hotels. Specifically, the degree of IT integration with the hotel’s main business should be further explored to unveil the recessive value of IT for hotel operation. Future studies can thus make a comparative analysis by collecting data from more hotels with various regional backgrounds. Furthermore, only one year of data was collected and analyzed in this study. Future research could use time series data and analyze the efficiency change trends with the development of IT in the hotel industry. Future studies could also collect practical data under typical uncertain social events, and a comparative analysis should be conducted to examine the role of IT in facilitating hotel operations.

**Author Contributions:** The following statements should be used Methodology, P.Y.; software, P.Y. and M.Y.; validation, R.Y. and M.Y.; formal analysis, P.Y.; data curation, P.Y.; writing—original draft preparation, P.Y.; writing—review and editing, M.Y. and R.Y.; visualization, P.Y. All authors have read and agreed to the published version of the manuscript.

**Funding:** This work was supported by the National Natural Science Foundation of China, grant No. 71701061, No. 7171074, and No. 71771074; Fundamental Research Funds for the Central Universities, grant no. JZ2019HGTB0097; China Postdoctoral Science Foundation, grant no. 2017M61207; and the Specialized Fund for the Doctoral Program of Higher Education of China, grant no. JZ2017HGBZ0925.

**Conflicts of Interest:** All authors declare no conflict of interest.

### Appendix A

**Table A1.** Data and descriptive statistical characteristics for measuring main business efficiency of Hong Kong hotels in 2014.

| DMUs | Inputs |  | Output |
|------|--------|---|--------|
|      | Total Wages | Total Fixed Cost Expenses | Total Revenues |
| 1    | 108,992,975.56 | 698,468.13 | 419,669,472.74 |
| 2    | 28,020,102.21 | 2,443,893.87 | 118,509,683.32 |
| 3    | 96,198,817.75 | 25,779,426.00 | 400,329,551.52 |
| 4    | 110,293,053.60 | 4,795,141.08 | 455,786,357.36 |
| 5    | 205,555,407.19 | 16,849,638.09 | 915,510,635.74 |
| 6    | 208,739,442.72 | 22,014,155.84 | 960,251,376.53 |
| 7    | 246,273,413.96 | 20,952,857.19 | 981,614,748.76 |
| 8    | 162,753,630.18 | 400,819.91 | 754,595,597.61 |
| 9    | 295,716,540.59 | 98,898,430.34 | 1,754,016,536.94 |
| 10   | 59,733,249.75 | 783,692.19 | 186,453,823.27 |
| Max  | 295,716,540.59 | 98,898,430.34 | 1,754,016,536.94 |
| Min  | 28,020,102.21 | 400,819.91 | 118,509,683.32 |
| Mean | 152,227,663.35 | 19,361,652.26 | 694,673,778.38 |
| S.D. | 85,849,741.22 | 29,691,986.97 | 487,284,867.9 |

Note: The units of measurement in these tables are omitted since they do not affect the result.
Table A2. Data and descriptive statistical characteristics for measuring IT efficiency of Hong Kong hotels in 2014.

| DMUs | Inputs | Output |
|------|--------|--------|
|      | Electricity | Telecom Salaries | Telecommunication Revenue |
| 1    | 12,600,418.10 | 1,294,105.84 | 600,074.20 |
| 2    | 4,622,847.00  | 1,414,224.61 | 202,535.13 |
| 3    | 11,391,171.79 | 2,412,582.48 | 1,068,728.99 |
| 4    | 11,604,224.19 | 1,786,137.52 | 355,834.51 |
| 5    | 24,646,142.97 | 1,783,950.30 | 1,950,458.33 |
| 6    | 22,041,627.96 | 4,201,597.52 | 1,848,899.91 |
| 7    | 27,179,653.01 | 2,073,710.57 | 2,299,095.17 |
| 8    | 13,595,456.36 | 2,720,771.24 | 2,720,771.24 |
| 9    | 45,350,479.10 | 4,461,403.71 | 3,293,319.03 |
| 10   | 9,914,952.64  | 1,609,034.66 | 312,555.45 |
| Max  | 45,350,479.10 | 4,461,403.71 | 3,293,319.03 |
| Min  | 4,622,847.00  | 1,294,105.84 | 202,535.13 |
| Mean | 18,394,697.31 | 2,375,751.85 | 1,465,227.20 |
| S.D. | 11,963,260.5  | 1,119,300.476| 1,108,341.929|

Note: The units of measurement in these tables are omitted since they do not affect the result.

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