ICT Paradox Lost? A Stepwise DEA Methodology to Evaluate Technology Investments in Tourism Settings[1]

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Despite the continuous increase of investment in information and communication technologies (ICT) in the tourism industry, empirical studies have not persuasively established corresponding increases in productivity. Indeed several shortcomings have been identified in past studies. This study proposes a new way of assessing ICT productivity. The methodology is tested in a data set from the three-star hotel sector in the United Kingdom using a nonparametric technique called data envelopment analysis (DEA). Empirical findings reveal that productivity gains accrue not from investments per se, but from the full exploitation of the ICT networking and informationalization capabilities. A model for managing ICT applications and benefits is proposed.

Keywords: *information technology; impact; productivity; data envelopment analysis (DEA)*

The increasing intensity of domestic and global competition has led organizations to search for more efficient and effective ways of managing their businesses. Many of these organizations, including in tourism and hospitality, have turned to information and communication technologies (ICT). Over the last decade, investments in ICT in the tourism and hospitality industry have substantially increased (Cline and Warner 1999; Sigala et al. 2000; Siguaw, Enz, and Namasivayam 2000). However, despite these investments, empirical studies have not persuasively established corresponding improvements in organizational performance and productivity in general and the tourism sector in particular (Brynjolfsson 1993; Baker, Sussmann, and Meisters 1999; Strassmann 1990). On the contrary, many such studies have found no significant relationship, or even negative relationships, between firm performance and such investment. Brynjolfsson (1993) first referred to the concept of the "IT productivity paradox," referring to the fact that the benefits of spending have not shown up in aggregate output statistics. Recent studies have also confirmed the productivity paradox (e.g., Shafer and Byrd 2000).

Several shortcomings in past studies have been identified, including measurement errors, redistribution of effects, and mismanagement of ICT resources (Brynjolfsson 1993; Kauffman and Weill 1989). Consequently, new evaluation methodologies are needed. The purpose of this study is to contribute to the existing body of knowledge regarding the ICT productivity paradox by developing and testing a methodology that is designed to overcome previous studies' methodological shortcomings. Following a summary of previous studies, a framework for measuring productivity gains from ICT investments is proposed based on data envelopment analysis (DEA). The results help to unravel the so-called paradox and provide a theoretical and practical basis for exploiting and managing ICT capabilities.

INVESTIGATING THE ICT PRODUCTIVITY PARADOX

Previous Studies

Several authors have summarized studies investigating the relationship between ICT and productivity (e.g. Brynjolfsson 1993; Hitt and Brynjolfsson 1996; Lucas 1993). However, the results of such studies are plagued with ambiguities and inconsistencies. Some researchers report no relationship between ICT investments and productivity (e.g. Banker and Kauffman 1988; Byrd and Marshall 1997; Dos Santos, Peffers, and Mauer 1993; Hitt and Brynjolfsson 1996; Loveman 1994; Mahmood et al. 1998; Roach 1991; Strassmann 1990, 1997; Venkatraman and Zaheer 1990). Others provide evidence that such a relationship does exist (e.g. Bender 1986; Brynjolfsson 1993; Harris and Katz 1991; Prattipati 1995; Rai, Patnayakuni, and Patnayakuni 1996; Roach 1991). A few studies show negative/dysfunctional ICT productivity impacts (e.g., Cron and Sobol 1983; Weill 1992).

Research within the hotel sector is limited, but it reaches similar conclusions (Sigala 2002b). In surveying hotel managers' perceptions of the ICT productivity impact, David, Graboski, and Kasavana (1996) report that hotel managers believe that some applications (e.g., reservation management systems, rooms-management systems) have improved

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productivity, while others (e.g., vending and entertainment) decreased it. Baker and Li (1996) obtained financial performance data from 29 Taiwan hotels; a significant correlation between past investment and corporate performance was not established, but the authors acknowledge problems in isolating the contribution of ICT from other factors.

Methodological Problems

Overall, past studies provide inconclusive evidence for the productivity impact. In large measure, this relates to methodological issues (Brynjolfsson 1993; Kauffman and Weill 1989). With these in mind, the following section explores the key methodological problems.

The quality of the data used and analyzed. A few studies rely on questionable data gathered for other purposes (e.g., data of Computerworld), while others do not control for contextual factors (Byrd and Marshall 1997). Particularly in hospitality, Singuaw et al. (2000) argued that research into the productivity impact should consider contextual factors such as firm size, operations, and market orientation. Cron and Sobol (1983) and Strassmann (1990) also suggested that ICT have an amplifier effect, meaning that their introduction into poorly run firms does not increase productivity, whereas ICT introduction into well-run firms pays off. This is ignored by previous studies simply incorporating ICT as an input factor of productivity functions.

The metrics measuring productivity. There is a misconception (Millar 1986; Roach 1991) that productivity metrics cannot capture the full ICT effect to include, for example, quality increases or avoidance of competitive disadvantage. In contrast, several authors have argued that financial productivity metrics (e.g. Ball 1993; Gummesson 1998; Johns and Wheeler 1991; Rimmington and Clark 1996) encapsulate both tangible and intangible productivity gains. Jurison (1996) claims that the productivity paradox is the result of bad management and not mismeasurement of productivity benefits. In other words, firms fail to translate intermediate benefits, such as better customer service, into final outcomes, such as increased revenues. A further problem is thought to be created by the level of analysis (Sigala 2002a). It is widely recognized that aggregated metrics of productivity inputs and outputs tend to obscure information, while partial metrics tend to hide information, trade-offs, and complementarities. To avoid this, partial metrics are sometimes considered simultaneously, but this is very laborious and sometimes may lead to conflicting results (Baker and Riley 1994).

The metrics measuring ICT. This is the major criticism of previous studies, since most of them place a disproportionate emphasis on ICT expenditures and budgets. The problem here is that budgets do not distinguish between different ICT tools and applications, while it is the different applications that lead to different results (Lucas 1993; Strassmann 1990). To address this, several studies separate budgets into hardware, software, personnel, and other expenses (Bender 1986; Cron and Sobol 1983), but still, the use of financial metrics for comparing ICT intensity across firms suffers from fluctuations over time of ICT costs and investments, waste of expenses and different ways of financing, and measuring expenditures. For example, when applications are outsourced through application service providers, costs are considered as current expenses and not as investments. Budgets also neglect two important facets of ICT, namely, their deployment and their evolving capabilities and features (Strassmann 1990; Willcocks, Graeser, and Lester 1998). This is because ICT are not a determinant of organizational or individual outcomes but rather an enabler whose effects are dependent on how they are used. In tourism, several authors (e.g. Sigala, Lockwood, and Jones 2001; Werthner and Klein 1999) also argue that the relationship with value is not a direct one but that ICT give value when they are used to redefine, differentiate, and informationalize products/services and to streamline and rationalize processes. ICT mismeasurement also leads to mismanagement problems—that is, inability to identify and exploit ICT applications and capabilities that can lead to productivity gains (Baker and Sussmann 1999; Rai, Patnayakuni, and Patnayakuni 1996; Sigala, Lockwood, and Jones 2001).

