

# The use of DEA (Data Envelopment Analysis) methodology to evaluate the impact of ICT on productivity in the hotel sector

Cidália Leal Paço & Juan Manuel Cepeda Pérez

The aim of this document is to propose a conceptual framework, based on a synthesis of the extant literature on this subject. This will illustrate how applications of information and communication technologies (ICT) can lead to a competitive advantage in hotel firms. DEA methodology is used to do so. This research will supply an appropriate approach for the selecting of inputs and outputs measurements in order to study the performance of hotels' services. In terms of results, various areas must be carefully evaluated in the development and implementation of ICT projects in order for them to give rise to a competitive advantage in hotel firms. When the decisions about ICT in hotels are analysed, there are four closely-related spheres. These are: the coherence between the business strategy and the ICT decisions, the types of ICT applications, the benefits expected from the ICT decisions and the decision-making style. The advance and complexity of technology, the management capacities and the integration of the resources are key questions in the application of ICT decisions.

Investments in ICT applications in hotels can lead them to greater ICT skills and capacities. These can later give rise to a lower cost, greater agility, innovation, added value for customers and better customer service. However, not all ICT investments become positive results or their results may last little time. Furthermore, there can be an interval of time between the decision of investing in ICTs and the obtaining of the results desired. Regarding the practical implications, there are various areas and subjects which must be taken into account in the preparing and applying of ICT investment decisions for them to contribute to the firm's competitive advantage. Hotel firms have to be selective in their ICT investment decisions. This article is one of the first in the hospitality sector field which offers a theoretical framework about how ICT applications can lead to a competitive advantage in hotels. Likewise, due to its theoretical and practical implications, it will be able to help hotel managers and researchers in the evaluation of ICT projects in hotel firms.

## Measurements of hotel performance

### *Classical measurements*

The literature on hotel management presents different studies which try to measure the efficiency and the performance of hotel firms. Much of the research uses the analysis of classical ratios and/or aggregated indices of market performance. Other works are centred on the behaviour of the revenues (Baker and Riley, 1994).

Wijeysinghe (1993) uses a general indicator of the efficiency of the hotel occupancy which examines the breakeven occupancy rates and develops an integrated system of management efficiency. This indicator is used to analyse and identify the causes of management inefficiency. Kimes (1989) uses a Perishable Asset Revenue Management (PARM) technique to measure performance in the hotel industry. PARM allows the administration to work out the best balance between the average daily rate and the occupancy rate. Questions related to PARM include overbooking, the class allocation rate and the length of the stay.

Gustke and Van Doren (1982) utilise the sales information to measure the sector's performance. These authors estimate economic growth in various states and metropolitan areas via the examining of the aggregated revenues and per capita revenue. This technique is useful to evaluate the hotel performance at the aggregated level, but it does not foresee specific measurements of the firm's performance.

The lodging index proposed by Wassenaar and Stafford (1991) offers an alternative indicator for the hotel sector's performance. This index is defined as the average revenue obtained for each room during a specific period of time. The authors suggest that the index is effective for destinations where the lodging average and the prices are not available. They state that it is a useful statistic as it reflects the revenues per room - a matter which concerns professionals. It combines the average

lodging rates and prices in a unique indicator. This reduces the potential ambiguity of evaluating various indicators, such as the ratio analysis.

Cost-volume-utility techniques – also called cost-volume-profit – have been used to analyse the performance of individual firms and can be applied at a regional level to compare various kinds of firms. This analysis is useful to the extent that it examines how firms turn volume of activity into profit (Coltman, 1978 and Fay et al, 1971).

#### *Technique of frontier efficiency and the measurement of performance*

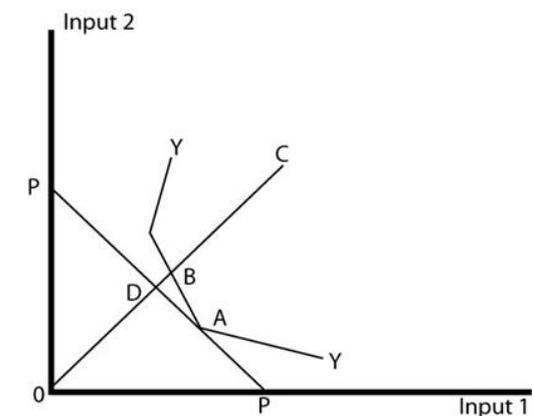
Other techniques compare the efficiency of similar organisations, explicitly considering the application of various inputs to produce various outputs. These efficiency techniques are generally divided into two categories. The first is made up of Data Envelopment Analysis (DEA) models. The second category consists of a set of regression-based techniques. These stem from estimations of the inefficiency in terms of error and are called Stochastic Frontier Analysis (SFA). Both techniques use a sample of firms to construct an efficient production frontier. The frontier is efficient in the sense that a firm that operates on the frontier cannot increase production without augmenting its inputs, or will not be able to reduce the use of inputs without reducing the output. Deviations from the frontier represent inefficiencies. These are called X inefficiencies in the financial and economics literature (Leibenstein, 1978, p. 204). Efficiency frontier techniques avoid the need to develop a standard cost for each service and are broader and more reliable than the use of a set of working ratios and profit measurements. These techniques allow service organisations to identify the units which are relatively inefficient, to determine the magnitude of the inefficiency and to propose alternative strategies to reduce it - all this in a composite measure. Furthermore, these techniques provide an estimation of the global efficiency of the sector in question.

#### *DEA (Data Envelopment Analysis) Methodology*

The first DEA model, proposed by Charnes, Cooper and Rhodes (1978)- named DEA-CCR in homage to their authors- had an input orientation and supposed that there were constant returns to scale (CRS). This methodology seeks to establish which firms of a sample determine the envelopment surface or efficient production frontier. The radial distance of a firm towards its frontier provides the

measurement of its efficiency. The second DEA model proposed presents the hypothesis of variable returns to scales (VRS), known as DEA-BCC (Banker, Charnes and Cooper, 1984). As well as these two important models, there are other DEA models which are less frequent in the literature. Hence, we identify at least five basic DEA models: the additive model (Charnes et al., 1985), the multiplicative model (Charnes et al., 1982), the cone-ratio DEA model (Charnes et al., 1990), the Assurance Region DEA model (Thompson et al., 1986, 1990) and the super-efficiency model (Andersen and Petersen, 1993).

