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Decomposition Baseball Team and Team-Type Efficiencies by Two-Stage DEA Model: Economic Views

Hsiang-Hsi Liu
Corresponding author, Distinguished Professor
Graduate Institute of International Business, National Taipei University, Taiwan
No.151, University Road, Sanxia District, 23701, New Taipei City, Taiwan
Tel: 886-2-2673-6270, Fax: 886-2-2673-6271
E-mail: hsiang@mail.ntpu.edu.tw

Tser-Yieth Chen
Professor, Graduate Institute of International Business
National Taipei University, Taiwan
E-mail: chenty@mail.ntpu.edu.tw

Jheng-Ming Huang
Master, Department and Graduate Institute of International Business
National Dong Hwa University, Taiwan
E-mail: m9533021@em95.ndhu.edu.tw

Abstract

This research conducted a two-stage data envelopment analysis (DEA) on resource operational efficiency and output valid efficiency, embedded with the decomposition of each efficiency to investigate the relationships between baseball team and baseball team-type efficiency in the Major League Baseball (MLB) in the US. According to this, we can effectively decompose teams into different efficiency levels, analyzing the efficiency of each level to discover the most efficient teams via the employment of efficiency decomposition approach. We can estimate that the efficient teams had the highest opportunity to win the championship and then compare if these teams can reach their expected economic performance by paying premium salaries to players. Additionally, we applied BCG matrix to illustrate the relationships between teams, based on resource operational efficiency and output valid efficiency under economic views, and proposed strategical implications for finding a "super star" team or teams with better managerial efficiency.

Keywords: Two-Stage Data Envelopment Analysis, Major League Baseball, Resource Operational Efficiency, Output Valid Efficiency, Efficiency Decomposition.
JEL Classification: L1, L10, L19, L60, L65

1. Introduction

The performance of a baseball team is usually regarded as the tool for evaluation; however, how to evaluate performance has always been an imposing economic issue. Numerous methods are utilized extensively in diversified industrial sectors such as banking, hospitals, education and semiconductors concerning how to obtain appropriate return of investment. Data envelopment analysis (DEA) is one of the methods among them. Managerial factors such as salary, at bats, and stadium costs are examined to influence baseball teams' performances via DEA. Thus, it is suitable to discuss if salary impacts on teams' performances with the provision of DEA method.

Many researchers have focused on measurement of team efficiency in the Major League Baseball (MLB). However, team efficiency may differ for different baseball teams or the type it belongs to. Portela and Thanassoulis (2000) stated that model of decomposition can be applied to catch the relationship between team efficiency and the team type they belong to. This is an overall consideration of efficiency because team-within-all-teams-efficiency (Teams within both leagues) of baseball teams can be illustrated from the model of decomposition of efficiency. Furthermore, they can be thoroughly analyzed and discussed from the perspective of team efficiency, team-type efficiency and team-division efficiency, respectively. Eventually, it is clear that the economic efficiencies of baseball teams differ on the account of different circumstances, thereby making it possible to compare their efficiencies according to decomposition of efficiency analysis. As such economic efficiencies can be easily realized from the perspectives of baseball team, team type and team-division, respectively.

As for the two-stage efficiency measurement, we investigate resource operational efficiency and output valid efficiency to cooperate with decomposition of efficiency in order to explore the relationship between team and team-type efficiency. If the efficiency of baseball teams can reach their expected performance via paying premium salaries to players, they will have the most opportunity to improve their performance and win the championship. We then expect to employ the two-stage DEA model to solve this issue and assist the team to achieve more economic efficiency. Conceptually, this research employs a data envelopment analysis (DEA) approach for measuring efficiency of decision processes which can be divided into two stages. The first stage uses inputs to generate outputs which become the inputs to the second stage. The first stage outputs are referred to as intermediate measures. The second stage then uses these intermediate measures to produce outputs.

Our three research purposes are as follows: firstly, we conduct a two-stage DEA model with decomposition of efficiency, and generate resource operational efficiency (ROE) and output valid efficiency (RVE) to assess the performing efficiency of MLB in the US. Secondly, to understand how team performance improves the team efficiency for all kinds of baseball teams, we analyze the decomposition of efficiency to be more efficient and effective via two-stage DEA. Finally, we also employ Boston Consulting Group (BCG) matrix (Udo-Imeh, Edet and Anani, 2012) to propose strategical implications for finding a "super star" team or teams with better managerial efficiency.

2. Literature Review

Charnes, Cooper and Rhodes (1978) were the one to firstly propose the DEA model (the CCR-DEA model), and used a mathematical programming model to identify the economic efficiency frontier based on the concept of Pareto optimum when using multiple measures. Charnes *et al.* (1978) assumed that the circumstance is the constant return to scale and formulated a linear programming problem for calculating DEA efficiency scores. Here, the DEA model is a non-parametric mathematical programming method for frontier estimation and assessing the management performance of a group of decision-making units (DMUs). The DEA model constructs a relative efficiency score via transforming the multiple-input/multiple-output into a ratio of a single virtual output or into a single virtual input (Boussofiane, Dyson, and Thanassoulis,1991). The focus is to optimize an engineering-type ratio of outputs to inputs, by solving for a set of weights that satisfy a system of linear equations (Barrow and Rouse, 2002). The DEA is a decisional approach that has been widely used for economic performance analysis in public and private sectors (Sueyoshi, 2000). A variety of DEA applications, along with its conceptual and methodological developments, had been found for many decisional cases in the past decades.

