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Using Data Envelopment Analysis for Measuring and Benchmarking Productivity in the Hotel Sector

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Marianna Sigala

SUMMARY. Low productivity within the hospitality industry has been a major concern, but this situation is unlikely to improve without a general change in the way productivity is measured and managed. This paper aims to illustrate the value of stepwise Data Envelopment Analysis (DEA) for measuring and benchmarking hotel productivity. The issues regarding productivity measurement as well as the advantages of using DEA for measuring productivity are analysed. However, the paper extends current DEA applications by developing a stepwise approach to DEA. The latter technique combines correlation and DEA analysis for developing robust DEA models and its advantages are illustrated by applying it in a dataset of three star hotels in the UK. *[Article copies available for a fee from The Haworth Document Delivery Service: 1-800-HAWORTH. E-mail address: <docdelivery@haworthpress.com> Website: <http://www.HaworthPress.com> © 2004 by The Haworth Press, Inc. All rights reserved.]*

KEYWORDS. Productivity, measurement, benchmarking, stepwise Data Envelopment Analysis

INTRODUCTION

Comparatively low productivity within the hospitality industry has been identified as a source of concern by a number of authors (McKinsey Global Institute, 1998; Witt & Witt, 1989; Johns & Wheeler, 1991). However, this situation is unlikely to improve without a general change in the way productivity is managed within the industry (Johns, Howcroft & Drake, 1997), but productivity management requires regular monitoring, measurement and benchmarking. Although there have been some attempts to identify satisfactory productivity monitoring procedures (e.g., Ball, Johnson & Slattery, 1986), these have been heavily criticised and no generally accepted means of productivity measurement exists in the hotel sector (Brown & Dev, 1999).

This paper aims to develop and illustrate the value of stepwise Data Envelopment Analysis (DEA) for measuring and benchmarking hotel productivity. To that end, after reviewing the issues regarding productivity measurement both in general terms and specifically within the hospitality industry, the paper debates the advantages of DEA relative to other frequently used productivity measurement methods. However, the paper extends current applications of DEA on productivity measurement and benchmarking by developing a stepwise model of DEA. The latter combines correla-

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tion and DEA analysis and its advantages for measuring productivity in the hotel industry are illustrated by applying it in a dataset from the three star hotel sector in the UK.

DEFINING AND MEASURING PRODUCTIVITY

The concept of productivity has been extensively researched in the manufacturing sector. For example, Schroeder (1985) defined productivity as the relationship between inputs and outputs of a productive system. Considering productivity in the hospitality industry, several authors based their approach on this original concept. Ritzer's (in Jones & Hall, 1996) concept of McDonaldization highlighted efficiency and predictability, Levitt (1972) talked about the "industrialisation" or "production-lining" of service, Dilworth (1989) defined productivity as the ratio of all outputs over all inputs, while Jones and Hall (1996) argued that the current thinking of productivity stems from and is a construct of the "manufacturing paradigm" developed during the Fordist period. However, Sigala (2002) questioned whether productivity should be approached differently in services and manufacturing, because in the knowledge era the distinction between products and services is blurred; services are increasingly being industrialised while products informalised.

Although the concept of productivity seems to receive approval from everyone, it is still rare that productivity has been defined satisfactorily and in fact, a widely accepted productivity definition cannot be found in the literature (Brown & Dev, 1999). Productivity means different things to different people, which is reflected in the different or even conflicting definitions and perceptions of productivity (Pickworth, 1987). Indeed, people have varying backgrounds, positions of responsibility, and goals, and so the way they conceive productivity and set about improving it is largely a reflection of their disciplinary predispositions, e.g., management, behavioural science or economics. In reviewing the productivity concept, Sigala (2002) argued that productivity has been approached both as an umbrella concept including efficiency, effectiveness, quality, predictability and other performance dimensions as well as a concept reflecting only production efficiency.

Confusion and disagreement over the concept and definition of productivity create difficulties in productivity measurement and vice versa, the numerous productivity measurements also lead to disagreement and confusion over the concept of productivity (Mahoney, 1988). Thus, some measurements relate to efficiency of performance (e.g., cost per unit, output per employee), other measurements relate to outcomes (e.g., sales, customer satisfaction) reflecting effectiveness. While efficiency measures show whether an organization is doing things in the right way, they do not indicate effectiveness and so, whether the organization is doing the right things.

Andersson (1996) identified three difficulties in measuring productivity, namely identification of the appropriate: inputs and outputs; measures of those inputs and outputs; ways of measuring the relationship between inputs and outputs. Productivity measurement in hospitality in particular faces additional difficulties due to the specific characteristics of its service nature that in turn create problems such as labour and process scheduling, consistency and demand (Witt & Witt, 1989). Indeed, several authors (Sasser, Olsen & Wyckoff, 1978; Jones & Lockwood, 1989; Witt & Witt, 1989; Jones, 1988) argued that productivity management and measurement has been limited in the hospitality sector by the features and characteristics of services. Specifically, the intangible nature of hospitality services suggests that it is difficult to objectively define and measure the service outputs being provided (e.g., number of guest-nights versus number of satisfied guests). The measurement and management of hospitality inputs and outputs is also complicated because of the simultaneous production and consumption of the hospitality services as well as their perishability and heterogeneity, as service encounters are experienced differently by different people or even by the same people at different circumstances. For example, in a hotel stay, only the physical items can be easily measured and controlled, while many of the other features of the hotel experience, such as service and atmosphere, are intangible. Moreover, because each transaction with each customer can be regarded as unique, a quality challenge is created.

In summary, Jones and Lockwood (1989) explained that productivity measurement and management in services is extremely difficult because: inputs and outputs are difficult to standardise (mainly due to the unique nature of service transactions); input/output relationships are not constant (not standardised between units or departments); inputs and outputs may be difficult to measure (due to their variability and intangibility). In this vein, Witt and Witt (1989) identified three problems regarding productivity measurement in hospitality which are compatible to those identified by Andersson (1996): the "definition problem"; the "measurement problem"; and the "ceteris paribus" problem.

The definition problem refers to those difficulties encountered when attempting to define precisely what are the outputs and inputs of a given industry, which is particularly difficult when the outputs/inputs are intangible or are highly heterogeneous. Thus, the definition problem is similar to the problem of identifying the right inputs and outputs. The measurement problem was described as the problem encountered when outputs/inputs can be defined but cannot be measured. However, even if outputs/inputs can be measured in some way, there may be problems in terms of using suitable units of measurement. The "ceteris paribus" problem involves holding the other influences constant when examining the impact of a particular factor on productivity. Productivity in hotels may be said to be a function of several factors both internal/controllable (e.g., type and classification of hotel) and external/uncontrollable (e.g., demand levels) to the hotel. Thus, comparisons of productivity metrics can be misleading unless "other factors" are held constant. Sigala (2002) illustrated that the way of relating inputs and outputs can be used to address the "ceteris paribus" problem.

The following analysis reviews the theoretical debates regarding the three difficulties in productivity measurement in order to identify and clarify the issues that a robust productivity metric and method should address.

Selecting Outputs and Inputs

Sigala (2002) illustrated that the selection of inputs/outputs refers and needs to deal with two issues: the approach to productivity definition, namely partial or total approach; the identification of the level and/or unit of analysis. Partial productivity metrics focus on specific inputs that can be easily identified and measured. However, because of the synergy between all inputs as well as the fact that hospitality inputs/outputs are amalgams of tangible and intangible/qualitative elements, a multi-factor (Chew, 1986) or total factor view to productivity is proposed that takes into account all inputs as well as the structural complexity of hospitality outputs/inputs, owning to the typical intangibility, perishability, heterogeneity and simultaneity characteristics of services (Mahoney, 1988). Indeed, because in the long-term, customer satisfaction is perhaps the most important service output, intangible elements that are an intrinsic part of the service experience, such as management style, staff flair and expertise, should undoubtedly consist crucial components of both productivity inputs and outputs.

