MEASURING THE MAJOR LEAGUE BASEBALL TEAM'S RELATIVE EFFICIENCY USING DATA ENVELOPMENT ANALYSIS MODELS FOR 2013 SEASON

C. Christopher Lee, Central Connecticut State University
christopher.lee@ccsu.edu

Raymond Schuh, Lake Superior State University
rschuh@lssu.edu

Jinhee Yoo, Gannon University
yoo002@gannon.edu

ABSTRACT

We developed Bilateral Data Envelopment Analysis (DEA) models to compute the relative efficiency scores of Major League Baseball (MLB) teams. DEA models compared the teams and took inputs and outputs into consideration. As inputs, we proposed total salary, population of host city, and total runs against (opponent's points). Outputs included wins, popularity (via Facebook likes), and team revenue. The data were collected from the 2013 season. 30 MLB teams were categorized into two groups. Group 1 included 15 high salary teams, while Group 2 included 15 low salary teams. Results show that low salary teams have significantly higher relative efficiency scores than high salary teams, on average.

Keywords: Data envelopment analysis, relative efficiency, Major League Baseball, Facebook likes

INTRODUCTION

This study will focus on Major League Baseball (MLB) teams and their relative efficiency. The Data Envelopment Analysis (DEA) models will compare player salaries, the population of the host city and total runs against the team's ability to win, generate revenue, and gain fans. Following this comparison, the study will show the correlation between payroll size and team success, with team success being measured by relative efficiency. Many studies have focused on salaries verses wins in the past, but, considering the other parameters, the DEA analysis seems to be lacking. In fact, there is currently no available DEA model for the 2013 season from which the data for this study will be gathered.

This study aims to show the relationship between payroll size and the relative efficiency of MLB teams. Since MLB has no salary cap, player salaries have soared to enormous levels. This results in a huge gap between total salaries for the top teams and total salaries for those at the bottom. There is almost a $207 million difference between the richest team, the New York Yankees, and the poorest, the Houston Astros. For example, Alex Rodriguez signed the 10 year $275 million contract with New York Yankees. This should, if you assume equal rates of pay for wins, mean that the New York Yankees win ten times as many games, but results of the season

show that this does not occur (Sly, 2012). The results of this DEA analysis will show if team owners benefit at all from paying these huge sums for talent.

The study employs DEA models for measuring relative efficiency of each Major League Baseball team's salary, population of host city, and runs against to wins, revenue, and popularity in the 2013 season. Since a DEA model measures relative efficiency among similar organizations or objects, it fit the goals of this study more than any other model. In its relative efficiency calculations, individual teams will be considered decision-making units. For the inputs and outputs the study will use data from statistics, Facebook.com likes, and censuses.

Before expounding on the research of this study, we will provide a list of reference material used in this paper along with a brief synopsis of the articles. These articles provided background on prior studies and information on what other researchers consider good variables for measuring success in the MLB. Using DEA with each team being a decision-making unit (DMU), we will compare their specific output (wins, popularity, revenue) to their input, (payroll, population, runs against). After performing the DEA, we will show the relative efficiency of the MLB teams compared to one another. Then, we will discuss the results and analyze. Finally, we will test which teams perform most efficiently.

LITERATURE REVIEW

Lewis and Sexton (2004) developed a DEA model that used reverse inputs and outputs as opposed to the standard DEA model. The study correlated total bases reached to wins, using the total bases as the input to the output of wins. Based on the 1999 season, results showed efficient teams to be the majority of the divisional winners in this study. The study also directly attributed the lack of a high salary to a team being unsuccessful.

Einolf (2004) looked into the efficiency of MLB and NFL franchises using salary as an input and wins as an output. The model compared the two leagues instead of the teams within the leagues. Using this model, the study found that MLB tended to be less efficient mostly due to large market teams having no force to stop excess expenditures for wins. With MLB leadership considering winning as the most important factor, the financial setup of the league contributed to inefficiency. Conversely, while winning is important in the NFL, teams have found a way to accomplish this while remaining efficient through the use of salary caps.

Chen and Johnson (2010) analyzed the performance of pitchers in MLB. Their paper aimed to uncover the strategy and historical usage of pitchers and their effectiveness. The paper found that conventional baseball knowledge was generally correct. It also has found that the important factors in pitching have changed as baseball has evolved. This would indicate that, while one factor may be important today in winning, that same factor over time may become more or less important.