DEA methodology is applied to the unitary evaluation of homogeneous units or firms, such as hotels. The evaluation unit – which is normally known as Data Management Unit (DMU) – is what transforms the inputs into outputs. This is why its identification in any study is a difficult and crucial aspect. According to the DEA, the performance of a firm is evaluated on an efficient frontier which is built by the linear combination of the existing firms. The procedure is based on a complex mathematical model. However, the following graph shows how the efficiency measurements are calculated.



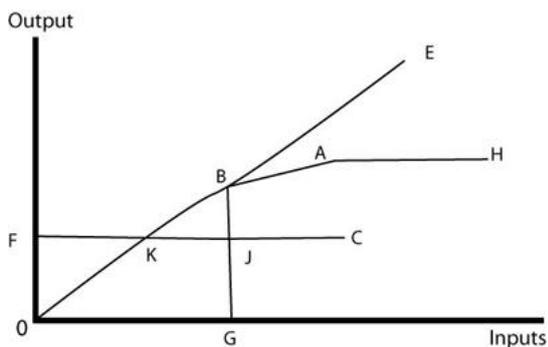
Document 1 - DEA methodology – global, technical and allocative efficiency

Document 1 presents the measurements of global, technical and allocative efficiency. In this example, we posit the existence of two inputs ( $X_1$  y  $X_2$ ) and one output ( $Y$ ) and CRS. On the other hand, we assume that the technology is fixed and that the input prices are represented by  $PP$ . Firm A is X efficient, as it produces along the *isoquantum* of output  $Y$ , using the minimum of inputs. Let us suppose that there is a firm which operates in C, producing the same level of output as is produced along  $Y$ . Firm C uses more inputs than firm A to produce output  $Y$ . This is why it is qualified as inefficient, with a global efficiency score of  $OD/OC$

(or what is the same, an inefficiency score of DC/OC).

Global inefficiency can be decomposed into its two components: technical and resource allocation. Without being able to change the inputs' allocation, the best that company C could have done was to operate at point B. The "extra" use of inputs for firm C, as a percentage of the total use of inputs, is the measurement of technical inefficiency and can be expressed as BC/OC. The technical efficiency of firm C is expressed as OB/OC. The inefficient allocation represents the failure of the management to use the optimum combination of inputs. Here the allocative inefficiency in firm C can be represented by DB/OC and the efficiency of the resource allocation as OD/OB.

Technical efficiency can be decomposed into the measurements of pure technical efficiency (PTE) and scale efficiency (SE). PTE refers to the deviations from the efficiency frontier resulting from the lack of an efficient use of the resources. Therefore this measure supposes that the firms are operating under the supposition of CRS. The scale inefficiencies, on the other hand, are losses due to the lack of operating with CSR. Document 2 illustrates the two efficiency measurements.



Document 2 – Scale efficiency and pure technical efficiency

In document 2, axis Y represents the output and axis X represents combinations of inputs which contain an equal quantity of input 1 and input 2. The graph shows three points indicated by A, B and C, respectively. Two frontiers are illustrated: one assuming CRS - OE - and the other frontier supposing VSR - GBAH. The PTE is measured in relation to the VSR. For firm C, the PTE is measured as PTE = FJ/FC. The SE is, therefore, FK/FJ. This measures the possible proportional reduction in the use of inputs if a firm operates with CRS, instead of growing or decreasing scale returns.

After completing this analysis, the measurement of SE is examined to determine if it is equal to one. If

SE is equal to one, then the firms are operating with CRS. If SE is not equal to one, then we must determine if the firms are operating with growing or decreasing scale returns.

#### DEA - CCR (Charnes, Cooper and Rhodes) Model

In mathematical terms, the basic DEA-CCR model that we are going to refer to would be:

$$\text{Maximise: } h_0 = \frac{\sum_{j=1}^s W_j Y_{j0}}{\sum_{i=1}^r V_i X_{i0}} \quad (1)$$

$$\text{Subject to: } \frac{\sum_{j=1}^s W_j Y_{jm}}{\sum_{i=1}^r V_i X_{im}} \leq 1 \quad m = 1, 2, \dots, n \quad (2)$$

$$W_j \geq 0; \quad j = 1, 2, \dots, s \quad (3)$$

$$V_i \geq 0; \quad i = 1, 2, \dots, r$$

Where:

$Y_{j0}$  = Output j of the DMU 0;

$X_{i0}$  = Input i of the DMU 0;

$W_j$  = Weight for the output j;

$V_i$  = Weight for the input j;

$n$  = N° of DMU;

$s$  = N° of outputs;

$r$  = N° of inputs

The unknown weights  $W_j$  and  $V_i$  are estimated for DEA, based on the data available, as a way of obtaining a measurement of relative efficiency for each unit. With this aim, DEA organises for the performance of each DMU, in relation to the performance of all the DMU, an optimisation contingent to convert the inputs into outputs (Miller et al., 1996). The weights of each DMU are separately calculated so that the level of maximum efficiency can be attainable.

Based on the CCR model, the equation (1) includes a case of multiple inputs and multiple outputs. The model seeks a set of values for  $W$  and  $V$  which maximises  $h_0$ . In this model, the results of maximum efficiency of DMU<sub>0</sub> will be  $0 < h_0 < 1$  due to the restrictions (2) and (3). The value  $h_0$  obtained by the model satisfies  $0 < h_0 < 1$  and in terms of the efficiency index,  $h_0 = 1$  represents the global efficiency and  $h_0 < 1$  indicates that it is inefficient. There are two ways of applying DEA, depending on the perspective that one wishes to consider - cost or profit. One is oriented to the input in which a specific level of output with the minimum quantity of input (minimisation of inputs) is obtained. The

other is oriented to the output, in which the output is maximised for a specific input level.