Productivity measurement becomes even more complex when one also examines the array of factors (e.g., aesthetics, ergonomics) that face managers attempting to enhance their companies' productivity. In summary, research revealed that productivity can be significantly impacted by the following major factors (Johns et al., 1997; National Economic Development Council, 1992; Van der Hoeven & Thurik, 1984; Brown & Dev, 1999; McKinsey Global Institute, 1998; Cizmar & Weber, 2000; Sigala, 2002): hotel size, location, service orientation, ownership and management arrangement; hotel age, design, type and number of facilities; demand patterns; staff flexibility (reflected in the use of part-time and full-time employees); marketing practices (e.g., distribution, promotion, frequent guest programs) effectiveness. It has been argued that such factors, acknowledged as "upstream" factors (Rimmington & Clark, 1996) or "top-line" factors (Heap, 1992) should be included in productivity definition and measurement.

Overall, there is no conclusive agreement to whether total factor productivity refers to: the inclusion of all inputs and outputs rather than the consideration of each input at a time (partial measures); the measurement of both tangible and intangible features of inputs/outputs regardless whether partial or total productivity ratios are calculated; the consideration of other factors that may be external to the control of management but can crucially affect productivity, e.g., level of competition, location; or to the consideration of all the previous factors or a combination of them. Nevertheless, such conflicting approaches clearly indicate and highlight the issues that should be taken into account when constructing and interpreting productivity measurement metrics. Although the importance of using a total approach to productivity has been highlighted, authors have simultaneously stressed the difficulty for one metric to encompass all different measured factors. In other words, the definition problem is closely interrelated to the other two measurement problems.

The selection of appropriate outputs/inputs is also related to the level and unit of analysis. Depending on what is the focus of analysis (e.g., hotel department, product, market segment) relevant inputs/outputs should be used (Johns & Wheeler, 1991). Aggregated input/output metrics can be disaggregated at any level in order to construct a whole "family"/"hierarchy" of partial productivity ratios. However, aggregated metrics tend to obscure information, whereas partial measures tend to hide information and trade-offs among other dimensions (e.g., departments, resources). The latter can be overcome by considering partial metrics simultaneously, but this is very laborious and sometimes may lead to conflicting results (Baker & Riley, 1994).

To overcome limitations of partial and aggregated metrics, Brown and Dev (1999) suggested that the unit of analysis should be modified from product-oriented measures to customer-oriented measures, e.g., productivity measurement at an even lower level of analysis and disaggregate inputs/outputs at the individual customer level. Sigala (2002) also advocated that revenue per available customer (RevPAC) is a crucial productivity measure for hotels in the information era, because as technological developments have enabled hotels to personally serve, satisfy and keep their most valuable customers, hotels should change the way they measure themselves. On the other hand, traditional ways in which hotels gauge performance (e.g., revenue per available room) reflect their historic roots and basic orientation to creating values, as the industry's fundamental structure and value proposition was long-based on physical assets (hotel rooms) as the driver of wealth.

Selecting Measurement Units of Inputs/Outputs

Ball et al. (1986) identified three main categories of measurement units, namely financial, physical and a combination of the previous two. Both financial and physical units have been used in previous studies. For example, in developing their DEA model, Johns et al. (1997) used simple inputs and outputs, no ratios or composite data were employed, and non-financial data was preferred. Specifically the following three outputs and five inputs were used: number of room nights sold, total covers served and total beverage revenue; and number of room nights available, total labour hours, total food costs, total beverage costs and total utilities cost. Anderson, Fish, Xia, and Michello (1999) used a stochastic frontier analysis in order to measure the performance of 48 hotels by using four outputs (total revenue generated from rooms, gaming, food and beverage and other revenues) and five inputs (number of full time equivalent employees, the number of rooms, total gaming related expenses, total food and beverage expenses and other expenses).

Sigala (2002) illustrated that the conceptualisation of productivity influence the use of units measuring productivity inputs/outputs. Specifically, it is generally agreed that quantitative physical measures reflect a quantitative approach to productivity that equates productivity with production efficiency only (Andersson, 1996), while a total factor approach would require more sophisticated and qualitative measures. However, there are arguments supporting the view that the truly quantitative, aggregate, "broad" measures (e.g., profit, sales) implicitly encapsulate intangible qualitative performance (Rimmington & Clark, 1996; Johns & Wheeler, 1991). This is for two reasons. First, only if the intangibles are as they should be will customer levels be sustained and income earned. Secondly, only if the tangibles are as they should be will income and costs be controlled in such a way that profit is produced at the required rate in relation to the capital employed.

Ways of Measuring the Relationship Between Inputs and Outputs

The complexity of the relationship between inputs and outputs is affected by both the number of inputs/outputs as well as their measurement units, because different combinations between number and types of units can result in a huge number of productivity metrics each one having its own information value and reflecting different things. In fact, there are several ways of comparing inputs and outputs. The most commonly used in the hospitality sector are ratio analysis, multi-factor ratios and regression analysis (Sigala, 2002), but their major limitations is their inefficiency in simultaneously handling multiple inputs and outputs. However, given the number of possible productivity measurements, there is a need to condense several measurements into a single productivity metric through multidimensional analysis that can combine two or more key ratios into one measurement. Moreover, the productivity metric that would take into consideration multiple inputs and outputs should be computed in a way that it does not directly relate certain inputs with outputs but it would rather highlight the interrelationships and trade-off between all of them.

To achieve that a technique called Data Envelopment Analysis (DEA) has been heavily applied, DEA is a powerful non-parametric, multivariate, multiple linear programming technique that benchmarks units by comparing their ratios of multiple inputs to produce multiple outputs at the same time (Charnes, Cooper & Rhodes, 1978; Charnes, Cooper, Lewin & Seiford, 1994). DEA constructs a frontier function in a piecewise linear approach by comparing like units (the decision-making units, DMU) with like taken from the observed dataset. Since DEA uses the production units that are "best in its class" as reference material, the method is very much in line with the basic ideas underlying the concept of benchmarking (Al-Faraj, Alidi & Bu-Bhsait, 1993). Overall, DEA's advantages relative to the previous techniques are summarised as follows (Cooper, Seiford & Tone, 2000; Sengupta, 1988; Banker & Thrall, 1992):

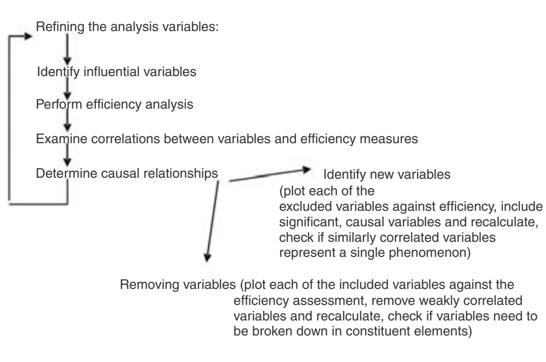
- It provides a comprehensive productivity evaluation as it generates a single aggregate score by comparing simultaneously multiple inputs and outputs of comparable units and using a benchmark of 100% efficiency;
- It is independent of the units of measurement allowing flexibility in specifying inputs/outputs to be studied;
- It objectively assesses the "importance" of the various performance attributes;
- It evaluates each entity in the best possible light–all alternative priorities will reduce performance;
- It calculates efficiency based on observed best practice–not against an "average" or "ideal" model;
- Best practices are identified;
- No functional relationship between inputs and outputs needs to be prespecified;
- Inefficient DMUs are identified as well as the sources and amounts of their inefficiency. Thus, DEA answers both questions: *"how well a unit is doing"*; *"which dimension and how much could the unit improve"*;
- DEA can identify economies of scale and take them into account.

