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Unravelling the Impact of Information Communication Technology (ICT) on Restaurant Productivity

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Abstract

Despite the continuous increase of investment in Information and Communication Technologies (ICT), research has not persuasively established corresponding productivity increases. In contrast, many studies investigating the ICT impact have found no significant relationships between productivity and ICT. However, several shortcomings have been identified in past studies, e.g. measurement errors, redistribution of impacts and mismanagement of ICT. This study proposes a methodology for assessing the ICT productivity impact that overcomes these shortcomings. The methodology is tested in a dataset of hotel restaurants in the UK by using a non-parametric technique called Data Envelopment Analysis (DEA). Findings revealed that productivity gains do not accrue from ICT investments per se, but from the exploitation of ICT "informate" and networking capabilities. Suggestions for enhancing the productivity impact of ICT are provided.

Keywords

Information & Communications Technologies, productivity, impact, restaurant, Data Envelopment Analysis

1. Introduction

Despite the increasing investments in ICT, research findings investigating the ICT productivity impact have always led to contradictory and/or questionable results. Robert Solow, a Nobel winning economist, is supposed to have said that *"PCs are showing up all over the place, except in productivity statistics"*, (in Lucas, 1993: 8), while Brynjolfsson (1993) first referred to the concept of the "IT productivity paradox", i.e. the fact that the benefits of IT spending have not shown up in aggregate output statistics. However, as several methodological shortcomings have been identified in past studies (e.g. Brynjolfsson, 1993), new IT evaluation methodologies are required to lessen or eliminate these. Coupled with the increasing spending and importance of ICT in the tourism and hospitality sectors, it is apparent that an investigation into the impact of ICT on productivity is warranted. This paper aims to investigate the ICT productivity paradox by developing a methodology that overcomes the previous studies' methodological shortcomings. To that end, after analyzing the latter, a framework for measuring the productivity gains of ICT investments based on Data Envelopment Analysis (DEA) is proposed. The framework is empirically tested by using data gathered from hotel restaurants in the UK. Suggestions regarding the management and architecture of ICT applications for enhancing the ICT productivity impact are provided.

2. Investigating the ICT Productivity Paradox

The seemingly obvious yet elusive relationship between ICT and productivity has been examined on four different levels (i.e. the economy, industry, firm and process- specific levels). Several authors summarise an extensive number of studies investigating the relationship between ICT and productivity (e.g. Brynjolfsson 1993, Hitt & Brynjolfsson 1996, Lucas 1993). However, research findings are plagued with ambiguities and inconsistencies. Some researchers reported no relationship between ICT investment and improvements in productivity (e.g. Strassmann 1990; Dos Santos, Peffers & Mauer 1993, Byrd & Marshall 1997), some others provided evidence that such a relationship does exist (e.g. Bender 1986, Brynjolfsson 1993, Roach 1988). Few studies shown negative / dysfunctional ICT productivity effects (e.g. Weill 1992). Research within the hospitality sector has been limited, but it draws to similar conclusions (Sigala 2002). Thus, non-conclusive evidence for the ICT productivity impact is provided, but as studies have been questioned on methodological grounds, findings reporting a negative ICT impact on productivity are claimed to be statistical artefacts. Methodological issues affecting research quality on the ICT-productivity relation are analysed as follows. Yet, the productivity paradox is due to a combination of all factors.

The quality of the data used and analysed. A few studies relied on questionable secondary data, while others did not control for contextual factors (Byrd & Marshall 1997). Cron and Sobol (1983) and Strassmann (1990) also suggested that ICT have an amplifier effect meaning that the introduction of ICT into poorly run firms does not increase productivity, whereas the introduction of ICT into well-run firms pay-off. Previous research that simply incorporated ICT as an input factor of productivity functions did not consider this issue. Thus, future research should firstly identify high and low performers and then investigate the impact of ICT on both of them.