However, researchers believe that DEA has some limitations (Othman, 2010). Some of the inconveniences are questions related to the sample size. This has a significant impact on the global result. A greater number of DMU will increase the possibilities of finding units close to the production frontier. Secondly, DEA does not offer a prediction model of the organisation's performance. This is due to its limitation to be able to be used outside the database employed. As a result, DEA should be considered as specific for the sample used. This means that the resultant model is only applicable to these data. In other words, DEA analysis is not appropriate to be compared with a theoretical maximum (Othman, 2010).

Nevertheless, since the DEA model was first introduced, it has been adopted as a research tool to measure operational efficiency. In particular, DEA has been frequently applied to measure the performance of organisations in the services sector, as is the case of measuring the efficiency of hotels. To sum up, the DEA method introduced by Charnes et al. (1978) is a non-parametric method for estimating the optimum Pareto frontiers through which the efficiency of organisations can be determined. The direct consequence of the DEA's non-parametric characteristic is that it does not require - as deterministic and stochastic parametric methods do - the specification of a functional form for the production technology. With DEA the problem of specifying an explicit production function is overcome by making suppositions about the technology. A complete exposition of these hypotheses is gathered by Ray (2004) and by Coelli et al. (2005). Another consequence of this non-parametric characteristic is that there are no restrictions in the sample. It has only been accepted that the sample size of DMU must be greater than the double of the sum of inputs and outputs to obtain reliable results (Nooreha et al., 2000), although Banker et al. (1989) established as a general rule that the number of firms be equal to or above the triple of the variables included in the model.

#### *Data, scale performance and inputs/outputs*

In the case of the hotel sector, and of the services sector in general, the definition of productivity is complicated, as the traditional concept of productivity was developed for the manufacturing of physical goods. Grönroos and Ojasalo (2000)

sustain that this concept is based on the hypothesis that production and consumption are separate processes. To leave the consumer out of the production process makes sense for manufacturing, but not for the services sector in which both processes are simultaneous. The specific characteristics of services and the underlying suppositions in the traditional concept of productivity show the classical models and tools to be inappropriate for the measuring of productivity. The efficiency measurements obtained are quite sensitive to the specifications which are carried out in terms of scale returns. Though this fact is recognised, the literature about efficiency does not offer much orientation about how to evaluate the suitability of decisions in this context. With DEA, the set of possibilities can be based on the supposition of CRS or can assume the hypothesis of VRS.

Metters et al. (1999) offer some practical orientations for applying the DEA methodology. These authors suggest a series of rules. For example, to use models with VRS when considering DMU which are to a great extent of a variable size, and when the size of the scale is controllable by the DMU. The choice of assuming CRS versus VRS is not irrelevant, as it conditions the representation of the set of possibilities. The supposition of CRS implies a long-term vision in which the size of the units can be modified. In the supposition of VRS, the reasoning is carried out in the short term and the size of the units is fixed. In the case of hotels, given that hotel chains have different sizes (according to the total number of hotels) and their length in terms of scale is controllable by the headquarters, the VRS hypothesis can be chosen.

The VRS scoring only measures the PTE. However, for comparative purposes, CRS rates can be calculated that include a non-additive combination of PTE and SE. The relation between the index of global efficiency (CRS score) and the index of PTE (VRS score) provides a measurement of the SE.

Another problem is the accurate definition of what is considered to be input and output in the services sector and their measurement. Productivity - measured by the comparison of an output with an input - requires both indicators to be quantifiable. The majority of the measurement problems in the services sector come from the measuring of the output. Its multidimensional nature (some of the elements or aspects are not quantifiable but are relevant), its intangible nature, there being external factors and the difficulty in the evaluation of quality, among others, are some of the difficulties

found when trying to measure the output. This is an important inconvenience for measuring this sector's productivity.

According to Adam Jr. et al. (1981), output is easy to measure when it is presented as a production of specific physical units, with the possibility of being stored. On the other hand, other economic sectors, such as the hotel industry and hospitality sector tend to offer a wide range of services, many of which are complicated to measure. For the hotel industry and hospitality sector, Renaghan (1981) points out that the problem worsens because the experience of a hotel customer is considered to be perceived as a whole, while in reality he/she receives many services: lodging, meals, laundry, etc. Output can be measured accurately if it is first identified. But rarely is it possible to clearly define a "service unit". This is why measurements of productivity in the tertiary sector tend to be partial - for example, the number of customers dealt with during a specific period by a waiter in a restaurant. This information can be interesting, but it does not supply information about the degree of efficiency of the transformation of all the inputs used.

The identifying and measuring of the input is also complex. The output obtained is generally the result of a combination of inputs such as the workforce, capital, raw materials and energy. In hotels, in which the labour costs are one of the greatest expenses, ratios are used for the measuring of productivity such as the relation between the output and the number of workers, the number of work hours or salaries. Bernolak (1980) indicates that the work input could in many cases be considered as a good alternative for a more complete multiple input as it is used in the definition of productivity.

When a service is produced, a change in the selection of inputs can easily alter the quality of this output. This is why, despite an apparently more efficient use of resources, the value of the service for the customer can change and even go down, and the capacity of the firm to generate revenues will not be the same as at the beginning. If the quality and the customer value diminish and the performance goes down as a consequence of the diminishing of the sales, a more efficient use of the factors would clearly not have supposed a greater productivity. This means that the inputs would not have been used more efficiently, but rather the change in the inputs entailed a lesser value of the output and therefore a lesser productivity. In the services sector there are often conflicts between

productivity and quality, as higher rates of productivity can imply lesser quality (Rathmell, 1974 and Gummesson, 1992). Different studies have argued that the service quality must be included in the concept of productivity (Grönroos, 1990; Gummesson, 1992). Only if the quality of the output is constant and there is not a significant variation in the relation between the inputs used and the outputs obtained can the productivity be measured by traditional methods (Grönroos, and Ojasalo, 2000).