DEA can also consider external factors that can affect productivity overcoming in some extent the "ceteris paribus" problem. Dyson, Thanassoulis and Boussofiane (1990) also argued that a key aspect of DEA is the incorporation of environmental factors into the model. Banker and Thrall (1992) distinguished between controllable and uncontrollable inputs (e.g., demand levels, competition) in order to measure and interpret performance in the context of uncontrollable environmental conditions. 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 only, while DEA models including demand factors also reflect market efficiency referring to the ability to control production efficiency given the demand factors.

However, the reliability and benefits of DEA are as good as the inputs/outputs that it uses. Sengupta (1988) introduced a useful way for selecting and using appropriate inputs/outputs in DEA analysis, which is called stepwise approach to DEA and is based on stepwise regression. The stepwise approach is an iterative procedure in which productivity is measured in terms of the important factors identified up to that step (Figure 1). Other important factors are identified by examining factors that correlate with the measure of efficiency and applying judgments in terms of cause and effect. Then, these factors are incorporated into the DEA model and the process is repeated until no further important factors emerge. At that stage, a metric accounting for all the identifiable factors that influence productivity is constructed.

In their study, Parkin and Hollingsworth (1997) also proposed and used a stepwise DEA approach by correlating potential variables with DEA efficiency scores in order to validate and get their DEA model specification. A stepwise approach also helps to interpret why particular units are efficient. A table of the efficiency scores of the units at each step can be produced whereby the efficient units introduced at each step can be separated. Basically, the units found to become efficient from one step to another are efficient because of the incorporation of the respective inputs/outputs in the step they were found to be efficient.

FIGURE 1. Stepwise Approach to DEA



DEA has been extensively used for performance and productivity benchmarking (Al-Shammari & Salimi, 1998; Chatzoglou and Soteriou, 1999) in various industries (Avkiran, 1999), the hotel industry included (e.g., Morey & Dittman, 1995; Johns et al., 1997; Avkiran, 1999; Anderson, Fok & Scott, 2000; Tarim, Dener & Tarim, 2000; Wöber, 2000, 2002; Sigala & Christou, 2001). However, the present paper extends previous applications by proposing a stepwise approach to DEA for identifying the appropriate DEA inputs/outputs and developing robust DEA models.

RESEARCH AIMS AND METHODOLOGY

Research Aims, Instrument and Sample Design

The main purpose of this paper is to develop and illustrate the value of using the stepwise DEA approach for developing robust productivity models and then determining appropriate productivity improvement strategies. A productivity model is considered as robust when it constructs productivity frontiers by identifying and simultaneously considering the multiple factors that can significantly determine productivity. The advantages, validity and value of this technique for productivity measurement and management are tested and illustrated by gathering data from the three star hotel sector in the UK. By focusing on a specific sector, contextual factors and business operational characteristics that could also have an impact on productivity are eliminated.

A structured questionnaire gathering information regarding several inputs, outputs and factors that can affect productivity in the hotel sector was developed. For ensuring consistency amongst respondents, all data were asked to refer to the financial year ending 1999. The questionnaire was also piloted with six hotel managers for testing its reliability and validity. Specifically, the format, wording and variables of the questions were pre-tested in order to ensure a mutual understanding between the researcher and the respondent. As a result, some fine-tuning was conducted in order to enhance the quality and accuracy of the research instrument, e.g., the term independent and consortia management was replaced with independent management and consortia membership and annual hotel profit with annual profit before fixed charges to enhance clarity.

In developing the study's sample, initially, the Automobile Association's hotel directory was used for compiling a random sample of 300 full service three star hotels in the UK. Hotel managers were targeted by a mail survey in June 2000. However, despite the use of a pre-paid envelope, a covering letter assuring managers for data confidentiality and a follow-up, the mail survey achieved a very low response rate (12 responses), mainly due to the sensitivity of the data required. To increase responses, contacts with consultancy companies, individual hotels, chains and consortia were used in order to identify potential hotels willing to participate in the study and provide information. The names of the latter cannot be identified due to confidentiality reasons. Overall, 93 questionnaires were received out of 1,233 hotels contacted.

Stepwise DEA Methodology for Constructing Robust DEA Productivity Models

As previously mentioned, in developing a productivity metric the first steps involve the selection of inputs/outputs and their measurement units, which in turn requires the identification of the approach and the level/unit at which the productivity analysis is undertaken. Concerning the approach to productivity definition, given the limitations of partial productivity metrics, this study adopted a total factor approach meaning that the productivity concept incorporated both efficiency and effectiveness dimensions. To achieve that, the productivity metric included all factors of production as well as other factors that may affect productivity. Moreover, a great variety of inputs/outputs was used including both financial and physical measurement units in order to encapsulate both tangible and intangible aspects of productivity inputs and outputs.

The study aimed to measure productivity of hotel properties and so, productivity inputs/outputs were identified and measured at the organisational level. However, because hotels are made up of different departments, with different characteristics and so with different factors determining their productivity (Baker & Riley, 1994; Johns & Wheeler, 1991), an aggregate productivity metric and model may obscure and hide trade-offs among productivity variables. To overcome this, productivity metrics were calculated both at the organisational as well as at two departmental levels. Specifically, the stepwise DEA was first applied to rooms and F&B division separately in order to identify the specific disaggregated productivity inputs and outputs that determine productivity in these two divisions. Subsequently, the latter were compiled into a single DEA model that in turn represented the hotel property overall productivity metric. So in this way, hotel property productivity was not constructed by using inputs/outputs aggregated at an organisational level that can obscure and hide productivity effects.

Table 1 summarises the productivity inputs/outputs and factors that were considered in the stepwise DEA process. The selection and use of these measures are justifiable and compatible with previous studies, which are also identified in Table 1.

The final step of productivity measurement requires the selection of a way to relate the productivity inputs and outputs. To achieve that, DEA was adopted by using the *Frontier Analyst 2* software package. However, as DEA's validity and reliability depend on the selection of appropriate inputs and outputs, a stepwise DEA approach was followed for identifying those inputs/outputs that significantly determine productivity and developing a robust DEA productivity model. To that end, the first step involved the calculation of a DEA score for each hotel by using aggregated inputs and outputs. DEA scores were then correlated (Pearson correlations, $\alpha = 0.05$) with disaggregated inputs/outputs for distinguishing those determining productivity. When significant correlations were found and a cause and effect relation existed, disaggregated inputs/outputs were included into the DEA model and the relevant aggregated data were adjusted. Finally, a robust DEA model was concluded

TABLE 1. Productivity Inputs, Outputs and Factors Influencing Productivity

Hotel productivity inputs included: number of full time employees in front office, housekeeping, F&B, telephone/switchboard, administrative and general, minor operations, marketing, maintenance and other; the number of heads and/or managers of departments; the number of information technology technicians; total number of part time employees; annual expenditure regarding direct material expenses, payroll and related expenses and/or other expenses; annual expenditure was also broken down in the following: hotel divisions front office, housekeeping, F&B, telephone/switchboard, minor operations, administrative and general, marketing, maintenance and training on ICT; annual energy expenses; annual management fees.

Hotel productivity outputs included: average room occupancy; average room rate (ARR); roomnights achieved; restaurant covers; banquet covers; hotel profit before fixed charges; hotel revenue; percentage of hotel revenue corresponding to the following departments: rooms division; F&B; minor operations; and telephone/switchboard.