As to the two-stage DEA model, Heskett, Jones, Loveman, Sasser and Schlesinger (1994) first developed the service-profit chain to investigate the linkages between marketing measures of quality and operational measures of quality. Seiford and Zhu (1999) examined the performance and/or operating efficiency of the top 55 US banks via the adoption of a two-stage production process that effectively separates profitability from marketability. Soteriou and Zenios (1999) developed a framework for combining operating efficiency, profitability and service quality in the banking industry. Chen (2002) incorporated multidimensional efficiency into a DEA model to evaluate the economic efficiency, marketing efficiency and financial efficiency of banks in Taiwan. Turning to the two-stage DEA model in baseball efficiency, Sexton and Lewis (2003) presented a two stage DEA model that incorporated managerial ability both on the field and in the front office. The first stage of their model takes total player salaries as the input and uses two outputs: total bases gained (TBG) and total bases surrendered (TBS). Einolf (2003) also investigated team economic efficiency with salaries as inputs and game wins as outputs. Lewis and Sexton (2004) then employed reverse input and output that analyzed baseball player performance. Kedrowski (2005) performed an economic evaluation of baseball player performance, and both qualitative and quantitative assessments were conducted. Kao and Hwang (2008) described a two-stage process where 24 non-life insurance companies used operating and insurance expenses to generate premiums in the first stage (resource operational efficiency) and then underwriting and investment profits in the second stage (output valid efficiency).

As to decomposition of economic efficiency with a DEA approach, Färe and Primont (1984) firstly used decomposition of efficiency of multi-plant firms into within-firms and between-firms efficiency. Färe (1990) indicated decomposition of an overall measure of efficiency of rice farms in California across actual efficiency and financial efficiency. Sueyoshi, Hasebe, Ito, Sskai and Ozawa (1998) decomposed efficiencies of Japanese agricultural co-operatives as regards DEA-bilateral performance comparison. Portela and Thanassoulis (2000) used the DEA approach for decomposition of economic efficiency into school and school-type efficiency.

Turning to the DEA model in baseball/football team economic efficiency, Anderson and Sharp (1997) developed an efficiency measure of baseball batters via DEA by choosing plate appearances as inputs while five outputs are defined as hits, one-base, two-bases, three-bases and homeruns. Sueyoshi, Ohnishi and Kinase (1999) illustrated a benchmark approach for baseball evaluation, by selecting two inputs and eight outputs. Two inputs are bats and double plays. Eight outputs are one-base, two-bases, three-bases, homeruns, runs batted in, steals, sacrifices and hits. Barros and Leach (2006) illustrated performance evaluation of the English Premier Football League; they used the four components as inputs, which are number of players, wages, net assets and stadium facilities expenditure. Three outputs are points obtained in the season, attendance and turnover. Singh (2011) measured the economic efficiency of cricket teams in the Indian Premier League by DEA. The total expenses which include players' wage bill and wage of the support staff and other miscellaneous expenses are used as inputs. Output is measured by the points awarded, net run rate, profit and revenues. When decomposing inefficiency into technical inefficiency and scale inefficiency, it can be shown that the largest part of inefficiency can be explained by less scale of production and inefficient transformation of inputs. Lewis (2014) tried to evaluate the performance of individual players and teams in MLB as comprised of a front office operation which consumes money in the form of player salaries to acquire offensive and defensive talent and an on-field operation which uses the talent to outscore opponents and win games. He applied network DEA to measure performance of the front office operation, the on-field operation and the overall MLB team.

3. The Analytical Methodology

In this section, the analytical methodology applying to measure baseball team and team-type economic efficiencies is discussed as follows:

3.1. The DEA Model

We employ the sense of CCR-DEA model (Charnes, Cooper and Rhodes, 1978), as all of DMUs operate at an optimal scale which is a mathematical programming model to measure the technical efficiency of decision-making units according to the concept of Pareto optimum. In the CCR-DEA model, output will increase in a constant rate if input increases. This model is applied to estimate the economic efficiency of a DMU to create a fixed amount of output with the minimum input. The CCR-DEA model can evaluate the efficiency of a DMU to produce a fixed amount of output with minimum input via construct an input-oriented model. Assume there are DUM ^{j} ($j=1,...,n$) with m inputs X ^{ij} ($i=1,...,m$) to produce s outputs Y $_{rj}$ ($r=1,...,s$), the relative efficiency score of DMU $_{k}$ is as follows:

$$E_k = Max \ \frac{\sum_{r=1}^{s} U_r Y_{rk}}{\sum_{i=1}^{m} V_i X_{ik}} \tag{1}$$

$$\text{s.t} \ \frac{\sum_{r=1}^{S} U_r Y_{rj}}{\sum_{i=1}^{M} V_i X_{ij}} \leq 1, \ j=1,...,N$$

$$U_r, V_i \geq \varepsilon > 0, r=1,...,S, i=1,...,M$$

Where Y_{rj}: The r-th output of DMU j. X_{ij}: The i-th input of DMU j. U_r: The weight of the r-th output. V_i: The weight of the i-th input. ε: A small non-Archimedean quantity. We find that the value of U and V such that the efficiency score of every DMU is maximized. But the above function is the fractional linear programming method that has an infinite number of solutions. The problem can be solved by transferring it into the linear programming method that we assume $\sum_{i=1}^{M} V_i X_{ik} = 1$, which provides:

$$\text{Max} \ h_k = \sum_{r=1}^{S} U_r Y_{rk} \tag{2}$$

$$\text{s.t.} \ \sum_{i=1}^{M} V_i X_{ik} = 1$$

$$\sum_{r=1}^{S} U_r Y_{rj} - \sum_{i=1}^{M} V_i X_{ij} \leq 0, \ j=1,...,N$$

$$U_r, V_i \geq \varepsilon > 0, r=1,...,S, i=1,...,M$$

3.2. Procedures for Two-Stage DEA Efficiency Analysis

This study builds a two-stage DEA model, taking into account the interrelationship of the processes within the system, to measure the efficiency of the system and those of the processes at the same time. The system efficiency is thus measured more properly represents the aggregate performance of the component processes. As to the analysis of economic efficiencies of teams in MLB, we could conduct two-stage efficiency analysis procedure in this study. Conceptually, this research adopts a data envelopment analysis (DEA) approach for measuring economic efficiency of decision processes which can be divided into two stages. The first stage uses inputs to generate outputs which become the inputs to the second stage. The first stage outputs are referred to as intermediate measures. The second stage then uses these intermediate measures to produce outputs. The first stage is estimated for the resource operational efficiency and the second stage is used to evaluate output valid efficiency. Within the first-stage measure for the resource operational efficiency, three components are used as inputs including total player salary, total at bats and stadium cost. Total player salary is when a team pays some kind of direct currency remuneration of player during the beginning stage (Lewis and Sexton, 2004). Counting of total at bat represents the original opportunity to obtain the score via batting appearances (Sueyoshi, Ohnishi and Kinase, 1999). As to four outputs, they are the team's total bases, batting average, run batted in and total home runs. These are the regular hitting outputs in a game (Anderson and Sharp, 1997). Next, we use the three components of a team as inputs which mentioned above. According to the inputs and outputs among players and teams as we select and compute, we conduct the decomposition of efficiency components.

The measure for the second stage is output valid efficiency, we employ team's outputs to regard as input items and the three components of player as the results, that is, game wins, total runs and attendance. Game wins is the final goal of baseball teams, which is obtained by the count of Regular Season game, except for the playoff Series game and World Series game (Lewis and Sexton, 2004). Attendance is the sum of the numbers of people who are going to watch the baseball games in each game, it represents the popularity, familiarity and reputation of the baseball team (Barros and Leach, 2006). Next, we consider three components of team as results, that are, game wins, total runs and attendances. According to outputs and results among of team and team-type, the decomposition of economic efficiency can be completed. Therefore, we can further conduct the decomposition of efficiency among team and team-type and employ mathematical programming model to assess team within all teams, team within team type, term-type within all teams, team within team-division and team-division within team-type.

To sum up the above discussions, we identify the sets of input items, output items and result items to be included in the model which are based on institution approach. Outputs are chosen via the following items: team's total bases, batting average, total runs batted in and, total home runs. Results are chosen via the following items: game wins, total runs and attendance. The above items represent the major activities of the team, and the reason that can lead the team to win. Input measures are selected by the above outputs committed resources. We choose the following three items as inputs, that is, total player salary, total at bats and stadium costs.

We refer to the first stage outputs as intermediate measures. For example, the team's total bases, batting average, run batted in and total home runs which are in turn used to generate results (outcomes) such as games wins, total runs and attendance. This study presents a two-stage process to measure the team efficiency (resource operational efficiency and output valid efficiency) in the Major League Baseball (MLB). In our research, resource operational efficiency is measured using total player salary, total at bats and stadium cost as inputs, and the outputs are team's total bases, batting average, run batted in and total home runs. In the second stage for output valid efficiency, team's total bases, batting average, run batted in and total home runs are then used as inputs, while game wins, total runs and attendance are used as outputs. We should point out that the term two-stage DEA, or sometimes 'second stage' DEA, is often used in other contexts, specifically when analyzing the influence of environmental/external/discretionary/categorical variables on DEA efficiency scores (Ruggiero, 1998).

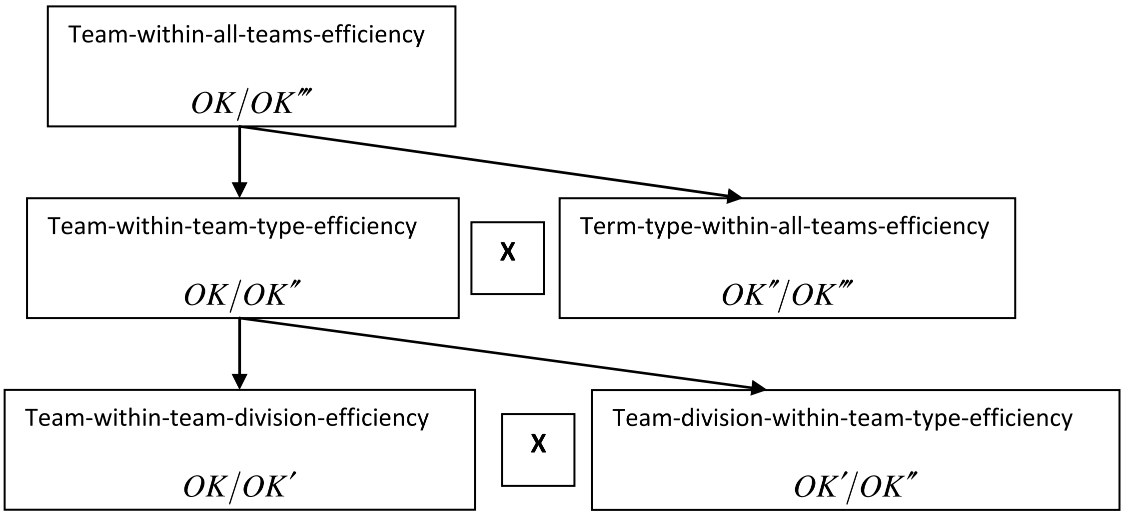
3.3. Conceptual Model for Two-Stage Efficiency Decomposition (of Team-Within-Both Leagues and Team-Within-Team-Type)

In this study, DEA is selected to assess the economic efficiency of players for MLB teams in the US. Efficiency decomposition approach is applied with DEA because the team operation will generate different efficiencies among team-within-all-teams-efficiency (players and teams). A similar method can be further used to generated different efficiencies among team-within-team-type-efficiency (team division and team type) (Portela and Thanassoulis, 2000).