The metrics measuring productivity. There is a misconception that productivity metrics cannot capture the full impact of ICT (e.g. quality increases, avoidance of competitive disadvantage). In contrast, several authors have argued that financial productivity metrics (e.g. Gummeson 1998, Ball 1993) encapsulate both tangible and intangible productivity gains, while Jurison (1996) claimed that the ICT productivity paradox is due to bad management and not to mismeasurement of the ICT productivity benefits. In other words, firms fail to translate intermediate ICT benefits (e.g. better customer service) into final outcomes (e.g. charge higher prices). Moreover, it is widely recognized that aggregated metrics of inputs/outputs tend to obscure information, while partial metrics tend to hide information, trade offs and complementarities among other dimensions (e.g. business departments, resources). To avoid this, researchers attempt to consider partial metrics simultaneously, but this is very laborious and sometimes may lead to conflicting results (Baker & Riley 1994).

The metrics measuring ICT. ICT budgets and expenditures are the most frequently used metrics of computerisation, as they are readily available and reasonably objective, but their reliability and validity are widely criticised, as they do not distinguish between different ICT tools, capabilities and applications, which actually provide different results and benefits (Lucas 1993, Strassmann 1990). In short, ICT budgets neglect two important facets of ICT namely their deployment and their evolving capabilities and features (Willcocks, Graeser & Lester 1998) and so, they fail to illustrate how ICT provide business value. Indeed, recent studies (Bresnahan, Brynjolfsson & Hitt 2002, Brynjolfsson & Hitt 2000) showed that ICT productivity benefits accrue only when ICT are embedded in a cluster of organisational changes including: increased ICT use; changes in organisational practices; and product/services changes. Sigala (2002) also found that increased integration amongst ICT systems and "informate" exploitation leads to greater ICT payoffs. Within the context of hospitality, it is also argued (e.g. Sigala, Airey, Jones & Lockwood 2001, Werthner & Klein 1999) that the relationship between ICT and value is not a direct one, but ICT give value when they are used to redefine, differentiate and informationalise product/services, streamline, rationalise and reengineer processes. ICT mismeasurement is also argued to lead to ICT mismanagement problems, i.e. inability to identify and exploit ICT applications and capabilities that can lead to productivity gains (Sigala et al. 2001). Financial metrics for comparing ICT across firms also suffer from: fluctuations over time (ICT budgets depend on the firms' accumulated ICT assets and ICT costs which are decreasing); waste of ICT expenses; different ways of financing e.g. outsourcing) and measuring ICT expenditures.

The level of analysis at which research is undertaken. This refers to the level of productivity and ICT measurement. Studies measuring productivity at the economy and industry level are limited because macro data do not capture firm level phenomena and they hide displacement effects (Brynjolfsson 1993). Menon (2000) argued that the best level of analysis is at the organisational level, because substitution, synergy and complementarities between resources, inputs and factors affecting productivity can be captured and because process-level analyses suffer from difficulties in: data collection and insufficient sample size, since a significant number of firms with similar processes should be found; separating ICT effects from non-ICT effects within a process; generalisability of results arising from the difficulty of finding similar processes performed with and without ICT across firms. Studies measuring the impact of specific ICT applications on business processes are also limited because they ignore (Lucas 1993): ICT impact on other processes; impact on final outcomes (intermediate effects on processes may not be translated into final outcomes); and synergy amongst ICT applications.

The statistical method used to relate IT with productivity metrics. The majority of studies have used regression and ratio analysis, which are limited since they can simultaneously consider only a limited number of variables. For example, a productivity metric of revenue to number of employees does not consider other factors of production, while aggregate productivity metrics, e.g. total revenue to total expenses does not distinguish the productivity impact of different productivity inputs/outputs. 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, which production functions are capable of modelling. Production function techniques also consider multiple inputs and outputs simultaneously and so they have been extensively used in ICT productivity studies. However, being parametric techniques, production functions assume a functional form of the technology transforming inputs into outputs and so, they can suffer from specification error.

Because of that, a non-parametric, multivariate technique called Data Envelopment Analysis (DEA) is used in this study. DEA benchmarks units by comparing their ratios of multiple inputs to produce multiple outputs at the same time and by using the concept of the performance frontier (Avkiran 1999). DEA shares the advantages of production function, but it is specification error free because it does not assume a functional form. Instead, DEA involves the estimation of the "best practice" frontier from the sample data. Other DEA advantages are reported as follows (Sengupta 1988, Banker & Morey 1986). DEA identifies bad from good performers by generating an overall, easy to interpret efficiency score, it identifies and measures the amount of inefficiency areas, it is independent of the units measuring inputs and outputs (giving flexibility in specifying outputs/inputs), and it can manipulate uncontrollable, environmental factors, e.g. demand variation. Indeed, Avkiran (1999) highlighted that failure to account for environmental factors is likely to confound DEA results leading to unreliable analysis. Norman and Stoker (1991) argued that DEA models not including demand factors measure production efficiency, while models including them reflect market efficiency, i.e. control of production efficiency given demand factors.

