Productivity in Hotels: A Stepwise Data Envelopment Analysis of Hotels' Rooms Division Processes

MARIANNA SIGALA, PETER JONES,
ANDREW LOCKWOOD and DAVID AIREY

Low productivity within service industries 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 productivity. The issues and problems regarding productivity measurement as well as the advantages of using DEA in productivity measurement are analysed. The article extends current DEA applications by developing a stepwise approach to DEA. The latter technique combines correlation and DEA analysis for developing robust models and sound productivity measurement. The advantages of the proposed methodology are illustrated by applying it to a dataset of three-star hotels in the UK. Six inputs and three outputs are identified as the factors affecting rooms division efficiency in three star hotels.

INTRODUCTION

Low productivity within service industries, and particularly the hospitality sector, has been identified as a source of concern by a number of authors [Witt and Witt, 1989; Johns and Wheeler, 1991; McKinsey Global Institute, 1998]. Witt and Witt [1989] and Witt and Clark [1990] presented an impressive body of evidence that poor productivity in the hospitality industry is related to a lack of understanding and application of quantitative and analytical techniques. Data envelopment analysis (DEA) has been used in response to these concerns and in a limited number of studies has been applied to performance and productivity benchmarking in the hotel industry [e.g. Morey and Dittman, 1995; Johns, Howcroft and Drake, 1997; Avkiran, 1999; Anderson, Fok and Scott, 2000; Tarim, Dener and Tarim, 2000; Wöber, 2000; 2002; Brown and Ragsdale, 2002]. However, the present article

Marianna Sigala is at the Business Administration Department, University of the Aegean, Michalon 8, Chios, Greece, GR-82100. Peter Jones, Andrew Lockwood and David Airey are at the School of Management, University of Surrey, Guildford, Surrey, GU8 4LL, UK.

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extends previous applications by proposing a stepwise approach to DEA for identifying the appropriate DEA inputs/outputs and developing robust DEA models.

The purpose of this article is to demonstrate the value of stepwise DEA for measuring productivity, identifying issues and envisaging strategies for productivity improvement. The article makes three contributions to the existing body of knowledge. First, in reviewing the literature, it consolidates the issues and concerns regarding the productivity concept and measurement by summarising them in a three-step framework. Second, it extends current applications of DEA by developing a stepwise DEA model to address and implement the proposed model for productivity measurement and management. Third, it develops and analyses a market-operational productivity matrix to isolate the productivity impact of demand factors and identify appropriate strategies for productivity improvement.

DEFINING AND MEASURING PRODUCTIVITY

Schroeder [1985] defined productivity as the relationship between inputs and outputs of a productive system. Although this concept of productivity is widespread, this definition is difficult to operationalise. In fact, a widely accepted productivity definition cannot be found in the literature [Brown and Dev, 1999; Johns, Howcroft and Drake, 1997]. Productivity means different things to different people [Prokopenko, 1987]. Different or even conflicting definitions and perceptions of productivity exist [Pickworth, 1987]. For instance, productivity has been approached as an umbrella concept including efficiency, effectiveness, quality, predictability and other performance dimensions, as well as a narrower concept reflecting only production efficiency.

Confusion and disagreement over the concept and definition of productivity create difficulties in productivity measurement. Whilst 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 organisation is doing things in the 'right' way, they may not indicate effectiveness and hence whether the organisation is doing the 'right' things.

Fitzimmons and Fitzimmons [1998] and Andersson [1996] identified three generic 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 and Witt, 1989]. Indeed, several authors [Sasser, Olsen and Wyckoff, 1978; Jones, 1988; Jones and Lockwood, 1989; Witt and Witt, 1989] 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 objectively to 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 in different circumstances.

Witt and Witt [1989] incorporate these issues into their identification of three problems regarding productivity measurement in hospitality, similar to the generic difficulties referred to previously:

- the 'definition problem';
- the 'measurement problem';
- 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. For example, there are distinctions to be made between input metrics such as 'per member of work-force', 'per man-hour' and 'per £100 wages' as the different units reflect different tangible and intangible elements. 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.