Referring to Figure 1, in this study, the four components of the decomposed model in two-stage for efficiency evaluation can be detected as follows: the first stage, the team-within-all-teams-efficiency { OK/OK''' } could be decomposed in the team-within-team-type-efficiency (OK/OK'') and the term-type-within-all-teams efficiency (OK''/OK'''), as follows:

$$OK/OK''' = (OK/OK'') \times (OK''/OK''') \tag{3}$$

Figure 1: Conceptual Model of Two-Stage (for Player and Team) Efficiency Decomposition



For example, since the New York Yankees are in the American League, we can investigate the efficiency of the New York Yankees; then further explore the efficiency of all teams in the American League, and catch the efficiency of the New York Yankees compared with all teams.

The second stage, the team-within-team-type-efficiency (OK/OK'') can be decomposed in the team-within-team-division-efficiency (OK/OK') and the team-division-within-team-type efficiency (OK'/OK''), as follows:

$$OK/OK'' = (OK/OK') \times (OK'/OK'') \tag{4}$$

In this procedure, if we investigate the efficiency of the New York Yankees in the East coast and also figure out the efficiency of teams in this region, it is possible to furthermore speculate the efficiency of the New York Yankees in the American League.

3.4. Data Collection and the Operation of DEA

Our data is selected from the Major League Baseball data belonging to the year 2007, when the Taiwanese player Chen-Ming Wang (leading pitcher) impressively led the New York Yankees with 19 wins for two consecutive years. This year's data presents strong evidences and we are quite interested in analyzing the economic performance of the player in relation to his team type, and also consider team within all teams in both leagues in a Two-stage decomposition data envelopment analysis. The data is from the MLB and ESPN official websites. Items of Inputs, outputs and results are generalized in Table 1.

When employing the DEA model effectively, it is necessary to carefully choose the inputs, outputs and results. According to the two-stage efficiency analysis procedure, we can conduct the relationships between not only the inputs and outputs but also the outputs and results. Concerning resource operational efficiency, the output items should be able to demonstrate the basic operation objective of the teams, being that the input items should invest the proper factor of production to outputs. For output valid efficiency, the items representing results should be able to demonstrate the main operation objective of the teams, as the output items should also invest the proper factor of production to results. If the measurement indices are inappropriate, they will lose the representative results of measurement.

Table 1: Definition of All inputs, Outputs and Results in This Research

Variable	Name	Definition	Reference
Inputs	Total Player Salary	Team pays a kind of direct currency remuneration of player during the beginning.	Sexton and Lewis,2003 Lewis and Sexton,2004 Yang, Lin & Chen ,2014
	Total at Bats	Batting appearances, not including bases on balls, hit by pitch, sacrifices, interference, or obstruction	Sueyoshi, Ohnishi and Kinase, 1999
	Stadium Cost	All of construction cost, equipment cost and maintenance cost	Clapp and Hakes, 2005
Outputs	Team's Total Bases	The number of bases a player has gained with hits	Kedrowski, 2005 Sexton and Lewis,2003
	Batting Average	Hits divided by at bats and measuring the performance of cricket batsmen and baseball hitters	Anderson and Sharp,1997
	Run Batted in	Number of runners who scored due to a batters' action, except when batter grounded into double play or reached on an error	Anderson and Sharp,1997
	Total Home Runs	Hits on which the batter successfully touched all four bases, without the contribution of a fielding error	Anderson and Sharp,1997 Sueyoshi, Ohnishi and Kinase, 1999
Results	Game Wins	The number of times of victory in team during regular season games exclude from post-season games and MLB champion games.	Sexton and Lewis,2003 Lewis and Sexton,2004 Yang, Lin and Chen ,2014
	Total Runs	Times reached home base legally and safely	
	Attendance	It is one of the primary revenue sources for many professional sports teams.	Barros and Leach, 2006 Lemke, Leonard & Tlhokwane, 2010 Lewis, 2014

Source: This study

The DEAP version 2.1 software is used to estimate and conduct the efficiency analysis of the CCR-DEA model. We discuss whether to increase or decrease the change of outputs when the variables of inputs remains unchanged (Charnes, Cooper, Lewin, Morey, and Rousseau, 1985). In the first stage, model A is our starting model (see Table 2). Runs batted in is omitted from Model A to obtain Model C. The correlation coefficients between Model A and Model B are calculated as 0.109. We find that the number of efficient DMUs is 10 in Model A and is 6 in Model C, this shows that Model C is better than Model A. Furthermore, the average efficiency score of Model A is 0.975 and that of Model C is 0.690; the least efficiency score of Model A is 0.914 and that of Model C is 0.382. Similarly, Model C is better than that of Model B, D, and E. Thus, we choose Model C as our analyzed model for evaluating resource operational efficiency.