In service firms, different inputs can produce a unique or multiple outputs (McLaughlin and Coffey, 1990). The problem consists of determining which inputs and outputs should form part of the calculation of the productivity. Some measurement techniques are only proportions with one output and one input, while others use multiple outputs as a result of multiple inputs. Therefore, there are various alternatives to measure productivity in services. Partial productivity ratios can be used (Kendrick, 1985), which relate the output with some type of input, or total productivity ratios (Kendrick, 1985), which relate the total production to the total input used.

Physical, financial or mixed measurements can also be used. Mixed measurements combine physical and monetary variables in which the physical quantity is compared to the monetary value of another quantity. The measurements least used are the purely financial ones and traditionally the ones most used are physical measurements (Cooper and Kaplan, 1991). In the case of the services sector, the most correct decision would be to use the former, as physical measurements ignore the characteristic aspects of the outputs, such as intangibility and heterogeneity. The problem with financial measurements is that they can be affected by price changes. Some examples of different ratios are gathered in Document 3.

	Physical measurements	Financial measurements	Mixed measurements
Hotels	N° rooms / N° workers;	Revenues / Total Salaries Reception	Revenues per room sold / N° workers reception
	N° rooms occupied / N° workers reception;	Added value / Staff expenses	Revenue per lodging / N° workers cleaning
	N° Beds / N° workers		Revenue / N° rooms
	Customer hours / N° workers		Revenues / N° beds

Document 3 – Measurements of the hotels' performance

## DEA Methodology: a practical application

The methodology that we are going to describe recognises that technical efficiency can be improved and how this is done. To use it, it is necessary to define the inputs and the outputs of the services. The inputs are the resources used, which include human, financial and material factors and their relative costs. These resources can be divided into those which are under the management's control and those that are not. The latter are called discretionary inputs to point out that, unlike the others, they are not under the control of the firm or the organisation. Some inputs do not imply the consumption of resources in the strict sense, presenting themselves in the form of information or decisions. The price of the goods or services is one of the inputs and the management of the prices is an important question to consider.

Any result which is obtained from the process is called an output. The outputs desired are revenues due to sales, frequent customers, brand loyalty and other types of market responses. Some outputs, such as contaminating emissions or toxic elements should be considered as negative outputs. In spite of them being able to be handled in such a way that they have the least presence possible in the firm's global production, they are inevitable with current technology and the strategy normally followed. The characterisation of inputs and outputs implies looking at the service process as a "black box". Indeed, the majority of approaches about productivity adopt this point of view only in the first stages of the analysis, with the qualification of the process. This can be considered as a composite of various business units, each one using the same types of inputs to produce the same types of outputs.

For the study of productivity in Portuguese hotels, the EMSD programme was used. This employs the DEA methodology to calculate the Malmquist Productivity Index (MPI). The approach used was broadened to incorporate the VRS in the technology. The result of this extension is, according to Fare, Grosskopf and Lovell (1994, pp. 231-232) and Fare, Grosskopf, Norris and Zhang (1994, pp.74-75), the decomposing of the PTE variation, calculated with the VRS technology and a residual component which captures the changes in the deviation between the technological frontier of CRS and VRS (change in the scale's efficiency). This work is a modest attempt to investigate the changes in productivity using the DEA-MPI methodology.

### List of inputs and outputs

Document 4 gathers the inputs and outputs used in the study of performance in hotels in Portugal from 2008 to 2011. The data were obtained from the database of the Portuguese National Institute of Statistics. The population analysed included hotels which responded to the surveys both in 2008 and 2011 - in total 184 hotel establishments. The aim of deciding to leave out data of other hotels was to have the information necessary to be able to carry out a dynamic or evolutive analysis which requires having data of the two periods analysed.

Name and type of variable	Designation
Nps (I)	Number of workers
Ncomp (I)	Number of computers
NcompNesp (I)	Number of computers adapted to workers with special needs
NpsUC (I)	Nº of workers who use computers at least once a week
Ncompl (I)	Number of computers with Internet connection
NpsUCI (I)	Nº of workers who use computers with Internet connection at least once a week
NTotCursos (I)	Total number of training courses in 2007 and 2010
NTotCursosTIC (I)	Total number of ICT training courses in 2007 and 2010
NFormand (I)	Total number of workers who attended training courses in 2007 and 2010
NFormandTIC (I)	Total number of workers who attended ICT training courses in 2007 and 2010
NpsTIC (I)	Total number of workers with ICT skills
NpsTICFS (I)	Total number of workers with ICT skills who with graduate studies
NTotalDormidas (O)	Total number of stays in the establishment in 2007 and 2010
NTotalDormidasInt (O)	Number of stays in the establishment in 2007 and 2010 resulting from Internet bookings

Document 4 - Inputs and outputs

### Empirical results. Evolution of the performance of the Portuguese hotels

There are two main sources of gains or losses in productivity: the variation of the technical efficiency and technological progress. Comparing both, if the variation in the efficiency is greater than the technical change (technological progress), the increase in the productivity will be due, to a greater extent, to the improvements in efficiency. The opposite takes place in the case of the technological progress being higher than the improvement of the efficiency. In turn, when decomposing the variation of the technical efficiency, this can determine which component, PTE or SE variation, was the essential source of its increase or decrease.

It is worth pointing out that the component technological progress (F) (displacement from the frontier) is the same in the suppositions of CRS and of VRS. In both cases the CRS' displacement from the technological frontier is measured (Thanassoulis, 2001, pp.191). Fare, Grosskopf and Norris (1997) and Fare, Grosskopf and Russell (1998) justify the use, as a reference, of a technology with CSR in the obtaining of the

technological change component. They base themselves on it being a long-term problem.

The results relative to the evaluation of the PTE in the periods 2008 and 2011, obtained with the BCC model, are presented in Table 3. Here there is a summary of the number of efficient and inefficient hotels, the number of hotels that remain in the same position to, get closer to or move away from the frontier in the two periods. It can be concluded that the number of efficient hotels increased in 2011 and that the number of hotels which moved closer to the frontier (became more efficient) was higher in relation to those which moved away from it (diminishing their efficiency). Next we will aim to explain what led to this increase in efficiency.

