MODELING OPERATIONAL EFFICIENCY USING DATA ENVELOPMENT ANALYSIS: EVIDENCE FROM ATLANTIC CITY HOTELS

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ABSTRACT

The casino entertainment industry is an intensely competitive environment with many operational risks, explaining why casino managers highly prioritize performance evaluation. This study develops a performance evaluation model based on data envelopment analysis (DEA) to determine casino managerial efficiency in 2007 and the change in efficiency for eleven casinos from 2003-2007 in Atlantic City. Analytical results suggest an apparently high technical efficiency and low scale efficiency, indicating that managerial inefficiency derives mainly from an inappropriate scale of business in the casino entertainment industry of Atlantic City. Moreover, weak industrial growth of casino entertainment implies that front runners should closely examine systematic problems in their management strategies.

JEL: C44, C61, G00

KEYWORDS: Data envelopment analysis (DEA); Performance evaluation; Casino management Slacks-based measure (SBM), Managerial efficiency

INTRODUCTION

Legalized gaming in the form of casino entertainment is burgeoning worldwide. As is widely assume, casino entertainment stimulates tourism driven industries, generates tax revenues, and provides employment opportunities (Long, 1995). According to the American Gaming Association (AGA), the casino entertainment industry in the United States garnered US$34.13 billion in revenue, contributed US$5.79 billion in direct gaming tax revenues, and employed 360,818 individuals who received wages of US$13.8 billion in 2007. The North American casino entertainment industry, with its successful corporate structure, operates in a transparent and highly competitive environment (Gu, 2002). Casino gambling has established itself as a strong economic and societal influence in the United States (Garrett and Nichols, 2007).

However, widespread layoffs, tight consumer credit and a depressed housing market stemming from the current global recession that originated in the United States adversely impacted the American casino entertainment industry in 2007. The current global economic recession and anemic consumer confidence may continue to deteriorate consumer demand for leisure activities and corporate revenues in this industry. Historical trading data of various hotel categories and related establishments suggest that luxury hotels, such as casinos, tend to be more vulnerable to operating risks than full and limited service hotels (Younes et al., 2007).

The stringently competitive nature of the casino entertainment market in the United States (Gu, 2002) necessitates that managers fully utilize knowledge expertise to increase efficiency in operations management. Therefore, this study analyzes resource utility efficiency in the casino entertainment industry in Atlantic City by closely examining the managerial efficiency, pure technical efficiency (PTE), mixed managerial efficiency (ME) and scale managerial efficiency (SE) of a sample of casinos through the adoption of data envelopment analysis (DEA). Additionally, cross-period efficiency analysis is performed via the Malmquist index, and a managerial decision-making matrix is developed based on relative efficiency by varying productivity across a certain period to increase the efficiency of the casino entertainment industry in Atlantic City. The remainder of this paper is organized as follows. The next section describes the literature review. The data and model are shows in section II. The empirical findings and discussed in section III. Finally, concluding remarks are presented in the last section.

LITERATURE

New Jersey citizens voted in 1976 to legalize casino gambling in Atlantic City. Its establishment significantly contributed to the expansion of casino gaming across the United States (Karmel, 2007). Las Vegas, Atlantic City, and metropolitan Chicago, Illinois accounted for 38% of casino generated revenues in the United States, with Atlantic City ranking as the second largest gambling market. The casino entertainment industry in Atlantic City grossed US$4.92 billion in revenue, employed approximately 40,000 individuals, generated US$ 474 million in tax revenues, and brought in 33 million visitors in 2007, all of which represent a tremendous contribution economically. Despite these impressive statistics, the casino entertainment industry in Atlantic City faces tremendous challenges and intensified competition from the economic downturn, global financial crisis, new gaming jurisdictions and further restrictions in local smoking laws, ultimately decelerating revenue growth in 2008. From that period, Atlantic City casinos declined in gross operating profits by 19.5%, which represents the largest decline of profit rate for the past five years.

Efficiency determination has received considerable interest as organizations struggled to increase productivity (Cook and Seiford, 2009). Efficient operations of tourist sites are important to help maintenance and obtainment market share of tourism in the world (Cracolici *et al*., 2008). Several studies have attempted to measure the efficiency and performance of the commercial hotel industry by using DEA. Table 1 lists the input/output variables of the categories. In those studies, production resources were input with categories in substance by distinguishing between operating expenses, labor and property. Revenues and non-revenue categories with respect to outputs were also measured.