Factors and their metrics that previous studies found to influence productivity included:

- location: rural, city centre or suburban (TRI Hospitality Consulting, 2002; McKinsey Global Institute, 1998; National Economic Development Council, 1992; Johns et al., 1997).
- hotel design: old/traditional, redesigned/converted, purpose built (McKinsey Global Institute, 1998).
- ownership structure: independently or chain owned (Johns et al., 1997; Brown & Dev, 1999).
- management arrangement: independent management, chain management, independent management and consortia membership, franchise (NEDC, 1992; Van der Hoeven & Thurik, 1984; Brown & Dev, 1999; McKinsey Global Institute, 1998; Sigala, 2002).
- demand variability was calculated by asking respondents to characterize fluctuations in business both over the year as well as over the week as greatly, somewhat or not at all. Responses were scored (1 = greatly, 2 = somewhat and not at all = 3) and an overall score of business variability was calculated by multiplying the score of demand variability per year with the score of business variability per week. The higher score was chosen to correspond to little demand variability because of the following reason. Theoretically, the lower the variability the higher the productivity (outputs). DEA models treat demand variability as an uncontrollable input. However, because in DEA, higher values of inputs should relate to higher values of outputs, that meant that higher values of demand variability (i.e., lower demand fluctuations) should lead to higher outputs (National Economic Development Council, 1992; Sigala, 2002).
- a percentage of repeat guests (Cizmar & Weber, 2000).
- average length of stay: number of days (Sigala, 2002; National Economic Development Council, 1992; McKinsey Global Institute, 1998).
- market segments served: percentages of total roomnights referring to business, leisure, conference travelers and/or other (TRI Hospitality Consulting, 2002; Van der Hoeven & Thurik, 1984).
- distribution channels: percentages of total reservations received through a property owned system (e.g., telephone), third parties and Internet (Sigala, 2002; Sigala et al., 2001; O' Connor, 2002).
- part time staff: percentage of total payroll expenses referring to full time staff as well as the number of full time and part time staff employed in their property (McKinsey Global Institute, 1998; National Economic Development Council, 1992; Sigala, 2002).
- hotel size: number of rooms, bedspaces, banquet capacity and restaurant seats (Johns et al., 1997; National Economic Development Council, 1992; Van der Hoeven & Thurik, 1984; Brown & Dev, 1999; McKinsey Global Institute, 1998; TRI Hospitality Consulting, 2002).

Inputs/outputs used in previous studies:

Johns et al. (1997). Outputs: number of rooms sold, total covers served; total beverage revenue. Inputs: number of roomnights available, total labor hours, total F&B costs, total utilities costs.

Anderson et al. (1999). Outputs: total revenue generated from rooms, gaming, F&B and other revenues. Inputs: FTEE, number of rooms, total gaming related expenses, total F&B expenses other expenses.

Avkiran (1999). Outputs: revenue and cost of a double room. Inputs: number of full time, permanent part time and casual staff, total bed capacity and largest meeting capacity

Morey and Dittman (1995). Outputs: total room revenue, average level of guest satisfaction. Inputs: number of rooms, rooms division expenditure, average occupancy rate, average daily rate for a group of competitors (uncontrollable input)

Ball et al. (1986). Revenue/FTEE, covers/FTEE

Brown and Dev (1999). Total annual sales per number of FTEE, gross operating profit per FTEE, income before fixed charges per FTEE.

Baker and Riley (1994). Added value per full time employee, sales per full-time employee and F&B sales per full time employee.

when no other inputs/outputs were found to affect the DEA productivity score. At that stage, a robust productivity metric is constructed, as all potential factors that could have affected productivity had been taken into account and only those that had a significant impact were included in the DEA model. Moreover, because of that, productivity differences between hotels can be attributed to factors that the stepwise DEA analysis has not so far considered.

ANALYSIS OF THE FINDINGS

Profile of Respondents

Respondents consist a sample representing the diversity of the three star hotel sector in the UK (Table 2). Indeed, 51.6% of respondents were independently owned with the remaining being owned by a hotel chain. Concerning management arrangement, 47% of respondents were managed by a hotel chain, 28% were independently managed while 18% represent independents that were also members of a consortium. Moreover, 39.7% of respondents were located in the city center, fewer (34.4%) in rural and 25.8% in suburban places. Concerning hotel size and operation, respondents' room capacity varied from 18 to 283 rooms (average 90.4 rooms), number of restaurant seats ranged from 20 to 300 seats (average 109.4 seats) and banqueting capacity from 0 to 600 covers. Statistics regarding number of employees revealed a similar diversity of size of operations; minimum numbers of full time and part time employees were reported as 4 and 2 respectively, while maximum numbers were 143 to 155 respectively. Regarding the market segments served by respondents, on average 47.1% of the annual roomnights were from business guests, 36.8% from leisure guests, 11.3% from conference and only 4.3% from other guests, but the high standard deviations revealed that several re-

TABLE 2. Respondents' Profile

Ownership structure	**N**	**%**	**Management arrangement**	**N**	**%**
Independently owned	48	51.61	Independent management	28	30.11
Chain owned	45	48.39	Chain management	47	50.54
			Independent management and consortia membership	18	19.35
Location	**N**	**%**	**Design**	**N**	**%**
Rural	32	34.40	Old and/or traditional	31	33.33
City centre	37	39.78	Redesigned/converted	25	26.88
Suburban	24	25.81	Purpose built	37	39.79
Number of:	**Min**	**Max**	**Mean**	**Std. Deviation**	
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	
Percentage of roomnights from:	**Min**	**Max**	**Mean**	**Std. Deviation**	
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:	**Min**	**Max**	**Mean**	**Std. Deviation**	
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 roomnights representing repeat customers	9	80	36.946	18.990	

spondents significantly differed from average values. Repeat customers represented on average 36.9% of annual roomnights, while respondents received a great majority of their annual reservations (69.4%) through property owned systems, fewer reservations (26.6%) from third parties and only 3.4% from the Internet. Great demand variations were also reported (average score 7.2).

Construction and Analysis of DEA Productivity Models

Productivity Measurement in Rooms Division

Table 3 illustrates the application of the stepwise DEA approach in rooms division, while Table 4 provides the DEA scores obtained for each hotel at the different steps. To ensure the validity of the DEA model specification, the following procedures were undertaken. Because inputs and outputs used in DEA should satisfy the condition that greater quantities of inputs provide increased output, the appropriateness of the inputs and outputs included at step 1 was tested by conducting an isotonicity test (Chen, 1997). An isotonicity test involves the calculations of all intercorrelations between inputs and outputs for identifying whether increasing amounts of inputs lead to greater outputs. Avkiran (1999, p. 50) also illustrated how intra-correlations among inputs and outputs can be used for identifying appropriate DEA variables. As positive intercorrelations were found (Pearson correlations, $\alpha = 0.05$), the isotonicity test was passed and the inclusion of the inputs and the outputs at step 1 was justified. DEA models assumed constant returns to scale, but their validity was tested by correlating the DEA scores obtained at all steps with a metric reflecting size of operation (number of rooms),

TABLE 3. Input and Output Metrics Included in the Stepwise DEA in Rooms Division

	Step 1 (input min)	**Step 2** (input min)	**Step 3** (input min)	**Step 4** (output max)
Outputs				
Non-F&B total revenue	*			
ARR		*	*	***(48.2%)**
Roomnights		*	*	***(41%)**
Non-roomnights revenue		*	*	***(32.3%)**
Inputs				
Rooms	*	*	*	***(5.4%)**
Rooms division total payroll	*	*		
Rooms division total non-payroll expenses (material and other)	*	*		
Front office payroll			*	***(16.3%)**
Administration non-payroll expenses (material and other)			*	***(28.5%)**
Other rooms division payroll			*	***(12.1%)**
Other rooms division non-payroll (material and other)			*	***(8%)**
Total demand variability				***N.A.**
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; length of stay; number of: full time staff; part time staff; IT staff; managers; full time staff in: rooms division, front office, housekeeping, telephone, administration, marketing, minor operations; % of payroll for full time staff; payroll and material and other expenses in: front office, housekeeping, telephone, minor operations, marketing, administration. **DEA outputs:** % of roomnights from: repeat customers, business, leisure, conference and other; occupancy; ARR; total roomnights; non-FB revenue (revenue from minor operations + revenue from telephone); hotel profit; rooms division revenue; non-rooms division revenue.				