	Year 2008	Year 2011
Efficient hotels	33	35
Inefficient hotels	151	149
Hotels which remained on the frontier	16	
Hotels which moved closer to the frontier	98	
Hotels which moved away from the frontier	70	

Document 5 - Summary of the results

It is verified that the number of efficient hotels (PTE) in the two periods is approximately the same. There are 16 hotels which remain on the frontier between 2008 and 2011. Furthermore, the average efficiency of the inefficient units increased due to the number of hotels which moved closer to the frontier being higher than those which moved away from it.

A dynamic analysis of the productivity is carried out using DEA to compare various years and various organisations. This allows the study of each hotel in particular and what takes place on the frontier of the sector considered as a whole. The MPI allow a dynamic analysis to be made. That is to say, after analysing their evolution to determine if the efficiency rates rise or fall over time, carrying out year by year an analysis of the frontier-shift and an analysis of the catch-up. Thus, the MPI mean to evaluate the variations in the growth of the total productivity of a specific organisation and it is calculated, in the case of VRS, by the multiplication of the pure technical variation by the SE and by the frontier variation.

#### *Interpretation of the results of a set of hotels*

In general terms, the results suggest that on average the sector's productivity increased during the period considered, obtaining a gain in

productivity of 95%. These gains are the result of a growth in the average efficiency of the hotels of 69% (measured by the distance of each hotel from its respective temporal frontiers) and a decrease of 76% with relation to the technological innovation (displacement from the frontier of efficiency). As the model is used with the supposition of VRS, the average efficiency of the hotels can be decomposed into PTE and SE. Thus, the average growth of 69% is due to 18% of variation of the PTE and only 3% of the scale variation.

Thoroughly analysing the results, it can be proved that not all the hotels have contributed to these results. To obtain conclusions, the MPI are calculated, as well as the technical change, the PTE variation and the scale variation of components for each hotel in the sample. As it is an index based on discrete time, each hotel will only have one index for the two years of the study.

We analyse the results obtained for each hotel in particular and also if the value of the MPI or any of their components for a specific hotel is less than one. This indicates a deterioration in the performance. If it is greater than the unit, this signifies an improvement in the performance translated into total productivity factors (TPF). It must also be pointed out that these measurements reflect the performance relative to the best practices in the sample, in which the best practice represents a "universal frontier". This universe is defined by the sample's hotels. As has been commented, on average the productivity increased throughout the 2008-2011 period for the sample's hotels. This growth was generally due to efficiency improvements (2.69), with a greater weight of the PTE (3.18) than the SE (1.03), then the innovation represented by technical change (0.76). This is why it is necessary to analyse the behaviour of the hotels in particular and the contribution of each of them to these average values.

A hotel's productivity can be influenced by technological progress and by the variation in the technical efficiency indicator. These can act in opposite directions, one cancelling out the other, or in the same direction, one adding to the other. If the productivity is growing mainly due to the displacement upwards from the frontier, there will be technological innovations which increase the potential production generated by the production process. On the other hand, if the gains of productivity are related to the reduction of the distance of the firm to the frontier, as occurs with the sample's hotels, these will proceed from an

increase of the technical efficiency of each unit individually. This is possible due to the technological dissemination or situational factors. The distinction of the sources of the variations of the TPF measurements is important for the adopting of appropriate policies. It therefore seems that a firm can obtain a greater productivity via the increase of the technical efficiency if it is not acting on the production frontier. When the firm is producing at the limit of the existing technology, the increases of productivity are only possible thanks to the technical progress.

As an illustrative example, we are going to analyse the results obtained by 14 hotels present in the sample Document 6:

HOTEL	MPI	Technical change	Change in efficiency	Change in the pure technical efficiency	Change in the scale
H1782	0.53	0.99	0.54	0.54	1.00
H1783	0.51	0.54	0.94	0.94	1.00
H1784	0.24	0.63	0.38	0.38	1.00
H1785	2.35	0.82	2.87	2.87	1.00
H1786	0.36	0.87	0.42	0.42	1.00
H468	0.53	0.74	0.71	0.71	1.00
H472	0.79	0.60	1.30	1.30	1.00
H473	1.00	0.75	1.33	1.33	1.00
H474	0.70	0.73	0.97	0.97	1.00
H476	1.96	0.86	2.27	2.24	1.01
H479	1.55	0.76	2.03	2.03	1.00
H480	0.50	0.66	0.75	1.00	0.75
H481	0.57	0.67	0.85	1.10	0.78
H482	0.83	0.73	1.15	1.15	1.00

Document 6 - Results of the 14 randomly-selected hotels

In the period considered, the hotels H1785, H476 and H479 experienced an increase of productivity, as is deduced from having MPI values greater than one. This increase was of 135%, 96% and 55%, respectively, due to the improvement of the efficiency and in the face of a technical or technological set-back. The improvement in the efficiency was, in the cases of the hotels H1785 and H479, only of PTE and the maintaining of the same scale of operation.

The hotels H1782, H1783, H1784, H1786, H468, H472, H473, H474 and H480 experienced a diminishing of the productivity, by the fact of the MPI values being less than 1. This was due to both a lesser efficiency and a technical set-back. Hotel H481 experienced a diminishing of productivity although its PTE increased 10%. Hotel H482 obtained less productivity although its technical efficiency increased 15% due to the same increase of its PTE and the maintaining of the SE.

#### Conclusion about the results of the total productivity factors (TPF)

The concepts of efficiency and productivity are often used with the same meaning. It is frequent to use the expression "more efficient" or "less efficient" with a meaning identical to that of "more productive" or "less productive". However, this can be an important mistake. The variation of productivity coincides with the variation of efficiency only in certain situations, specifically when the production technology, the scale and the operating environment are identical.

The difference between efficiency (technical) and productivity stems from global efficiency being able to be decomposed into technical efficiency and price efficiency. Most of the works which use DEA as an analysis methodology have been centred on the measuring of technical efficiency. There are many fewer studies which deal with the measurement of allocative efficiency, given the additional difficulty that the knowledge of the prices of the inputs and the outputs represents.