The level of analysis at which research is undertaken. Problems regarding the level of analysis refer to both productivity and ICT. Studies at the economy and industry level are limited because macrodata do not capture firm-level phenomena, and they hide displacement effects (Brynjolfsson 1993; Hitt and Brynjolfsson 1996; Roach 1991). Menon (2000) argues that the best level of analysis is the organization because substitution, synergy, and complementarities between resources, inputs, and factors affecting productivity can be captured. By contrast, process-level analyses suffer from difficulty in data collection and insufficient sample size and difficulty in separating ICT effects from non-ICT effects. Studies measuring the impact of specific ICT applications on business processes are also limited because they ignore (Lucas 1993) any impact on other processes and on final outcomes as well as the synergy between different applications.

Dos Santos, Peffers, and Mauer (1993) identify two streams of studies, namely, functional and aggregate. Functional studies are limited in terms of the lack of a direct link between the observed, functionally related performance effects, and measurable performance in terms of organizational goals (Venkatraman and Zaheer 1990). On the other hand, studies of aggregate investments are important because they provide evidence that such investments could affect firms' ultimate outcomes. However, their usefulness is limited because of their reliance on aggregate measures that do not allow the investigation of the relationship between specific ICT applications and functional performance. Because of this Dos Santos, Peffers, and Mauer (1993) conclude that "research is required that would overcome the limitations of the two previous research streams by making a distinction between different IT investments and taking into consideration that activity based results are not always translated into firm level outcomes" (p. 521). The methodology of this study combines the strengths of these two streams of research.

The statistical method used to relate ICT with productivity metrics. The majority of studies use regression and ratio analysis. However, these techniques are limited since they only consider a limited number of variables at the same time. Regression is also limited in investigating the effect of one input (or output) to multiple outputs (or inputs). These techniques also assume away inefficiency in production (Menon 2000). Production function techniques, by contrast, consider multiple inputs and outputs simultaneously, and they have been extensively used in ICT productivity studies. However, being parametric techniques, they assume a functional form for the technology, transforming inputs into outputs, and as a result, they can suffer from specification error. Because of that, a nonparametric technique called data envelopment analysis (DEA) is increasingly being adopted for researching the productivity paradox (e.g. Shafer and Byrd 2000; Dasgupta, Sakris, and Talluri 1999). After analyzing the benefits of DEA, the following section details how this study applied and refined the use of DEA for investigating the ICT productivity paradox.

METHODOLOGY

Data Envelopment Analysis (DEA)

DEA is a multivariate, nonparametric technique that constructs a frontier function in a stepwise linear approach by comparing the ratios (of multiple inputs to multiple outputs) of similar units taken from the observed dataset (Charnes, Cooper, and Rhodes 1978; Charnes et al. 1994). Thus, DEA shares the advantages of a production function, but it is specification error free because it does not assume a functional form.

In using DEA, the productivity score of any unit is computed as the maximum of a ratio of weighted outputs to weighted inputs, subject to the condition that for all other units of the dataset, similar ratios are less than or equal to one. The productivity of a hotel can be obtained by solving the following model (M1) (Charnes, Cooper, and Rhodes 1978):

$$\text{Max } h_0 = \frac{\sum_{r=1}^{t} U_r Y_{rj_0}}{\sum_{i=1}^{m} V_i X_{ij_0}} \text{(M1)} \quad (1)$$

subject to

$$\frac{\sum_{r=1}^{t} U_r Y_{rj}}{\sum_{i=1}^{m} V_i X_{ij}} \leq 1 \text{ for all } j = 1, \ldots n. \quad (2)$$

$$U_r, V_i > 0;\ r = 1, \ldots s;\ i = 1, \ldots m.$$

Y_{rj} and X_{ij} are the amount of the rth output and the ith input for the jth hotel, and U_r and V_i are the weights to be estimated by the data of all comparable hotels that are being used to arrive at the relative productivity for the oth hotel. The model has t output variables, m input variables, and n hotels.

If a hotel is on the frontier isoquant—that is, among the reference set—the solution will be $h_o = 1$ and the productivity score is 1, which can be described as being 100% productive as compared with other hotels of the dataset. Other hotels, using these inputs less efficiently, will locate above the frontier isoquant, and their productivity score will be smaller than 1. For example, a hotel having the productivity score of 0.75 can be interpreted as being 75% as productive as a hotel on the frontier isoquant.

Other advantages of using DEA for productivity benchmarking that can also overcome the previously discussed methodological issues of the ICT productivity impact are reported as follows (Cooper, Seiford, and Tone 2000; Sengupta 1988; Banker and Morey 1986). DEA identifies bad from good performers by generating an overall easy-to-interpret efficiency score (this actually addresses the ICT amplifier effect); it is independent of the units measuring inputs and outputs allowing great flexibility in specifying the outputs/inputs to be studied; and it can manipulate uncontrollable, environmental factors such as competition by introducing them as constraints into DEA models (Cooper, Seiford, and Tone 2000). Avkiran (1999) highlighted that failure to account for environmental factors is likely to confound the DEA results and lead to unreliable analysis. Norman and Stoker (1991) argued that DEA models not including demand factors measure production efficiency, while DEA models including them reflect market efficiency or the ability to control production efficiency given demand factors.

