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COVID-19 and Hotel Productivity Changes: An Empirical Analysis Using Malmquist Productivity Index

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Abstract. This research investigates the impact of COVID-19 on hotel productivity change using the Malmquist Productivity Index (MPI). For 26 U.S. hotel brands, productivity changes over 10 quarters from the first quarter of 2018 to the second quarter of 2020 were analyzed. After the COVID-19 outbreak, the investigated hotels' productivity deteriorated. Decomposition revealed that, whereas technical efficiency change (EC) improved, technological change (TC) regressed, resulting in deterioration of the MPI. The investigated hotels' EC-related practices included enhanced cleaning operations, partnering with a hygiene brand, cutting the workforce, and pay cuts. Practices related to TC included the adoption of new hygiene technology and setting a new standard at the organizational level through the formation of a global council and accreditation related to disinfection and hygiene. Our results show that though U.S. hotels are trying to improve their productivity by efficiently utilizing resources, frontier technology's regress is decreasing productivity. Our results support the importance of investment in technology for productivity management. This research provides empirical evidence for the need for hotels to pursue technological advances to overcome the pandemic.

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Keywords: COVID-19 • hotel productivity • hotel efficiency • Malmquist Productivity Index (MPI) • technical efficiency change (EC) • technological change (TC)

1. Introduction

Over the past few decades, the tourism industry has grown rapidly. The hotel industry has expanded dramatically with the increasing numbers of tourists. But this growth is being challenged by the unprecedented COVID-19 crisis. The pandemic is having a devastating impact on the hotel industry. Leading to high vacancy rates and plunging sales, COVID-19 is bringing about the most challenging period in the hotel industry. With the pandemic dragging on, hotel sales are expected to take several years to recover (Krishnan et al. 2020). Despite diverse efforts, such as cutting labor costs and employing new operations to raise the hygiene level, the hotel industry is struggling.

As COVID-19 rocks the hotel industry, increasing numbers of studies are investigating the impact of COVID-19 on the hotel industry and strategies to overcome the effects of the pandemic. For example, Hao et al. (2020) reviewed COVID-19's impact on China's hotel business and developed a COVID-19 management framework, which specifies antipandemic phases, principles, and strategies from a disaster management perspective. Through a review of previous studies, Jiang and Wen (2020) suggested a research agenda that includes topics such as artificial intelligence and robotics, hygiene and cleanliness, and health and healthcare. From a human resource management perspective, Filimonau et al. (2020) demonstrated that, during the pandemic crisis, organizational resilience and corporate social responsibility practices enhance employees' organizational commitment via the perception of job security. Through experimental studies, Shin and Kang (2020) showed that technology-based services such as mobile/kiosk check-in and a robot cleaning system decrease perceived health risks, which leads to an increase in hotel booking intention.

The current study investigates the impact of COVID-19 on hotel productivity. Hotel productivity means how effectively inputs are transformed into outputs for hotel service providers and customers

(Grönroos and Ojasalo 2004), which can be measured as the ratio of a hotel's outputs to its inputs (Baker and Riley 1994). To stay competitive, hotels must achieve greater productivity, producing more from fewer resources. However, the rapid growth of the hotel industry has brought market saturation and fierce competition, so achieving high productivity is a challenging goal. The hotel industry's labor-intensive nature, together with other characteristics such as high fixed costs and seasonal demand, often impedes efficient operations, resulting in relatively low productivity compared with other industries (Medlik 1988, Shaw 1988, Kilic and Okumus 2005). Therefore, improving efficiency has been a key issue in hotel operations, and the research topic of hotel productivity has received significant attention (Kilic and Okumus 2005, Song et al. 2012).

To manage productivity, it is important to understand the impact of external factors such as the pandemic crisis. When hotels suffer from decreasing sales and increasing idle labor and facilities as a result of the pandemic, hotel productivity can deteriorate. Before strategies to facilitate efficient operations during the crisis can be developed, COVID-19's impact on hotel productivity must be identified. To understand and evaluate the impact of a specific practice or external factor on productivity, productivity must first be measured (Tzeremes 2020). An appropriate strategy can be developed when the causes of inefficiency are identified based on an objective measurement. The current study measures hotel productivity changes during the pandemic using the Malmquist Productivity Index (MPI). Based on the MPI, we analyze COVID-19's impact on hotel productivity. The MPI is a nonparametric technique using production frontiers. MPI allows decomposition of productivity change into technical efficiency change (EC) and technological change (TC), which represent changes due to management capabilities and changes due to technological progress/regress, respectively (Färe et al. 1994). Thus, drivers of productivity changes can be identified as managerial efforts versus technological advancement (Peypoch et al. 2021).

The current study considers the role of technology in hotel productivity management. The importance of technology to the hotel industry's sustainable development has been frequently highlighted (e.g., Sangster 2001, Victorino et al. 2005, Law et al. 2019). Technology is also being suggested as a solution to tackle the devastating impact of COVID-19 (e.g., Shin and Kang 2020, Kim et al. 2021, Pillai et al. 2021). Through an MPI analysis, the current study investigates the role of technology in hotel productivity management in response to COVID-19. By analyzing EC and TC, we can understand the effects of managerial efforts and technology, respectively. Based on the MPI analysis result, productivity management strategies during crises are further discussed. The current study addresses the following questions: (1) How has hotel productivity changed during the pandemic? (2) Does EC or TC drive the change in total factor productivity (TFP)? (3) Does the pandemic's impact on productivity differ by hotel segment?

The rest of this article is organized as follows. To provide a relevant rationale, Section 2 reviews the role of technology in the growth of hotel productivity and the impact of external crises on hotel productivity. Section 3 is devoted to providing an understanding of MPI. The research model and data used in this study are introduced in Section 4, and results are presented in Section 5. Section 6 discusses implications and limitations.

2. Literature Review

2.1. Technological Progress and Hotel Productivity Growth

Many studies have examined various internal and external factors to find drivers of productivity growth (e.g., Assaf and Agbola 2011, Lopez et al. 2013, Oukil et al. 2016). This line of research supports technology's key role in hotel productivity growth. For instance, Peypoch et al. (2021) investigated the role of TC in productivity change in the Chinese hotel sector. The EC, TC, and MPI of 30 provinces in mainland China were analyzed during the period from 2005 to 2015. Different patterns of productivity changes were found depending on the hotel's star rating. Whereas two- and three-star hotels showed deterioration in EC, the progress of TC was inversely proportional to the star rating—the fewer the stars, the greater the TC. TFP growth was the highest for two-star hotels, revealing that productivity growth was mainly driven by TC. The different progress of TC was attributed to the different initial status of hotels. Compared with hotels with more stars, the level of initial production technology of hotels with fewer stars was low, thus they could achieve relatively greater progress by enhancing management systems that improve production technology.

Studies by Kim (2011) and Barros (2005) also support the importance of TC in productivity growth. Kim (2011) analyzed productivity changes of 157 Malaysian hotels during the period 2002–2004 using a stochastic frontier method. Decomposition revealed that the growth of TFP of Malaysian hotels was mainly driven by technical progress that is equivalent to TC in MPI. The average growth rate of technical efficiency, which is equivalent to EC in MPI, deteriorated steadily, whereas technical progress, which was low in 2002, remarkably increased in the subsequent two years. TFP increased in accordance with the changing direction of technical progress. Barros (2005) tested the productivity of 42 Portuguese hotels for the period 1999–2001 using MPI. The result is consistent with the previous two studies. Most of the investigated hotels' productivity decreased, and decomposition showed improvement of EC and deterioration of TC.