It is useful to distinguish between the two terms frequently used as synonyms: productivity and efficiency (technical). When there is talk of productivity "generally this refers to the concept of average productivity per factor, that is to say, the number of units of output obtained by a unit of factor used" (Álvarez, 2002, p. 20). It can be said as a conclusion that "a unit can be technically efficient, but even so it will be capable of improving its productivity through the exploitation of scale economies" (Coelli, Prasada Rao and Battese, 1998, p. 4).

Fare et al. (1994) disaggregate the variation of technical efficiency into two components: variation in PTE (relative to the frontier in the VRS environment) and the variation in the SE. This makes the oscillations of the TPF begin to depend on three variables: the variations of the technical and scale efficiency, as well as the variation of the technological progress. As the gains in TPF were measured by the MPI with an orientation to the output and supposing there being VRS, the TPF variation was decomposed into the variations of PTE and SE, as well as of technological progress.

The DEA-Malmquist methodology allows the capturing of the variations in the technical, technological and scale efficiencies throughout the period analysed, as well as the variation in the TFP. The values higher than the unit indicate an

improvement in the index, a fall when they are lower and unaltered when they are equal to one. The results of the technological variations (F), of the PTE, of SE and of the TFP are summarised in the following table:

	MPI	Technical change (F)	Change in the pure technical efficiency (PTE)	Change in the scale (SE)
Average	1.95	0.76	3.18	1.03
Minimum	0.06	0.47	0.07	0.35
Maximum	116.68	1.19	157.47	6.05
Typical deviation	8.9	0.1	15.7	0.4

Document 7 - Summary of MPI, F, PTE and SE

We can conclude that the results obtained allow the generating of a new ranking of hotels, ordering them based on their greater gains (or lesser losses) in the TPF, decomposing this according to the variations in the PTE and SE, as well as in the oscillations of technological progress. The greatest decrease in the TPF was that of hotel H83, especially based on the accentuated drop of its PTE. It can be also mentioned that those hotels which had values  $MPI < 1$  present PTE values higher than one.

In view of this, we can conclude that the technological set-back was the main cause of the decrease in production of these hotels. Thus, of the sample's 184 hotels, only six managed to register gains due to technological advances and for five of them the values are very low (between 1% and 7%). Hotel H971 had the greatest gain (19%).

HOTEL	MPI	Technical change (F)	Change in pure technical efficiency (PTE)	Change in scale (SE)
H112	0.49	1.07	0.45	1.00
H1340	0.85	1.06	0.80	1.00
H1345	1.24	1.001	1.24	1.00
H1761	0.96	1.04	0.95	0.97
H92	0.99	1.01	0.99	1.00
H971	1.83	1.19	1.53	1.00

Document 8 - Summary of MPI, F, ETP e EE

An increase in the first component is interpreted as evidence of catching up with the efficient frontier. An improvement of the second reveals there being technological innovation. In this sense, the MPI allows the separating of the catching-up related to the frontier and the displacements from the frontier. These are two different phenomena.

Therefore, productivity can be influenced by technological progress and by the change in the technical efficiency indicator. This can act in opposite directions –cancelling each other out – or in the same direction - adding both together. If the productivity is increasing mainly due to the displacement upwards from the frontier, technological innovation will be being produced. This increases the potential output generated by the production process.

On the other hand, productivity gains which are related to the reduction of the distance of the firm from the frontier come from an increase in the firm's technical efficiency. This is facilitated by the technological dissemination or other situational factors. The distinguishing of the causes of the variations in the TFP measurements is important for the adopting of decisions and policies.

A firm can therefore obtain a greater productivity via the increasing of the technical efficiency if it is not working on the production frontier. When the firm is producing at the limit of the existing technology, the productivity increases are only possible thanks to technical progress. Hence, if a hotel alters its productivity in a period of time, this can be due to four factors: a change of technology or frontier-shift, a change in catch-up, a change in the SE or a change in the PTE.

## Conclusion

Using DEA techniques an organisation can measure the efficiency of the service units, giving each unit an objective index of efficiency, within a significant set of units, even in the case of disagreement about the relative importance of the outputs. Productivity and profitability are improved through a better defining of the aims and processes of the performance evaluation. The method allows the diagnosis of the deficiencies and possible ways to improve efficiency. The current efficiency can be measured. This could be sacrificed for a better long-term effectiveness. All this can be done in the context of management control in real time. These elements are compatible with the budget, allocation and reallocation of resources decisions, with an emphasis on the long term rather than the short term and on decisions aiming to obtain competitive intelligence. Through the restrictions of "envelopment", the DEA techniques combine and perfect the traditional linear programming (LP) models with the capital budget, product mixture and other matters.

The efficient frontier is an ascertainment of the relation between inputs and outputs. These are more significantly handled than with traditional regression models. The reduction of a great number of measurements of performance to a single efficiency index helps to give sense to the avalanche of data that inundates administrators these days.

The DEA efficiency curve differs from the production function of microeconomics in ways which have a greater realism. It is easier to measure and therefore has a greater potential for managers' practical use. The first among many differences is that it is not linear, but sectionally linear or sectionally loglinear or by segments. The classic production function does not intend to lead to efficient positions, except indirectly through prices. Indeed, and economic theory normally defends it in this way, the attention can be limited to the efficient points, although at times it is not specified how one can be sure of the efficiency of these points. If the output, represented by the classic function, is a composite of various outputs - a set of common weights, generally monetary values - this will reduce these outputs to a sole element. The DEA efficiency curve does not use common weights but assigns to each decision unit a unique set of multipliers (weights) for its inputs and outputs. The DEA production function is a vector function (many outputs), contrary to the output function of traditional microeconomics theory.