As to the second stage, the Model F is selected as our starting model (see the Table 3). We discuss increasing or decreasing the change of outputs when the variables of results are unchanged. Runs batted in is still omitted from Model F to obtain Model H. Now, the correlation coefficients between Model F and Model H are calculated as 0.440. We find that the number of efficient teams is 13 in Model F and is 6 in Model H, it shows that Model H is superior to Model F. Additionally, the average efficiency score of Model F is 0.966 and that of Model H is 0.889, moreover, the least efficiency score of Model F is 0.886 and that of Model H is 0.733. Again, Model H is superior to that of Model G, I, and J and we then select Model H as our analyzed model for evaluating output valid efficiency.

Table 2: Results of Sensitivity Analysis in the First stage (Inputs and Outputs)

	Items	Model A	Model B	Model C	Model D	Model E
Outputs	Total Bases	*	*	*	*	—
	Batting Average	*	*	*	—	*
	Runs Batted in	*	*	—	*	*
	Total Home Runs	*	—	*	*	*
Inputs	Total Player Salary	*	*	*	*	*
	Total at Bats	*	*	*	*	*
	Stadium Cost	*	*	*	*	*
Estimate result：Correlation coefficients by model A		—	0.110	0.109	0.167	0.113
Number of efficiency value (value=1)		10	6	6	6	6
Average efficiency value		0.975	0.680	0.690	0.677	0.692
Standard deviation		0.027	0.211	0.213	0.211	0.211
Least efficiency value		0.914	0.370	0.382	0.386	0.386

Note: Model C is a chosen model finally

Based on the above sensitivity analysis for related variables, our selected model owns three inputs, three outputs and three results. Items of Inputs are total player salary, total at bats and stadium cost. Items of outputs are total bases, batting average and total home runs. Items of Results are game wins, total runs and attendance.

Table 3: Results of Sensitivity Analysis in the Second Stage (Outputs and Results)

	Items	Model F	Model G	Model H	Model I	Model J
Results	Game Wins	*	*	*	*	*
	Total Runs	*	*	*	*	*
	Attendance	*	*	*	*	*
Outputs	Total Bases	*	*	*	*	—
	Batting Average	*	*	*	—	*
	Runs Batted in	*	*	—	*	*
	Total Home Runs	*	—	*	*	*
Estimate result：Correlation coefficients by model F		—	0.440	0.440	0.440	0.377
Number of efficiency value (value=1)		13	6	6	6	8
Average efficiency value		0.966	0.889	0.889	0.889	0.926
Standard deviation		0.039	0.090	0.090	0.090	0.062
Least efficiency value		0.886	0.733	0.733	0.733	0.813

Note: Model H is a chosen model finally

4. Empirical Results—Efficiency Evaluation

4.1. Estimated Results of Two-Stage DEA Efficiency Analysis

The scores for resource operational efficiency (ROE) and output valid efficiency (OVE) are calculated for each team in Table 4. We find that average resource operational efficiency and output valid efficiency are 0.690 and 0.889 respectively. As to the ROE, we also find that six of thirty baseball teams are categorized as technically efficient DMUs. The six efficient teams in ROE are the Oakland Athletics, Seattle Mariners, Tampa Bay Rays, Colorado Rockies, Florida Marlins and Los Angeles Dodgers. Additionally, in the OVE, we find that six of thirty teams are categorized as technically efficient DMUs. The six efficient teams in OVE are the Boston Red Sox, Cleveland Indians, Detroit Tigers, New York Yankees, Houston Astros and Los Angeles Dodgers, respectively.

Table 4: Estimated Efficiencies of Resource Operational and Output Valid Efficiencies

Team Name	ROE.	OVE.	Team Name	ROE.	OVE.
1. Baltimore Orioles	0.595	0.814	16. Atlanta Braves	0.42	0.89
2. Boston Red Sox	0.382	1	17. Chicago Cubs	0.855	0.904
3. Chicago White Sox	0.855	0.758	18. Cincinnati Reds	0.588	0.879
4. Cleveland Indians	0.623	1	19. Colorado Rockies	1	0.953
5. Detroit Tigers	0.655	1	20. Florida Marlins	1	0.816
6. Kansas City Royals	0.879	0.733	21. Houston Astros	0.494	1
7. Los Angeles Angels of Anaheim	0.481	0.99	22. Los Angeles Dodgers	1	1
8. Minnesota Twins	0.815	0.835	23. Milwaukee Brewers	0.76	0.881
9. New York Yankees	0.386	1	24. New York Mets	0.417	0.929
10. Oakland Athletics	1	0.801	25. Philadelphia Phillies	0.525	0.992
11. Seattle Mariners	1	0.926	26. Pittsburgh Pirates	0.697	0.748
12. Tampa Bay Rays	1	0.808	27. San Diego Padres	0.547	0.971
13. Texas Rangers	0.654	0.843	28. San Francisco Giants	0.555	0.788
14. Toronto Blue Jays	0.572	0.87	29. St. Louis Cardinals	0.507	0.827
15. Arizona Diamondbacks	0.53	0.949	30. Washington Nationals	0.896	0.763
			Mean	0.690	0.889
			Std. Dev.	0.213	0.090

Note: ROE= resource operational efficiency; which is obtained in the first stage, and OVE=output valid efficiency; which is obtained in the second stage.

4.2. Estimated Results for Two-Stage Efficiency Decomposition

As indicated in the conceptual model for two-stage economic efficiency decomposition (Figure 1), an efficiency decomposition where the overall efficiency of the two-stage process is a product of the efficiencies of the two-individual stages. In this study, efficiency decomposition approach was applied with DEA because the team operation will generate different efficiencies among term and team divisions. Evidently, we can conduct economic efficiency analysis of two- stage efficiency model and compare with champion team of World Series game in 2007. The Boston Red Sox enjoys efficient output valid efficiency and they were the champion team of World Series game in 2007 (Table 4). However, the Boston Red Sox is not an efficient team in resource operational efficiency. Another team such as the Los Angeles Dodgers enjoys both efficient output valid efficiency and efficient resource operational efficiency. The Los Angeles Dodgers also earns a better ranking within the whole baseball season in MLB.