DEA has been extensively used for productivity measurement in various industries (e.g. Avkiran 1999), as well as for measuring the ICT productivity impact (Banker, Kauffman & Morey 1990, Paradi, Reese & Rosen 1997, Dasgupta, Sakris & Talluri 1999, Shafer & Byrd 2000). However, as the validity of DEA crucially depends on the inputs and outputs used, these studies present several methodological limitations in their use of DEA for investigating the ICT productivity impact: ICT are included in DEA models as inputs measured in financial terms, which also does not allow the separation of low and high performers for eliminating the ICT amplifier effect; use of few and aggregated productivity inputs and outputs. Banker et al. (1990) used DEA for assessing the impact of Electronic Point Of Sales (EPOS) in a restaurant chain, but one of the contributions of this study is the expansion of DEA at a macro level, i.e. across firms within the same sector. The proposed DEA methodology overcomes all previous methodological problems, while also extending previous studies by using a stepwise DEA approach for constructing robust DEA productivity models.

3. Restaurant ICT and Productivity

Electronic-point-of-sale-system (EPOS), devices used to take and manage customers' orders, represent the core catering ICT applications. EPOS perform such functions as guest check control, communication between servers and the kitchen and sales data tabulation. An EPOS system is made up of a number of terminals that typically interface to a remote central processing unit and/or back office systems. Back-office systems provide the food cost analysis, labour scheduling and financial and inventory controls required at the restaurant level. System interfaces accomplish the basic objectives of electronic data handling, reduce errors/ manual entries and save time. EPOS can: improve customer service, satisfaction and personalization e.g. through interfaces with customer databases; enable staff to be more productive; improve communications and control of activities among employees in food preparation and service delivery; reduce and monitor costs; increase revenue per seat-hour (Buergermeister, 2001; David, Grabski & Kasavana 1996).

E-purchasing/inventory control systems track the items on order, details of suppliers, inventory on-hand and minimum levels for automating ordering. By creating files for each recipe and menu item, menu/recipe management/engineering software permits the analysis of the impacts of changes of ingredient costs, ingredient quantities and price changes. Food costs percentages can also be calculated for pre-costing menus and events. Other production support systems can provide sales forecasting, production planning, workforce scheduling. Table management systems (e.g. reservation, floor-plan, waiting list management and table availability) track table status for improving timeliness of services and speed turns.

Although different and numerous ICT handle these restaurant functions, integration among them and with other departmental ICT (marketing, financial databases) is crucially important for enhancing operations' efficiency and effectiveness. For example, interfaces can streamline the whole process by allowing perpetual inventory of food ingredients to be kept in the following way. When the sale of an item is registered in the EPOS, its component ingredients can be calculated and transmitted to the inventory where the food inventory amount is subtracted from the quantity on hand. In multi-unit restaurants, additional interfaces, enabling data sharing between units and from each unit to head office, allow everybody to benefit from the others' experience, for online consolidation of sales, financial reports and centralised procurement. Figure 1 illustrates the restaurant applications and their potential interfaces.