The selection of inputs/outputs is dependent on two issues. First the approach to productivity definition, namely a partial or total approach; and second 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 intan gible/qualitative elements, a multi-factor [Chew, 1986] or total factor view to productivity is proposed. 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 be 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. Specifically, in the hotel industry, research has shown that productivity can be significantly impacted by the following factors [Van der Hoeven and Thurik, 1984; National Economic Development Council, 1992; Johns, Howcroft and Drake, 1997; McKinsey Global Institute, 1998; Brown and Dev, 1999; Cizmar and Weber, 2000]:

- hotel size,
- location,
- service orientation,
- ownership and management arrangement;
- hotel age, design, type and number of facilities;
- demand patterns and variability;
- staff flexibility (reflected in the use of part-time and full time employees);
- marketing practices' effectiveness (e.g. distribution, promotion, frequent guest programs).

It has been argued that such factors, acknowledged as 'upstream' factors [Rimmington and Clark, 1996] or 'top-line' factors [Heap, 1992] should be included in productivity definition and measurement. Overall however, there is no conclusive agreement to whether such '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 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.

The selection of appropriate outputs/inputs is also related to and dependent on 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 and Wheeler, 1991]. Aggregated input/output metrics can be disaggregated at any level in order to construct a whole 'family' or '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 some times may lead to conflicting results [Baker and Riley, 1994].

Ball, Johnson and Slattery [1986] identified three main categories of measurement units namely, financial, physical and a combination of the previous two. For example, in developing their DEA model, Johns, Howcroft and Drake [1997] used simple inputs and outputs, no ratios or composite data were employed, and non-financial data were 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 et al. [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).

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 [Johns and Wheeler, 1991; Rimmington and Clark, 1996]. This is for two reasons. First, only if the intangibles are as they should be will customer levels be sustained and income earned. Second, 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.

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, but their major limitations are 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 combines 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 such a way that it does not directly relate certain inputs with outputs but it rather highlights the interrelationships and trade off between all of them.

Production function techniques consider multiple inputs and outputs simultaneously, and so have been widely used for productivity studies. However, being parametric techniques they assume a functional form for the technology transforming inputs into outputs and so, they can suffer from specification error. On the other hand, because in many cases there is no known functional form for the production function, and, so, it may be inappropriate to talk in terms of such a 'production' function, a non-parametric approach for cons tructing the production function may be used. Under this approach no assumptions are made about the form of the production function. This will necessarily be piecewise linear, and as such, would be an approximation to the 'true' function, if such a one existed.

DATA ENVELOPMENT ANALYSIS

DEA is such an approach and so, it has been heavily applied for productivity measurement. 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 and Rhodes, 1978; Charnes et al., 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 and Bu-Bhsait, 1993].

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

$$\text{Max } \mathrm{h_o} = \frac{\sum_{r=1}^{t} U_r Y_{rj0}}{\sum_{i=1}^{m} V_i X_{ij0}} \text{(M1)}$$

subject to

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

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

Y_{rj} and X_{ij} are the amount of the rth output and the ith input for the jth hotel, and $\mathrm{U_r}$ and $\mathrm{V_i}$ are the weights to be estimated by the data of all comparable hotels that are being used to arrive at the relative productivity for the oth hotel. The model has t output variables, m input variables and n hotels. In practice, the DEA model M1 is first linearised 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 [Boussofiane, Dyson and Thanassoulis, 1991; Dyson, Thanassoulis and Boussofiane, 1990]:

$$\text{Max } \mathrm{h_o} = \sum_{r=1}^{t} U_r Y_{rj0} \text{ (M2)}$$

subject to

$$\sum_{i=1}^{m} V_i X_{ij0} = 1 \text{ (say).}$$

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

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

If a hotel 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 per cent productive as compared with other hotels of the dataset. Other hotels, using these inputs less efficiently, will locate above the frontier isoquant and their productivity score will be smaller than 1. For example, a hotel having the productivity score of 0.75 can be interpreted as being 75 per cent as productive as a hotel on the frontier isoquant.