These studies show that TC decisively contributes to the growth of TFP. They provide empirical evidence that the improvement of production technology through innovation, such as online booking systems and big data analytics, drives the growth of hotel productivity. EC is technical efficiency change resulting from managerial efforts, such as direct marketing, promotions, downsizing labor, and on-the-job training (Kim 2011). Such practices focus on better resource allocation to catch up to the given production frontier. These can help to achieve the best operational efficiency within a given production frontier but are not sufficient to radically improve the structure of productivity, which spurs productivity growth from a long-term perspective. With the rise of the fourth Industrial Revolution, the digital transformation of the hotel business will accelerate. Beyond simple information technology utilization, digitalization and technology are resulting in fundamental changes in hotel operations. Such changes include changes in optimal hotel operating systems such as automation of back office finance and accounting. This implies that, in the coming era, the success of hotel productivity management will depend on appropriate technology adoption and research and development investment.

2.2. External Crisis and Hotel Productivity Change

The 2008 financial crisis resulted in huge damage to the hotel industry, drastically decreasing sales. Previous studies that analyze the financial crisis's impact on hotel productivity provide useful information on the impact of external crises on hotel productivity changes. For instance, González-Rodriguez et al. (2015) analyzed the MPI of 38 Spanish hotels during 2007–2010. With a 5.6% decrease in the tourism gross domestic product, the Spanish tourism sector was severely influenced by the financial crisis in 2008 and 2009. Their results show that, whereas the sample hotels' EC improves, TC deteriorated, decreasing TFP. Twenty-two of 38 hotels had a positive change in EC, whereas progress in TC was observed only in four hotels.

Christopoulos et al. (2020) investigated productivity changes of England's 24 high capitalization firms that belong to the industrial goods and service sectors. Using Bootstrap MPI, productivity changes were analyzed during the period 2009–2016, just after the financial crisis. They also found the aftermath of the global financial crisis. Deterioration of MPI was observed in more than 70% of the sample firms. Although an improvement of EC was observed in 53% of the firms, TC was found to have deteriorated in all firms.

These two studies corroborate the negative impact of the financial crisis on hotel productivity. The trends of EC and TC show hotels' reactions to the financial crisis. Both studies found that most of the sample hotels' TC deteriorated after the financial crisis. EC, on the other hand, was found to have improved in more than half of the sample hotels. This means that hotels relied on managing organizational factors such as downsizing labor and decreasing food and beverage costs to better allocate resources, rather than investing in technology. In addition, the deterioration of TFP, despite the improvement of EC, shows that their strategy of relying on the management of organizational factors was not effective to overcome the destructive impact of the financial crisis.

Research by Tzeremes (2020) shows slightly different results. To investigate the impact of the financial crisis on Spanish hotels, he tested MPI changes of 820 hotels in the Balearic Islands and the Canary Islands during the period 2004–2013. His research found the negative impact of the financial crisis not to be severe. Productivity was decreased by the financial crisis, but it recovered soon in the following period. Decomposition revealed that the improvements in TC and scale efficiency led to the recovery. This result shows that investments in technology help hotels resist the economic crisis by allowing them to operate at optimal scales, adjusting to the economic challenges.

As shown in these studies, the impact of an external crisis on hotel productivity varies according to the region, time, and strategy of each hotel. The MPI analysis lets us know how productivity is affected by an external crisis and which strategy each hotel employs. Through MPI analysis, the current study understands the impact of COVID-19 on the U.S. hotel productivity and the U.S. hotels' responses to manage their productivity. Though many researchers are investigating the impact of COVID-19 on the hotel industry, research quantitatively analyzing hotel productivity changes is still lacking. This research fills this gap.

3. Malmquist Productivity Index

Data envelopment analysis (DEA) and stochastic frontier analysis (SFA) are the most widely used techniques to measure productivity (Assaf and Magnini 2012). SFA is a parametric method that estimates a frontier model. Since SFA separates statistical noise from efficiency scores, a high specification is provided, but an assumption for distribution is required and frontier functional form should be specified. On the other hand, DEA is a nonparametric method using mathematical programming. For productivity measurement, DEA calculates a ratio of total weighted outputs to total weighted inputs for each decision-making unit (DMU) and does not require distributional assumptions and specification of functional forms. Given these advantages, DEA has been widely adopted to analyze hotel productivity (e.g., Pulina et al. 2010, Honma and Hu 2012, Fernández and Becerra 2015, Kim and Chung 2020).

MPI, which was introduced by Caves et al. (1982) based on the quantity index by Malmquist (1953) that calculates the ratio of distance functions, is a measure of productivity change. Compared with DEA and SFA, MPI considers changes over time. MPI represents a change of TFP of DMU between two time periods in a multiple inputs and outputs setting (Färe et al. 1994, Tone 2004). MPI calculates the productivity measure of a particular year in relation to the previous year while allowing the production frontier to shift. Therefore, whereas DEA is suitable for static analysis, MPI is used for dynamic analysis assuming variations of unit and time flow (Fuentes et al. 2001). Since Färe et al. (1994) decomposed MPI into EC and TC, allowing MPI analysis to provide information on the sources of productivity growth, MPI analysis has been widely adopted to analyze productivity changes over time in hospitality research (e.g., Fuentes et al. 2001, Barros 2005, Lopez et al. 2013, González-Rodriguez et al. 2015, Christopoulos et al. 2020, Tzeremes 2020).

When information to establish assumptions for production function is not available, MPI can calculate the growth/decline of TFP over time using input and output data. MPI is defined based on the output distance function by Shephard (1970):

$$\begin{aligned} D_0{}^t(x_t, y_t) &= \inf\{\theta : (x_t, y_t/\theta) \in S_t\} \\ &= (\sup\{\theta : (x_t, \theta y_t) \in S_t\})^{-1} \end{aligned}$$

To define MPI, two output distance functions with different time periods are needed. An output distance function, $D_0{}^t(x_{t+1}, y_{t+1})$ is the maximum proportional change in outputs required to realize (x_{t+1}, y_{t+1}) with the technology at t. The other output distance function, $D_0{}^{t+1}(x_t, y_t)$, is the maximum proportional change in outputs required to realize (x_t, y_t) with the technology at t + 1. MPI is defined as the ratio between these two distance functions corresponding to inputs and outputs vectors in periods t and t + 1 (Caves et al. 1982, Fuentes et al. 2001). To prevent an arbitrary benchmark, MPI is calculated by the geometric mean of two MPI values of period t and period t + 1, and is expressed as follows:

$$M_0(x_{t+1}, y_{t+1}, x_t, y_t) = \left[\frac{D_0{}^t(x_{t+1}, y_{t+1})}{D_0{}^t(x_t, y_t)} \times \frac{D_0{}^{t+1}(x_{t+1}, y_{t+1})}{D_0{}^{t+1}(x_t, y_t)}\right]^{1/2}.$$

An MPI value greater than 1 indicates progress of TFP from period t to period t + 1. An MPI value less than 1 indicates the regress of TFP. An MPI value of 1 indicates the status quo. The expression $M_0(x_{t+1}, y_{t+1}, x_t, y_t)$ is decomposed into two elements:

$$M_0(x_{t+1}, y_{t+1}, x_t, y_t) = \frac{D_0{}^{t+1}(x_{t+1}, y_{t+1})}{D_0{}^t(x_t, y_t)} \times \left[\left(\frac{D_0{}^t(x_{t+1}, y_{t+1})}{D_0{}^{t+1}(x_{t+1}, y_{t+1})}\right)\left(\frac{D_0{}^t(x_t, y_t)}{D_0{}^{t+1}(x_t, y_t)}\right)\right]^{1/2}.$$

The first element outside the brackets, which is the ratio between two successive output distance functions, is EC. As shown in the previous equation, EC is measured by a relative deviation from the production frontier. It means the change in terms of how far observed production is from maximum potential production between the two periods, t and t + 1. EC reflects how efficiently a DMU transforms inputs into outputs, which is generally determined by the operational decisions of DMU. EC improves when DMU allocates resources without wasting and uses economic inputs more efficiently, under the existing technology. Better management of organizational factors such as effective marketing activities, service quality improvement, staff expertise enhancement, and better balance among resources lead to the improvement of EC.