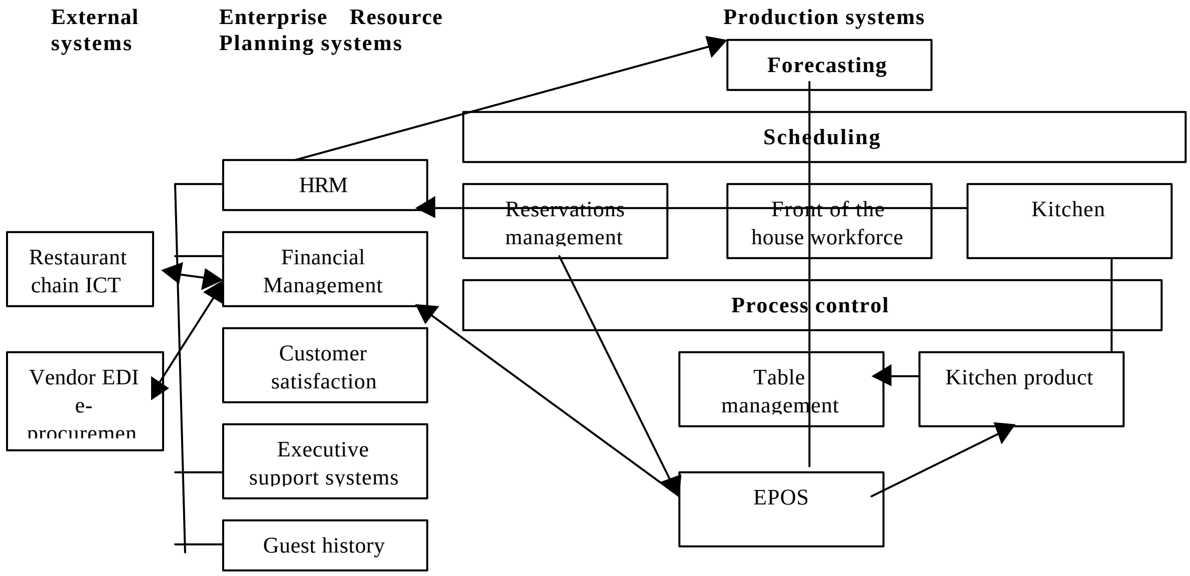

Figure 1. Restaurant ICT applications infrastructure

Overall, the use of restaurant ICT aims to effectively and efficiently manage and maximize exploitation of each of the four core restaurant resources as well as to eliminate time bottlenecks in resources' co-ordination. Table 1 summarises the use of ICT for the management and co-ordination of these four resources, namely, customers (demand), employees, space/seats/physical capacity and menu/inventory items.

	ICT application for enhancing productivity per restaurant resource			
Productivity enhancement method	**Employees**	**Customers/ Demand**	**Space/seats/ physical capacity**	**Menu/ Inventory items**
Reduce uncertainty of arrivals/demand	Forecasting required labor levels (54%)	Forecast demand (68%) Overbooking (54%) Reduce no-shows (43%)	Forecast table availability (23%) Manage reservations (table configuration optimization) (13%)	Forecast raw goods to order (48%) Inventory control (69%) Just-in-time procurement (32%)
Shifting/ managing demand: Development and management of non-physical and physical fences:	Improve labour scheduling (71%)	Advanced reservations (63%) Duration charges (0%)	Differential pricing for floor/room sections (1%) Differential pricing for consuming space at different times (weekday/rush hours etc) (77%)	Differential pricing for menu items (82%)
Differential / personalisation of pricing and/or experience		Develop guest history systems (9%) Frequent customer programmes (0%)		Recipe database and nutritional analysis (0%) Cost accounting and pricing formulation (89%)
Reduce meal duration uncertainty	Improve staff communication (75%) Improve bussing (73%) Speed check delivery (69%)	Direct customer-order-entry systems (0%)	Track consumption times (4%) Service status-zone conditions (10%) Table-status by	Menu engineering (67%) Order by table and time (21%) Track food-preparation (15%)

	Server-station management (42%)		meal part (3%)	Track meal duration by meal part (3%)
Continued …				
Reduce time between customers	Buzzer systems (alert staff) (65%) Improve communication (77%)	Buzzer systems (customer paging) (0%)	Table management (9%) Estimate waiting time (1%)	
e-business benefits webification of business processes	e-recruitment (2%) e-training (8%)	e-reservations (3%) e-customer service (4%)	Mutli-channel distribution/promotion (13%)	e-procurement (6%)
Multi-unit management	Centralized training (23%) Centralized staff scheduling (5%)	IT reservations systems to direct customers to other units (1%) Share of customer databases – histories (1%)	Multi-unit space scheduling (0%)	Centralized procurement (6%)

Table 1. ICT & Restaurant productivity (management of four resources), (% of respondents)

4. Research Aims and Methodology

As the study aimed at assessing the ICT impact on restaurant productivity, its methodological approach, arguing to overcome the previous identified limitations, was designed as follows. Primary data were gathered from restaurants within the four star UK hotel sector. By concentrating on a specific sector, contextual factors and business operational characteristics that would have impacted on the ICT-productivity relationship are eliminated, while by obtaining data from a large sample, findings can be generalised. The ICT productivity impact is investigated at the organizational level, since this is regarded as the best level of analysis. To overcome limitations relating to quality of data, productivity measurement and the statistical methods relating inputs and outputs, the following steps were undertaken. Financial, objective and easily obtainable productivity inputs and outputs that encapsulate both tangible and intangible ICT impacts were gathered. Demand variability was also measured (9 point scale, from low variability to high variability) to consider the productivity impact of environmental factors. Multiple productivity inputs/outputs/factors were considered simultaneously by using DEA (Frontier Analyst package).