Moreover, in contrast to econometric methods, DEA also identifies and provides information about peer organizations, while DEA is also not as vulnerable to small numbers of observations as regression analyses. Although there are no theoretical grounds for preferring DEA over econometric methods and vice versa (Guiffrida and Gravelle 2001), previous studies comparing the two methods provide some guidelines regarding when to use one method over another. Smith (1997) and Banker, Gadh, and Gorr (1993) proved that DEA gives more precise estimates over a deterministic cost frontier with small samples (as in this study) as well as when inefficiency has an exponential distribution (which is also true in this study as nonhotel had an inefficiency score of less than 30%). In comparing stochastic frontier regression, Gong and Sickles (1989, 1992) found that the former outperform DEA if the assumed functional form is close to the underlying technology, but as the misspecification of the functional form becomes serious, DEA estimates become more accurate than the econometric-based estimates. In comparing stochastic frontier methods with DEA where the assumed specification of the production function was good, Read and Thanassoulis (1995) provided evidence that the former methods are more vulnerable to extreme values. Their estimates were worse than DEA when one of the input or output variables was very large or very small. Thus, the DEA is more appropriate in this study since the research sample includes a great variety of hotel sizes having very small and large inputs/outputs.

DEA has been extensively used for productivity measurement in various industries (e.g. Al-Shammari and Salimi 1998; Avkiran 1999) as well as for measuring the ICT productivity impact (Banker, Kauffman, and Morey 1990; Dasgupta, Sakris, and Talluri 1999; Paradi, Reese, and Rosen 1997; Shafer and Byrd 2000). However, the validity and usefulness of DEA crucially depends on the inputs/outputs used, and these studies present several methodological limitations in their DEA use. First, they measure ICT in financial terms and include them as inputs of DEA models, which, in turn, does not allow them to distinguish between low and high performers in eliminating the ICT amplifier effect. Most studies also use few and aggregated productivity inputs/outputs. As Banker, Kauffman, and Morey (1990) used DEA for assessing the effect of electronic point of sales (EPOS) in a restaurant chain, one of the contributions of this study is the expansion of DEA at a macrolevel—that is, across firms within the same sector. The proposed DEA methodology also extends previous studies in overcoming previous methodological problems by using a stepwise DEA approach for constructing robust DEA productivity models. The stepwise process and its benefits are explained below.

Study Aims and Methods

The study aimed to assess the ICT productivity impact by overcoming previously identified methodological problems. To achieve this the following methodology was adopted. Primary data were gathered from hotels within the three-star U.K. hotel sector. By concentrating on a specific sector, contextual factors and business operational characteristics that would have effected the ICT-productivity relation are eliminated. The productivity impact is investigated at the organizational level since, as previously advocated, this is regarded as the best level of analysis. To overcome limitations relating to data quality, the productivity measurement, and the statistical methods relating inputs and outputs, the following steps were undertaken. Arguments in the operations management literature stress the need to adopt a total factor approach to productivity measurement that considers both the tangible and intangible elements of inputs and outputs (Heap 1992; Chew 1986). This study adopted a total factor approach to productivity measurement also for eliminating the previously discussed issues regarding the quality of productivity data. To achieve this, financial, objective, and easily obtainable productivity inputs and outputs that encapsulate both tangible and intangible effects (Johns and Wheeler 1991; Rimmington and Clark 1996) were gathered. Data regarding potential contextual/environmental factors that could have affected productivity (e.g., demand variability, markets served) were also gathered (Johns, Howcroft, and Drake 1997; Sigala 2002a; Wöber 2000). To consider multiple inputs/outputs/factors simultaneously, the DEA technique was applied by using the statistical package Frontier Analyst 2 (Banxia Ltd., 1999). By using DEA, the level, and type of hotel, productivity is first identified and then the impact of ICT on different performers is assessed (avoiding the amplifier effect). To address the issues related to the level of analysis, the data analysis simultaneously manipulated both ICT and productivity aggregate measures (e.g., number of ICT, total revenue) and partial/disaggregated metrics (e.g., specific functional applications, food and beverage [F&B] and rooms division [RD] revenue) so as to combine the strengths of both the functional and aggregate streams of research. To achieve this, a stepwise DEA approach was adopted for measuring productivity. Moreover, because the quality and validity of DEA are only as good as the inputs/outputs/factors that DEA includes (Avkiran 1999), the stepwise process was also used for identifying appropriate inputs/outputs and constructing robust DEA productivity models.

The stepwise regression approach to DEA (introduced by Sengupta 1988) is an iterative process measuring productivity on the basis of the important factors identified up to that step. Other important factors are identified by examining those that correlate with the measure of productivity and applying judgments in terms of cause and effect. These are incorporated into DEA, and the process is repeated until no further important factors emerge. At that stage, a robust productivity metric accounting for all the identifiable factors influencing productivity is constructed, and productivity differences can be attributed to factors that the stepwise process has not so far considered.

Specifically, because aggregate metrics may obscure information, the first step of DEA uses aggregate input/output metrics, but in later steps, these are disaggregated into their constituent parts (partial metrics) when the latter are found significantly to affect productivity scores (i.e., significant Pearson correlations, $\alpha = 0.05$, between DEA scores and partial metrics). Moreover, because different factors can determine productivity in different hotel divisions (e.g., Ball 1993) and to avoid limitations relating to the level of analysis and aggregated metrics, a stepwise DEA was applied at two levels namely the RD and the F&B division. The disaggregated inputs/outputs that were found to affect the productivity of the two divisions were used for constructing the DEA model at the level of the whole hotel property. As a result, the hotel overall productivity was not constructed on the basis of hotel level aggregated inputs/outputs that can obscure and hide productivity effects.

In this vein, data regarding the following productivity inputs were gathered: number of rooms, F&B capacity (i.e., restaurant seats plus banqueting covers), full-time and part-time employees, number of managers and/or heads of departments and IT staff, number of full-time employees per division, material and other (M&O) expenses per division, payroll expenses per division, total energy expenses, management fees, training costs. Data regarding the following environmental/contextual factors that may affect productivity were also gathered: demand variability (using a 9-point Likert-type scale ranging from *not at all* to *great fluctuations* as validated by Sigala 2002a); percentage of annual room nights from repeat customers, business, leisure, conference and other guests; and percentage of annual reservations taken through a property-owned system, third parties, and Internet. Data regarding productivity outputs included number of room nights, occupancy (%), length of stay (days), average room rate (ARR), number of restaurant and banqueting covers served, and total annual revenue from RD, F&B, minor operations, and telephone. These metrics are consistent with previous studies of hotel productivity (e.g., Johns Howcroft, and Drake 1997; Sigala 2002a; Wöber 2000).

