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Robust data envelopment analysis with uncertain date: An analysis to measure hotel efficiency in Crete

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Abstract

Due to strict competition in the global market for Tourism services and Hotels in the tourism industry and also the importance of satisfying tourists, awareness about the efficiency of hotel for hotel owners and hotel managers is very important. The purpose of this paper is measuring performance of hotels in Crete by using Robust Data Envelopment analysis (RDEA) technique considering uncertain data. The proposed method of this paper develops a RDEA method with the consideration of uncertainty on output parameters. In order to use robust optimization methods in this article, after the introduction of input and output, we calculate the efficiency of 50 luxury hotel in Crete by means of GAMS software. The method is based on the adaption of robust optimization approaches proposed in the literature. Finally, we compare the performance achieved with previous research on these hotels and our results. It is found that the efficiency decreases, but the level of confidence increases.

Keywords: data envelopment analysis, uncertainty, robust, hotel efficiency.

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1. Introduction

With time and further clarify the importance of the development of monetary and financial markets, and especially the hotels, as a contributing factor to support the economy and ultimately economic prosperity, evaluating the performance of hotels has attracted researchers' attention in recent years. Performance reflects the concept that an organization or an enterprise how much uses their resources in production, compared to the best possible performance at any point in time. Therefore, when it comes to functionality, enterprises or institutions measure all inputs and outputs carefully in order to successfully produce the maximum possible output of a series of fixed production technology [24]. Efficiency in the DEA context deals with the optimization of the resource allocations among alternative uses. DEA yields a linear production surface which, in economic terms, represents the best production possibility frontier. By reflecting a decision making unit (DMU) to this frontier and comparing it with a single reference unit or a convex combination of other reference units, the DMU's efficiency is estimated. DEA developed by Charnes, Cooper, and Rhodes [9] based on Farrell [12] idea. This approach estimates relative efficiency of sets of decision making units by using of inputs and outputs. DEA separates units in two different category including efficient and inefficient units. Charnes, Cooper, and Rhodes [9] presented CCR as first model in DEA. Banker, Charnes, and Cooper [4] presented BCC with assumption of variable return to scale (VRS). This assumption makes BCC more real than CCR.

Donthu, Hershberger, and Osmonbekov [11] developed a model in which DEA focuses on input and outputs. The first step entails identifying a company (or set of companies) that is acknowledged as the best performer and the second step is setting benchmarking goals. Inputs of the model include Advertising cost, Manger experience, and Number of employees. Oliveira, Pedro, and Marques [21] investigated DEA under VRS and CRS. They collected data related to a sample of 84 hotels in Portuguese region of the Algarve. Also, they considered physical characteristics associated with the hotels, particularly the number of rooms, number of employees, the food & beverage (F&B) capacity and the other costs as an input and total revenue as an output. Omrani [22] applied fuzzy robust DEA (FRDEA). The proposed model of this paper considers fuzzy uncertainties for both input and output data by introducing an efficient FRDEA where the level of uncertainty is a fuzzy number and decision maker (DM) can easily determine it. The resulting FRDEA is formulated as a non-linear programming and a parametric model is incorporated to solve the model. The proposed FRDEA model is used for a set of gas distribution companies and the results are analyzed. Hafezalkotob, Banihashemi, Akhavan, and Tavakoli [14] proposed two main robust optimization approaches to immune DEA results against suppliers' data uncertainty. In the case study of SAPCO, they focused on main safety parts which include brake system, safety belt, and lighting system. It is shown that the efficiency quantity suppliers in traditional DEA are higher than robust ones due to the effect of uncertain data. Jalali Naini and Nouralizadeh [17] utilized two-stage data envelopment analysis DEA model to analyze the effects of entrance deregulation on the efficiency in the Iranian insurance market. The first results from DEA model indicates a decline in efficiency over the entrance deregulation period while further statistical analysis confirms that the solvency ignorance which is a widespread paradigm among state owned companies is one of the main drivers of efficiency in the Iranian insurance market. DEA has different applications in different studies. The results of comprehensive study done by Roghanian and Foroughi [25] shows that most of the active airlines are practically inefficient and the government could significantly increase the efficiencies of the airports by setting new regulations and rules. They decided to choose 21 active airports to provide a meaningful comparison. The results indicate that eighteen units use their terminal space very efficiently. Moreover, Studies conducted in the field of DEA is summarized in the Table (1).