Table 1 Evaluation of Data Envelopment Analysis variables in commercial hotels

Input/Output	Categories	Variables	Literature
Inputs	Expenses	. Operating expenses	Botti *et al*., 2009
		. Other expenses	Chen, 2009
	Labor	. Number of employees	Barros and Dieke, 2008
		. Wages	Yu and Lee, 2008
		. Labor working hours	Chiang, 2006
	Property	. Dimension of hotel/meal	Wang *et al*., 2006
		. Number of guestrooms	Barros, 2005
		. Book value of property	Barros and Mascarenhas, 2005
Outputs	Revenue	. Total revenue/sales	Sun and Lu, 2005
		. F & B/Room/other revenue	Chiang *et al*., 2004
	Non-revenue	. Number of guests	Brown and Ragsdale, 2002
		. Customer satisfaction	
		. Occupancy rate	

This table shows input and output, data envelopment analysis measures used by authors in the literature.

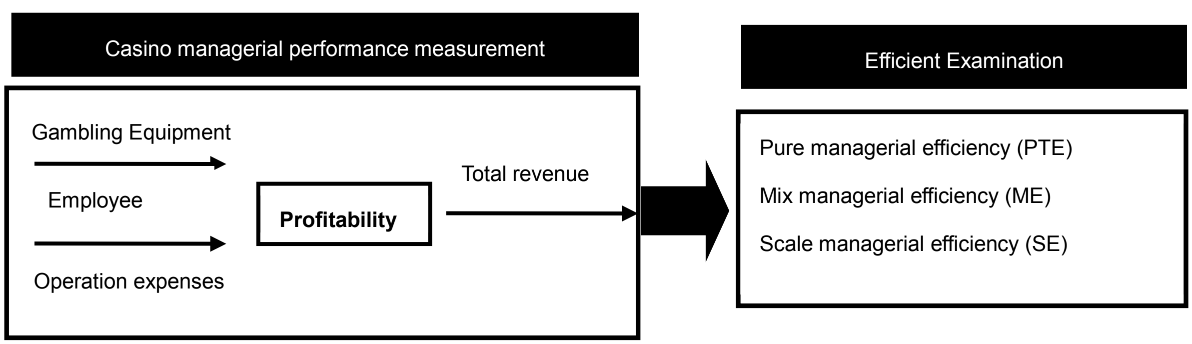
The operational performance of the casino entertainment industry has been evaluated based on regression analysis. Lee and Park (2009) focused on factors involving the financial performance of casinos, in which they examined how corporate social responsibility (CSR), firm value and profitability for hotels and casinos are related. According to their results, CSR has a simultaneous and positive relation with financial performance. Several studies that evaluated the performance of the casino entertainment industry undertook financial analysis. While adopting the Grey system method, Lin and Lee (2008) devised financial criteria to discuss the operational performance of casinos. Gu (2002) conducted financial ratio analysis to identify performance gaps in the casino entertainment industry between the United States and Europe by analyzing revenue efficiency, profitability and cost performance. Jang and Yu (2002) analyzed return on hotel and casino investment based on financial data, indicating casinos are extremely effective in using assets to generate revenue. More than a reference in decision making, performance evaluation is also the basis of improvements productive efficiency and strategies (Zhou, Huang and Hsu, 2008; Jang and Yu, 2002). While solving a portion of a problem, financial ratio analysis does not offer a comprehensive perspective on resource adjustment and improvements. There are few studies in develop a model to assess managerial efficiency of casinos.

DATA AND METHODOLOGY

Data were obtained from the State of New Jersey Casino Control Commission, based on financial reports and New Jersey casino gaming economic impact reports from 2003-2007. Eleven casinos comprised the sample size, with each casino treated as a decision making unit in this study. This study assumed that DEA inputs and outputs should be selected according to the common services that the casino industry provides. Casino hotels provide two main primary services: (1) gambling and (2) other services, including accommodations, food and beverages. These services constitute more than 80% of all casino revenues from slot and table games and other revenues from rooms, food and beverage, which do not exceed 20%.