The DEA efficiency frontier is categorised (for example, from A to C; C to D, etc.). The categories are defined by the similar efficient units and each inefficient unit is enveloped by a similar efficient unit, associated within a sole category (a mathematically necessary result in the formulating of the LP). The DEA efficiency frontier is not an analytical function which must be calculated via a reiterative process of optimisations. All the variables are simultaneously fit to the new optimum values with each change of the original data. This realist approach in which "all things are considered simultaneously" or *mutatis mutandis* (changing what should be changed) can be considered an analysis of all the system. The traditional vision of "all things in equal conditions" or *ceteris paribus* (the rest remaining constant) is based on the notion of calculating a partial derivative. Here only the variation of one variable at a time is allowed, with all the rest of the variables remaining constant, such as the concept of marginal cost. On the other hand, the classical function means (or has as its aim) to show the whole set of production possibilities for a unique decision variable. The efficiency curve uses

comparative or relative analysis to obtain the frontier from the behaviour of many units. The position of a unit is flexible only in its immediate vicinity. The subset of efficient hotels observed defines an empirical efficiency frontier, once there are, as is defined by the DEA, the lesser technology coefficients in their respective production ranges and inputs uses.

When the productivity analysis is applied, the DEA methodology broadens the concepts of the production function and operates with them. It reconciles the engineering efficiency, the Pareto efficiency and the Cobb-Douglas functions, and resolves a certain tension between the approaches of "production function" and "activity analysis" in microeconomics. The previous analysis mode allows the substituting of factors but is more conceptual than operational.

DEA methodology challenges some statistical conventions. In accordance with these conventions, the variability of a set of observations is interpreted as a measurement error and random deviations which hide a true underlying relation. This relation is interpreted as causal when it is between an output and one or more inputs, in an input and output process. In the analysis of productivity with DEA, it is supposed that the normal fluctuations and the measurement errors are small compared to the real differences between the performance observed between the decision-making units. The empirically-derived efficiency frontier is interpreted as a declaration of possibilities instead of causality. Each unit is a separate individual and has an interest in the real world.

The DEA-based efficiency models increase the traditional tools of LP, integrating considerations of allocative and technical efficiency in a situation of multiple units. The task of gathering and preparing data for the analysis of productivity can seem strange for a firm and their cost accountancy system often has a transversal logic. Another possible obstacle is the need to develop a customer-oriented mentality which leads to gathering data on satisfaction and a willingness to act on this. If the firm intends to avail itself of productivity improvement programmes, a clear commitment at all the levels of the organisation is necessary (Kendrick, 1984).

The analysis of productivity is relevant in the current scenario of competitiveness. This is why DEA models based on identifying and taking advantage of diversity - taking into account each

decision unit as a sole entity - allow flexible evaluations through individualised evaluations. They then proceed to a stage of market segmentation. The idea of discretionary inputs, at the hotel unit level, recognises the freedom of action of these decision-making units, as should occur in current decentralised organisms. Finally, DEA analysis takes advantage of and promotes computer

and statistics trends, via the resolving of an LP proposition for each unit analysed on a continuous basis, and using and broadening the techniques of exploratory data analysis. The rapid dissemination of the DEA methodology and its numerous applications gathered together in the literature support renovation for the improvement of productivity in services. Hotels are a part of this.

#### EDITOR'S NOTE

One preliminary version of this paper was presented at the V Jornadas de Investigación en Turismo, University of Seville, being selected for award and to be published in this journal, after passing the reviewing process. The rights on the final version presented here, with the corrections arising from that reviewing process, belong to Via@.

#### REFERENCES

- Adam E., Hershauer J. & Ruch W., 1981, *Productivity and Quality - Measurement as Basis for Improvement*, New Jersey, Prentice Hall.
- Andersen P. & Petersen N.C., 1993, "A procedure for ranking efficient units in data envelopment analysis", *Management Science*, vol. 39 (10), pp. 1261-1264.
- Banker R. Charnes A. & Cooper W., 1984, "Models for Estimation of Technical and Scale Inefficiencies in Data Envelopment Analysis", *Management Science*. vol. 30, pp.1078-1092.
- Banker R. Charnes A., Cooper W., Swartz J. & Thomas D.A., 1989, Thomas D.A., 1989, W., of Technical and Scale Inefficiencies in Data Envelopment Analysis *Research in Governmental and Nonprofit Accounting*, n° 5, pp. 125-163.
- Baker M. & Riley M., 1994, "New Perspectives on Productivity in Hotels: Some Advances and New Directions", *International Journal of Hospitality Management*, vol. 13(4), pp. 297-311.
- Barros C., 2005, "Measuring Efficiency in the Hotel Sector", *Annals of Tourism Research*, vol. 32, pp. 456-477
- Bernolak I., 1980, Interfirm Comparison in Canada, in Bailey D. & Huber T. (eds.), *Productivity Measurement: An International Review of Concepts, Techniques, Programmes and Current Issues*, Gower, UK.
- Charnes A., Cooper W. & Rhodes E., 1978, "Measuring the efficiency of decision making units", *European Journal of Operations Research*, vol. 2(6), pp. 429-444.
- Charnes A., Cooper W., Seiford L. & Stutz J., 1982, "Multiplicative Model for Efficiency Analysis", *Socio-Economic Planning Sciences*, vol. 16, pp. 223-235.
- Charnes A., Cooper W., Seiford L. & Stutz J., 1983, "Invariant multiplicative efficiency and piecewise Cobb-Douglas envelopments", *Operations Research Letters*, vol. 2(3), pp. 101-103.
- Charnes A., Cooper W., Golany B., Seiford L. & Stutz J., 1985, "Foundations of data envelopment analysis for Pareto-Koopmans efficient empirical production functions", *Journal of Econometrics*, vol. 30, pp. 91-107.
- Charnes A., Cooper W., Huang M. & Sun D., 1990, "Polyhedral Cone-Ratio DEA Models with an Illustrative Application to Large Commercial Banks", *Econometrics*, vol. 46, pp. 73-91.
- Coelli T., Rao D., O'Donnell C. & Battese G., 2005, *An introduction to efficiency and productivity analysis*, Berlin, Springer, 2<sup>nd</sup> ed.
- Christina S., Matthias F. & Wolfram H., 2010, "ICT Efficiency and Effectiveness in the Hotel Sector: A Three Stage DEA Approach", *Proceedings of the International Conference Information and Communication Technologies in Tourism*, vol. 1, pp. 642-654.
- Coltman M., 1978, *Hospitality Management Accounting*, Boston, CBI Publishing Co.
- Cooper R. & Kaplan R., 1991, "Profit Priorities from Activity-Based Costing", *Harvard Business Review*, May-June, pp. 130-135.
- Fay C., Rhoads R. & Rosenblatt R., 1971, *Managerial Accounting for Hospitality Service Industries*, Dubuque, William C. Brown Publishers.
- Farrell M., 1957, "The measurement of productive efficiency", *Journal of the Royal Statistical Society*, vol. 120(3), pp. 253-290.
- Grönroos C., 1990, "Relationship Approach to Marketing in Service Contexts: the Marketing and Organisational Behaviour Interface", *Journal of Business Research*, vol. 20, pp. 3-11.