To overcome limitations relating to ICT measurement, the following analysis was undertaken. As it is the deployment of ICT tools and capabilities and not investments per se that actually lead to productivity gains, the ICT construct was operationalized by using three metrics reflecting ICT exploitation: (1) number of available functional applications, (2) integration of applications with the property management systems (PMS; being the digital hotel nervous system) and amongst each other, and (3) sophistication of use of available critical success (CS) ICT, including PMS, Web site, e-mail, Intranet, Extranet, and customer data warehouse. The use of these metrics is justified as follows. ICT's capability to foster and support business process reengineering (BPR) initiatives is widely recognized, while there is evidence (Sigala 2002b; Willcocks, Graeser, and Lester 1998) that integration among ICT is a vital condition for fostering BPR and providing operational efficiencies because it eliminates manual reentry of data and facilitates easy retrieval, and it supports sharing of consolidated databases that is vital for informationalizing product/services and streamlining processes. By extending Cline and Warner's (1999) CS technologies exploitation practices, Sigala, Lockwood, and Jones (2001) proposed and validated (Sigala 2001) a model of ICT exploitation whereby higher integration and exploitation levels (ranging from automational to informational to transforming activities) were related to higher productivity benefits. Because of this, for each CS technology, a number of activities were identified reflecting automational, informational, and transformational ICT exploitation (see Table 1). Since these activities have a different business value, when calculating the ICT exploitation sophistication score of each CS ICT, the activities were weighted (1, 3, or 5), and load factors instead of number of activities were summed.

Data were gathered by constructing a structured questionnaire, whose reliability and validity was tested through pilot interviews with six hotel managers. To ensure consistency amongst respondents, all data were asked to refer to the financial year ending in 1999. In developing the study's sample, initially, the U.K. Automobile Association's hotel directory was used for compiling a random sample of 300 three-star hotels. Hotel managers were targeted by a mail survey in June 2000. However, despite the use of a prepaid envelope, a covering letter assuring managers of data confidentiality and a reminder, the mail survey achieved a very low response rate (12 responses) mainly because of the sensitivity of the data required (e.g., ARR, revenues). To increase responses, contacts with consulting companies, individual hotels, chains, and consortia were used. Overall, 93 questionnaires were received out of 1,233 hotels contacted. The number of responses further supports the use of DEA (please refer to previous arguments) but does not allow generalization of findings. However, sample representativeness is not crucial for this study because the research question was not focused on examining whether ICT had any effect on the productivity of the three-star hotel sector as a whole. Instead, the study aimed to investigate the validity of the ICT productivity paradox by reexamining the ICT-productivity relation through the application of a robust methodology that overcomes previous limitations.

TABLE 1

SOPHISTICATION OF EXPLOITATION OF CRITICAL SUCCESS INFORMATION AND COMMUNICATION TECHNOLOGY (ICT) (% OF RESPONDENTS)

	%
Property management system (PMS)	
Automate front office operations (1)	96.2
Automate back office operations (1)	88.5
Communicate and share information (3)	44.9
Collect and store data (3)	71.8
Analyze data and/or produce reports (5)	65.4
Platform enabling other applications (5)	50.0
Web site	
Information provision (1)	96.6
Links to other sites (1)	63.6
Online bookings (3)	30.7
Customer communications (3)	64.8
Collect customer information (5)	34.1
Provide customized content (5)	18.2
E-mail	
Automate front office operations (1)	n/a
Automate back office operations (1)	n/a
Store information (1)	n/a
Make room reservations and bookings (3)	81.3
Conduct transactions with suppliers (3)	29.7
Enable internal communication (5)	38.5
Enable external communication (5)	52.7
Intranet	
Automate front office operations (1)	20.0
Automate back office operations (1)	20.0
Store information (1)	70.0
Make room reservations and bookings (3)	36.7
Conduct transactions with suppliers (3)	20.0
Enable internal communication (5)	76.7
Enable external communication (5)	26.7
Extranet	
Automate front office operations (1)	0.0
Automate back office operations (1)	0.0
Store information (1)	0.0
Make room reservations and bookings (3)	40.0
Conduct transactions with suppliers (3)	20.0
Enable internal communication (5)	0.0
Enable external communication (5)	60.0
Customer data warehouse	
Automate tasks of front and/or back office staff (1)	59.7
Automate tasks of sales and marketing staff (1)	61.2
Enable staff of different departments to access customer information (3)	44.8
Develop personal customized promotions and/or sales offers (3)	76.1
Deliver customer relationship management activities (5)	22.4
Plan the hotel strategy (5)	29.9

NOTE: 1, 3, and 5 reflect weights used in the calculation of the ICT exploitation sophistication scale.

ANALYSIS AND DISCUSSION OF FINDINGS

Respondents' Profile

Respondents represent the diversity of the three-star hotel sector in the United Kingdom (Table 2). Slightly more than 51% were independently owned, with the remaining being part of a hotel chain. Details of management arrangements are shown in Table 2. Nearly 40% of respondents were located in the city center, with rather fewer in rural (34.4%) and suburban areas (25.8%). Room capacity varied from 18 to 283 (average 90.4 rooms), number of restaurant seats ranged from 20 to 300 (average 109.4 seats), and banqueting capacity ranged from 0 to 600 covers. Statistics regarding number of employees revealed a similar pattern of size of operations—that is, minimum numbers of full-time and part-time employees were 4 and 2, respectively; maximum numbers were 143 to 155, respectively. On average, 47.1% of the annual room nights were from business guests, 36.8% from leisure guests, 11.3% from conference, and 4.3% from other guests, but the high standard deviations revealed that several respondents significantly differed from average values. Repeat customers represented on average 36.9% of annual room nights, while respondents received a great majority of their annual reservations through property-owned systems (69.4%), fewer reservations from third parties (26.6%), and a small percentage (3.4%) from the Internet. Great demand variability was reported (average score 7.2).