Hadley and Ruggiero (2006) considered the use of DEA model in order to determine the value of MLB players in the arbitration process. Through their study, they aimed to learn the efficiency of arbitration with respect to the two arbitrating entities, MLB and the union. The unions wanted more money for equal work while the MLB owners cited players who made less and who were more efficient. The study found that arbitration tended to gain a player a value closer to the "market

value" in free agency, increasing the total cost of players while decreasing the overall efficiency of teams.

Garcia-Sanchez (2007) applied a three-stage DEA model to the Spanish Professional Football League. Teams were separated into three components: operating efficiency, athletic effectiveness and social effectiveness. The paper indicated that teams that were most operationally effective and athletically effective were the most effective teams. The study found social effectiveness to be related to the level of play itself. Results from year to year varied, but steadily improving was found to be the most efficient strategy.

Zhang, Li, Meng, and Liu (2009) used the DEA model to discover the relationship between underlying preferences and the performance of nations at the Olympics. The study proposed new models with Lexicographic preferences to measure the performances at the Olympics. The DEA model indicated a strong desire at even a non-business level for sports to be efficient.
Glenn, Schwandt, and Triantis (2006) measured the efficiency of collegiate athletic departments. Performance measures in this environment presented difficulties due to the dual system for success. In this combined academic and athletic sphere, efficiency requires both on the field and off the field success. The study then provides commentary as to which organizations perform most efficiently and then suggests areas for improving underperforming programs. The information gathered is mainly policy to performance related.

While mainly representing the world of politics, Sexton and Lewis (2012) proposed that inefficiency tended to increase in the face of head-to-head competition between two entities. Those favored to win (incumbents) were more likely to overspend in terms of efficiency in an attempt to guarantee votes. This behavior has become worse over time and the inefficiency has been shown to relate directly to losses.

Tiedemann, Francksen, and Latacz-Lohmann (2011) used the DEA model to measure the efficiency between performance, positions and the rankings of teams at the end of the year in the German Football League. It used a "metafootballer" technique to optimize player position in order to increase efficiency, which was to say that players were not always most efficient in their designated position regardless of their prior beliefs.

Cameron (2012a) compared wins to salary. This comparison shows quite a low correlation of just 0.18. As the author pointed out, this was an anomaly year, as bottom-tier teams seemed to over-perform while many top tier-teams folded. This made the correlation the lowest it has been since the mid-eighties.

Garcia (2012) compared salary to wins using a normalized standard to compare team performance. With this, he showed that the ratio of salary to wins was not one to one, even though the top teams outperformed their lower tier counterparts. For example, the Oakland Athletics paid 44% less than the league average but still managed 94 wins. This was 60% above the average for salary to wins compared to the normalized average.

Recent studies have investigated the efficiency of MLB teams by modeling and assessing the impact of salary upon wins (Bertin, 2012; Fry, 2012; Sly, 2012). Bertin (2012) makes a significant

addition by including the effects of injuries and minor league call-ups upon the roster and resultant performance of the teams under study.

Pheifer (2013) showed that about half of all teams in MLB paid recommended salary amounts. Additionally, some teams were considered under-achievers simply because of the division in which it played. Due to the division being stronger and the fact that these teams must play a large number of games against much better teams, this article showed that these teams were not performing to the ideal standard.

Cameron (2012b) discussed the unfairness of the current collective bargaining agreement for rookies up to 3rd year pros. These players made a relatively low salary as compared to their outputs. Cheap quality players existed in the star-driven, no-capped league.

Hasan (2008) tracked the salary-to-win performance from 1992 through 2007 to show trends of salary and wins. Hasan then relates the performance on the field directly to the amount of money spent by the organizations on salaries.

Schwartz and Zarrow (2009) talked about the lack of a salary cap in MLB since all other professional team sports have salary caps. They found that MLB is unique in that not only does it not have a cap, but players have the ability to be free agents. Players who are not chosen by a team or who are released from their contract can entertain offers from any teams and accept at their own will. This practice has resulted in top players, or Type A free agents, getting extremely lucrative offers, often into the tens of millions of dollars per year.