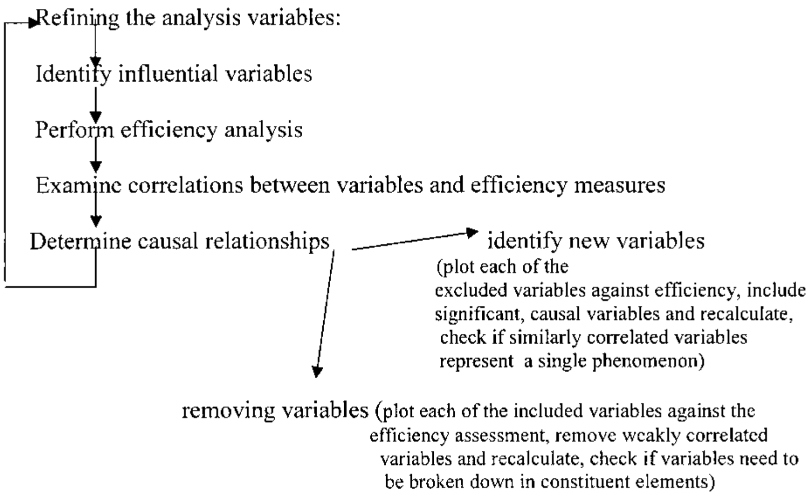
Overall, DEA's advantages relative to the previous techniques are summarised as follows [Sengupta, 1988; Banker and Thrall, 1992; Cooper, Seiford and Tone, 2000]:

- 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 per cent 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 pre- specified.
- 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 be used for considering external factors that can affect productivity in order to overcome in some extent the 'ceteris paribus' problem. Dyson, Thanassoulis and Boussofiane [1990] 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 the 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

FIGURE 1
STEPWISE APPROACH TO DEA



that correlate with the measure of efficiency and applying judgements 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] and Sigala [2003] 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.

However, being a non-parametric technique DEA does not allow for random deviations from the efficient frontier which in turn tends to over-estimate X-inefficiencies. To address this, studies have also applied stochastic frontier approaches [initially proposed by Aigner, Lovell and Schmidt, 1977]. The latter incorporate a two-part error term: one part assumes normal distribution and captures random error, the other reflects inefficiencies assuming different common distributions, e.g. half-normal, exponential and truncated distributions. Thus, stochastic production functions assume the existence of technical inefficiency of different firms such as that for specific values of factor inputs, the levels of production are less than what would be the case if firms were fully technically efficient. Although the majority of earlier applications of frontier production functions involved cross-sectional data, more recent studies have applied them in the analysis of time-series data on firms involved in production [Battesse and Tessema, 1993]. Thus, initially the firm effects associated with the existence of technical inefficiency were assumed to be time-invariant random variables or independent and identically distributed over time. More recently, models of frontier production functions have been proposed in which firm effects associated with technical efficiency are assumed to be time varying [e.g. Battese and Coelli, 1988; 1992; 1995; Kumbhakar, 1990]. To achieve that frontier functions model analyse panel of data from different time periods. Similar panel data analysis can also be achieved by DEA models [e.g. Avkiran, 1999]. However, the purpose of this article is not to illustrate this sophisticated process of determining and measuring the time impact on productivity but rather to illustrate the benefits of using DEA on productivity measurement and benchmarking. This is argued to be the first step into the adoption of DEA.

RESEARCH AIMS AND METHODOLOGY

The main purpose of this article is to develop and illustrate the value of using the stepwise DEA approach for developing robust productivity models that can in turn be used for determining appropriate productivity improvement strategies. A productivity model is considered as robust when it constructs productivity frontiers by identifying and simultaneously considering the multiple inputs/outputs/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 respondents. 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 three-star hotels in 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 of data confidentiality and a follow-up letter, 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 reasons of confidentiality. Overall, 93 questionnaires were received out of 1,233 hotels contacted.

STEPWISE DEA METHODOLOGY

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 to be 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 might affect productivity. Moreover, a 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 the productivity of the rooms division of hotel properties and so, productivity inputs/outputs were identified and measured at the rooms division level. However, because hotels are made up of different departments, with different characteristics and so with different factors determining their productivity [Baker and Riley, 1994; Johns and Wheeler, 1991], an aggregate productivity metric and model may obscure and hide trade-offs among productivity variables. Moreover, productivity levels are impacted by the complementarities, synergies and trade-offs among several resources as well as outputs. To address these issues, both disaggregated and aggregated metrics of inputs and outputs were gathered and simultaneously analysed through the stepwise DEA approach for the following departments: front office, housekeeping, telephone/switchboard, minor operations, administrative and general, marketing, maintenance. Concerning inputs, departmental as well as aggregated metrics were gathered and distinguished into the following resources: human, physical/capacity and material. A distinction between full and part time staff was made. Although the full time equivalent employee (FTEE) metric provides a more reliable metric to measure human inputs, this was not used as hoteliers rarely track and record this metric. Instead, two metrics were gathered and analysed as proxies of human inputs: a physical metric namely the number of full-time (broken down into departments) and part-time employees; a financial metric namely the percentage of annual payroll paid to full-time employees.