The second element, which is the geometric mean of the two ratios, is TC. It corresponds to the production frontier's shift between the two periods. A frontier shifts by factors such as the adoption of new technology and policy changes, which result in significant and systematic changes in operations and productivity (Kao and Liu 2016). If new technology adoption or operational innovation systematically improves hotel performance, TC progresses. For example, digitalization and automation of the hotel service process, which provides a better guest experience and higher labor productivity, can lead to the progress of TC. On the other hand, negative changes in the fundamentals of the hotel business result in the deterioration of TC. For example, the emergence of the sharing economy, such as Airbnb, has changed the structure of the accommodation market. With intensifying market competition and decreasing demand, the hotel industry's TC deteriorated by the sharing economy (Zervas et al. 2017).

4. Data and Model

We employ a hotel brand as a DMU and analyze data from 26 U.S. hotel brands. As hotels in the same brand follow the same service operations and strategy, an assumption of the same production function is possible. The 26 sample hotels belong to three global hotel chains. Nine brands belong to Marriott, seven brands belong to Hyatt, and 10 brands belong to Hilton. Data were collected from annual reports and investor reports. Ten quarter periods from 2018 Q1 to 2020 Q2 that include the period after the COVID-19 outbreak were analyzed. MPI was calculated for the nine pairwise-quarter-period (T1: 2018 Q1–Q2; T2: 2018 Q2–Q3; T3: 2018 Q3–Q4; T4: 2018 Q4–2019 Q1; T5: 2019 Q1–Q2; T6: 2019 Q2–Q3; T7: 2019 Q3–Q4; T8: 2019 Q4–2020 Q1; T9: 2020 Q1–Q2).

Our model is shown in Figure 1. Input factors were the number of properties and the number of rooms, which were measured as the total number of hotel buildings belonging to each hotel brand and the total number of available rooms held by each hotel brand, respectively. Both are the primary drivers of operating costs and used as input factors in many previous hotel productivity studies (e.g., Hwang and Chang 2003, Barros 2005, Sun and Lu 2005, Wang et al. 2006, Perrigot et al. 2009, Shang et al. 2010, Wu et al. 2010, Huang et al. 2012, Luo et al. 2014). Output factors were occupancy rate and average daily revenue (ADR). Occupancy rate refers to the ratio of the number of occupied rooms to the total number of available rooms in a unit period of time. ADR refers to the average rental revenue earned from an occupied room per day. Both are robust measures of hotel performance. Many previous productivity studies employed occupancy rate and ADR as output factors (e.g., Sun and Lu 2005, Pulina et al. 2010, Honma and Hu 2012, Huang et al. 2012, Ashrafi et al. 2013, Manasakis et al. 2013, Luo et al. 2014, Kim and Chung 2020). The descriptive statistics of input and output factors are shown in Table 1.

5. Results

We analyzed productivity by hotel segment and chain. Whereas luxury segment hotels such as the Four Seasons and Conrad pursue providing high-end services and building strong brand equity, economy segment hotels such as Motel 6 and Days Inn pursue creating value for money, which mostly requires offering limited services (Brotherton 2004). Service operations and strategies, therefore, differ depending on the hotel segment, and this can result in differences in resource utilization and cost structure. Also, within a hotel chain, hotels share resources and customers and use the same marketing channels following coordinated policies. Considering these, we analyze productivity changes by hotel segment and chain.

5.1. Productivity Change by Hotel Segment

The hotel industry is primarily divided based on ADR (Kim and Canina 2011). In hotel research, the Smith Travel Research (STR) hotel classification is widely adopted. Based on STR's classification, we divided 26 hotel brands into four segments: Luxury, Upper Upscale, Upscale, and Upper Midscale (see the Appendix). Upper midscale hotel brands were relatively few compared with the other segments, thus they are not included in the discussion by hotel segment.

The values of EC, TC, and MPI were averaged, respectively, in each segment (see Table 2). It is found that MPI decreased from T8, that is, after the COVID-19 outbreak, in every segment (see Figure 2). In T8 and T9, in all three segments, while TC deteriorated, EC improved (see Figures 3 and 4). These show that, after the COVID-19 outbreak, hotels are trying hard to efficiently allocate and utilize resources without wasting, enhancing their managerial efficiency. But, through the deterioration of TC, it is inferred that hotel systems are not working normally due to restrictions caused by COVID-19, and thus the production frontier is shifting inward, regressing production technology. The deterioration of TC implies that the current technologies adopted for hotel operations are not enough to handle the malfunction of hotels' normal revenue system, which is caused by the pandemic.

Patterns of EC, TC, and MPI provide an interesting finding. Until T7 (before COVID-19), the trend of MPI was similar to that of EC. For example, Upscale's MPI increased in T2 and decreased in T3, and increased again in T4. Upscale's EC shows a similar pattern. However, from T8 (after COVID-19), the trend of MPI follows that of TC. MPI decreased consecutively over T8 and T9, which is consistent with the pattern of TC. On the other hand, EC shows a different pattern by increasing consecutively. These results show that hotels were employing an EC-based strategy that pursues maximizing a catch-up effect to increase productivity, and this strategy is being adhered to after the COVID-19 outbreak. However, the consistent pattern between TC and MPI after the COVID-19 outbreak shows that the negative effect of technology deterioration is large enough to offset the improvement of EC.