Based on above discussions, now we can further construct team efficiency and team type efficiency by the economic efficiency decomposition method as mentioned above. We apply the two components of the analyzed model: 1) team within all team efficiency = team within team type efficiency multiplied by team type within all teams efficiency; and 2) team within team type efficiency = team within team division efficiency multiplied by team division within team type efficiency. Similarly, we investigate two-stage efficiency of resource operational efficiency and output valid efficiency within the decomposition efficiency.

Firstly, we select Model C and assign it as team within all teams' efficiency in the resource operation efficiency. All teams are subdivided into the American League and National League to obtain efficiency scores from those two leagues, respectively. We can find that the efficiency score of these two leagues are regarded as team within team type efficiency. Subsequently, we then utilize team-within-all-teams-efficiency scores and team-within-team-type-efficiency scores to estimate team-type-within-all-teams-efficiency scores. Next, all teams are divided into the East Division, Central Division and West Division and estimate efficiency scores from these three divisions, respectively. Additionally, we can also find the efficiency score of the three divisions regarded as team-within-team-division-efficiency scores and then obtain team-within-team-type-efficiency scores. Finally, we can further estimate team-division-within-team-type-efficiency scores via team-within-team-type-efficiency scores and team-within-team-division-efficiency scores.

Secondly, we select model H and deem as team-within-all-teams-efficiency in the output valid efficiency. Again, a similar method is employed to subdivide all teams into American League and National League and estimate their efficiency scores, respectively. Thus, we obtain the efficiency score of two leagues which are regarded as team within team type efficiency. We can then estimate team type within all teams' efficiency scores via team within all teams' efficiency scores and team within team type efficiency scores. Next, we divided all teams into the East Division, Central Division and, West Division and estimate their economic efficiency scores, respectively. As such, the efficiency score of the three divisions can be utilized in regard to team-within-team-division-efficiency and, team within team type efficiency scores can be obtained. Finally, we can estimate team division within team type efficiency scores via team within team type efficiency scores and team within team division efficiency scores.

4.2.1 Estimated Results for Efficiency Decomposition in Resource Operational Efficiency

The first-stage for economic efficiency decomposition in resource operational efficiency (ROE) is discussed as follows (Table 5 and Table 6):

Dividing 30 teams into the American League Alliance and National League Alliance, New York Yankees and Boston Red Sox both take much money in player's salaries and hitting performances of the two teams are better than the other teams. Hence, team-within-all-teams-efficiency scores (0.382 and 0.386) are worst than the others. The findings of results show input factors of Red Sox and Yankees generate inappropriate output factors and cause inefficiency teams. In other words, efficient teams show proper input factors react on the output factors such as Oakland Athletic Colorado Rockies, etc.

Table 5: The First Stage Decomposition of Efficiency in Resource Operational and Output Valid Efficiencies

League	Team	(1-1)	(1-2)	(1-3)	(2-1)	(2-2)	(2-3)
American League	1. Baltimore Orioles	0.595	0.913	0.652	0.814	0.912	0.893
	2. Boston Red Sox	0.382	0.909	0.420	1.000	1.000	1.000
	3. Chicago White Sox	0.855	0.602	1.420	0.758	0.880	0.861
	4. Cleveland Indians	0.623	0.871	0.715	1.000	1.000	1.000
	5. Detroit Tigers	0.655	1.000	0.655	1.000	0.964	1.037
	6. Kansas City Royals	0.879	1.000	0.879	0.733	1.000	0.733
	7. Los Angeles of Anaheim	0.481	1.000	0.481	0.990	1.000	0.990
	8. Minnesota Twins	0.815	0.945	0.862	0.835	0.935	0.893
	9. New York Yankees	0.386	0.900	0.429	1.000	1.000	1.000
	10. Oakland Athletics	1.000	1.000	1.000	0.801	0.904	0.886
	11. Seattle Mariners	1.000	1.000	1.000	0.926	0.924	1.002
	12. Tampa Bay Rays	1.000	1.000	1.000	0.808	0.883	0.915
	13. Texas Rangers	0.654	0.906	0.722	0.843	0.944	0.893
	14. Toronto Blue Jays	0.572	0.820	0.700	0.870	0.935	0.930
National League	1. Arizona Diamondbacks	0.530	0.778	0.681	0.949	1.000	0.949
	2. Atlanta Braves	0.420	0.952	0.441	0.890	0.962	0.925
	3. Chicago Cubs	0.855	0.988	0.865	0.904	0.983	0.920
	4. Cincinnati Reds	0.588	0.816	0.721	0.879	0.930	0.945
	5. Colorado Rockies	1.000	1.000	1.000	0.953	1.000	0.953
	6. Florida Marlins	1.000	1.000	1.000	0.816	0.917	0.890
	7. Houston Astros	0.494	0.843	0.586	1.000	0.932	1.07.0
	8. Los Angeles Dodgers	1.000	1.000	1.000	1.000	1.000	1.000
	9. Milwaukee Brewers	0.760	0.805	0.944	0.881	0.960	0.918
	10. New York Mets	0.417	0.891	0.468	0.929	1.000	0.929
	11. Philadelphia Phillies	0.525	0.993	0.529	0.992	1.000	0.992
	12. Pittsburgh Pirates	0.697	0.956	0.729	0.748	0.938	0.797
	13. San Diego Padres	0.547	0.830	0.659	0.971	1.000	0.971
	14. San Francisco Giants	0.555	0.939	0.591	0.788	0.972	0.811
	15. St. Louis Cardinals	0.507	0.917	0.553	0.827	0.988	0.837
	16 Washington Nationals	0.896	1.000	0.896	0.763	0.972	0.785