Many have researched the efficiency of baseball teams regarding the payroll to win ratio; however, most have only taken these two factors into consideration. Finding high correlations between payroll and team success seems rather intuitive, yet some teams break from this. While all teams would like to be able to get more value for their money spent, some contravene that equation. Teams like the New York Yankees spend money on huge player contracts, yet one may argue that the results of these contracts give them overwhelming advantage on a season-to-season basis. Teams like the Oakland Athletics have found a way to have a successful season despite having one of the lowest payrolls in the league. Many studies have included cost-per-win figures, a reasonable tool for estimating a team's efficiency through a simple ratio of salary to wins. This figure only takes into account two factors in its calculation however. Through this study, we hope to show how many other factors determine a team's overall success or failure. In our comparison, we also considered total bases reached. This statistic does not mesh well with other input statistics, though, due to its odd nature of being inverse from a standard input. (Inputs usually work better when lower in organizations.

Many have studied baseball teams' efficiencies with only the variables including salary and wins because of all professional sports leagues MLB alone has no salary cap. As such, outsiders often consider teams to be "out of the running" or "not trying to compete" if they have low payrolls. In this kind of system, players can demand outrageous salaries. If team owners deem the players worth it, the players will get paid. MLB also allows free agency to players not under contract. If players satisfy their contractual obligations to a team, regardless of whether the team wishes to renew or resign those players to a new contract, those players have the freedom to test their value

on the free agent market. This can create a bidding war to secure the services of top tier players, or in some cases, the best available player for a desired position. These bidding wars may be part of the reason behind the inflated salaries of the best players over the past several years. Additionally, contractual arbitration, a practice allowed in baseball, contributes to the inflation since players may bring contracts to which they are currently obligated and can request changes that will bring pay or benefits more in line with the level of play. Due to the lack of other variables, other studies were used to find additional common rating factors for success in various sporting leagues. These studies also compared salary to wins, and factors such as social effectiveness, positional performance and available resources also bore consideration.

METHODOLOGY

This paper uses DEA models to measure the relative efficiencies of MLB teams using inputs: total payroll, runs against, the metro area population, and outputs: team revenue, total wins, team loyalty as measured by Facebook.com likes. DEA model is a tool for measuring relative efficiency among similar organizations or objects. These organizations or objects that will be measured are known as decision-making units or DMUs. Since DEA identifies relative efficiency, it works well for benchmarking and comparisons.

To explore the mathematical property of DEA, let E_0 be a relative efficiency score for the base DMU *0* then,

$$\text{Maximize } E_0 = \frac{\left\{\sum_{r=1}^{R} u_{r0} y_{r0}\right\}}{\left\{\sum_{i=1}^{I} v_{i0} x_{i0}\right\}} \qquad (1)$$

subject to

$$\frac{\left\{\sum_{r=1}^{R} u_{r0} y_{rk}\right\}}{\left\{\sum_{i=1}^{I} v_{i0} x_{ik}\right\}} \le 1 \text{ for all } k \qquad (2)$$

$$u_{r0}, v_{i0} \ge \delta \text{ for all } r, i, \qquad (3)$$

where

y_{rk}: the observed quantity of output r generated by unit $k = 1, 2, \ldots, N$,
x_{ik}: the observed quantity of input i consumed by unit $k = 1, 2, \ldots, N$,
u_{r0}: the weight to be computed given to output r by the base unit *0*,
v_{i0}: the weight to be computed given to input i by the base unit *0*,
δ: a very small positive number.

Assuming a linear relationship between variables, it would be easiest to convert the fractional programming model to a common linear programming (LP) model. Using a piecewise LP model one can use a non-proportional returns-to-scale like increasing, decreasing or variable. Depending on the returns-to-scale selected and/or various modeling approaches, different types of DEA models are available.

This study uses a Charnes-Cooper-Rhodes (CCR) model, a Banker, Charnes, and Cooper (BCC) (1984) model, and a slack-based measure of efficiency (SBM) to determine operational efficiencies. First, we measure the relative efficiency of DMUs using the CCR and BCC models respectively. Second, we will apply SBM to the data in order to evaluate the efficiency of variables with non-radial properties. Finally, we try to compare the results of the three models to determine what level of salary has the higher value of relative efficiency, high or low salaried teams.