Table 1. Descriptive Statistics

Factor	Max	Min	Mean	Median	Standard deviation
Input factors					
The number of properties (x1)	2,582	17	423.29	226	528.45
The number of rooms (x2)	271,951	3,782	76,067.19	52,407.5	71,659.02
Output factors					
Occupancy rate (y1)	84.9	4.2	67.65	74.3	18.70
ADR (y2)	446.8	87.95	196.19	168.37	81.68

Table 2. EC, TC, and MPI by Hotel Segment

Hotel type	T1 2018 Q1– 2018 Q2	T2 2018 Q2– 2018 Q3	T3 2018 Q3– 2018 Q4	T4 2018 Q4– 2019 Q1	T5 2019 Q1– 2019 Q2	T6 2019 Q2– 2019 Q3	T7 2019 Q3– 2019 Q4	T8 2019 Q4– 2020 Q1	T9 2020 Q1– 2020 Q2	After COVID-19
Luxury										
EC	0.9750	0.9973	1.0101	1.0767	1.0291	1.0352	0.9771	1.0097	1.2530	11.10%
TC	1.0162	0.9630	0.9875	0.9213	0.9661	0.9200	1.0083	0.8576	0.3739	−40.20%
MPI	0.9908	0.9604	0.9975	0.9919	0.9942	0.9524	0.9853	0.8659	0.4685	−34.47%
Upper Upscale										
EC	1.2057	0.9929	1.0020	1.1199	1.0625	1.0672	1.0423	1.1032	1.9146	38.50%
TC	0.8626	0.9591	0.9181	0.8801	1.0196	0.8919	0.8750	0.7069	0.1782	−55.88%
MPI	1.0401	0.9523	0.9199	0.9856	1.0833	0.9518	0.9120	0.7798	0.3412	−46.03%
Upscale										
EC	1.0025	1.3163	0.7589	1.0365	1.0124	0.9665	0.9823	1.0709	1.0923	8.19%
TC	1.0718	0.9934	0.8613	0.9418	1.0714	1.0114	0.8990	0.7787	0.5194	−33.97%
MPI	1.0744	1.3076	0.6536	0.9761	1.0846	0.9775	0.8830	0.8339	0.5673	−28.75%

An average (i.e., geometric mean) of index values of T8 and T9, which are periods after the COVID-19 outbreak, was compared with the average of index values from T1 to T7. The percentage decrease is shown in the right-most column of Table 2. The percentage decrease differed depending on the segment. MPI decreased by the greatest percentage in the Upper Upscale segment (−46.03%), followed by Luxury (−34.47%) and Upscale (−28.75%).

To investigate the differences in productivity change between segments, we tested differences of MPI between segments using Kruskal-Wallis one-way analysis of variance, which is a nonparametric test. Before COVID-19, the differences of MPI were not significant between segments. However, we found a significant difference of MPI between Upper Upscale and Luxury after COVID-19. The mean rank of Upper Upscale was significantly lower than that of Luxury ($p < 0.05$), showing that deterioration of productivity is worse in the Upper Upscale segment than in the Luxury segment after COVID-19.

The difference between segments is considered due to differences in the revenue structure of each segment. In general, break-even point and break-even occupancy are different for each segment that differs in strategy and revenue mix. According to Eisen (2021), as costs are being reduced by retrenchment after COVID-19, the occupancy rate needed to break even is also decreasing to a different extent by segment. After COVID-19, U.S. hotels' break-even occupancy, which was much higher than 30%, dropped to the 20% range, and it was highest in full-service hotels. The higher the break-even occupancy, the higher occupancy is needed for better productivity. Therefore, when hotel guests decrease, the productivity of a segment with higher break-even occupancy is likely to be more impacted. Upper Upscale, which mostly corresponds to full-service, likely had the highest break-even occupancy after COVID-19, and as the high occupancy rate could not be met, this segment's productivity might have been impacted the most.

Figure 1. Model

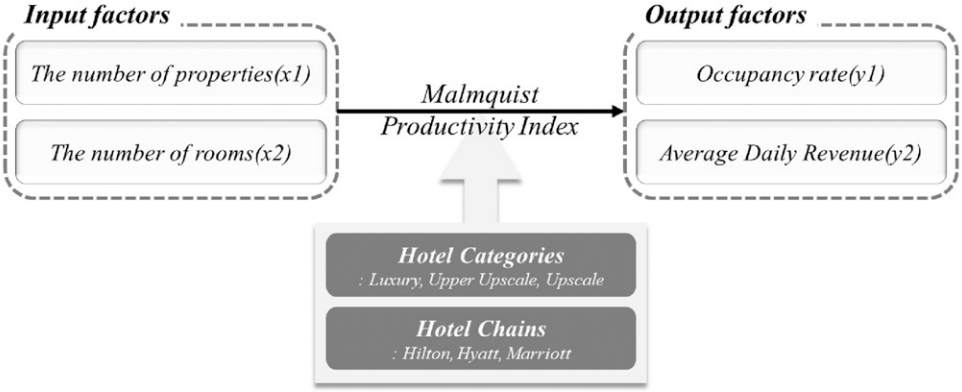
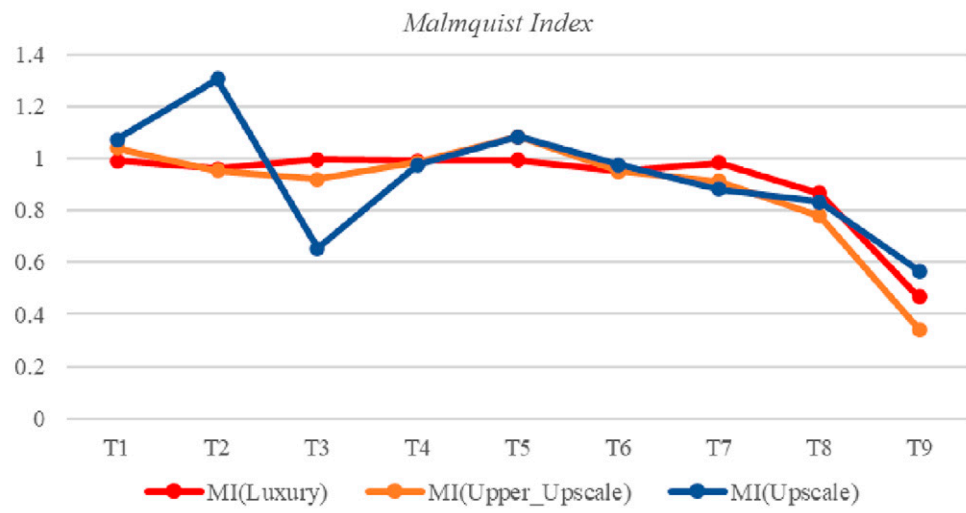


Figure 2. MPI by Hotel Segment



The changes in output factors also help to understand the difference between segments. After COVID-19, occupancy rate and ADR decreased by 56% and 19%, respectively, in the Upper Upscale segment, but by 58% and 12% in the Luxury segment. This shows that though the Upper Upscale segment conducted a bigger hotel rate discount, its occupancy rate decreased to a similar degree with the Luxury segment, failing to recover the discounted room rate. Thus, the deterioration of Upper Upscale's productivity might be worse than Luxury.

5.2. Productivity Change by Hotel Chain

An analysis by hotel chain (i.e., Hilton, Hyatt, and Marriott) shows a similar result to that of the segment-based analysis (see Table 3, Figures 5, 6, and 7). All three hotel chains' MPIs decreased after the COVID-19 outbreak. Although EC increased, TC deteriorated in all three hotel chains. The trends of EC, TC, and MPI were also similar to the result of the segment-based analysis. Before the COVID-19 outbreak, MPI's trend was consistent with that of EC. But, after the COVID-19 outbreak, MPI shows a similar pattern with TC's trend. Though U.S. major hotel chains are trying hard to maintain their productivity, the significant deterioration of technology is decreasing their productivity and their strategies focusing on managerial efforts are not effective.