Table 1. Summarized literature review in the field of DEA

Paper	Method	Application	Inputs	Outputs
Huang, Mesak, Hsu, and Qu [15]	DEWA & dynamic Tobit model	Chinese hotel industry	(1) Number of employees, (2) Guest rooms, (3) Fixed assets.	(1) Total revenue, (2) Average occupancy rate
Aissa and Goaied [2]	DEA and ROA	Using financial data derived from 27 hotel companies operating covering the period 2000-2010 in Tunisia.	(1) Size, (2) Indebtedness, (3) International chain affiliation, (4) Affiliation contract, (5) Hotel location, (6) General manager education, (7) Financial manager education.	Profitability
Shi, Ji, Wang, and Lib [27]	traditional ordinary least squares (OLS) panel model and a threshold panel model	31 administrative regions (provinces) in China during the 2004–2013 period.	–	–
De Jorge and Suárez [10]	DEA Tobit panel model	303 hotels/1999–2007	(1) Employment, (2) Labor costs, (3) Number of rooms, (4) Operational costs	(1) Sales, (2) Market share
Ashrafid, Seowb, Lee, and Lee [3]	the non-radial DEA called the Slacks-Based Measure (SBM)	This study focuses on the efficiency of hotel industry in Singapore from 1995 to 2010.	(1) Standard average room rate, (2) total international visitor arrivals, (3) GDP.	(1) Identified as hotel room revenue, (2) hotel food and beverage revenue, (3) Occupancy rate and gross lettings.
Manasakis , Apostolakis , and Datseris [18]	DEA-CCR DEA-BCC	50 superior hotels of operating in Crete in 2008.	(1) Operational style, (2) Beds, (3) Employees, (4) Operational cost, (5) Revenues, (6) Region, (7) Class.	(1) total revenues (room revenue, food and beverage revenue and other sources of revenue), (2) Total number of nights spent which is a fullness indicator.

2. Robust Data Envelopment Analysis

After specifying models to evaluate efficiency, in this section robust modeling approach is examined including Soyster [28], Ben-Tal and Nemirovski [7] and Bertsimas and Sim [8]. First of all, their weaknesses and strengths are discussed. It is clear that Soyster approach usually find solutions which are conservative. In order to ensure solution robustness in this approach, we may be far away from nominal problem optimality. Ben-Tal and Nemirovski's approach, lead to nonlinear and conical robust formulations so their approach cannot be used directly for discrete optimization problems. Bertsimas and Sim's approach can operate in a reasonable conservative level and leads to a linear optimization pattern, so we can use this approach for discrete optimization patterns. With respect to this feature and linearity of robust solution in this approach, we use it for data envelopment analysis designing. Now we can apply robust CCR model based on Bertsimas and Sim's approach for considering outputs data uncertainty that presented in Peykani and Mohammadi [23] as below:

$$
\begin{aligned}
& Max\ \Theta \\
& s.t.\ \ -(\sum_{r=1}^{s} y_{ro} u_r) + Z_0 \Gamma_0 + \sum_{r=1}^{s} P_{r0} \le -\Theta \\
& \sum_{i=1}^{m} x_{io} v_i = 1 \\
& \sum_{r=1}^{s} y_{rj} u_r - \sum_{i=1}^{m} x_{ij} v_i + Z_j \Gamma_j + \sum_{r=1}^{s} P_{jr} \le 0\ ; \\
& j = 1,...,n\ ; \quad r = 1,...,s \\
& Z_0 + P_{r0} \ \ge\ \delta\, y_{ro}\, \eta_r \\
& Z_j + P_{jr} \ \ge\ \delta\, y_{rj}\, \eta_r\ ; \\
& j = 1,...,n\ ; \ r = 1,...,s \\
& -\eta_r \le u_r \le \eta_r \quad r = 1,...,s \\
& P_{jr} \ge 0 \qquad j = 1,...,n\ ; \quad r = 1,...,s \\
& \eta_r \ge 0 \qquad r = 1,...,s \\
& Z_j \ge 0 \qquad j = 1,...,n \\
& u_r \ge 0 \qquad r = 1,...,s \\
& v_i \ge 0 \qquad i=1,...,m
\end{aligned}
\qquad (1)
$$

3. Case study

In this article, we have three inputs and two outputs for 50 hotels in Crete and they have gained a solid performance, so we can do calculation by using them. The selection of the sample for the purposes of this paper is based on a database maintained by the ICAP Group, the largest company offering business information services in the Balkans. Also, the year of study is 2008.