This study identifies various operational inefficiencies in casinos, which are subsequently decomposed into pure technical managerial efficiency (PTE), mixed managerial efficiency (ME) and scale managerial efficiency (SE) in Atlantic City via the transformation process by using DEA.The DEA-based measurement model considers three inputs and one output parameter. The inputs which are defined as follows: (1) input variables indicated the gambling equipment (I_1) as tables and slot machines to generate gambling revenue; (2) employees (I_2) indicated all departmental employees; and (3) operational expenses (I_3) indicated expenses spent on operations. The outputs defined as follows: total revenues (O_1) indicated revenues from casinos, room, foods and beverage and other revenues. Figure 1 shows the managerial performance analysis procedure.

Figure 1: The Managerial Performance Analysis Procedure



This figure shows the managerial performance measurement procedure.

Charnes *et al*. pioneered the data envelopment analysis (DEA) model in 1978, with many related models developed in recent years. DEA rests on the premise that, within a set of comparable decision making units (DMUs), those that exhibit the best practice can be identified and form an efficient frontier (Cook and Seiford, 2009). DEA-related models such as constant returns to scale (CRS) and varying returns to scale (VRS) compare many input/output parameters simultaneously to provide both a scalar measure of relative efficiency and efficient targets, as well as benchmark peer groups for inefficient firms (Cooper *et al*., 2006; Tone, 2001). Additionally, the DEA-based Malmquist productivity index can measure changes in the efficiency of production unit in transforming inputs into outputs according different periods, as well as analyze which DMUs are an improvement or are slow.

Constant Returns to Scale (CRS) Model

The optimum practice frontier that exhibits constant returns to scale is determined using the CCR model (Charnes *et al*., 1978). Assume that there are n DMUs, with each DMU $j\,(j = 1,2,\cdots,n)$, and consumes m inputs $x_{ij}\ (i=1,2,\cdots,m)$ and produces s outputs $y_{rj}\ (r=1,2,\cdots,s)$.

$$\begin{aligned} Max \quad & \theta=\sum_{r=1}^{s}u_r y_{ro} \\ s.t. \quad & \sum_{i=1}^{m}v_i x_{io}=1 \\ & \sum_{r=1}^{s}u_r y_{rj}-\sum_{i=1}^{m}v_i x_{ij}\le 0, \quad j=1,2,\cdots n \qquad u_r, v_i\ge 0 \end{aligned} \tag{1}$$

where $y_{ro}=$ the amount of output r from unit o, $x_{io}=$ the amount of input i to unit o, $u_r=$ the weight given to output r, $v_i=$ the weight given to intput i, and $o=$ the number of units.

Variable Returns to Scale (VRS) Model

Banker *et al.* (1984) extended an earlier work involving the CCR model by providing for variable returns to scale. The VRS model is shown below:

$$\begin{aligned} Max \quad & \theta=\sum_{r=1}^{s}u_r y_{rj}-u_o \\ s.t. \quad & \sum_{i=1}^{m}v_i x_{ij}=1 \\ & \sum_{r=1}^{s}u_r y_{rj}-\sum_{i=1}^{m}v_i x_{ij}-u_o\le 0, \quad j=1,2,\cdots n \quad v_i\ge 0, \quad u_r\ge 0 \end{aligned} \tag{2}$$

where u_o refers to the intercept and the latter being free in sign may be positive or negative. According to the above description, the CRS scale is called technical efficiency (TE). The VRS model assumes the convex combinations of the observed DMUs as the production possibility set, and the VRS score is called pure technical efficiency (PTE). Based on the CRS and VRS scores, scale efficiency (SE) is defined as Eq. (3) if a DMU has the full VRS efficiency but a low CRS score.