TABLE 2
RESPONDENTS' PROFILE

Ownership Structure	*N*	%	Management Arrangement	*N*	%
Independently owned	48	51.61	Independent management	28	30.11
Chained owned	45	48.39	Chain management	47	50.54
			Independent management & consortia membership	18	19.35
Location	*N*	%	Design	*N*	%
Rural	32	34.40	Old and/or traditional	31	33.33
City center	37	39.78	Redesigned/converted	25	26.88
Suburban	24	25.81	Purpose built	37	39.79

	Minimum	Maximum	*M*	*SD*
Number of:				
Rooms	18	283	90.419	65.005
Restaurant seats	20	300	109.408	48.316
Banqueting covers	0	600	191.311	149.823
Full-time employees	4	143	50.817	38.012
Part-time employees	2	155	38.924	35.441
% of room nights from:				
Business guests	0	90	47.153	21.349
Leisure guests	2	90	36.841	23.810
Conference guests	0	47	11.831	10.464
Other guests	0	50	4.344	8.229
% of reservations taken through:				
Property-owned system	37	90	69.467	12.237
Third parties	5	62.8	26.658	12.088
Internet	0	20	3.411	4.215
% of annual room nights representing repeat customers	9	80	36.946	18.990

Regarding respondents' availability and sophistication of ICT, the following information is found. E-mail and Web site were the most heavily adopted ICT. A total of 97.8% and 94.6% respondents reported availability, respectively. Most respondents (83.9%) also had a PMS, and slightly fewer respondents (72%) claimed availability of a customer data warehouse. A smaller percentage (32.3%) had invested in Intranet, while Extranet was the least adopted (only five respondents claimed availability). Concerning availability of other ICT, front office systems were the most heavily adopted, attracting 92.5% of respondents, followed by telephone (80.6%), property-based reservation systems (PBRS) (78.5%), and finance and accounting (75.3%) systems. The remaining ICT applications were adopted by significantly fewer hotels. As the PMS represents the digital nervous system of hotels, integration levels between specific ICT and PMS were investigated by calculating the percentage of respondents with availability integrated with their PMS. Integration levels were lower than adoption levels, meaning that not all respondents claiming ICT availability also had their PMS integrated. This is not surprising when considering that hotels have been following a piecemeal approach to investments, which frequently causes compatibility problems. Limited direct integration was also found among ICT. Such integration was generally concentrated within three clusters of ICT: distribution and reservation, F&B, and front office ICT applications. The latter cluster had the greatest number of direct links (33). Most hotels also used CS ICT only for automational activities, fewer for informational, and very few for transformational activities (please refer to Table 1). Thus, very low levels of sophistication in the exploitation of CS ICT were also found.

Stepwise DEA Productivity Analysis and Results

Table 3 illustrates the stepwise DEA approach in RD, whereby aggregated metrics in the first step were disaggregated into productivity-significant determinant factors to give a robust DEA productivity metric in step 4. Because inputs and outputs used in DEA should satisfy the condition that greater quantities of the selected inputs provide increased output, an isotonicity test between inputs and outputs at step 1 was conducted. As positive intercorrelations between inputs and outputs were found (Pearson correlations, $\alpha = 0.05$), the isotonicity test was passed, and the inclusion of inputs/outputs in step 1 was justified. Constant returns to scale were assumed, but their validity was tested by correlating DEA scores in all steps with a metric reflecting size of operation (number of rooms) (Avkiran 1999). As no significant correlations (Pearson correlations, $\alpha = 0.05$) were identified, the assumption of constant returns to scale was maintained.

Initially, DEA models assumed input minimization, meaning that hotels aim to maintain at least the same level of outputs (be effective) while minimizing inputs (be efficient). However, because at step 4 an uncontrollable input (demand variability) was included, it did not make sense to use input minimization (managers cannot determine/control demand variability), and so output maximization was assumed. However, this did not affect the analysis across steps as constant

TABLE 3

INPUTS/OUTPUTS/FACTORS INCLUDED IN THE STEPWISE DATA ENVELOPMENT ANALYSIS (DEA) IN ROOMS DIVISION

Factors	Step 1 (input minimum)	Step 2 (input minimum)	Step 3 (input minimum)	Step 4 (output maximum)
Outputs				
Non-F&B total revenue	X			
ARR		X	X	X
Room nights		X	X	X
Non–room nights revenue		X	X	X
Inputs				
Rooms	X	X	X	X
RD total payroll	X	X		
RD total M&O expenses	X	X		
Front office payroll			X	X
Administration M&O expenses			X	X
Other RD payroll			X	X
Other RD M&O expenses			X	X
Demand variability				X

Other inputs/outputs and factors correlated with DEA scores in all steps

DEA inputs: % of reservations from property-based reservation system, third parties and Internet, and length of stay; number of full-time staff, part-time staff, IT staff, and managers; full-time staff in rooms division, front office, housekeeping, telephone, administration, marketing, and minor operations, and % of payroll for full time staff; and payroll, material, and other expenses in front office, housekeeping, telephone, minor operations, marketing, and administration.

DEA outputs: % of room nights from repeat customers, business, leisure, conference, and other; occupancy; ARR; total room nights; non-F&B revenue (revenue from minor operations + revenue from telephone); hotel profit; rooms division revenue; and non–rooms division revenue.

NOTE: Non-F&B total revenue refers to all hotel revenue except revenue obtained from the F&B division (i.e. it includes revenue from room nights, telephone and minor operations). Non–room nights revenue refers to revenue obtained from telephone and minor operations. Minor operations include activities such as laundry services and souvenir sales, which, in three-star hotel properties, occupy staff from the rooms divisions department. X = indicates that a variable is included in the DEA model; F&B = food and beverage; ARR = average room rate; RD = rooms division; M&O = material and other.

returns to scale were also assumed, and under constant returns to scale, input minimization and output maximization give the same DEA results. It has also been suggested that the number of units in the dataset should be substantially greater than $N \times M$ (where N = number of inputs and M = number of outputs) (Dyson, Thanassoulis, and Boussofiane 1990). This is because there are $N \times M$ possibilities that units could be efficient and so one could expect the identification of at least $N \times M$ units to be efficient. Here, the use of 3 outputs and 6 inputs in a dataset of 93 hotels clearly allows suitable discrimination between hotels.

In brief, the stepwise DEA approach in RD was applied as follows (see Table 3). At step 1, the following aggregated outputs and inputs were used: non-F&B total revenue, representing revenue from room nights, telephone, and minor operations (e.g., laundry, souvenir sales, etc.); number of rooms, representing the capital investment; total RD payroll; RD total M&O expenses. By correlating the DEA scores obtained at step 1 with the disaggregated productivity inputs/outputs, significant positive correlations between DEA scores and ARR (p = 0.601, α = 0.0000), number of room nights (p = 0.495, α = 0.0004), and non–room nights revenue (p = 0.562, α = 0.0000) revealed that the latter can significantly enhance and determine productivity levels. This is not surprising and is compatible with previous findings (e.g., Johns 1993). Thus, in constructing the DEA model at step 2, instead of the non-F&B total revenue, the three productivity determinant factors, disaggregated outputs were used. The DEA score was recalculated and then correlated with disaggregated outputs/inputs.