Non-F&B total revenue refers all hotel revenue except of revenue obtained from the FB division, i.e. it includes revenue from roomnights, telephone and minor operations.
Non-roomnights revenue refers to revenue obtained from telephone and minor operations.
Minor operations include activities such as laundry services, souvenirs' sales, that in three star hotel properties occupy staff from the rooms divisions department.
*Indicates that a variable is included in the DEA model.

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

as advocated by Avkiran (1999). As no significant correlations were identified, the assumption of constant returns to scale was maintained. Furthermore, because outliers in the dataset can create serious distortions in the DEA, the existence of outliers was also investigated. Since none outlier was found, all 93 hotels were included in the analysis.

Initially, DEA models assumed input minimisation, meaning that hotels aim to maintain at least the same level of outputs (be effective) while minimising inputs (be efficient). However, it does not make sense to use input minimisation when uncontrollable inputs are included in the DEA analysis (Avkiran, 1999, p. 51), since such an assumption is unrealistic given that managers have no control on determining/managing uncontrollable inputs. Thus, output maximisation was assumed at step 4, because an uncontrollable input (demand variability) was included in the DEA model. However, this did not affect the DEA analysis and comparisons across steps. This is because constant returns to scale were also assumed and under constant returns input minimisation and output maximisation give the same DEA scores. It has also been suggested that the number of units in the dataset should be substantially greater than N * M (where N = number of inputs and M = number of outputs) (Dyson, Thanassoulis & Boussofiane, 1990). This is because there are N * M possibilities that units could be efficient and so, one could expect the identification of at least N * M units to be efficient. In this study, 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 rooms division was applied as follows. At step 1, the following aggregated metrics were used in order to capture the rooms' division outputs and inputs: non-F&B total revenue representing revenue from roomnights, telephone and minor operations (e.g., laundry, souvenir sales, etc.), in other words, revenue from the major activities occupying rooms' division employees; number of rooms representing the capital investment; and total rooms' division payroll and Material and Other (M&O) expenses for accounting the labor resources and other rooms' division inputs. By correlating the DEA scores obtained at step 1 with the disaggregated productivity inputs/outputs, significant positive correlations between DEA scores and ARR ($P = 0.601$, $\alpha = 0.0000$), number of roomnights ($P = 0.495$, $\alpha = 0.0004$) and non-roomnights revenue ($P = 0.562$, $\alpha = 0.0000$) revealed that the latter can significantly enhance and determine productivity levels. This is not surprising and compatible with findings from previous studies (e.g., Johns, 1997; National Economic Development Council, 1992; Van der Hoeven & Thurik, 1984). Thus, in constructing the DEA model at step 2, these three productivity determinant, disaggregated outputs were used instead of the non-F&B total revenue. The DEA score was recalculated and then correlated with disaggregated outputs/inputs. Although the correlations of DEA scores with ARR, roomnights and non-roomnights revenue disappeared (which is not surprising since the productivity impact of the latter was now being considered through the specification of the DEA model), significant negative correlations between DEA scores and front office payroll ($P = -0.811$, $\alpha = 0.0000$) and administration M&O expenses ($P = -0.592$, $\alpha = 0.0000$) were found. In order to include these two productivity determinant factors in the DEA model at step 3, the two inputs, namely total payroll and total M&O expenses, were adjusted to exclude the former. So, total payroll was changed to other payroll, referring to total payroll excluding payroll for front office staff, while total M&O expenses were changed to other M&O expenses, referring to total M&O expenses excluding the administration M&O expenses (Table 3). 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 ($P = -0.203$, $\alpha = 0.0512$), which justified the inclusion of the latter in the DEA model at step 4. The productivity impact of demand variability is widely argued in the literature (e.g., National Economic Development Council, 1992; Johns & 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 (meaning that none other disaggregated input/output is a significant determinant of productivity), it was concluded that the DEA model at step 4 is a robust productivity metric in rooms division reflecting all inputs/outputs that hotels should effectively manage to be productive. Overall, the following disaggregated inputs/outputs were found to be significant determinants of rooms division productivity: ARR, roomnights, non-roomnights revenue, number of rooms, front office payroll, administration M&O expenses, other rooms' division payroll, other rooms' division M&O expenses and demand variability.

As previously argued, a thorough examination of the DEA scores across the different steps can also indicate the reason for which a hotel is found productive. Specifically, hotels that become efficient from step 1 to step 2 (e.g., hotel 17, 23, 27 in Table 4) become efficient because they can effectively manage and improve their ARR, roomnights (occupancy) as well as non-room revenue (revenue from telephone and minor operations). In this vein, the investigation of the effectiveness and implementation of the yield management practices, distribution and marketing strategies of these hotels becomes of a great interest and importance. Hotels that become efficient from step 2 to step 3 (e.g., hotel 8, 9, 39) achieve this because they can successfully manage their front office payroll and administration M&O expenses. Further investigation of these hotels might reveal best practices, for example, in staff scheduling, information technology applications and paperless office strategies. Finally, hotels that become efficient at step 4 (e.g., hotel 1, 4, 79) achieve this because of demand factors and so, further investigation of such cases might reveal either attractive hotel locations and/or best practices in managing demand fluctuations.

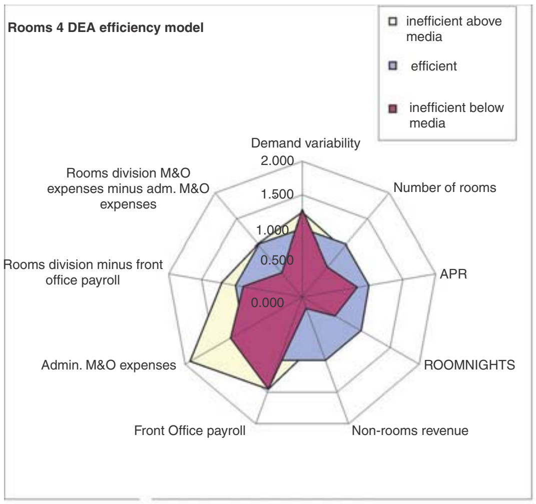
To better illustrate how the disaggregated inputs and outputs determine productivity frontiers, the configuration of inputs/outputs of three groups of hotels was calculated: 100% efficient hotels; inefficient hotels with a DEA score above the median; inefficient hotels with a productive score below the median. The median rather than the average DEA score was used as a cut off point among hotel types, as DEA scores were not normally distributed (none hotel was less than 30% productive). A radar plot was used for visually representing the configuration of the inputs/outputs of the three types of hotels. The dimensions of the radar plot correspond to the ratios of the average input/output scores of the inefficient units to the average input/output scores of the efficient units. These ratios rather than the raw average scores of inputs and outputs for each hotel group were calculated (Table 5) and plotted (Figure 2), because inputs/outputs were measured in different units (e.g., responses varied from one-digit numbers–number of rooms–to five-digit numbers–revenue) and so, average scores would not allow easy illustration in a radar plot.