- Grönroos C. & Ojasalo K., 2004, "Service productivity: Towards a conceptualization of the transformation of inputs into economic results in services", *Journal of Business Research*, vol. 57 (4), pp. 414-423.
- Gummesson E., 1998, "Productivity, quality and relationship marketing in service organizations", *International Journal of Contemporary Hospitality Management*, vol. 10(1), pp. 4-15.
- Kimes S., 1989, "The basics of yield management", *Cornell Hotel & Restaurant Administration Quarterly*, vol. 30 (3), pp. 14-19.
- Kendrick J., 1984, *Improving company productivity*, Baltimore, The Johns Hopkins University Press.
- Kendrick J., 1985, "Measurement of Output and Productivity in the Service Sector", in Inman R. ed., *Managing the Service Economy*, New York, Cambridge University Press, pp. 111-123.
- Leibenstein H., 1978, "X-Inefficiency Xist. Reply to an Xorcist", *The American Economic Review*, 68, pp. 203-211.
- McLaughlin C. & Coffey S., 1990, "Measuring productivity in services", *International Journal of Service Industries Management*, vol. 1(1), pp. 46-64.
- Metters R., Frei F. & Vargas V., 1999, "Measurement of multiple sites in service firms with data envelopment analysis", *Production and Operations Management*, vol. 8(3), pp. 264-81.
- Miller S. & Noulas A., 1996, "The Technical Efficiency of Large Bank Production", *Journal of Banking and Finance*, vol. 20, pp. 495-509.
- Min H., Min H, Chung K., 2002, "A data envelopment analysis-based balanced scorecard for measuring the comparative efficiency of Korean luxury hotels", *International Journal of Quality & Reliability Management*, vol. 25, n°4, 2008, pp. 349-365.
- Nooreha H., Mokhtar A. & Suresh K., 2000, "Evaluating public sector efficiency with data envelopment analysis: a case study in road transport department, Selangor, Malaysia", *Total Quality Management*, vol. 11(4), pp. 830-836.
- Othman M., Foo L., Karim M. Andaziz Y., 2010, "Total Factor Productivity Efficiency Changes In A Malaysian Hotel Chain", *Int. J. Revenue Management*, vol. 4, pp. 327-343.
- Quindós Mª, Rubiera F. & Vicente Mª R., 2003, "Análisis envolvente de datos: una aplicación al sector de los servicios avanzados a las empresas del Principado de Asturias", *Rect@*, vol. 21 (1).
- Ray S., 2004, *Data envelopment analysis: theory and techniques for economics and operations research*, Cambridge University Press, Cambridge.
- Renaghan L., 1981, "A new marketing mix for the hospitality industry", *Cornell Hotel and Restaurant Association Quarterly*, August, pp. 30-35.
- Seiford L., 1986, "A bibliography of data envelopment analysis", *Working Paper*, College of Business, Amherst, The University of Massachusetts at Amherst.
- Seiford L., 1989, *A bibliography of data envelopment analysis (1978-1989)*, Working Paper, Version 4.0, Department of Industrial Engineering and Operations Research, The University of Massachusetts, Amherst.
- Sigala M., 2003, "The ICT Productivity Impact on the UK Hotel Sector", *International Journal of Operation & Production Management*, vol. 23, pp. 1224-1245.
- Thompson R. Singleton E. Thrall R. & Smith B., 1986, "Comparative Site Evaluations for Locating High Energy Physics Lab in Texas", *TIMS Interfaces*, vol.16, pp. 35-49.
- Thompson R., Langemeier L., Lee C., Lee E. & Thrall R., 1990, "The Role of Multiplier Bounds in Efficiency Analysis with Application to Kansas Farming", *Econometrics*, vol. 46(1), pp. 93-108.
- van Doren C. & Gustke L., 1982, "Spatial analysis of the US lodging industry", *Annals of Tourism Research*, vol. 9(4), pp. 543 - 563.
- Wassenaar K. & Stafford E., 1991, "The lodging index: an economic indicator for the hotel/motel industry", *Journal of Travel Research*, vol. 30(1), pp. 18-21.
- Wijeysinghe B. S., 1993, "Breakeven occupancy for a hotel operation", *Management Accounting*, vol. 71(2), pp. 32-33.
- Yen F.L. & Othman M., 2011, "Data envelopment analysis to measure efficiency of hotels in Malaysia", *SEGI Review*, vol. 4, n° 1, July, pp. 25-36.

#### TO CITE THIS ARTICLE

##### Electronic reference:

Cidália Leal Paço & Juan Manuel Cepeda Pérez, The use of DEA (Data Envelopment Analysis) methodology to evaluate the impact of ICT on productivity in the hotel sector, *Via@, Varia*, n°1, 2013, posted on June 14th, 2013. URL : [http://www.viatourismreview.net/Article18\\_EN.php](http://www.viatourismreview.net/Article18_EN.php)

**AUTHORS**

**Cidália Leal Paço**

Escola Superior de Gestão, Hotelaria e Turismo. University of Algarve  
Campus Penha, 8005-139, Faro, Portugal  
cpaco@ualg.pt

**Juan Manuel Cepeda Pérez**

Faculty of Business Sciences. University of Huelva  
Plaza de La Merced, 11. 21071 Huelva  
cepeda@uhu.es

**TRANSLATION**

**Giles Collins Genovese**