Although the correlations of DEA scores with ARR, room nights, and non–room nights revenue disappeared (which is not surprising since their productivity impact was now being considered), significant negative correlations between DEA scores and front office payroll (p = –0.811, α = 0.0000) and administration M&O expenses (p = –0.592, α = 0.0000) were found. These two productivity determinant factors were included in the DEA model at step 3 by adjusting the two inputs, namely, RD total payroll and total M&O expenses. So total payroll was changed to other payroll, referring to total payroll excluding payroll for front office staff, while total RD M&O expenses were changed to other M&O expenses, referring to total M&O expenses excluding the administration M&O expenses. The DEA score was then recalculated and correlated with disaggregated inputs/outputs. The only significant correlation that was found was between the DEA score and demand variability (p = –0.203, α = 0.0512), which justified the inclusion of the latter in the DEA model at step 4. The productivity impact of demand variability is widely argued (e.g., Johns and Wheeler 1991; Jones 1988). The DEA score was then recalculated and correlated. As no correlation was found between the new DEA score and disaggregated inputs/outputs, it was concluded that the DEA model at step 4 is a robust productivity metric in RD including all productivity determinant inputs/output.

TABLE 4
DATA ENVELOPMENT ANALYSIS (DEA) SCORES PER STEP IN ROOMS DIVISION

Hotel	Step 1	Step 2	Step 3	Step 4	Hotel	Step 1	Step 2	Step 3	Step 4
1	32.47	47.99	53.14	**100**	**48**	70.17	74.86	88.36	**100**
2	16.22	30.69	37.91	44.97	**49**	45.59	46.64	51.39	53.39
3	37.73	53.99	54.08	72.08	**50**	51.73	68.39	68.39	85.9
4	32.59	44.41	44.53	**100**	**51**	100	100	100	100
5	44.48	68.03	87.37	87.39	**52**	21.37	47.57	47.57	50.92
6	53.56	50.06	50.06	51.06	**53**	48.09	59.98	91.93	92.23
7	54.34	67.61	99.94	**100**	**54**	47.59	58.73	90.59	90.39
8	82.7	96.34	**100**	**100**	**55**	48.74	64.88	64.88	65.25
9	45.69	86.9	**100**	**100**	**56**	48.07	58.42	57.92	62.17
10	28.08	57.9	70.58	70.72	**57**	29.04	52.22	53.01	54.21
11	25.94	55.3	55.39	55.70	**58**	39.77	58.79	58.06	59.06
12	63.41	93.74	87.2	87.76	**59**	58.56	72.67	72.67	73.67
13	41.93	77.01	89.35	89.76	**60**	29.9	53.83	53.95	54.95
14	37.88	65.18	65.33	65.63	**61**	45.07	88.67	80.06	95.41
15	**100**	**100**	**100**	**100**	**62**	64.92	88.7	85.1	97.34
16	29.4	55.64	67.91	**100**	**63**	43.72	78.34	79.31	81.69
17	29.56	**100**	**100**	**100**	**64**	54.02	72.12	72.95	74.62
18	33.74	63.77	63.77	67.77	**65**	59.48	**100**	**100**	**100**
19	32.4	73.82	60.67	66.04	**66**	53.1	**100**	98.58	**100**
20	28.72	63.08	63.19	63.65	**67**	55.85	65.83	66.24	71.79
21	29.89	58.89	58.96	58.16	**68**	57.41	62.02	62.22	65.62
22	35.72	66.2	66.38	66.58	**69**	63.27	81.06	82.28	90.9
23	41.29	**100**	**100**	**100**	**70**	99.15	83.87	85.42	**100**
24	56.64	92.57	82.82	85.12	**71**	59.5	74.82	87.39	**100**
25	24.23	66.59	66.7	70.32	**72**	38	60.9	61.34	93.02
26	36.75	65.76	74.11	74.11	**73**	**100**	**100**	**100**	**100**
27	62.59	**100**	**100**	**100**	**74**	98.47	**100**	**100**	**100**
28	70.44	**100**	92.87	92.87	**75**	33.11	51.89	54.42	83.22
29	41.6	90.49	95.86	**100**	**76**	79.18	80.3	**100**	**100**
30	22.02	56.91	57.01	59.11	**77**	23.82	40.73	40.73	43.73
31	33.63	67.19	67.19	68.59	**78**	36.2	44.89	86.53	**100**
32	25.22	39.49	39.49	90.33	**79**	65.07	65.27	67.76	**100**
33	39.97	36.4	60.61	**100**	**80**	60.42	75.25	75.25	77.25
34	49.95	60.79	60.79	**100**	**81**	51.15	73.76	75.33	**100**
35	27.77	35.16	35.16	85.11	**82**	38.85	62.12	62.9	74.9
36	59.75	68.13	68.82	72.9	**83**	42.61	61.03	71.6	**100**
37	64.84	71.34	74.21	80.66	**84**	77	76.76	86.54	**100**
38	32.79	44.66	44.66	62.06	**85**	45.02	81.38	82.14	**100**
39	71.14	80.29	**100**	**100**	**86**	47.12	56.37	53.54	69.59
40	43.91	64.29	64.29	70.6	**87**	46.07	59.89	55.21	57.21
41	33.06	40.43	81.43	96.87	**88**	47.24	**100**	**100**	**100**
42	34.03	61.53	61.54	61.54	**89**	52.94	94.72	**100**	97.28
43	46.34	59.3	94.56	96.56	**90**	**100**	**100**	**100**	**100**
44	34.11	47.27	49.13	74.63	**91**	51.5	74.38	**100**	87.06
45	35.83	53.7	54.07	69.82	**92**	69.55	40.88	40.86	95.05
46	57.12	68.46	73.84	75.81	**93**	53.85	50.26	51.23	**100**
47	49.69	50.61	65.95	**100**					

NOTE: DEA scores in bold indicate efficient units/hotels.