In using DEA, the productivity score of restaurants 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 restaurant is obtained by solving the following model (M1):

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

subject to

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

$U_{r,} V_i > 0$; r=1, … s; i=1,… m.

Y_{rj} and X_{ij} are the amount of the *r*th output and the *i*th input for the *j*th 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 *o*th hotel. The model has *t* output variables, *m* input variables and *n* hotels. In practice, the DEA model M1 is first linearized and then solved by using the methods of linear programming. The linear programming version of the model known as the multiplier form is shown in model M2:

$$\text{Max } h_o = \sum_{r=1}^{t} U_r Y_{rj_0} \quad \text{(M2)}$$

subject to

$$\sum_{i=1}^{m} V_i X_{ij_0} = 1$$

$$\sum_{r=1}^{t} U_r Y_{rj} - \sum_{i=1}^{m} V_i X_{ij} \leq 0 \quad \text{for all j=1, … n.}$$

$U_{r,} V_i > 0$; r=1, … s; i=1,… m.

If a restaurant is on the frontier isoquant, i.e., 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 restaurants of the dataset. Other restaurants, using these inputs less efficiently, will be located above the frontier isoquant and their productivity score will be smaller than 1. For example, a restaurant having the productivity score of 0.75 can be interpreted as being 75% as productive as a restaurant on the frontier isoquant. Thus, by using DEA, bad and good performers are first identified and then, the impact of ICT on both of them is assessed, i.e. the ICT amplifier effect is addressed. However, because DEA reliability and validity are as good as its inputs/outputs, the following process was used for constructing robust DEA productivity models.

The stepwise approach to DEA was introduced by Sengupta (1988) as a useful way for selecting appropriate inputs/outputs in DEA analysis that is based on stepwise regression (an iterative procedure in which productivity is measured based on the important inputs/outputs identified up to that step). Correlations between inputs/outputs and productivity metrics as well as cause and effect judgements are examined for identifying inputs/outputs that can significantly determine productivity. When productivity determinant inputs/outputs are identified, these are incorporated into DEA and the process is repeated until no further significant correlations emerge. At that stage a robust productivity metric accounting for all the identifiable inputs/outputs influencing productivity is constructed. Specifically, because aggregate metrics may obscure information, the first step of DEA uses aggregate input/output metrics, but these are later disaggregated into their constituent parts (partial metrics) when the latter are found significantly to affect productivity scores (i.e. significant Pearson correlations, á=0.05, were found between DEA scores and partial metrics). Using this stepwise DEA approach for selecting appropriate productivity inputs/outputs/factors, robust productivity metrics are constructed, as the method considers all factors that can have a productivity impact, but ultimately only those that are found significantly to affect productivity are included. Because of that, productivity differences between units can be attributed to factors that the stepwise DEA analysis has not so far considered.

In this vein, data reflecting the four major restaurant resources/inputs were gathered: number of seats and banqueting covers (physical capacity); number of full time equivalent employees (FTEE) and payroll expenses for both full and part time staff (human resources); material & other (M&O) expenses; management fees; ICT training costs; demand variability (uncontrollable input); percentage of annual covers from repeat customers. Research data regarding productivity outputs included: number of restaurant and banqueting covers served; total revenue.

To overcome limitations relating to ICT measurement, the following analysis was undertaken. Because it is the deployment of ICT tools and capabilities that leads to productivity gains and not investments in ICT per se, the ICT construct was operationalised by using three metrics: 1) number of ICT systems (Table 2); 2) number of interfaces among ICT systems (ICT networking capabilities); and 3) use of ICT and their generated information (as classified in Table 1 (number of activities performed by ICT). Integration among ICT results in great operational efficiencies and value added activities, as it eliminates manual re-entry of data, facilitates easy retrieval, sharing and search of consolidated databases, which are vital actions for informationalising product/services and streamlining processes.