Regarding the input and output variables used in the present study, these are Chosen in a way that to make this study's results comparable with the relevant literature. The Variables which are chosen as inputs in the study reflect the required resources to achieve particular managerial goals. The number of employees measures the human Resources in a hotel [6, 16], the number of beds and the total operational cost of a hotel [13,19] measure the capital inputs used. The variables which are chosen as outputs in the present study reflect broad managerial goals and objectives. The first output variable is total revenues, comprising of room revenue, food and beverage revenue and other sources of revenue[1, 20]. The second output variable which is chosen is the total number of nights spent which is a fullness indicator [28]. It should be noted that these two output variables are consistent, since total revenues depends on the total number of nights spent; and both of them were used in Barros [6] and Barros and Mascarenhas [5]. All variables except overnight stays (collected through direct contact with hotel managers) were collected through the ICAP Group Databank. The data sources guarantee data integrity, as well as standardization and non-measurement errors which suggest reliability of the results.

4. Results

The models are solved in GAMS software and following results for the implementation of robust optimization is provided. Numerical results are presented in this section.

Table 2. Results of robust CCR model

	Γ=0	**Γ=0.25%**			**Γ=0.50%**			**Γ=100%**		
Hotels	**δ=0**	**δ=0.01**	**δ=0.02**	**δ=0.05**	**δ=0.01**	**δ=0.02**	**δ=0.05**	**δ=0.01**	**δ=0.02**	**δ=0.05**
H1	0.8050	0.7961	0.7922	0.7803	0.7922	0.7844	0.7618	0.7921	0.7844	0.7619
H2	0.3370	0.4811	0.4787	0.4716	0.4787	0.4740	0.4604	0.4781	0.4734	0.4599
H3	0.2949	0.5786	0.5758	0.5672	0.5758	0.5701	0.5537	0.5742	0.5686	0.5523
H4	0.4455	0.6878	0.6844	0.6742	0.6844	0.6777	0.6582	0.6833	0.6766	0.6572
H5	0.5008	0.7614	0.7577	0.7465	0.7577	0.7502	0.7287	0.7565	0.7491	0.7277
H6	0.4593	0.7456	0.7419	0.7309	0.7419	0.7346	0.7135	0.7404	0.7332	0.7122
H7	0.0734	0.2709	0.2695	0.2654	0.2695	0.2669	0.2591	0.2674	0.2647	0.2572
H8	0.3203	0.4995	0.4970	0.4897	0.4970	0.4921	0.4780	0.4962	0.4914	0.4773
H9	0.3309	0.4953	0.4929	0.4856	0.4929	0.4881	0.4740	0.4922	0.4873	0.4734
H10	0.5691	0.6971	0.6936	0.6834	0.6936	0.6868	0.6671	0.6932	0.6864	0.6668
H11	0.3787	0.5144	0.5119	0.5044	0.5119	0.5069	0.4923	0.5114	0.5064	0.4920
H12	1.0000	0.7870	0.7831	0.7714	0.7831	0.7754	0.7530	0.7835	0.7758	0.7536
H13	0.3639	0.5706	0.5678	0.5594	0.5678	0.5622	0.5461	0.5669	0.5613	0.5453
H14	0.3285	0.5302	0.5276	0.5198	0.5276	0.5224	0.5075	0.5268	0.5217	0.5067
H15	0.4008	0.6135	0.6105	0.6015	0.6105	0.6045	0.5872	0.6095	0.6035	0.5863
H16	0.3764	0.5394	0.5367	0.5288	0.5367	0.5314	0.5162	0.5361	0.5309	0.5157
H17	0.4616	0.5347	0.5321	0.5240	0.5321	0.5269	0.5115	0.5316	0.5264	0.5113
H18	0.4544	0.6850	0.6816	0.6715	0.6816	0.6749	0.6555	0.6805	0.6739	0.6546
H19	0.3459	0.5285	0.5259	0.5180	0.5259	0.5207	0.5057	0.5251	0.5199	0.5051
H20	0.4401	0.6592	0.6560	0.6463	0.6560	0.6495	0.6309	0.6551	0.6487	0.6301
H21	0.5049	0.8374	0.8332	0.8209	0.8332	0.8250	0.8013	0.8316	0.8234	0.7999
H22	1.0000	0.9950	0.9901	0.9753	0.9901	0.9804	0.9520	0.9901	0.9804	0.9524