Regarding the different factors that could impact on productivity the following data were gathered: hotel size, design, location, ownership structure and arrangement, market segments served, distribution channels used, percentage of repeat guests. Table 1 summarises the productivity inputs/outputs and factors as well as their operationalisation that were considered in the stepwise DEA process. The selection and use of these constructs and metrics 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

TABLE 1
PRODUCTIVITY INPUTS, OUTPUTS AND FACTORS INFLUENCING PRODUCTIVITY

Hotel productivity inputs included: number of rooms and bedspaces; number of full time employees in front office, housekeeping, 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, telephone/switchboard, minor operations, administrative and general, marketing, maintenance; annual energy expenses; annual management fees.

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

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

- location: rural, city centre or suburban [McKinsey Global Institute, 1998; National Economic Development Council, 1992; Johns, Howcroft and Drake, 1997].
- hotel design:old/traditional, redesigned/converted, purpose built [McKinsey Global Institute, 1998].
- ownership structure: independently or chain owned [Johns, Howcroft and Drake, 1997; Brown and Dev, 1999].
- management arrangement: independent management, chain management, independent management and consortia membership, franchise [NEDC, 1992; Van der Hoeven and Thurik, 1984; Brown and Dev, 1999; McKinsey Global Institute, 1998].
- demand variability [National Economic Development Council, 1992].
- a percentage of repeat guests [Cizmar and Weber, 2000].
- average length of stay: number of days [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 [Van der Hoeven and Thurik, 1984].
- distribution channels: percentages of total reservations received through a property owned system (e.g. telephone), third parties and Internet [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].
- hotel size: number of rooms, bedspaces [Johns, Howcroft and Drake, 1997; National Economic Development Council, 1992; Van der Hoeven and Thurik, 1984; Brown and Dev, 1999; McKinsey Global Institute, 1998].

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 relationship existed, disaggregated inputs/outputs were included into the DEA model and the relevant aggregated data were adjusted. Finally, a robust DEA model was determined where no other inputs/outputs were found to affect the DEA productivity score. At that stage, a robust productivity metric was constructed, as all potential factors that could affect productivity have been taken into account but 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 so far not considered.

ANALYSIS OF THE FINDINGS

The sample of hotels represented the diversity of the three-star hotel sector in the UK. Indeed, 51.6 per cent of respondents were independently owned with the remaining being owned by a hotel chain. Concerning management arrangements, 50.54 per cent of respondents were managed by a hotel chain (two on a management contract), 30.11 per cent were independently managed while 19.35 per cent represent independents that were also members of a consortium. 39.7 per cent of respondents were located in the city centre, fewer (34.4 per cent) in rural locations and 25.8 per cent in suburban areas. Concerning hotel size, respondents' room capacity varied from 18 to 283 rooms (mean 90.4 rooms). Statistics regarding the number of employees revealed a similar diversity of size of operations; the minimum numbers of full-time and part-time employees were reported as four and two respectively, while maximum numbers were 143 to 155 respectively. Regarding the market segments served by respondents, on average 47.1 per cent of the annual room-nights were from business guests, 36.8 per cent from leisure guests, 11.3 per cent from conference and only 4.3 per cent from other guests, but the high standard deviations revealed that several respondents significantly differed from average values. Repeat customers represented on average 36.9 per cent of annual room-nights, while respondents received a great majority of their annual reservations (69.4 per cent) through property owned systems, fewer reservations (26.6 per cent) from third parties and only 3.4 per cent from the Internet. Great demand variations were also reported (see below).

Table 2 illustrates the application of the stepwise DEA approach in rooms division. 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 calculation of all intercorrelations between inputs and outputs for identifying whether increasing amounts of inputs lead to greater outputs. Avkiran [1999] 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. The DEA model assumed constant returns to scale, but its validity was tested by correlating the DEA scores obtained at all steps with a metric reflecting size of operation (number of rooms), 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 no outlier was found, all 93 hotels were included in the analysis.