A structured questionnaire was developed and sent to a random sample of 400 four star UK hotels (compiled from the Automobile Association's directory) in June 2002. To ensure consistency, managers were asked to report data referring to the financial year ending in 2001. The mail survey included a pre-paid envelop and a covering letter assuring data confidentiality. After a follow-up, 103 usable responses were gathered.

5. Analysis of Findings

5.1 Respondents' Profile

Respondents represent a diversified sample. Indeed, 34.1% and 25% were independently owned and managed respectively with the remaining being owned and managed respectively by a hotel chain. 48% of respondents were located in city centres, fewer (22%) in rural and 30% in suburban places. Data regarding size and nature of respondents' operations also reveal a diversified sample. Respondents' capacity varied from 30 to 300 seats and from 0 to 600 covers regarding banqueting capacity. Statistics regarding FTEE revealed a similar pattern of size of operations, i.e. minimum FTEE for full time and part time employees 8 and 5 respectively, maximum 28 to 59 respectively. Repeat customers represented on average 23.1% of annual covers, while great demand variability was also reported (average score 7.2). Table 2 provides data regarding ICT availability, Table 1 illustrates the percentage of respondents using ICT tools for each activity. Regarding ICT integration, the ratio number of ICT interfaces to the maximum number of potential ICT interfaces was calculated for each respondent. The average of this ratio was 38%, indicating limited exploitation of ICT networking capabilities.

ICT system	**% of respondents**
Marketing systems	51%
HRM systems	23%
Finance & Accounting systems	79%
EPOS	68%
Table management systems	22%
Production support systems	54%
Inventory / procurement systems	61%

Table 2. ICT availability

5.2 Productivity Results

Table 3 illustrates the stepwise DEA approach, whereby aggregated metrics in the first step were disaggregated into productivity-significant determinant factors to give a robust DEA productivity metric in step 4. 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 (i.e. number of seats). As no significant correlations (Pearson correlations, á=0.05) were identified, the assumption of constant returns to scale was maintained. Initially, DEA models assumed input minimisation, meaning that restaurants aim to maintain at least the same level of outputs (be effective) while minimising inputs (be efficient). However, because on step 4 an uncontrollable input (demand variability) was included, input minimisation was not appropriate (as management cannot determine demand variations) and so, output maximisation was assumed. However, this did not affect the analysis across steps as constant returns to scale were assumed and under constant returns to scale input minimisation and output maximisation give the same DEA scores.

Step 1 included revenue, FB capacity, total payroll and M&O expenses (their inclusion was confirmed by an isotonicity test that revealed positive intercorrelations among inputs and outputs). DEA score was calculated and correlated with the dissagregated inputs/outputs. Significant negative correlations between FTEE referring to part time staff and DEA score revealed that the efficient use of part time staff can significantly impact productivity and thus, in step 2, total payroll was replaced by FTEE for full time and part time staff. By recalculating DEA scores and conducting the correlations, a significant positive correlation was found between the ratio banqueting to restaurant covers and DEA scores. This is not surprising since, restaurant covers that are complex operations and staff demanding, while banqueting operations are usually mass produced, delivered and streamlined. Thus, DEA scores were recalculated again in step 3 to incorporate all these factors. By conducting the correlations at step 3, demand variability was found to significantly affect productivity and so, it was included at step 4. DEA scores were recalculated and since no other significant correlations were found, the DEA model at step 4 was concluded to be a robust model including all productivity determinant factors.

	Step 1 (min.)	**Step 2 (min.)**	**Step 3 (min.)**	**Step 4 (max.)**
Outputs				
FB revenue	*	*	*	*
Ratio of banqueting to restaurant covers			*	*
Inputs				
FB capacity (banqueting & restaurant seats)	*	*	*	*
Total payroll	*			
FTEE full time staff		*	*	*
FTEE part time staff		*	*	*
M&O expenses	*	*	*	*
Demand variability (uncontrollable input)				*
Other disaggregated Inputs/Outputs correlated with DEA scores				
Inputs: FTEE and payroll expenses for full and part time staff; M&O expenses; management fees; ICT training costs; % of annual covers from repeat customers. **Outputs:** number of restaurant, banqueting and total covers served; % of: banqueting to total covers served, restaurant to total covers served, banqueting to restaurant covers served				