Note: (1-1), (1-2) and, (1-3) represents team-within-all-teams-efficiency, team-within-team-type -efficiency and, team-type-within-all-teams-efficiency in the resource operational efficiency, respectively. (2-1), (2-2) and, (2-3) represents team within all team's efficiency, team within team type efficiency and, team type within all team's efficiency in the output valid efficiency, respectively. Amongst, team-within-all-teams-efficiency = (team-within-team-type-efficiency) X (team-type-within-all teams-efficiency)

Table 6: The Second Stage Decomposition of Efficiency in Resource Operational and Output Valid Efficiencies

Division	Team	(3-1)	(3-2)	(3-3)	(4-1)	(4-2)	(4-3)
East Division	1. Baltimore Orioles	0.913	1.000	0.913	0.912	0.823	1.108
	2. Boston Red Sox	0.909	1.000	0.909	1.000	1.000	1.000
	3 New York Yankees	0.900	1.000	0.900	1.000	1.000	1.000
	4. Tampa Bay Rays	1.000	1.000	1.000	0.883	0.808	1.093
	5. Toronto Blue Jays	0.820	0.901	0.910	0.935	0.881	1.061
	6. Atlanta Braves	0.952	0.993	0.959	0.962	0.890	1.081
	7. Florida Marlins	1.000	1.000	1.000	0.917	0.816	1.124
	8. New York Mets	0.891	0.91	0.979	1.000	0.929	1.076
	9. Philadelphia Phillies	0.993	1.000	0.993	1.000	1.000	1.000
	10.Washington Nationals	1.000	1.000	1.000	0.972	0.763	1.274
Central Division	1. Chicago White Sox	0.602	0.618	0.974	0.880	0.799	1.101
	2. Cleveland Indians	0.871	0.952	0.915	1.000	1.000	1.000
	3. Detroit Tigers	1.000	1.000	1.000	0.964	1.000	0.964
	4.Kansas City Royals	1.000	1.000	1.000	1.000	0.796	1.256
	5. Minnesota Twins	0.945	0.977	0.967	0.935	0.876	1.067
	6. Chicago Cubs	0.988	1.000	0.988	0.983	1.000	0.983
	7. Cincinnati Reds	0.816	1.000	0.816	0.930	0.883	1.053
	8. Houston Astros	0.843	0.801	1.052	0.932	1.000	0.932
	9. Milwaukee Brewers	0.805	1.000	0.805	0.960	0.943	1.018
	10. Pittsburgh Pirates	0.956	1.000	0.956	0.938	0.816	1.150
	11. St. Louis Cardinals	0.917	0.845	1.085	0.988	1.000	0.988
West Division	1. Los Angeles of Anaheim	1.000	1.000	1.000	1.000	1.000	1.000
	2. Oakland Athletics	1.000	1.000	1.000	0.904	0.862	1.049
	3. Seattle Mariners	1.000	1.000	1.000	0.924	0.957	0.966
	4. Texas Rangers	0.906	1.000	0.906	0.944	0.979	0.964
	5. Arizona Diamondbacks	0.778	0.953	0.816	1.000	1.000	1.000
	6. Colorado Rockies	1.000	1.000	1.000	1.000	1.000	1.000
	7. Los Angeles Dodgers	1.000	1.000	1.000	1.000	1.000	1.000
	8. San Diego Padres	0.830	0.880	0.943	1.000	1.000	1.000
	9. San Francisco Giants	0.939	1.000	0.939	0.972	1.000	0.972

Note: (3-1), (3-2) and, (3-3) represents team within team type efficiency, team within team division efficiency and, team division within team type efficiency in the resource operational efficiency, respectively. (4-1), (4-2) and, (4-3) represents team within team type efficiency team within team division efficiency and, team division within team type efficiency in the output valid efficiency, respectively. Amongst, team within team type efficiency = team within team division efficiency multiplied by team division within team type efficiency.

The second-stage for efficiency decomposition in resource operational efficiency (ROE) is discussed as follows (still see Table 5 and Table 6):

Dividing 30 teams into the east division, central division and west division, the efficiency value of each team is very average. The show input factors of each division generate proper output factors. Excepting Chicago White Sox, the team-within-team-type-efficiency score (0.602) is lower than the others and team's manager must find out factors of inefficiency in the central division to adjust construct of input factors.

4.2.2. Estimated Results for Efficiency Decomposition in Output Valid Efficiency

The results of first-stage for economic efficiency decomposition in the output valid efficiency (OVE) are shown in the Table 5 and Table 6.

Now, we discuss hitting performance impact on game wins. Such as York Yankees and Boston Red Sox both are efficient teams. The team-within-all-teams-efficiency scores are one and show their hitting performance impact on game wins and ticket's income of attendance. In the two-stage efficiency model inefficiency teams need to adjust team's hitting performance and input factors of most teams can reflect proper output factors.

The second-stage efficiency decomposition in the output valid efficiency (OVE) is discussed as follows (still see Table 5 and Table 6):

For example, according to division York Yankees and Boston Red Sox are efficient teams and their game wins and attendances are better than the others. Hence, inefficient team improves hitting performance to obtain game win and to receive ticket's income of attendance.