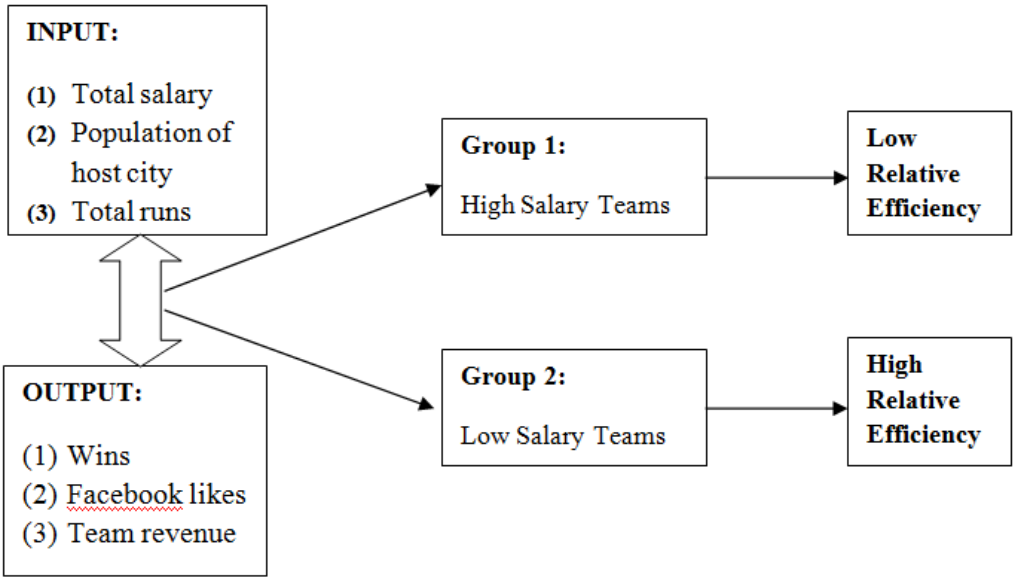
The DMU's for this study are the thirty MLB teams. These teams are all located in North America, with the vast majority in The United States of America. The teams are split between two Leagues, the American League (AL) and the National League (NL), which have similar rules and regulations with the exception that AL uses the designated hitter instead of having the pitcher bat. When interleague play does occur, the home leagues rules are used. All teams compete in order to make the playoffs. From there, teams compete in the Divisional Series, with the winners rising in the competition to play in an interleague World Series. As previously mentioned, MLB has no salary cap unlike most North American professional sports. The teams range in salary from a payroll of $20 million to $220 million.

This research selects three input variables such as total salary, population of host city, and total runs against. DEA models employ three output variables such as wins, popularity (via Facebook likes), and team revenue. No other research was found involving MLB that used runs against or metro population as inputs, or used revenue or loyalty/popularity as outputs. These factors were included in other studies involving other sports such as Spanish football teams (Garcia-Sanchez, 2007).

We propose Facebook likes to serve as a proxy to measure a MLB team's popularity (Facebook Like Information, 2013). Some research indicates the noisiness of the Facebook like signal (Shruti, Roy, & Zeng, 2014). There have been numerous studies on Facebook likes (Dijck & Poell, 2013; Kosinski, Stillwell, & Graepel, 2013). No studies have tested data from the 2013 MLB season, using the DEA models with the six variables proposed by this paper. Therefore, we propose the following research hypothesize. Figure 1 presents a research framework for this paper.

Research Hypothesis: Low salary teams tend to have higher relative efficiency than high salary teams, given that total salary, population of host city, total runs against as three inputs, and wins, Facebook likes, team revenue as three inputs, are taken into consideration.

Figure 1. Research Framework



RESULTS

The data was collected from MLB teams and their respective statistics and total salaries (MLB Team Stats, 2013; MLB team values: the business…, 2013). This included the league's thirty teams from all over the United States of America and one team from Toronto, Ontario, Canada. The numbers for the Canadian team, namely the salary and revenue were given in US Dollars to provide a direct comparison between teams. Using total team salary allowed a fair comparison of the relative efficiency of each team, while runs against allowed for an unbiased comparison of each team's proficiency at the game. As the old adage goes, "offense wins games, defense wins championships." Runs against was used to show the team's defensive ability, with a lower number indicating a better defensive team that most likely resulted from a mix of pitching and fielding capability.