A thorough examination of the DEA scores across the different steps (see Table 4) also indicates the reasons for a hotel being productive. For example, hotels that become efficient from step 1 to step 2 (e.g., hotel 23 in Table 4) do so because they can effectively manage and improve their ARR, room nights (occupancy), as well as non–room nights revenue (i.e., the outputs incorporated from step 1 to 2). Similarly, hotels that become efficient from step 3 to step 4 attribute this to their ability to manage market conditions (e.g., hotel 33 in Table 4). Thus, DEA scores at step 3 reflect operational efficiency, while as a demand variable is also included in the DEA model at step 4, DEA scores at step 4 reflect combined efficiency (operational and market). Hotels that are efficient only at step 4 are considered as efficient with respect to the market, and efficient hotels at step 3 that become inefficient at step 4 are considered as operationally efficient only (as it is the market conditions make then inefficient at step 4). Hotels that are inefficient at step 3 and step 4 are considered to be inefficient in both an operational and market sense. Based on these and by using a two axis operational-market efficiency matrix, hotels are categorized into 4 clusters (see Table 5). In this vein, hotels in clusters 3 and 4 represent market efficient hotels, while hotels in clusters 1 and 2 represent market inefficient hotels. For operational efficient hotels, their raw DEA productivity score is provided by the DEA model at step 3, while for market and

TABLE 5

OPERATIONAL-MARKET PRODUCTIVITY MATRIX IN ROOMS DIVISION

	Operational Productivity	
Market Productivity	Inefficient (In Step 3)	Efficient (In Step 3)
Inefficient (In Step 4)	Cluster 1: Units = 58 Hotels: 2, 3, 5, 6, 10, 11, 12, 13, 14, 18, 19, 20, 21, 22, 24, 25, 26, 28, 30, 31, 32, 35, 36, 37, 38, 40, 41, 42, 43, 44, 45, 46, 49, 50, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 67, 68, 69, 72, 75, 77, 80, 82, 86, 87, 92 Demand variability score: Minimum = 1, Maximum = 9, Average = 3.6	Cluster 2: Units = 2 Hotels: 89, 91 Demand variability score: Minimum = 2, Maximum = 6, Average = 4
Efficient (In Step 4)	Cluster 3: Units = 19; Hotels: 1, 4, 7, 16, 29, 33, 34, 47, 48, 66, 70, 71, 78, 79, 81, 83, 84, 85, 93 Demand variability score: Minimum = 1, Maximum = 4, Average = 1.7	Cluster 4: Units = 14; Hotels: 8, 9, 15, 17, 23, 27, 39, 51, 65, 73, 74, 76, 88, 90 Demand variability score: Minimum = 1, Maximum = 6, Average = 4.5

operational efficient hotels, their raw DEA productivity score is given by the DEA model at step 4 (combined productivity performance).

The construction of a robust DEA productivity metric in the F&B division followed a similar stepwise process. Findings illustrate that the following disaggregated factors determine productivity in the F&B division: F&B revenue, percentage of banqueting covers to restaurant covers, F&B capacity, F&B payroll, F&B M&O expenses, and demand variability. The significant positive correlation between DEA scores and percentage of banqueting covers to restaurant covers indicated that banqueting covers contributed to more efficient F&B operations than restaurant covers. This is not surprising considering that banqueting operations are more predictable, standardized, and streamlined than restaurant operations (Jones 1988), and they involve fewer labor and material consuming operations. Finally, by comparing the efficiency scores across steps, hotels with different types of productivity were found—that is, operational efficiency, market efficiency, as well as combined efficiency.

Finally, the disaggregated inputs/outputs previously found to affect departmental productivity were used to construct a robust DEA model for the whole hotel property. This included five outputs (ARR, room nights, non–room nights revenue, F&B revenue, and ratio of banqueting to restaurant covers) and nine inputs (number of rooms, total F&B capacity, front office payroll, administration M&O expenses, F&B payroll, F&B M&O expenses, other payroll, other M&O expenses, and demand variability). Hotels that displayed market, operational, and combined efficiency were identified.

ICT Productivity Impact

DEA productivity scores represent ultimate productivity levels constructed by a composite of intermediate factors that were found significantly to affect productivity. Thus, when a metric is found to affect DEA scores, then ICT is argued to affect both ultimate as well as intermediate productivity metrics (i.e., addressing the shortcoming regarding the level of analysis). To investigate the impact of ICT availability on operational and combined productivity, *t*-tests were applied to two groups (hotels with and without ICT systems) to examine whether there are significant differences in their DEA scores for operational and combined productivity. *t*-tests were applied at all levels in which productivity was measured namely in RD, F&B, and overall hotel property. Similarly, ANOVA tests were used for examining the effect of ICT integration on both operational and combined productivity. Specifically, the ANOVA tests investigated productivity differences between three hotel groups: those without ICT, those with ICT but not PMS integrated, and those with PMS integrated systems. Finally, chi-square tests were performed to investigate the ICT effect on market productivity as market efficiency scores were not available and hotels were classified as market and not market efficient.

The findings show that the effect of ICT availability only becomes apparent when an integration productivity impact is evident. For example, the availability of any F&B ICT does not affect F&B productivity. However, hotels having their F&B ICT integrated with their PMS had significantly higher hotel property operational productivity. This indicates that integration between PMS-ICT in the F&B division is vital for achieving productivity benefits because it enables synergies, coordination, and better management among hotel divisions. For example, an F&B manager can better schedule operations by having information regarding hotel occupancy and hotel guests' patterns of restaurant use. Videoconferencing systems are another example of synergy effects. Their availability can significantly enhance F&B and hotel overall productivity as hotels can benefit from increased F&B and room sales. Moreover, the post hoc Scheffé tests indicated that the productivity impact of the ICT integration was evident in two groups: between ICT holders and holders of integrated ICT and between holders of integrated ICT and non-ICT holders. Moreover, as no significant productivity differences were found between ICT holders and non-ICT holders, it can be concluded that ICT integration is more important than availability for realizing productivity benefits. However, hotels with a greater number of direct links among their ICT did not have significantly higher productivity scores (Pearson correlations among number of direct integrations and productivity scores). This suggests that direct integration among ICT is not as important as ICT integration with PMS.

Tests (Pearson correlations and *t*-tests) were also conducted for examining the productivity impact of ICT clusters, and these provided interesting findings. Although, holders and nonholders of any single functional ICT did not significantly differ in their market efficiencies in RD, F&B, and hotel division, this does not mean that ICT availability cannot enhance market productivity. This is because *t*-tests revealed that market-efficient hotels had a significantly greater number of distribution and reservation ICT than market inefficient hotels. This highlights the existence of synergies and complementary effects among distribution and reservation systems, and it justifies the use of multiple distribution strategies. The finding also indicates that market benefits are realized only after a threshold level of investment on distribution and reservation ICT. As other clusters of ICT (F&B, RD) were also found to have a productivity impact (significant Pearson correlations among productivity scores and number of available technologies in ICT clusters), it can be concluded that the findings reveal that the productivity benefits are only apparent after a threshold ICT investment level has been reached.