5.3. COVID-19 and Changes in Productivity Management Strategy

We placed hotel brands in pre- and post-COVID-19 quadrants (Figures 8 and 9), which have EC and TC as

Figure 3. EC by Hotel Segment

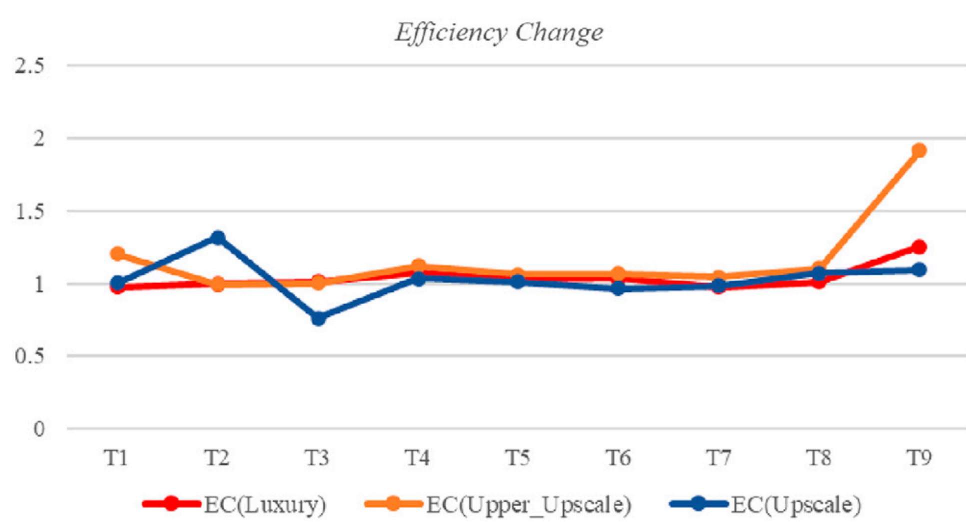


Table 3. EC, TC, and MPI by Hotel Chain

Hotel type	T1 2018 Q1–2018 Q2	T2 2018 Q2–2018 Q3	T3 2018 Q3–2018 Q4	T4 2018 Q4–2019 Q1	T5 2019 Q1–2019 Q2	T6 2019 Q2–2019 Q3	T7 2019 Q3–2019 Q4	T8 2019 Q4–2020 Q1	T9 2020 Q1–2020 Q2	After COVID-19
Hilton										
EC	1.0561	1.3664	0.6726	1.0173	1.0698	0.9895	0.8320	1.0433	1.3261	19.60%
TC	1.0034	0.9382	1.0122	0.9631	0.9945	0.9795	1.0928	0.7539	0.3456	−48.62%
MPI	1.0597	1.2820	0.6808	0.9798	1.0639	0.9692	0.9092	0.7866	0.4583	−37.65%
Hyatt										
EC	1.0350	0.9994	0.9511	1.0252	1.0715	1.0137	0.9369	0.9961	1.2348	10.53%
TC	0.9695	0.9810	0.9826	0.9254	0.9688	0.9362	0.9963	0.7743	0.4210	−39.45%
MPI	1.0034	0.9804	0.9345	0.9488	1.0381	0.9491	0.9334	0.7713	0.5198	−33.58%
Marriott										
EC	1.0348	0.9851	0.9863	1.0452	1.0172	1.0144	0.9337	1.1682	1.9818	51.98%
TC	1.0355	0.9878	0.9314	0.9536	1.0601	0.9649	0.9810	0.7292	0.3208	−50.32%
MPI	1.0715	0.9731	0.9187	0.9967	1.0784	0.9788	0.9160	0.8519	0.6358	−25.27%

the two axes. For the pre-COVID-19 quadrant, the geometric means of values of EC and TC during T1–T7 were calculated. For the post-COVID-19 quadrant, the values of EC and TC during T8–T9 were averaged. Hotel brands were located in the second and third quadrants. Hotels where EC is greater than 1 and TC is less than 1 fall into the second quadrant. These hotels achieved efficiency in terms of organizational resource utilization but failed to improve the production frontier through technological progress. In the third quadrant, hotels with both EC and TC less than 1 are placed. These hotels failed not only to improve production frontiers but also to manage resources efficiently.

In the pre-COVID-19 quadrant, 21 hotel brands are located in the second quadrant and five brands are located in the third quadrant, showing that the majority of the hotel brands were relying on managerial efforts rather than pursuing technological advancement. The post-COVID-19 quadrant shows that most of the hotels are suffering from COVID-19. All hotels moved to the left on the TC axis, showing deterioration of TC. It is also revealed that the productivity management strategy focusing on resource management strengthened after the COVID-19 outbreak. Most hotel brands that were in the third quadrant before COVID-19 moved to the second quadrant or closer to it after COVID-19. This means that even hotels that were poorly utilizing resources before COVID-19 adopted a productivity management strategy that focuses on better resource allocation after the COVID-19 outbreak.

5.4. Robustness Check

To better understand hotels' responses to COVID-19, we investigated the actual practices that three hotel chains are employing to cope with the COVID-19 pandemic. MPI analysis assesses an improvement or

Figure 4. TC by Hotel Segment

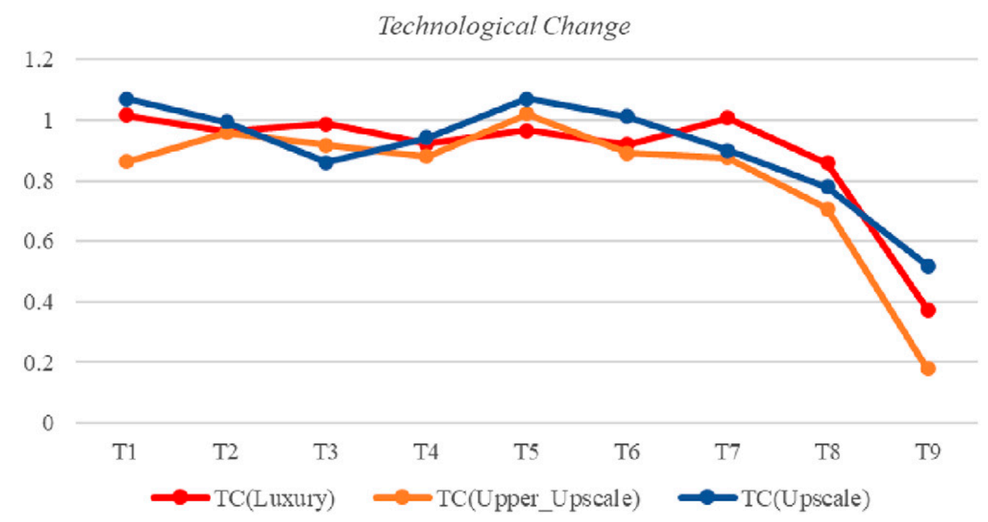
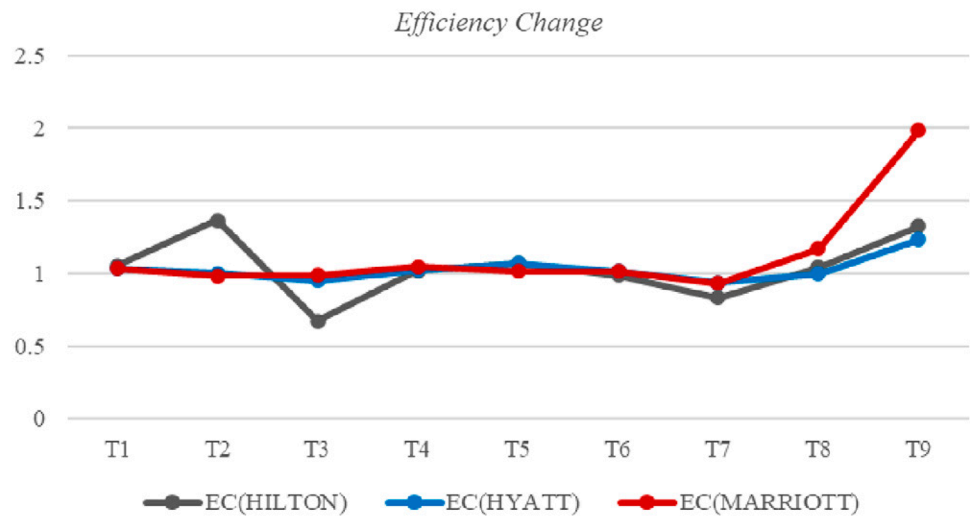


Figure 5. EC by Hotel Chain



deterioration of DMU's productivity using mathematical programming. As MPI analysis does not statistically test causality between a specific practice and productivity, specific causes of productivity change might not be directly understood by MPI analysis. Investigating actual practices adopted by hotels in response to COVID-19 can help us to identify the substantive meanings of increasing EC and decreasing TC, captured in this study, and their implications.