$$SE=\frac{\theta^*_{CRS}}{\theta^*_{VRS}} \tag{3}$$

The VRS expresses the pure technical efficiency under VRS circumstances. Using these concepts, relationship Eq. (3) demonstrates a decomposition of efficiency as Eq. (4):

$$TE=PTE\times SE \tag{4}$$

Slacks-Based Measure (SBM) of Efficiency Model

Tone (2001) proposed a slacks-based measure (SBM) of efficiency in DEA and measure deals directly with the input excesses and the output limitations of the DMU concerned. A SBM of efficiency is defined, along with its interpretation as a product of input and output inefficiencies. Two efficiency measures are radial and non-radial measures of efficiency, and CCR and SBM are also called radial and non-radial measures of efficiency, respectively. By assuming that n DMUs with the input and output matrices $X=(x_{ij})\in R^{m\times n}$ and $Y=(y_{ij})\in R^{s\times n}$, respectively, the input-oriented SBM model is formulated as follows:

$$\begin{aligned} Min \quad & \rho_{in} = \frac{1-(1/m)\sum_{i=1}^{m} s_i^- / x_{io}}{1+(1/s)\sum_{r=1}^{s} s_r^+ / x_{ro}} \\ s.t. \quad & x_o = X\lambda + s^- \\ & y_o = Y\lambda - s^+ \qquad \lambda \geq 0, \quad s^- \geq 0, \quad s^+ \geq 0 \end{aligned} \tag{5}$$

where ρ_{in}^* denotes SBM scores and λ represents a nonnegative in R^n. Additionally, s^- and s^+ represent the input excess and output shortfall of expression, respectively, and are called slacks. The mixed efficiency (ME) is defined as $ME = \frac{\rho_{in}^*}{\theta_{CRS}^*}$. By using Eq. (4), the non-radial technical efficiency ρ_{in}^* has the decomposition into ME, PTE and SE, as shown $\rho_{in}^* = ME \times PTE \times SE$.

Cross-Period Efficiency

Färe *et al*. (1992) constructed the Malmquist productivity index to extend the DEA-based assessment of the cross-period efficiency model. The Malmquist productivity index can be used to determine productivity change in a production unit, which measures changes in the efficiency of a production unit in transforming inputs into outputs from time t to time $t+1$. Evaluating the change in the technology frontier and the other change in technical efficiency are two components for the Malmquist productivity index. The input-based Malmquist productivity index can be formulated as Eq. (6).

$$M_o = \left[\frac{\theta_o^t(x_o^t, y_o^t)}{\theta_o^t(x_o^{t+1}, y_o^{t+1})} \frac{\theta_o^{t+1}(x_o^t, y_o^t)}{\theta_o^{t+1}(x_o^{t+1}, y_o^{t+1})} \right]^{\frac{1}{2}} = \frac{\theta_o^t(x_o^t, y_o^t)}{\theta_o^{t+1}(x_o^{t+1}, y_o^{t+1})} \cdot \left[\frac{\theta_o^{t+1}(x_o^{t+1}, y_o^{t+1})}{\theta_o^t(x_o^{t+1}, y_o^{t+1})} \frac{\theta_o^{t+1}(x_o^t, y_o^t)}{\theta_o^t(x_o^t, y_o^t)} \right]^{\frac{1}{2}} \tag{6}$$

where M_o refers to the productivity change between periods t and $t+1$. Additionally, $\theta_o^t(x_o^t, y_o^t)$ and $\theta_o^{t+1}(x_o^{t+1}, y_o^{t+1})$ denote the technical efficiency score for DMUs in time period t and $t+1$, respectively.

EMPIRICAL ANALYSIS

Table 2 summarizes the results of correction analysis with input and output variables. The three inputs have two inputs that are positively associated with each other. Hence, casinos that use high input levels tend to achieve a high performance in each output category. The highest correlation coefficient is 0.9925, found between the total operating expense (I_3) and total revenue (O_1). The lowest correlation coefficient is 0.8186, which also belongs to the highest correlation coefficient, found between gambling equipment (I_1) and number of employee (I_2).

Table 3 summarizes the information of inputs and outputs variables. The gambling equipment ranges from 2,024 to 5,346, with a mean value of 3,384. The two input measures are summarized as follows. The number of employees has a mean value of 3,727, ranging from 2,152 to 6,950. Total operating expenses have a maximum (min.) value of $789,697 ($267,013), with a mean value of 455,219. Casino revenue ranges from $303,545 to $1,034,679 with a mean value of $568,730.

Table 2 Correction Coefficients among Input and Output Variables

Input/Output	Gambling equipment (I_1)	Number of employee (I_2)	Total operating expense (I_3)	Total revenue (O_1)
Gambling equipment (I_1)	1			
Number of employee (I_2)	0.8186	1		
Total operating expense (I_3)	0.8482	0.9896	1	
Total revenue (O_1)	0.8431	0.9696	0.9925	1

Table 2 shows the results of correlation analysis between the input and output variables.