Initially, the DEA model assumed input minimisation, meaning that hotels aim to maintain at least the same level of outputs (be effective) while minimising

TABLE 2
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 FB total revenue	*			
ARR		*	*	* (48.2%)
Room-nights		*	*	* (41%)
Non room-nights revenue		*	*	* (32.3%)
Inputs				
Rooms	*	*	*	* (5.4%)
Rooms division total payroll	*	*		
Rooms' division total material and other expenses	*	*		
Front office payroll			*	* (16.3%)
Administration material and other expenses			*	* (28.5%)
Other rooms' division payroll			*	* (12.1%)
Other rooms' division material and other expenses			*	* (8%)
Total demand variability				* N.A.

*indicates that a variable is included in the DEA model.
Other inputs/outputs and factors correlated with DEA scores in all steps.

DEA inputs: percentage 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; percentage of payroll for full time staff; payroll and material and other expenses in: front office, housekeeping, telephone, minor operations, marketing, administration.

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

Non FB total revenue refers to all hotel revenue except that obtained from the FB division, i.e. it includes revenue from room-nights, telephone and minor operations Non room-nights revenue refers to revenue obtained from telephone and minor operations.

Minor operations include activities such as laundry services, souvenirs' sales, that in three star hotel properties occupy staff from the rooms divisions department.

inputs (be efficient). However, it does not make sense to use input minimisation when uncontrollable inputs are included in the DEA analysis [Avkiran, 1999], 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. 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.

Using output maximisation at this point 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 $N \times M$ (where $N =$ number of inputs and $M =$ number of outputs) [Dyson, Thanassoulis and Boussofiane, 1990]. This is because there are $N \times M$ possibilities that units could be efficient and so, one could expect the identification of at least $N \times M$ units to be efficient. In this study, the use of three outputs and six 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 FB total revenue representing revenue from room-nights, 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 accounting for the labour 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-room-nights 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 and Thurik, 1984]. Thus, in constructing the DEA model at step 2, these three productivity determinants, disaggregated outputs were used instead of the non FB 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 room-nights 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. 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 and Wheeler, 1991; Jones, 1988]. The DEA score was then recalculated and correlated. As no other correlation was found between the new DEA score and disaggregated inputs/outputs (meaning that no 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, room-nights, non room-nights revenue, number of rooms, front office payroll, Administration M&O expenses, other rooms' division payroll, other rooms' division M&O expenses and demand variability.

DISCUSSION

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 become efficient because they can effectively manage and improve their ARR, room-nights (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 great interest and importance. Hotels that become efficient from step 2 to step 3 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 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 per cent 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 (no hotel was less than 30 per cent productive). A radar plot was used for representing visually 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 3) 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.

TABLE 3
AVERAGE AND RATIO SCORES OF INPUTS/OUTPUTS PER EFFICIENCY TYPE OF HOTEL

	Mean score for the group					
	Efficient units (A)	Inefficient above the median (B)	Units below the median score (C)	Ratio A/A	Ratio B/A	Ratio C/A
Demand variability	2.91	3.62	3.74	1	1.24	1.28
Number of rooms	107	100	63	1	0.93	0.59
ARR	£64.80	£56.35	£53.92	1	0.87	0.83
Room-nights	28,760	24,967	15,943	1	0.87	0.55
Non room revenue	£379,005	£26,5789	£73,044	1	0.70	0.19
Front office payroll	£96,134	£140,326	£139,981	1	1.46	1.46
Admin. M&O	£92,559	£177,697	£113,250	1	1.92	1.22
Rooms payroll minus front office payroll	£312,605	£373,208	£277,538	1	1.19	0.89
Rooms M&O minus administration M&O	£254,717	£258,274	£116,484	1	1.01	0.46