ESPN's website was consulted to retrieve statistics on team performance. All information gathered pertaining to team revenues and salary was found at Forbes website under "The Business of Baseball." The United States government census website directly provided information about the population of the host cities (Population by City, 2012), except for the population of Toronto, Ontario. Information about Toronto came from a "backgrounder" of the city that used data from the Canadian census (2011 Census: Age and Sex Counts; Population of Toronto, 2013). Table 1 shows the raw data collected from 2013 MLB season.

Table 1. Sample Data from MLB 2013 Season

	Input Variables			Output Variables		
Team Name	**Total Salary** (in millions)	**Total Runs Against**	**Population of Host City** (in thousands)	**Facebook Likes** (in thousands)	**Wins**	**Revenue** (in millions)
New York Yankees	229	671	8337	6530	85	471
Los Angeles Dodgers	217	582	3857	1650	92	245
Philadelphia Phillies	165	749	1547	1345	73	279
Boston Red Sox	151	656	636	4102	97	336
Detroit Tigers	148	624	701	1363	93	238
San Francisco Giants	140	691	826	1820	76	262
Los Angeles Angels	128	737	3857	623	78	239
Chicago White Sox	119	723	2715	1072	63	216
Toronto Blue Jays	118	756	2615	563	74	203
St. Louis Cardinals	115	596	318	1566	97	239
Texas Rangers	114	636	376	1603	91	239
Washington Nationals	114	626	632	259	86	225
Cincinnati Reds	107	589	297	741	90	202
Chicago Cubs	104	689	2715	1833	66	274
Baltimore Orioles	91	709	621	542	85	206
Atlanta Braves	90	548	444	1436	96	225
Arizona Diamondbacks	89	695	1489	354	81	195
Milwaukee Brewers	83	687	599	672	74	201
Kansas City Royals	81	601	147	368	86	169
Pittsburgh Pirates	80	577	306	528	94	178
Cleveland Indians	78	662	391	626	92	186
Minnesota Twins	76	788	393	838	66	214
New York Mets	73	684	8337	682	74	232
Seattle Mariners	72	754	635	591	71	215
Colorado Rockies	72	760	634	560	74	199
San Diego Padres	67	700	1338	440	76	189
Oakland Athletics	61	625	401	445	96	173
Tampa Bay Rays	58	646	348	505	92	167
Miami Marlins	36	646	414	335	62	195
Houston Astros	22	848	2160	507	51	196

This study used CCR, BCC and SBM models to determine operational efficiencies. The models were first run with an emphasis on inputs and then again with an emphasis on outputs. It used DEA models because these models can determine relative efficiency without bias towards a particular variable, assigning weight of the variables from a mathematical basis. Complete results of the models appear in the charts at the end of the study. Bilateral DEA models were adopted because

this research focuses on the two groups: high salary team group (Group 1) and low salary team group (Group 2). Table 2 reports the relative efficiency scores computed by various Bilateral DEA models.