Figure 2 shows the productivity frontiers and input/output configuration of the three hotel groups. One hundred percent efficient hotels clearly outperform other hotels in the management of all productivity determinant factors. Specifically, although of a smaller room capacity than the efficient units, the inef-

TABLE 5. Average and Ratio Scores of Inputs/Outputs per Efficiency Type of Hotel

	Efficient units (1)	Units above the median score (2)	Units below the median score (3)	Ratio (1)/(1)	Ratio (2)/(1)	Ratio (3)/(1)
Demand variability	2.909091	3.62069	3.741935	1	1.245	1.286
Number of rooms	107.303	100.1034	63.3871	1	0.933	0.591
ARR	64.80364	56.35517	53.91935	1	0.87	0.832
Roomnights	28,760.52	24,967.83	15,943.26	1	0.868	0.554
Non-room revenue	379,005.9	265,789.8	73,044.6	1	0.701	0.193
Front office payroll	96,134.18	140,326.6	139,981.8	1	1.46	1.456
Adm. M&O	92,559.97	177,697.2	113,250.9	1	1.92	1.224
Rooms payroll minus front office payroll	312,605.8	373,208	277,538.5	1	1.194	0.888
Rooms M&O minus administration M&O	254,717.7	258,274.5	116,484.5	1	1.014	0.457

FIGURE 2. Configuration of Productivity Determinant Inputs/Outputs in Step 4 DEA Productivity Model in Rooms Division



ficient units below the median (59% of the rooms of the efficient units) only achieve 55% of the roomnights of the efficient units, meaning that they achieve 4% less roomnights than would be expected due to their smaller room capacity. The former also achieve only the 83% of the ARR and the 19% of the non-room revenue of the efficient units and despite their smaller size they spend 105.6% and 122.4% of the front office payroll and administration non-payroll expenses of the efficient units. The overspend in resources is less for other payroll and other non-payroll expenses than the previous expenses (88% and 45% of those of the efficient units respectively), which illustrates the fact that it is the former expenses rather than other payroll and other non-payroll expenses that significantly determine efficiency.

On the other hand, relative to the efficient units, inefficient units above the median are doing better than the inefficient units below the median in terms of ARR and non-room revenue (the former achieve 87% of the ARR and 70% of the non-room revenue of the efficient units). The same is true in terms of expenses management. So, the inefficient above the median have similar overspends in terms of front-office payroll, administration non-payroll expenses, other payroll and other expenses as inefficient units below the median. However, as the former are of a greater room capacity than the latter, this overspend is easier justified. However, when comparing the inefficient above the median with the efficient units, it is evident that although the former have 93% of the efficient units room capacity, they achieve proportionally fewer roomnights (86% of the efficient units roomnights meaning 7% fewer roomnights than expected). Moreover, although efficient units are of a smaller size inefficient units, the latter achieve less ARR and non-room revenue than the efficient units (87% and 70% respectively). Overall, inefficiencies are attributed to both underachievement of outputs and overspend of inputs.

However, for an operations manager, it is not only important to find how productive the operation is, but also to identify ways to improve productivity. DEA can also estimate how much outputs could be increased and/or the magnitude of inputs that could be conserved by each unproductive hotel. Table 3 provides (% in parentheses) the average amount of improvement for each productivity determinant input/output in the hotel dataset. Although individual amounts of improvement can be obtained for each individual hotel, average amounts of improvement are provided here (mainly for reasons of economy) to illustrate the value and use of this type of analysis. ARR and roomnights consist the major areas of improvement and so the application of appropriate managerial techniques, e.g., yield management, multi-channel distribution strategies, should be considered. However, because it is unrealistic to argue that a manager should also aim to reduce demand variability (as it is an uncontrollable/external factor), the following analysis is conducted for identifying appropriate improvement strategies for each hotel.

An operational-market productivity matrix was developed in order to categorise hotels based upon their type/reason for being productive (Table 6). The DEA model including demand variability (step 4) reflects combined productivity, which refers to the ability to be operational efficient while also effectively managing/coping with market conditions. On the other hand, when demand variability is not included (step 3), the DEA score reflects only operational productivity measuring the ability

TABLE 6. Operational-Market Productivity Matrix in Rooms Division

Market productivity	Inefficient (In Step 3)	Efficient (In Step 3)
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: Min = 1 Max = 4 Aver. = 1.7*	**Cluster 4** *Units:* 14 *Hotels:* 8, 9, 15, 17, 23, 27, 39, 51, 65, 73, 74, 76, 88, 90 *Demand Variability score: Min = 1 Max = 6 Aver. = 4.5*
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: Min = 1 Max = 9 Aver. = 3.6*	**Cluster 2** *Units:* 2 *Hotels:* 89, 91 *Demand Variability score: Min = 2 Max = 6 Aver. = 4*
	Operational productivity	

of hotels to efficiently manage their production operations only. In other words, hotels that were inefficient in step 3, but became efficient in step 4 attribute their efficiency to the fact that they can effectively manage demand variability (and so, they are market efficient only), while inefficient hotels in both step 3 and 4 are both operational and market inefficient. Hotels in cluster 3 (operational inefficient hotels, but market efficient–as they became efficient only in step 4) need to improve their operational efficiency by improving their operating system and processes. Hotels in cluster 2 represent hotels that although were found efficient in step 3, they became inefficient in step 4 when demand variations were considered, and so they need to better manage their operating system in light of the market conditions. Hotels in cluster 1 represent hotels that were found inefficient in both step 3 and 4 and so, they need to improve their productivity by configuring a more efficient operating system while also controlling (managing or exploiting) demand levels.

Productivity Measurement in the F&B Division

For developing the DEA productivity metric in the F&B division, the same stepwise process was undertaken (Table 7 and Table 8). Aggregated metrics were used in step 1, DEA scores were calculated and then correlated with disaggregated inputs/outputs. When significant correlations were found and a cause and effect relationship existed between variables, disaggregated inputs/outputs were included into the model. A robust model is concluded (step 3) when no other significant correlations between DEA scores and disaggregated inputs/outputs are found. Findings illustrated that the following factors determine productivity in the F&B division: F&B revenue, percent of banqueting covers to restaurant covers, F&B capacity, F&B payroll, F&B M&O expenses and demand variability.

Specifically, the significant positive correlation between DEA scores and percent of banqueting covers to restaurant covers indicated that banqueting covers contributed to more efficient F&B operations than restaurant covers. The positive productivity impact of banqueting covers is not surprising when considering that banqueting operations are more predicable, standard and streamlined as well as less labor and material consuming operations than restaurant business (Jones, 1988; Levitt, 1972). Because of that, strategies aiming at increasing the percentage of banqueting covers served were found to have the greatest

TABLE 7. Input and Output Metrics Included in the Stepwise DEA in FB

	Step 1 (input min)	Step 2 (output max)	Step 3 (output max)
Outputs			
FB total revenue	*	*	*(37.3%)
Ratio of banqueting to restaurant covers			*(43.2%)
Inputs			
Total FB capacity (banqueting and restaurant seats)	*	*	*(2.3%)
FB payroll	*	*	*(24%)
FB material and other expenses	*	*	*(17.1%)
Demand variability (uncontrollable input)		*	*N.A.
Other inputs/outputs and factors correlated with DEA scores in all steps			
DEA inputs: % of roomnights from: repeat customers, business, leisure, conference and other; occupancy; total capacity; number of restaurant seats; banqueting max capacity; F&B M&O expenses; F&B payroll; roomnights; number of: full time and part time staff; % of payroll for full time staff. **DEA outputs:** number of: restaurant covers served, banqueting covers served; % of: banqueting served to total covers served, restaurant served to total covers served, banqueting served to restaurant covers served; total covers served; F&B revenue; hotel profit.			

*Indicates that a variable is included in the DEA model.

potential for improving F&B productivity (43.2% average improvement). The radar plot illustrating how these disaggregated factors affect the F&B productivity frontiers was also constructed (Figure 3).