FIGURE 2
CONFIGURATION OF PRODUCTIVITY DETERMINING INPUTS/OUTPUTS IN STEP 4 OF THE DEA PRODUCTIVITY MODEL

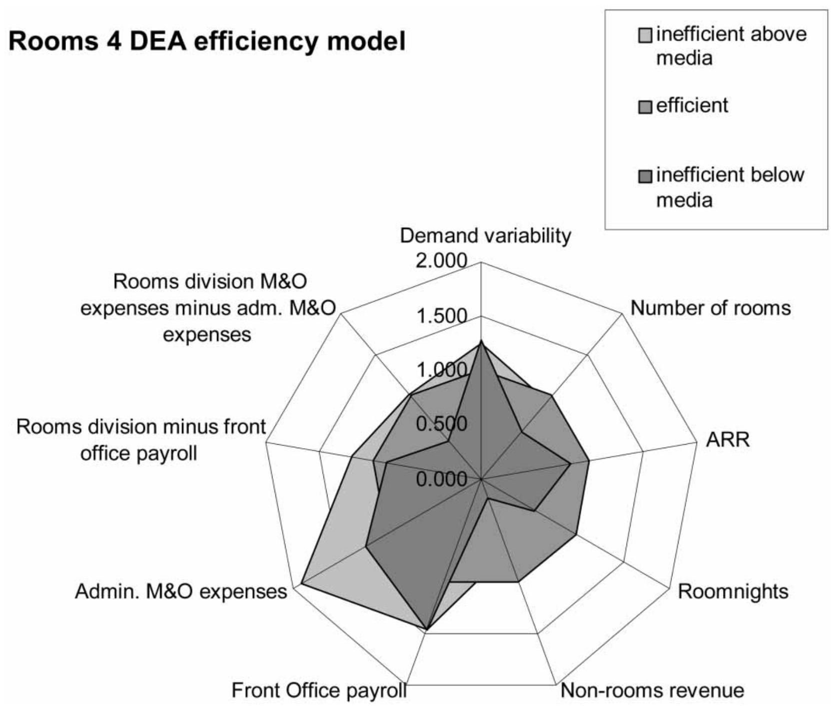


Figure 2 shows the productivity frontiers and input/output configuration of the three hotel groups. 100 per cent efficient hotels clearly outperform other hotels in the management of all productivity determining factors. Specifically, although having smaller rooms capacity than the efficient units, the inefficient units below the median (59 per cent of the rooms of the efficient units) only achieve the 55 per cent of the room-nights of the efficient units, meaning that they achieve 4 per cent fewer room-nights than would be expected due to their smaller room capacity. The former also achieve only 83 per cent of the ARR and 19 per cent of the non-room revenue of the efficient units and despite their smaller size they spend 1,456 per cent and 1,224 per cent 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 per cent and 45 per cent 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 per cent of the ARR and 70 per cent of the non-room revenue of the efficient units). The same is true in terms of expenses management. So, the inefficient above the median units 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 per cent of the efficient units room capacity they achieve proportionally fewer room-nights, (86 per cent of the efficient units room-nights meaning 7 per cent fewer room-nights than expected). Moreover, although efficient units are of a smaller size than inefficient units, the latter achieve less ARR and non-room revenue than the efficient units (87 per cent and 70 per cent respectively). Overall, inefficiencies are attributed to both underachievement of outputs and overspend of inputs.

Since the DEA productivity metrics were argued to be robust, productivity differences amongst hotels can be attributed to factors that the stepwise DEA has not so far considered. Statistical tests were conducted for investigating the productivity impact of the following factors: 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 in rural locations faced significantly higher fluctuations in demand than hotels in city centres. 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 in the DEA models. In accordance with previous studies [e.g. McKinsey Global Institute, 1998], hotel design was found to affect operational productivity significantly.

Specifically, purpose built hotels significantly outperformed old and/or traditional properties. Hotel chain-owned hotels significantly outperformed independently owned hotels in terms of combined productivity. This might be explained by the fact that chain-managed hotels as well as hotels linked to a consortium have access and are promoted to several distribution and reservation systems that can in turn significantly impact demand and capacity management. It was also previously found that chain-managed hotels practice more sophisticated management techniques, e.g. labour scheduling, demand forecasting, that independent hoteliers were not even familiar with [McKinsey Global Institute, 1998; Johns and Wheeler, 1991].

However, repeat customers, market segments served and distribution channels used were not found to have a significant impact on productivity.

CONCLUSIONS

The article 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. The DEA provides an overall productivity metric that can be easily interpreted, is 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 for the efficiency of the former and the areas of improvement of the latter. Overall, the proposed stepwise DEA can overcome productivity measurement problems related to:

- the simultaneous manipulation of several inputs/outputs and productivity determinant factors irrespective of their units of measurement;
- the ‘ceteris paribus’ problem; and
- 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:

- average room rate (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.

Future research could investigate whether the same conclusions can be replicated and generalised in different hotel segments and/or countries.

Statistical tests were conducted for 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 adoption and implementation of more sophisticated operational and market strategies.

However, this study has some limitations that need to be acknowledged, but which at the same time lend themselves 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 few hotels use this measure and so have such figures available. 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) could be seen to encapsulate soft, qualitative dimensions of productivity inputs/outputs such as customer satisfaction and employees 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 also 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.

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