Table 3 Descriptive Statistics for Eleven Casinos in Atlantic City in 2007 (US$)

Input/Output	Variables	Mean	Minimum	Maximum	Std. Deviation
Inputs	Gambling equipment (I_1)	3,384	2,024	5,346	991.35
	Number of employee (I_2)	3,727	2,152	6,950	1,448.22
	Total operating expense (I_3)	455,219	267,013	789,697	158,953.54
Output	Total revenue (O_1)	568,730	303,545	1,034,679	227,541.70

This table provides summary statistics for the input and output variables.

Table 4 shows that the three forms of managerial efficiency, i.e. PTE, ME and SE, by applying input-oriented CCR, BBC and SBM models of DEA. The top three of the eleven casinos evaluated by efficient with a managerial efficiency score are Borgata (A_3), Caesars (A_4) and Harrah's (A_5).

Table 4: Decomposition of Managerial Efficiency for Atlantic City Casinos

No	Casinos in Atlantic City (DMU)	SBM efficiency	PTE	ME	SE	Returns to scale
A_1	AC Hilton	0.788	0.941	0.968	0.865	Decreasing
A_2	Bally's Park Place	0.825	0.933	0.898	0.985	Decreasing
A_3	Borgata	1	1	1	1	Constant
A_4	Caesars	1	1	1	1	Constant
A_5	Harrah's	1	1	1	1	Constant
A_6	Resorts	0.699	0.924	0.879	0.861	Decreasing
A_7	Showboat	0.875	1.000	0.888	0.985	Decreasing
A_8	Tropicana	0.860	0.975	0.917	0.961	Decreasing
A_9	Trump Marina	0.788	1.000	0.942	0.837	Decreasing
A_{10}	Trump Plaza	0.799	0.980	0.941	0.867	Decreasing
A_{11}	Trump Taj Mahal	0.857	0.929	0.940	0.981	Decreasing
	Mean	**0.863**	**0.971**	**0.943**	**0.940**	

This table shows the three forms of managerial efficiency by applying input oriented models.

Table 5 summarizes the analysis results of the cross-period efficiency change. The model evaluates the change in efficiency via Malmquist analysis to assess the performance of effectiveness variations from 2003 to 2007. According to the results, over the past five years, the best efficiency change is Borgata (A_3).

Figure 2 shows the decision-making matrix and the analysis results. This matrix is divided into four groups by the two criteria of relative efficiency and efficiency change. By integrating the analysis results of the relative efficiency and efficiency change, this study illustrates a decision-making matrix to help casino entertainment managers to position themselves in the industry and to provide directions for increasing efficiency. Four groups described as following.

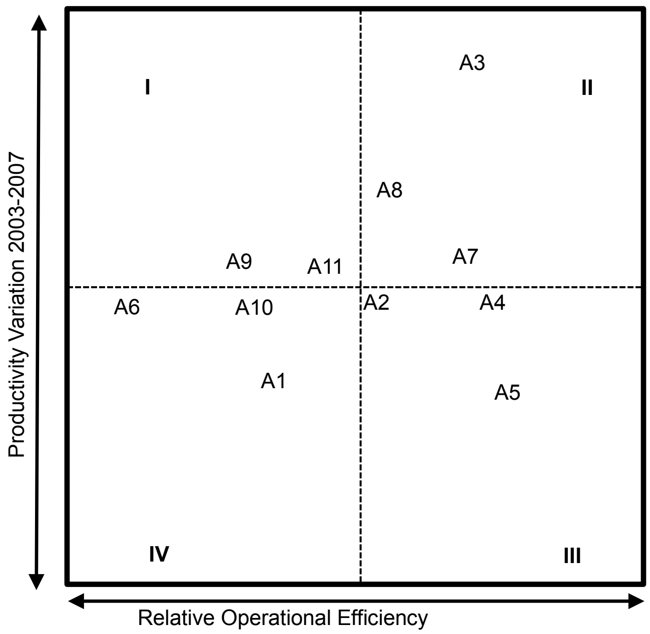
In the quadrant Ⅰ there are no category in this area of the decision-making matrix decreases, indicating that casino entertainment industry in Atlantic City get has matured and is likely in a stage of decline. The quadrant Ⅱ includes three casinos are Borgata (A_3), Showboat (A_7) and Tropicana (A_8). Casinos in this area belong mainly to mixed inefficiency problems and not only suggest resource adjustment in scale diminution and renewable equipment, such as a slot machine, to attract tourists but also increase revenue at same time.