Below the median inefficient units have 82% and 89% of the restaurant and banqueting capacity of the efficient units but they achieve proportionally less revenue than the efficient units would have achieved with the same capacity (slack/underused resources); specifically, they achieve 40% of the efficient units' revenue meaning approximately 40% (82% – 40%) less revenue than what they would have been expected to achieve. Below the median inefficient units also make a proportionally greater use of resources. They achieve 40% revenue of efficient units with 52% and 74% of the payroll and non-payroll expenses of the efficient units, meaning that they overspend 12% (52% – 40%) in payroll and 34% (74% – 40%) in non-payroll expenses than they would have expected if they were going to be considered as efficient.

On the other hand, above the median inefficient units are doing better than below the median inefficient units in terms of using their capacity and controlling their expenses. In particular, above the median inefficient units have the 88% and 93% of the restaurant and banqueting capacity of efficient units (they are of greater banqueting capacity than units below the median) but they achieve the 72% of the revenue of the efficient units, meaning approximately 18% less revenue than expected (instead of 40% as the below the median units). In the same vein, the 72% revenue is achieved with 73% of payroll and 94% of the non-payroll of the efficient units, which means that actually units above the median can control their payroll as efficiently as the efficient units (only 73% – 72% = 1% expected difference), while they are overspending in terms of non-payroll expenses (94% – 72% = 22%), but which is still less than that of the below median units.

However, because demand variability was included in the F&B DEA analysis from step 2, it was not possible to distinguish between operational and market efficiency and develop the market-operational productivity matrix.

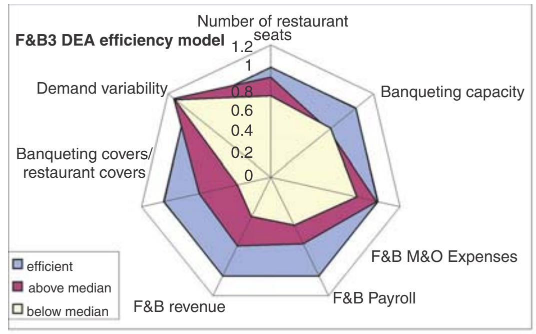
Productivity Measurement at the Hotel Property Level

Based on the findings of the previous DEA analysis in the rooms and F&B division, a robust DEA hotel property productivity metric was constructed by including in a single DEA model all the previously identified disaggregated inputs/outputs determining departmental productivity. Specifically, the hotel property DEA model considered the following five outputs (ARR, roomnights, non-roomnights

TABLE 8. DEA Scores in F&B Division

Hotel	Step 1	Step 2	Step 3	Hotel	Step 1	Step 2	Step 3
1	84.38	85.34	85.14	50	81.43	100	100
2	25.85	25.82	37.91	51	88.74	100	100
3	69.07	69.23	74.08	52	51.43	55.72	47.57
4	73.5	87.35	94.53	53	72.66	73.98	91.93
5	100	100	87.37	54	80.65	78.72	90.59
6	51.28	71.31	80.06	55	65.14	72.21	74.88
7	76.21	78.2	99.94	56	60.44	62.29	67.92
8	52.03	52.26	100	57	61.42	63.2	53.31
9	95.38	81.02	100	58	62.68	64.26	68.06
10	90.59	92.59	100	59	45.62	45.99	72.67
11	49.42	60.79	65.39	60	82.19	82.91	83.95
12	58.73	60.5	87.2	61	49.76	51.65	80.06
13	65.06	66.98	89.35	62	57.68	82.24	85.1
14	65.7	65.48	72.33	63	52.5	54.03	79.31
15	61.77	61.73	100	64	59.62	60.94	72.95
16	69.61	100	67.91	65	81.35	83.24	100
17	65.7	100	100	66	65.24	73.21	98.58
18	52.03	53	63.77	67	87.58	86.7	86.24
19	77.02	78.36	80.67	68	100	78.01	82.22
20	62.98	63.92	68.19	69	55.86	56.2	82.28
21	86.27	86.23	88.96	70	42.37	43.45	85.42
22	74.24	74.53	76.38	71	41.41	42.02	87.39
23	69.31	73.84	100	72	43.56	100	61.34
24	85.87	88.72	92.82	73	92.28	92.7	100
25	61.02	96.86	96.7	74	100	100	100
26	85.98	88.45	99.11	75	96.66	100	54.42
27	82.34	85.43	100	76	100	100	100
28	97.53	99.13	92.87	77	44.68	46.06	46.73
29	50.87	64.22	85.86	78	51.08	51.58	86.53
30	65.68	66.28	57.01	79	68.67	81.56	87.76
31	63.78	64.65	67.19	80	45.13	57.92	75.25
32	22.13	51.79	39.49	81	66.78	84.88	85.33
33	76.13	79.19	60.6	82	83.73	86.21	82.9
34	53.7	100	60.79	83	44.37	46.21	71.6
35	32.91	39.53	35.16	84	50.5	70.77	86.54
36	55.82	57.39	68.82	85	50.84	51.85	82.14
37	53.96	74.3	74.21	86	72.76	84.38	93.54
38	63.88	65.88	44.66	87	94.78	96.48	99.21
39	43.33	43.32	100	88	70.02	71.1	100
40	72.92	76.34	64.29	89	65.35	66.64	100
41	89.85	100	81.43	90	60.48	62.38	100
42	100	100	61.54	91	92.62	95.1	100
43	37.24	61.29	94.56	92	51.88	61.29	70.86
44	44.69	63.54	49.13	93	56.62	62.27	71.23
45	53.09	54.89	54.07				
46	58.53	58.96	73.84				
47	59.48	79.39	65.95				
48	59.96	85.25	88.36				
49	100	100	51.39				

FIGURE 3. Configuration of Productivity Determinant Inputs/Outputs in Step 3 DEA Productivity Model in F&B Division



revenue, F&B revenue, 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, demand variability). Following the same process as described before, the following calculations were conducted for identifying appropriate productivity improvement strategies: average improvement for each factor, combined (demand variability is included in the DEA model), operational (demand variability is not included in the DEA model) productivity scores. The operational-market productivity matrix was also developed in order to identify the hotels that were market efficient or market inefficient.

Impact of Contextual Factors on Productivity

Since the DEA productivity metrics were argued to be robust, productivity differences amongst hotels can be attributed to other factors that the stepwise DEA has not so far considered. Statistical tests were conducted for investigating the productivity impact of the following factors (Table 9): hotel location; hotel design; ownership structure; management arrangement; market segments served; repeat customers; distribution channels used.

Location was not found to affect productivity, which was quite surprising. However, hotel location may significantly determine levels of demand variability. Indeed, an ANOVA test (0.007, $\alpha = 0.05$) revealed that hotels located

TABLE 9. Impact of Contextual Factors on Productivity Metrics

	Rooms division			F&B	Hotel property		
	Oper.	Mark.	Comb.	Comb.	Oper.	Mark.	Comb.
Hotel location (ANOVA test)							
Hotel design (ANOVA test)	* F = 6.910, Sign. 0.002, df = 2 **31 rural hotels** (67.0, 19.7) **25 city cent. hotels** (68.1, 17.7) **37 rural hotels** (81.4, 15.9)				* F = 5.502 Sign. 0.006 df = 2 **31 rural hotels** (85.2, 16.6) **25 city cent. hotels** (89.9, 11.4) **37 rural hotels** (95.3, 8.1)		
Ownership structure (T-test)			* t = −2.541 df = 91 Sign. 0.013 **48 indiv.** (71.1, 18.8) **45 chain** (75.0, 18.9)	* t = −3.305 df = 91 Sign. 0.001 **48 indiv.** (78.4, 19.4) **45 chain** (87.4, 13.9)	* t = −2.878 df = 91 Sign. 0.005 **48 indiv.** (86.9, 14.4) **45 chain** (94.3, 10.0)		
Management arrangement (ANOVA test)			* F = 3.456 Sign. 0.036 **28 indep.** (75.8, 18.9) **47 chain** 86.3, 15.2) **18 ind&consor** (84.5, 18.4)	* F = 3.677 Sign. 0.029 **28 indep.** (75.8, 18.9) **47 chain** 86.3, 15.2) **18 ind&consor** (84.5, 18.4)			
% of roomnights from business, leisure, conference (Pearson correlations)							
% of roomnights from repeat customers (Pearson correlations)							
% of reservations from property owned system, third parties, Internet (Pearson correlations)							