The productivity impact of ICT sophistication exploitation was confirmed by conducting Pearson correlations between CS ICT sophistication scores and operational and combined productivity scores at the RD, F&B, and hotel property levels as well as *t*-tests for examining any significant difference in the CS sophistication score among market-efficient and market-inefficient hotels. The results of these tests are provided in Table 6. The findings reveal that higher PMS and customer database sophistication scores, indicating hotels using PMS and customer database for informational and transformational activities, achieved significantly greater productivity scores than those using ICT for automation only. The productivity impact of sophistication of use of newer ICT (e-mail, Web site and Intranet) is zero or minimal, which is not surprising when considering the very limited and basic use of these new technologies by respondents as well as the very few reservations gained through the respondents' Web site (Table 2). Sigala (2001) also found that limited exploitation of Internet technologies leads to limited benefits. Thus, the findings revealed that ICT productivity impacts are realized when ICT are exploited to informationalize and rationalize process and products/ services.

CONCLUSIONS

Despite the increasing ICT investments, the productivity impact has been elusive. After reviewing the literature on the productivity paradox, the study developed and empirically tested a methodology for assessing the paradox that overcomes methodological shortcomings of previous studies. The results are argued to provide robust conclusions highlighting that the productivity paradox debate has been a methodological artifact. The methodology was based on the application of DEA, a nonparametric technique whose value is increasingly being recognized both within academic as well as managerial circles.

The methodology was tested in a dataset of three star hotels in the United Kingdom. Thus, findings measuring productivity and investigating its determinant factors are valid within a specific context. Future research could investigate whether the same conclusions can be replicated and generalized in different hotel segments and/or countries. Given the great product differentiation, operational, environmental and clientele diversity of the global hotel industry, the application of DEA across hotel segments and countries could produce interesting results with crucial academic and managerial implications.

Results investigating the productivity impact reveal that this becomes apparent only when the exploitation of the network/integration, informational and transformational capabilities are considered. To optimize business value, hotels should adopt a more strategic approach to ICT implementation and management. Specifically, three capabilities—information, systems' integration, and architecture—should be managed and aligned with business strategy and operations. The study also highlights that when dealing with ICT issues, both academic and professional studies have been focusing on the word *technologies* rather than *information and communication*.

Notwithstanding the results, this study has some limitations that need to be acknowledged, but which also point toward future research avenues. First, a more accurate metric for labor inputs would have been desirable. The study used the number of full-time and part-time employees as a proxy of labor resources. Full-time equivalent employee (FTE) metrics could have been used, but hotels hardly measure and have such figures (specifically, small independent properties [see Sigala 2002a]). It is also worth mentioning that DEA methodologies are sensitive to DEA outliers. Although this study tried to eliminate the effect of outliers on the reliability of findings, future research could also try to investigate the productivity paradox by applying different statistical analyses and comparing their results.

The study also argued that the aggregate, financial productivity outputs (such as revenue and payroll) should encapsulate qualitative dimensions of productivity inputs/ outputs, such as customer satisfaction and employee skills. Irrespective of the strength of this argument, such an approach did not allow the distinction of tangible (efficiency) and intangible (effectiveness) productivity issues (e.g., customer satisfaction, service quality) and, as a result, the investigation of potentially different ICT productivity impacts. Future research could actually try to develop better metrics for such qualitative dimensions and then apply DEA for investigating any potential effects. Indeed, because DEA can deal with qualitative data, it offers a great potential for redefining service productivity and solving some of the problems of its measurement. However, when soft data are used, issues of instrument reliability and validity become extremely important, and DEA would need to be combined with other research approaches and methodologies. The adaptation of the methodology in other sectors could also investigate how other businesses can best manage ICT applications, while future cross-sector studies could also further enhance, refine, and test the validity of the proposed methodology.

TABLE 6

PRODUCTIVITY IMPACT OF INFORMATION AND COMMUNICATION TECHNOLOGY (ICT) SOPHISTICATION (0.05 LEVEL, TWO-TAILED)

			Rooms Division			F&B Division			Hotel Property		
	p for Oper. + Comb. Efficiency	Market Efficiency *t*-Tests	Operational Efficiency	Market Efficiency	Combined Efficiency	Operational Efficiency	Market Efficiency	Combined Efficiency	Operational Efficiency	Market Efficiency	Combined Efficiency
PMS Sophistication	Pearson correlation	Efficient (51)	0.17644		0.308355	0.37099		0.45099	0.41426		0.59277
	Significance	Inefficient (27)	0.12226		**0.006021**	**0.0.0045**		**0.0096**	**0.00317**		**0.00908**
	n = 78	*t* =		**0.00***			**0.01***			**0.00***	
Web site sophistication	Pearson correlation	Efficient (58)	0.20771		0.057248	0.22761		0.20152	0.14410		0.15937
	Significance	Inefficient (30)	**0.04914**		0.596256	0.72763		0.05972	0.18040		0.13803
	n = 88	*t* =		0.155			0.871			0.762	
E-mail sophistication	Pearson correlation	Efficient (60)	0.00860		–0.01138	0.16714		–0.0614	0.07580		0.10992
	Significance	Inefficient (31)	0.93546		0.914725	0.98291		0.56296	0.47512		0.29964
	n = 91	*t* =		0.281			0.654			0.234	
Intranet sophistication	Pearson correlation	Efficient (14)	0.27537		0.168732	0.32413		0.11213	0.07893		0.27925
	Significance	Inefficient (16)	**0.04078**		0.372752	0.64312		0.55522	0.67843		0.13506
	n = 30	*t* =		0.43			0.123			0.810	
Customer database sophistication	Pearson correlation	Efficient (45)	0.30192		0.252039	0.56488		0.42458	0.24106		0.25946
	Significance	Inefficient (27)	**0.00995**		**0.032696**	**0.01220**		**0.00020**	**0.04135**		0.02774
	n = 72	*t* =		**0.04***			**0.04***			0.051	

*Statistically significant differences at 0.05 level.
NOTE: F&B = food and beverage, PMS = property management systems. Numbers in bold indicate efficiency differences that were found to be statistically significant.

NOTE

1. Detailed data regarding the stepwise data envelopment analysis (DEA) productivity measurement and the tests conducted for testing the information and communication technologies (ICT) productivity relation are available on request from the authors.

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