Table 5: Decomposition of the Malmquist Index from 2003-2007

No.	Casinos in Atlantic City (DMU)	Cross-period performance (2003-2007)		
		Catch-up	Frontier	Malmquist
A_1	AC Hilton	0.878	1.112	0.976
A_2	Bally's Park Place	1.006	1.106	1.113
A_3	Borgata	1.639	1.073	1.759
A_4	Caesars	0.970	1.129	1.096
A_5	Harrah's	0.901	1.055	0.950
A_6	Resorts	0.991	1.105	1.095
A_7	Showboat	1.016	1.120	1.138
A_8	Tropicana	1.142	1.107	1.264
A_9	Trump Marina	1.000	1.109	1.109
A_{10}	Trump Plaza	0.975	1.109	1.082
A_{11}	Trump Taj Mahal	1.013	1.111	1.126
	Mean	1.048	1.103	1.155

This table shows a decomposition of the Malmquist Index. The analysis uses data from 2003-2007.

Figure 2: Managerial Decision-Making Matrix of the Performance Model in Atlantic City



Note: A_1: AC Hilton; A_2: Bally's Park Place; A_3: Borgata; A_4: Caesars; A_5: Harrah's; A_6: Resorts; A_7: Showboat; A_8: Tropicana; A_9: Trump Marina; A_{10}: Trump Plaza; A_{11}: Trump Taj Mahal

The quadrant Ⅲ area includes Caesars (A_4) and Harrah's (A_5), which represent higher efficiency than the remaining ones without A_3. The casinos falling in this area largely stress feeble growth and rather than improving, this far-reaching systematic problem arises from a significant decline in growth annually. Casinos belonging to this category must cautiously approach future strategies. Finally, the quadrant Ⅳ includes AC Hilton (A_1), Resorts (A_6), Trump Marina (A_9) and Trump Taj Mahal (A_{10}). Casino belonging to this area is unsuitable for scale productivity and apparently decreasing returns to scale. Therefore, casinos should reduce its operating scale to achieve optimum productive scale by taking measures such as disposing of idle assets and previously used equipment.

Both casinos A_2 and A_{11} perform moderately in terms of contemporary efficiency and do not significant increase in variation in productivity, which requires attention in the decline in quadrant Ⅳ. The problem in this area is largely attributed to technical inefficiency in advanced services or technical productivity, such as in improvements in novel slot machines to attract tourists.

CONCLUSIONS AND DISCUSSION

The tourism sector is especially sensitive to reductions in discretionary consumer spending as a result of economic downturns. Casinos have high operational risks and belong to a much more competitive environment than commercial hotels. Assets and production resource management have a heightened role of importance owing to the challenge posed by intensified competition and declining profits. Performance evaluation is thus a critical aspect of casino management because performance evaluation provides information deemed essential for coordinating casino resources and capturing a market advantage. However, previous studies failed to develop a measurement model in order to increase casino managerial efficiency. Importantly, this study contributes to efforts of casino entertainment managers to increase overall productivity through performance evaluations, as well as strengthen its industrial competitiveness. Furthermore, results of this study provide a valuable reference for future casino managerial practices. Empirical results indicate that casinos generally experience decreasing returns to scale and weak growth rate in Atlantic City.

This study develops an evaluation model to assess the operating performance of casinos, in which the DEA method is adopted to evaluate the comparative efficiency of the casino entertainment industry in Atlantic City. Moreover, managerial inefficiency and strategy are improved with respect to the extent of managerial inefficiency caused by scale, technical or mixed inefficiency that is integrated with cross-period analysis. Future research can use DEA model to evaluation managerial efficiency and performance in gambling market. And then future research can explore the managerial performance by pure technical managerial efficiency (PTE), mixed managerial efficiency (ME) and scale managerial efficiency (SE).

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