*Indicates a significant effect ($\alpha = 0.05$)
Numbers in parenthesis give Average DEA score and standard deviation.

in rural places faced significantly higher fluctuations in demand than hotels in city centers. Thus, it can be argued that the impact of hotel location on productivity has already been incorporated into productivity scores when demand variability was included into DEA models. In accordance with previous studies (e.g., McKinsey Global Institute, 1998), hotel design was found to significantly affect operational productivity in rooms division and hotel property level. Specifically, purpose built hotels significantly outperformed old and/or traditional properties. Chain owned hotels significantly outperformed independently owned hotels in terms of combined productivity in rooms and F&B and in terms of operational productivity in hotel property level. Independently managed hotels had significantly lower combined DEA productivity scores in rooms and F&B. This might be explained by the fact that chain managed hotels as well as hotels of a consortium have access and are promoted to several distribution and reservation systems that in turn can significantly impact on demand and capacity levels management. Chain managed hotels were also previously found to practice more sophisticated management techniques, e.g., labor scheduling, demand forecasting, that independent hoteliers were not even familiar with (McKinsey Global Institute, 1998; Johns & Wheller, 1991).

However, repeat customers, market segments served and distribution channels used were not found to have a significant impact on productivity. Sigala (2002) also reported that Internet reservations and the use of electronic distribution channels had none impact on hotel productivity for two major reasons. First, electronic channels were not integrated with existing computer systems and databases, which meant that a lot of manual work was required for data entry and updates, while errors were easy to make (e.g., over/under-bookings). Lack of systems integration is also claimed to inhibit the effective practice of yield management across distribution channels as well as the maximization of profit per loyal customer and hotel location in the case of hotel chains (Sigala et al., 2001). Moreover, as the very small percentage of Internet reservations were not found to positively affect productivity, Sigala (2002) concluded that a threshold level of Internet reservations is required in order to counterbalance the new types of expenses involved for online distribution (e.g., website development, maintenance, promotion and online hotel rates discounts/offers).

CONCLUSIONS

The paper aimed to illustrate and advocate the value of using a stepwise approach to DEA for measuring productivity and identifying appropriate productivity improvement strategies in the hotel sector. To that end, the problems of productivity measurement and the different productivity methods were reviewed and debated, while the advantages of the stepwise DEA were analysed and illustrated by gathering data from the three star hotel sector in the UK. DEA provides an overall productivity metric that can be easily interpreted, used as a tool for identifying specific local problems and so, deciding appropriate strategies for improvement. In addition, a stepwise approach to DEA was proposed for identifying and considering only the factors that significantly determine productivity frontiers. In this way, a robust productivity metric is obtained that can discriminate between efficient and inefficient units as well as identify the reasons of efficiency of the former and the areas of improvement of the latter. Overall, the proposed stepwise DEA can overcome productivity measurement problems related with: the simultaneous manipulation of several inputs/outputs and productivity determinant factors irrespective of their units of measurement; the "ceteris paribus" problem; the impact of the level and/or unit of analysis on productivity measurement.

The evidence gathered from the three star hotel sector in the UK revealed that the following factors can significantly determine productivity in the rooms' division: ARR, number of roomnights, non-rooms revenue, number of rooms, front office payroll, administration and general M&O expenses, other payroll, other M&O expenses, demand variability. Findings also revealed that the following factors determine productivity in the F&B division: F&B revenue, percent of banqueting covers to restaurant covers, F&B capacity, F&B payroll, F&B M&O expenses and demand variability. However, the productivity impact of these factors has been confirmed by analyzing data from the three star hotel sector in the UK. Thus, 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 can produce interesting results and findings that can have both crucial academic and managerial implications. For example, one would apply DEA for investigating the productivity impact of different hotel locations and operational procedures.

The present paper demonstrated the use of DEA as a diagnostic tool for problems of capacity, demand and utilisation of resources. By using DEA, it was also possible to identify the areas of improvement and so the appropriate strategies that managers could use for increasing productivity. For example, yield management techniques and multi-channel distribution strategies are advisable for hotels that need to improve ARR and roomnights, while ICT applications are advisable for automating/streamlining front office processes and reducing front office expenses. In the F&B division, the pursuit of increasing the provision of banqueting services can significantly increase productivity. The analysis also provided another way that DEA can facilitate decision making. As demand variability was found to be a crucial productivity determinant, an operational-market matrix was developed in order to illustrate how hotel managers can identify the reasons of their inefficiency (operational and/or market inefficiency) and implement appropriate improvement strategies.

DEA productivity scores were robust, meaning that they discriminate between efficient and inefficient units after taking into consideration numerous inputs/outputs but finally including only those that significantly impact productivity. In this way, the "ceteris paribus" problem is overcome and productivity differences among hotels can be attributed to factors that have not so far considered. Thus, statistical tests were conducted for testing the impact of hotel location, design, ownership structure, management arrangement, market segments served, percentage of repeat customers and type of distribution channels used on productivity. Consistent with previous research, findings revealed that hotel design, management arrangement and ownership structure significantly affect productivity levels. Specifically, as independently owned and managed hotels had significantly lower productivity scores than chain managed hotels, it is suggested that the former would need to consider the adaption and implementation of more sophisticated operational and market strategies that the latter may have. To achieve that, independent hoteliers may need to seriously consider a hotel consortia membership that can provide them with access to and transfer them to technological resources and managerial know-how.

However, this study has some limitations that need to be acknowledged, but which at the same time lend themselves nicely towards identifying future research avenues. First, a more accurate metric for labour inputs would have been desirable. The study used the number of full-time and part-time employees as a proxy of labour resources. Full-time equivalent employee (FTE) metrics could have been used, but hotels hardly measure and have such figures (specifically, small independent properties; Sigala, 2002). However, the use of FTE would have more effectively investigated productivity issues regarding labour numerical flexibility. The study also argued that the aggregate, financial productivity outputs (such as revenue, payroll) should encapsulate soft, 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 identification of specific qualitative factors that can significantly determine productivity. Future research could actually try to develop better metrics for such quantitative dimensions and apply DEA for investigating their productivity impact. So, for example, aspects such as customer satisfaction and service quality could be considered. Indeed, because DEA can deal with soft, 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 so DEA would need to be combined with other research approaches and methodologies.

Despite of the above acknowledged limitations that can provide food for future research, the outcomes and methodology of this study provide useful and valuable findings for both academics and professionals. Research efforts for the replication, enhancement and refinement of the DEA methodology and its findings can significantly contribute to the body of knowledge. At the same time, DEA application requires the collection and analysis of many data and so professionals should seriously consider the establishment of procedures and systems for continuously and periodically gathering, benchmarking and monitoring their businesses' performance in key productivity input and output factors. The implementation of operational and information management systems and techniques is deemed crucial since the hospitality industry has been criticized for its lack of and/or unsophisticated approach to information systems and data collection (e.g., Johns et al., 1997; Sigala, 2002). As the operating environment of the hotel industry is highly competitive and more conducive to efficient operations, productivity measurement and benchmarking is a critical strategic issue, and so methodologies and procedures/systems to achieve the former become a strategic necessity.

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