4.3. Results of BCG Matrix

Based on the above discussion, we employ a business strategy matrix via the Boston Consulting Group (BCG) matrix to illustrate the relationship among the thirty baseball teams. We can employ the "resource operational efficiency (ROE) score in input and output matrix (I/O matrix)" together with the "output valid efficiency (OVE) score in output and result matrix (O/R matrix)" as two types of management matrix. That is, we can compare the efficiency score within the resource operational efficiency and the output valid efficiency. In Figure 2, we can observe that one of thirty teams (Los Angeles Dodgers) is located in quadrant as the "super stars" group via the I/O matrix and O/R matrix. It represents that the efficiency score equals one both in I/O matrix and in O/R matrix, indicating that the Los Angeles Dodgers team enjoys better performances both in terms of resource operational efficiency and the output valid efficiency and is classified as a "super star".

Similarly, five of thirty teams are distributed in quadrant as the "problem child" group, which are characterized as inefficient teams (efficiency score is smaller than one) in I/O matrix and efficient teams (efficiency score equal one) in O/R matrix. We then suggest that the problem child teams should rearrange input to improve their performance in resource

Figure 2: Estimated results of BCG matrix

		Problem Child	**Super Star**
Efficiency score in output and result (output valid efficiency-OVE)	Efficient team	1. Boston Red Sox 2. Cleveland Indians 3. Detroit Tigers 4. New York Yankees 5. Houston Astros	1. Los Angeles Dodgers
		Dog	**Cow**
	Inefficient team	1. Baltimore Orioles 2. Chicago White Sox 3. Kansas City Royals 4. Los Angeles Angels of Anaheim 5. Minnesota Twins 6. Texas Rangers 7. Toronto Blue Jays 8. Arizona Diamondbacks 9. Atlanta Braves 10. Chicago Cubs 11. Cincinnati Reds 12. Milwaukee Brewers 13. New York Mets 14. Philadelphia Phillies 15. Pittsburgh Pirates 16. San Diego Padres 17. San Francisco Giants 18. St. Louis Cardinals 19. Washington Nationals	1. Oakland Athletics 2. Seattle Mariners 3. Tampa Bay Rays 4. Colorado Rockies 5. Florida Marlins
		Inefficient team	Efficient team
		Efficiency score in input and output (resource operational efficiency-ROE)	

operational efficiency. Conversely, there are five of thirteen teams is categorized in quadrant as the "Cow" group, which is categorized as the efficient teams in I/O matrix and inefficient teams in O/R matrix. It should be noted that these cow teams could rearrange input to improve their performance in output valid efficiency. Finally, there are nineteen out of thirty teams in the quadrant remarked as the "dog" group, which represents inefficient teams (efficiency score is smaller than one) both in I/O matrix and in O/R matrix.

We find that the majority of the teams are found within the inefficient team's quadrant of "dog" group in the BCG matrix. Conversely, only one team (Los Angeles Dodgers) is located within the "super star" group which enjoys sufficient performance and has the high relatively opportunity to win the championship. The results of BCG matrix can provide efficiency locus to distinguish with the team of high performance.

5. Concluding Remarks

In this study, we discussed the economic performance of each baseball team of Major League Baseball in the US. The process of research mainly employed data envelopment analysis (DEA) and decomposition of economic efficiency to evaluate team performance. In the first-stage efficiency model, the concept of inputs was set up as one with outputs including the total bases, batting average and total home runs. In the second-stage efficiency model, the concept of outputs was set up as one, and the results included the game won, total runs and attendance. Decomposition of economic efficiency was an overall measure of efficiency and we could employ the method to calculate the efficiency of each team level. The element of efficiency attributable to the team was further decomposed into team within team type efficiency and team within all teams' efficiency. In addition, team within team type efficiency was also decomposed into team within team division efficiency and team division within team type efficiency (Portela and Thanassoulis, 2000). Employing decomposition of efficiency could effectively decompose teams into different efficiency levels and analyzing the efficiency of each level will reveal the most efficient teams. According to these teams we could estimate that they had the most opportunity to win the championship and to compare if these teams can reach their expected performance by paying premium salaries to players. We also further applied a two-stage decomposition efficiency model. The decomposable narration understood the efficiency of each team level and might provide useful information to the team. Such information might help the bosses of teams to manage efficiently regarding different team levels and further improve the situation of inefficient teams.

The main finding of this study is that the efficiency of teams in the American League is better than in the National League; moreover, game won from each team also reflects the same situation. In addition, the final goal of each team is to be the champion of the World Series game. In fact, the Boston Red Sox were indeed in the American League and then won the MLB champion. The Boston Red Sox in the first stage efficiency model were not more efficient than the Los Angeles Dodgers. This is because the efficiency team only can explain that inputs, outputs and results of the teams were more suitable. The inefficient teams can compare with efficient teams to find inputs, outputs and results of unsuitableness to further improve. Then each team will all expect to be the champion of the World Series game in the next season and earn more revenue from attendance.

Finally, the BCG matrix is applied to illustrate the relationship of teams, divided each team into I/O efficiency (ROE) and O/R efficiency (OVE), and proposed management implications to find a "Super Star" group, "cow" group, "problem child" group and "dog" group. In the BCG matrix there are nineteen teams in the "dog" group, five teams in the "problem child" group, five teams in the "cow" group and one team in the "super star" group. The Los Angeles Dodgers according to the two-stage efficiency model were "Super Star" and showed greater efficiency than others.

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