We investigated the three hotel chains' practices and policy changes from diverse sources including news articles, annual reports, 10-K reports, and hotel websites (See Table 4). Cutting workforce and financial measures such as pay cuts and suspension of dividends were the most prominent practices taken to improve EC. These practices are managerial efforts to recover sales through better operations and marketing or to allocate reduced resources in a better way. Enhanced cleaning operations such as frequent cleaning and partnering with a hygiene brand were also identified as practices related to EC. The improvement of EC shows these practices are effective. Practices related to TC included employing new hygiene technology such as electrostatics and ultraviolet light and adopting a new policy by organizing a global council and accreditation related to disinfection. These are new technology adoption and policy changes to cope with the COVID-19 pandemic. However, the

Figure 6. TC by Hotel Chain

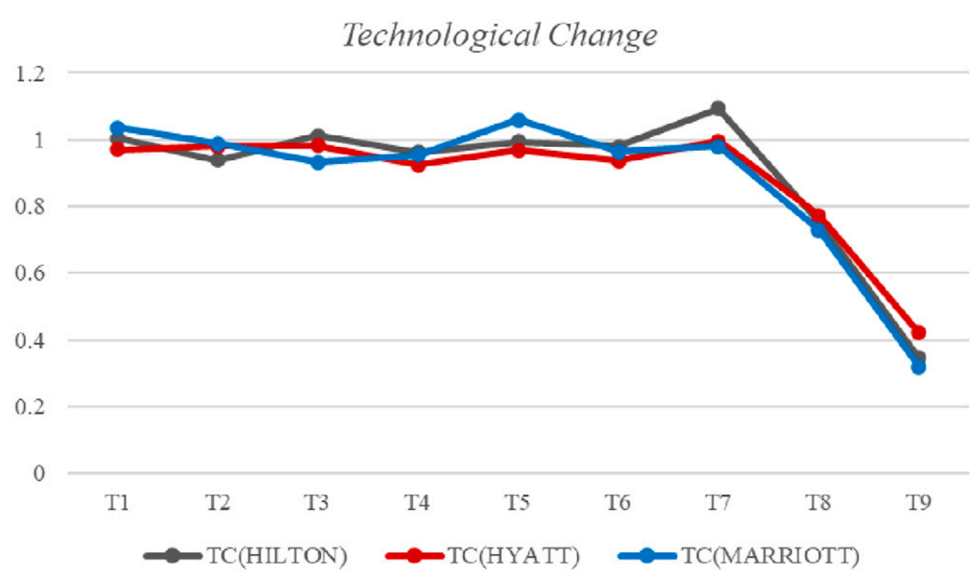
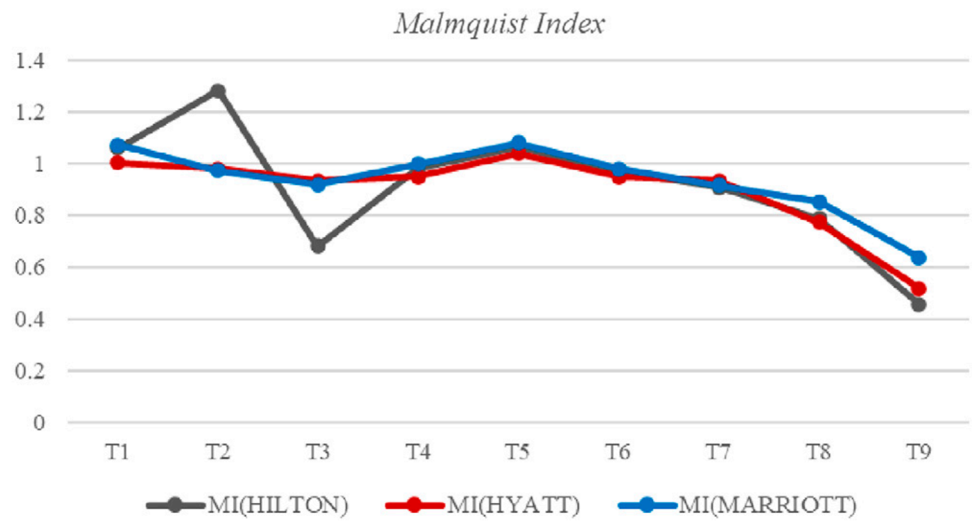


Figure 7. MPI by Hotel Chain



deterioration of TC shows that the effects are not significant. Though the effect is not obvious yet, applying new technologies to hotel operations is a new attempt. If more innovative and effective technologies are developed and adopted, the deterioration of TC caused by the pandemic might be alleviated in the future. In particular, policy changes and the organization of a new standard are considered promising changes. Through organizational and institutional changes, a new crisis management paradigm will be set up, which will increase the hotel industry's capability to resist the pandemic.