Table 3. Stepwise DEA

The stepwise DEA was also used for clustering hotels depending on their type/reason for being productive (Figure 2). Specifically, the DEA model including business variability (step 4) reflects combined efficiency, i.e. production efficiency given the market conditions, while when business variability is excluded (step 3) the DEA score reflects only operational efficiency. Thus, inefficient restaurants at step 3 becoming efficient at step 4 attribute their efficiency to the fact that they can effectively manage demand variability (i.e. they are market efficient only), while inefficient hotels in both step 3 and 4 are both operational and market inefficient.

Market efficiency	Efficient in step 4	Market efficiency only (7)	Combined efficiency (22)
	Inefficient in step 4	Combined inefficiency (71)	Operational efficiency only (3)
		Inefficient in step 3	Efficient in step 3
		Operational efficiency	

Figure 2. Market – Operational productivity matrix (number of restaurants)

5.3 ICT Productivity Impact

The ICT productivity impact was investigated by relating the three ICT metrics with the different productivity DEA scores and types. No significant Pearson correlations between DEA scores at step 3 (operational productivity) and 4 (combined productivity) and number of ICT systems (P=0.231, P=0.173, á=0.05 respectively) revealed that ICT availability alone does not affect productivity. ICT availability did not also affect market productivity, since a t-test (df=101, t=0.542) revealed that market efficient restaurants (i.e. 7 + 22 = 29, Figure 2) did not significantly differ from market inefficient (71+3 =74) restaurants in their number of ICT systems. However, a significant Pearson correlation (P= 0.682, á=0.05) between the ratio of available to potential interfaces and DEA scores at step 4 revealed that ICT integration significantly impacts on combined restaurant productivity. Moreover, exploitation of ICT and their generated information have significant productivity impacts as: a) significant positive Pearson correlations were found between operational DEA scores at step 3 and 4 and number of ICT productivity improvement activities (P=0.692, P=0.713, á=0.05 respectively); market efficient restaurants reported to use ICT for a statistically significant greater number of productivity improvement activities (t=0.002, á=0.05). Multi-unit management ICT activities were not included in this analysis, as 25% of respondents did not belong to a chain.

DEA can also identify and calculate the level of inefficiency for each restaurant. To do this, DEA calculates what the performance of each unit for every of its input/output would have been if the unit had been as efficient as the other units of its reference set and compares it with the actual input/output performance. In this way, the inefficiencies of the four inputs for every restaurant at step 4 (combined productivity) were calculated and then correlated with the number of productivity improvement activities (Table 4). Findings revealed that ICT supported activities did not have a significant productivity effect on the management of single resources apart from material/inventory management. Thus, it is concluded that the ICT productivity benefit is maximised when ICT exploitation is not focused on the management of a single resource but rather on the efficient co-ordination, combination and management of all resources. In other words, ICT should aim at maximising processes' (combination of resources) rather than resources' efficiencies.

Number of ICT activities / Percentages of inefficiencies	Employees	Customers/ Demand	Space/seats/ physical capacity	Menu/ Inventory items
Employees	(P=0.201)			
Customers/ Demand		(P=0.103)		
Space/seats/ physical capacity			(P=0.382)	
Menu/ Inventory				*(P=0.601)*

Table 4. ICT productivity impact per resource and type of ICT supported activity (a= 0.05)

6. Conclusions and Recommendations

Despite the increasing ICT investments, the productivity impact of ICT has been elusive. The study proposed and empirically tested a methodology for assessing the ICT productivity paradox that overcomes methodological shortcomings of previous studies. Findings from a dataset of restaurants from the four star hotel sector in the UK revealed that the ICT productivity impact becomes apparent only when the exploitation of the ICT networking/integration and informational capabilities are considered. For optimizing ICT business value, restaurants should adopt a more strategic approach to ICT implementation and management. Three ICT capabilities namely information, systems' integration and architecture should be managed and aligned with business strategy and operations. In achieving this, businesses should exploit ICT tools with the aim to streamline and increase processes' rather than individual resources performance. Future research should investigate how businesses in different sectors can achieve this, while cross-sectors studies can also further enhance, refine and test the validity of this study's methodology.

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