H23	0.2788	0.5559	0.5531	0.5448	0.5531	0.5477	0.5318	0.5516	0.5462	0.5306
H24	0.4267	0.9950	0.9901	0.9754	0.9901	0.9804	0.9522	0.9862	0.9765	0.9486
H25	0.2442	0.4691	0.4668	0.4599	0.4668	0.4622	0.4490	0.4657	0.4611	0.4480
H26	0.5399	0.6070	0.6040	0.5951	0.6040	0.5980	0.5809	0.6037	0.5978	0.5807
H27	0.3834	0.5288	0.5262	0.5184	0.5262	0.5210	0.5060	0.5256	0.5205	0.5056
H28	0.4584	0.6371	0.6340	0.6246	0.6340	0.6278	0.6098	0.6333	0.6271	0.6092
H29	0.4142	0.6104	0.6074	0.5985	0.6074	0.6015	0.5842	0.6066	0.6007	0.5835
H30	0.8759	0.7675	0.7637	0.7524	0.7637	0.7562	0.7345	0.7639	0.7565	0.7348
H31	0.3039	0.4723	0.4700	0.4631	0.4700	0.4654	0.4520	0.4693	0.4647	0.4514
H32	0.3896	0.5683	0.5655	0.5571	0.5655	0.5599	0.5439	0.5648	0.5593	0.5433
H33	0.6719	0.8051	0.8011	0.7894	0.8011	0.7933	0.7706	0.8007	0.7928	0.7702
H34	0.4519	0.6291	0.6260	0.6168	0.6260	0.6199	0.6021	0.6253	0.6192	0.6015
H35	1.0000	0.9950	0.9901	0.9755	0.9901	0.9804	0.9523	0.9901	0.9804	0.9524
H36	0.4069	0.5945	0.5915	0.5829	0.5915	0.5857	0.5690	0.5908	0.5850	0.5682
H37	0.4008	0.5375	0.5349	0.5270	0.5349	0.5296	0.5144	0.5344	0.5292	0.5140
H38	0.5604	0.7219	0.7183	0.7077	0.7183	0.7113	0.6909	0.7178	0.7107	0.6904
H39	0.4496	0.6424	0.6393	0.6298	0.6393	0.6330	0.6148	0.6385	0.6322	0.6141
H40	0.4219	0.5662	0.5634	0.5551	0.5634	0.5579	0.5419	0.5629	0.5573	0.5414
H41	0.4842	0.5871	0.5841	0.5755	0.5841	0.5784	0.5618	0.5838	0.5781	0.5615
H42	0.3895	0.5496	0.5469	0.5388	0.5469	0.5415	0.5260	0.5463	0.5409	0.5254
H43	0.4337	0.6930	0.6895	0.6793	0.6895	0.6828	0.6631	0.6884	0.6817	0.6622
H44	0.3169	0.5104	0.5079	0.5003	0.5079	0.5029	0.4884	0.5071	0.5021	0.4878
H45	0.5086	0.6797	0.6763	0.6664	0.6763	0.6697	0.6505	0.6757	0.6691	0.6499
H46	0.4797	0.6529	0.6497	0.6400	0.6497	0.6433	0.6248	0.6491	0.6427	0.6244
H47	0.4494	0.5638	0.5610	0.5528	0.5610	0.5555	0.5396	0.5606	0.5551	0.5393
H48	0.4187	0.6445	0.6413	0.6317	0.6413	0.6350	0.6167	0.6403	0.6340	0.6159
H49	0.3100	0.4919	0.4894	0.4822	0.4894	0.4846	0.4707	0.4887	0.4839	0.4701
H50	0.4681	0.7165	0.7129	0.7025	0.7129	0.7059	0.6857	0.7118	0.7049	0.6847

5. Conclusions

Due to the importance of the hotel industry and its sensitivity robust optimization is a suitable method for analyzing the performance. This article is a robust optimization method based on CCR, BCC and additive models .In this article, we examined the performance of hotels in CRETE with robust optimization methods then results compared with previous studies conducted by researchers in previous works. The results showed that, although the efficiency is reduced, but we can get access to more accurate results. Future studies in this topic could consider uncontrollable factors such as volume, weather and… in solving the DEA and robust optimization to achieve tangible and more accurate answer. In addition, researchers can use the stochastic frontier analysis (SFA) to compare the performance of two methods nonparametric data envelopment analysis and parametric stochastic frontier analysis. This design method based on production function (cost) border and econometric estimation methods is performed. In this method, the boundary function is estimated according to the assumptions considered. It should be noted that this method is applied to estimate the distance function.

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