6. Discussion

6.1. Findings and Implications

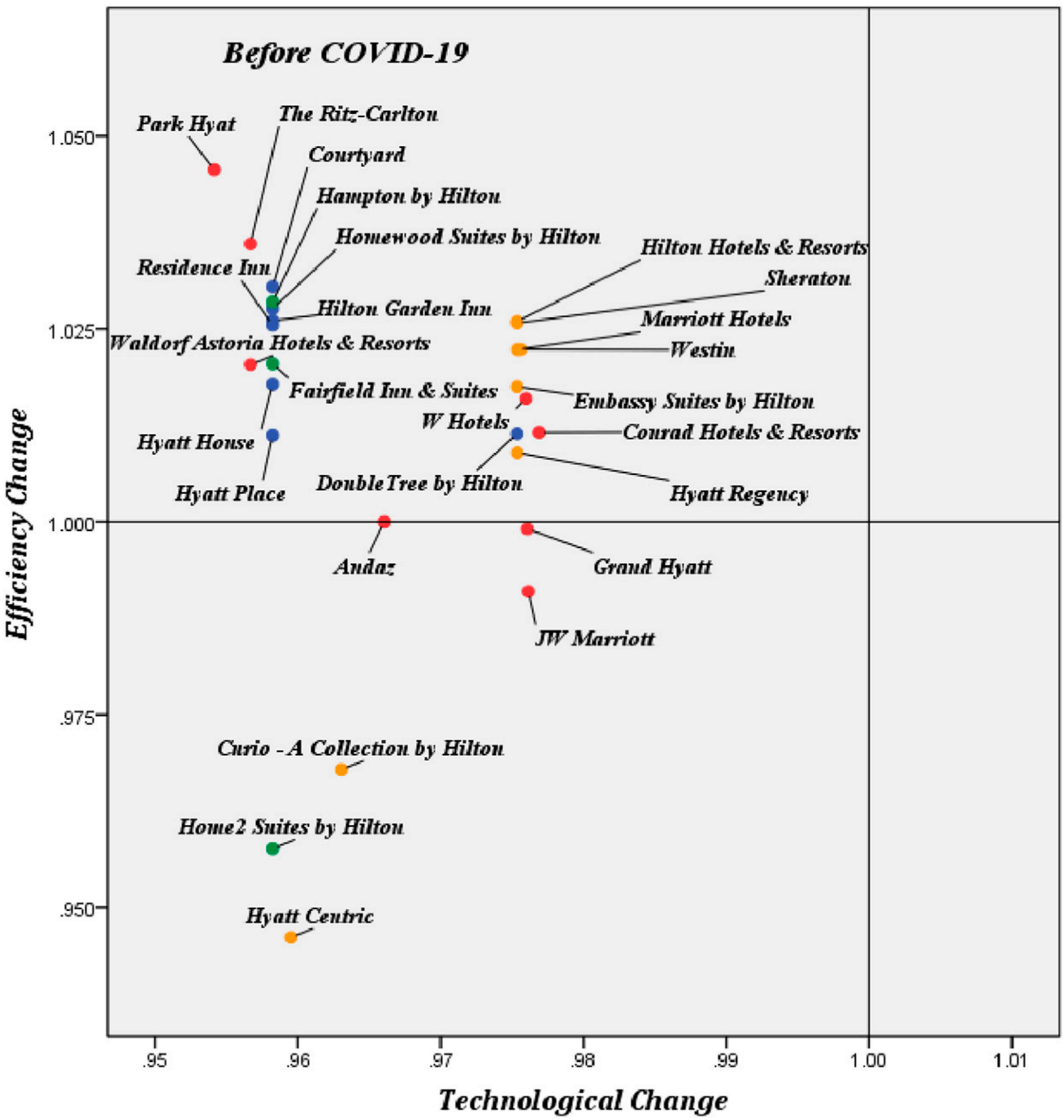
This research investigated the impact of COVID-19 on U.S. hotels' productivity. Though many researchers are investigating the impact of COVID-19 on the hotel industry, studies that quantitatively analyze COVID-19's impact on hotel productivity are limited. This research is meaningful in that it provides empirical evidence that hotels should pursue technological advancement that can lead to fundamental improvements.

Our results show that U.S. hotels' productivity is decreasing after the COVID-19 outbreak. Decomposition revealed improvement of EC and deterioration of TC, indicating that U.S. hotels are putting significant efforts into efficient resource management to cope with the devastating circumstances. The three sample hotel chains' actual practices related to EC included enhanced cleaning operations, partnering with a hygiene brand, cutting workforce, pay cuts, etc. Hotels were trying hard to utilize and allocate reduced resources in a better manner, and those efforts were effective.

On the other hand, the deterioration of TC shows that due to the restrictions caused by COVID-19, the hotel business is not working in a normal way, harming the service process and revenue system, shifting the production frontier inward. Practices related to TC were found to include the adoption of new hygiene technology and setting a new standard at the organizational and institutional level through the formation of a global council and accreditation related to disinfection and hygiene. Though new hygiene technologies, such as electrostatics and ultraviolet light, have started to be applied to hotel operations, their effects are not significant yet. More advanced and innovative technologies that can help hotel operations resist an external crisis need to be developed. Also, though the effects are not obvious yet, the organization of a new standard to improve hygiene policies is a promising change. By establishing a new crisis management paradigm, the hotel industry's capability to cope with the pandemic will be strengthened down the road, ultimately enabling the hotel industry to defend its productivity from external crises.

Hotels were employing an EC-based productivity management strategy before the COVID-19 outbreak, and are still adhering to the EC-based strategy, pursuing the maximization of a catch-up effect to increase productivity. However, the deterioration of TC, which is leading to decreases in MPI, underlies the importance of TC in productivity management. Managerial efforts to catch up to the given production frontier through better resource allocation are helpful to achieve the best operational efficiency within a given production frontier. However, the EC-based productivity management strategy might not be sufficient to cope with the fatal impacts of external crises. The

Figure 8. EC and TC Matrix Before COVID-19



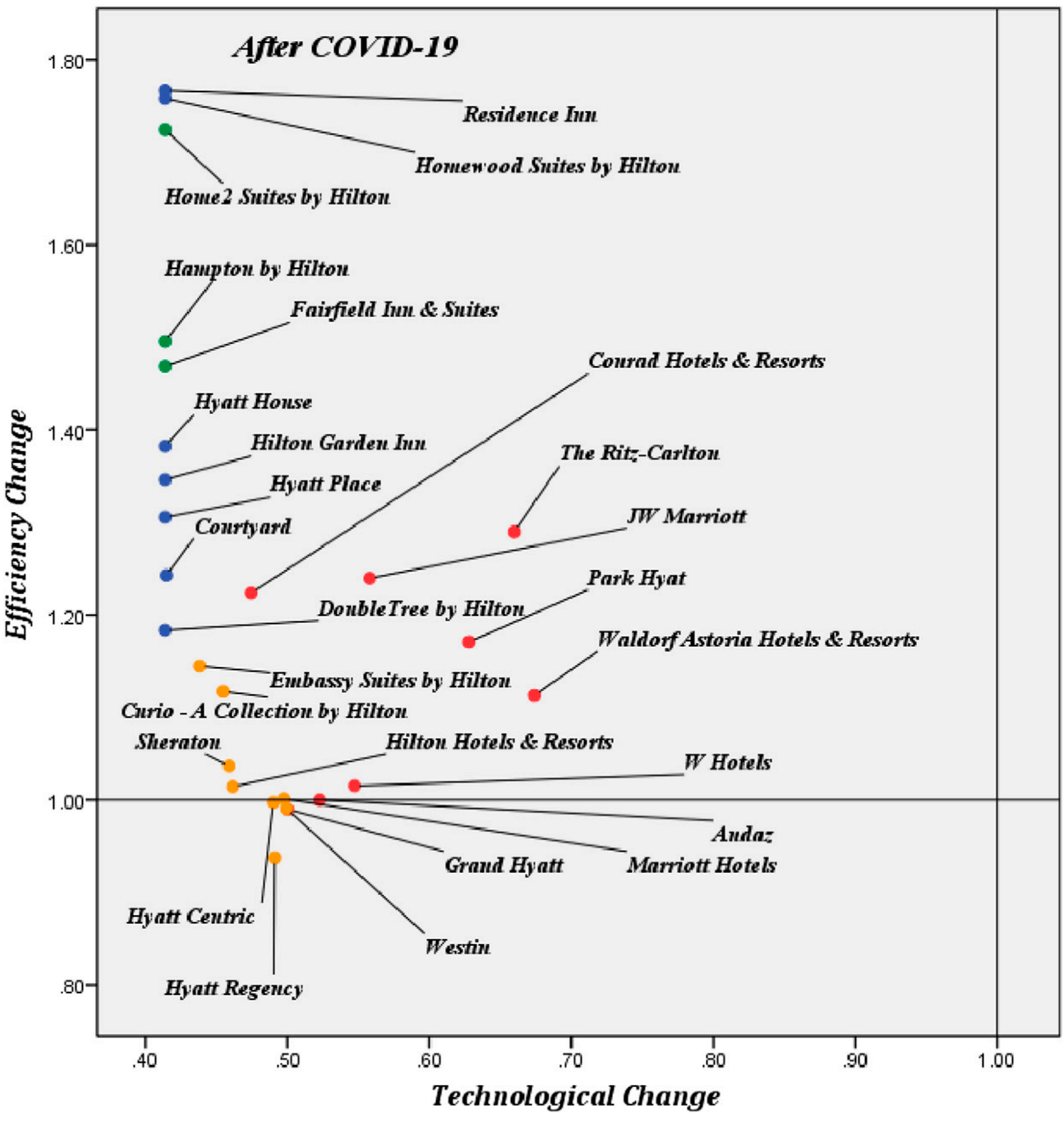
hotel industry needs to approach the productivity management issue from a long-term perspective and develop fundamental and systematic remedies.

The hotel industry's current reactions to COVID-19 might be passive. Cutting the workforce and suspending salaries, which are the most conspicuous actions taken, are not solutions that can prevent the pandemic or improve hotel operations during the crisis but are passive measures that are taken after sales decrease. The hotel industry needs to take more active steps. Developing new cleaning protocols that use new technologies such as cleaning robots and advanced disinfection systems would be helpful to relieve customers' health-related concerns. Contactless check-in/out systems using mobile or kiosks need to be further adopted. It is also necessary to introduce innovative technology-based new services. For example, hotels can include a health check function in their apps or kiosks and provide connecting services to medical care if needed. Above all, fundamental solutions that can improve the structure of productivity and enhance resilience to crises need to be developed. Automation of the optimal hotel operating system would be a key challenge. Heavy reliance on

Table 4. Practices to Cope with the COVID-19 Pandemic

Focus	Practices
EC-related	• Increased frequency of cleaning and disinfecting routines. • CleanStay program partnering with a hygiene product brand, Reckitt, to enhance cleaning and disinfection level • Workforce reductions through layoffs and furlough • Pay cuts for leadership positions • Suspended dividend and share buybacks
TC-related	• Organization of global cleanliness council that includes hygiene and health experts, such as food safety scientists, infectious disease specialists, and professors of food microbiology • Introduction of a GBAC STAR accreditation through an infectious disease prevention program to establish safe and clean hotel environments • Adoption of new technology for hygiene such as electrostatic sprayers with hospital-grade disinfectant and ultraviolet light technology

Figure 9. EC and TC Matrix After COVID-19



human labor, along with the high fixed costs invested in facilities, is the nature of the hotel industry. For the hotel business, which has a seasonal demand cycle, labor costs in the off-season are a burden. If a pandemic such as COVID-19 causes entails plunging sales, it gets worse, and thus hotels reduce their workforce first during crises. However, firing employees during crises and hiring new employees when circumstances get better cannot be a fundamental solution. It is detrimental in terms of securing superior employees with expertise. Using technology, hotels need to automate their operations including back-office functions and enhance labor productivity. The utilization of big data is also critical. Big data enables accurate targeting and identification of niches. By applying big data, hotels might be able to develop new business models suitable for periods when demand is low and normal operations are not available.

6.2. Limitations and Future Research Direction

This research has several limitations. Due to data availability, we analyzed 10 quarter periods from 2018 Q1 to 2020 Q2. Since COVID-19 is ongoing, its impact can change over time, generating different implications. In our results, TC showed a decreasing trend in T8 and T9. Considering that the effects of new technology adoption and policy changes might take time to be observed, the trend of TC might change along with the maturation of the pandemic. As hotel guests become used to the pandemic situation, their behavioral responses to COVID-19, including risk perception and stay intention, might also change, leading to different consequences.

Our model also has a limitation. Our model used the number of properties and number of rooms as input factors. These are critical factors that generate fixed costs. However, as labor is also an important input in hotel operations, it is ideal to include labor-related factors such as the number of employees or labor costs as input factors in the model (Tzeremes 2020). As frontier methods have different results depending on the selection of inputs and outputs (Assaf and Tsionas 2018), a different spectrum of results might have been drawn if a labor factor were included in our analysis.

Though our model did not include total employees, it stably measured the degree that a hotel transforms its fixed assets into revenue. During a pandemic that entails high vacancy rates, efficient utilization of fixed assets is important. Hotels can control labor costs through furlough or by cutting the workforce. But controlling costs of fixed assets and their disposal in a short period of time are difficult. Therefore, efficient utilization of fixed assets has contextual and significant implications, especially in the pandemic period.

Based on our results, suggestions for future research are developed. The impact of COVID-19 on hotel productivity might be different depending on the geographical footprint. For hotels located in areas where the pandemic is less severe or is under control, the impact might be less significant. Patient numbers and death rates vary depending on the government's policies and measures. In Vietnam, for example, the government thoroughly blocked the influx of people from abroad from the early stage of the pandemic. Thus, COVID-19 cases were relatively few until the first quarter of 2021. Vietnam's hotel industry might be less influenced in this period. However, there is still a high chance that blocking international travelers decreased occupancy rate, impeding productivity. Research that takes into account each hotel's unique structure and factors contributing to productivity, such as geographical footprint, government responses to the pandemic, and its own revenue structure, is needed.

Though the importance of new technology in hotel operations has been consistently highlighted, new technology adoption to hotel services, which have been developed based on human labor for a long time, is a big challenge. Not every technology will improve the production frontier. Unexpected inefficiencies and side effects may occur. Strategies to more effectively incorporate new technologies into hotel operations need to be investigated. In the context of hotel operations, specific characteristics of technology that contribute to the improvement of the production frontier and the detailed process by which technological advances improve productivity need to be identified.

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Appendix. Decision-Making Units (DMUs)

Hotel brand	Chain	Segment
Andaz	Hyatt	Luxury
Conrad Hotels & Resorts	Hilton	Luxury
Courtyard	Marriott	Upscale
Curio - A Collection by Hilton	Hilton	Upper Upscale
DoubleTree by Hilton	Hilton	Upscale
Embassy Suites by Hilton	Hilton	Upper Upscale
Fairfield Inn & Suites	Marriott	Upper Midscale
Grand Hyatt	Hyatt	Luxury
Hampton by Hilton	Hilton	Upper Midscale
Hilton Garden Inn	Hilton	Upscale
Hilton Hotels & Resorts	Hilton	Upper Upscale
Home2 Suites by Hilton	Hilton	Upper Midscale
Homewood Suites by Hilton	Hilton	Upscale
Hyatt Centric	Hyatt	Upper Upscale
Hyatt House	Hyatt	Upscale

(Continued)

Hotel brand	Chain	Segment
Hyatt Place	Hyatt	Upscale
Hyatt Regency	Hyatt	Upper Upscale
JW Marriott	Marriott	Luxury
Marriott Hotels	Marriott	Upper Upscale
Park Hyatt	Hyatt	Luxury
Residence Inn	Marriott	Upscale
Sheraton	Marriott	Upper Upscale
The Ritz-Carlton	Marriott	Luxury
W Hotels	Marriott	Luxury
Waldorf Astoria Hotels & Resorts	Hilton	Luxury
Westin	Marriott	Upper Upscale

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