Table 2. Relative Efficiency Scores by Four DEA Models

ID	MLB Team	Group	Bi-CCR-I	Bi-BCC-I	Bi-SBM-C	Bi-SBM-V
1	New York Yankees	1	3.7138	1.0000	1.5078	1.7672
2	Los Angeles Dodgers	1	1.0819	1.0000	1.0263	1.0758
3	Philadelphia Phillies	1	0.9072	1.0000	0.4904	1.0678
4	Boston Red Sox	1	2.3863	1.0000	1.2991	1.4930
5	Detroit Tigers	1	0.9289	1.0000	0.6993	1.0182
6	San Francisco Giants	1	1.0051	1.0000	1.5934	1.1330
7	Los Angeles Angels	1	0.7898	1.0000	0.3488	1.0155
8	Chicago White Sox	1	0.7276	0.7580	0.4296	0.4296
9	Toronto Blue Jays	1	0.6673	0.7332	0.3344	0.3344
10	St. Louis Cardinals	1	1.5226	1.0000	1.1698	1.1925
11	Texas Rangers	1	1.3182	1.0000	1.1019	1.1211
12	Washington Nationals	1	0.8754	0.8754	0.3090	0.3090
13	Cincinnati Reds	1	1.0069	1.0842	1.0023	1.0078
14	Chicago Cubs	1	1.0966	1.0000	1.0313	1.1518
15	Baltimore Orioles	1	0.7900	0.8137	0.5085	0.5085
16	Atlanta Braves	2	1.2497	1.2556	1.0926	1.1168
17	Arizona Diamondbacks	2	0.9744	1.0225	0.5608	1.0142
18	Milwaukee Brewers	2	1.0647	1.1203	1.0210	1.0477
19	Kansas City Royals	2	1.9179	2.0204	1.2627	1.4471
20	Pittsburgh Pirates	2	1.3550	1.3625	1.1006	1.1355
21	Cleveland Indians	2	1.3199	1.3462	1.0982	1.1181
22	Minnesota Twins	2	1.2563	1.3011	1.0789	1.1268
23	New York Mets	2	1.2961	1.3147	1.0987	1.1133
24	Seattle Mariners	2	1.2943	1.2969	1.0900	1.1036
25	Colorado Rockies	2	1.1999	1.2664	1.0668	1.0891
26	San Diego Padres	2	1.2354	1.3582	1.0785	1.1237
27	Oakland Athletics	2	1.6950	1.8525	1.2047	1.2579
28	Tampa Bay Rays	2	1.7323	1.8103	1.2160	1.2801
29	Miami Marlins	2	2.2975	2.5278	1.3975	1.6039
30	Houston Astros	2	3.4439	4.1364	1.7286	2.0454

A Mann-Whitney model was then used to test differences in relative efficiency scores between the high and low salaried team groups. This paper used the non-parametric Mann-Whitney test instead of a parametric t-test method due to a small sample size and insufficient normality of the relative efficiency scores. The use of "high" salary team refers to the fifteen highest-paying teams and that of "low" salary teams to the fifteen lowest-paying teams. The group statistics reported that in every

single DEA model the lower salary teams had a higher mean relative efficiency score. Results indicated that using a one-tailed test in every case yielded a p-value below .01. With two models (Bi-CCR-I, Bi-BCC-I), results indicated a p-value below .001 as shown in Table 3.

Table 3. Mann-Whitney Test Results

	Bi-CCR-I	Bi-BCC-I	Bi-SBM-C	Bi-SBM-V
Overall Mean	1.4050	1.3085	6.2565	1.1083
Group 1 (high salary teams) Mean	1.2545	0.9510	11.3734	0.9750
Group 2 (low salary teams) Mean	1.5555	1.6661	1.1397	1.2416
Group 1 Rank Sum	292	344	277	276
Group 2 Rank Sum	173	121	188	189
Mann-Whitney Test Statistic	2.4679***	4.6248***	1.8458**	1.8043**

**p<.01 ***p<.001

Table 4 shows the total rank of each MLB team. The total rank added up four ranks from the four relative efficiency scores. As shown earlier, Group 1 indicates the high salary teams, while Group 2 indicates the low salary teams. Based on the relative efficiency scores by DEA models, four ranks were generated. Rank Total sums up the four ranks. The overall relative efficiency rank was determined by rank total. The least rank total means the highest overall relative efficiency rank. More teams in Group 2 report the lower rank total, which means the more efficient. In overall, Houston Astros is ranked the most efficient among MLB teams in 2013 season. Top five most efficient teams are Houston Astros, Miami Marlins, Kansas City Royals, New York Yankees and Tampa Bay Rays. Table 4 reveals all the ranks.

Table 4. Overall Relative Efficiency Rank by Rank Totals of Four DEA Models

MLB Team	Group	Bi, CCR-I, Rank	Bi, BCC-I, Rank	Bi, SBM-C, Rank	Bi, SBM-V, Rank	**Rank Total**	**Overall Relative Efficiency Rank**
Houston Astros	2	2	1	2	1	**6**	**1**
Miami Marlins	2	4	2	4	3	**13**	**2**
Kansas City Royals	2	5	3	6	5	**19**	**3**
New York Yankees	1	1	17	3	2	**23**	**4**
Tampa Bay Rays	2	6	5	7	6	**24**	**5**
Oakland Athletics	2	7	4	8	7	**26**	**6**
Boston Red Sox	1	3	17	5	4	**29**	**7**
Pittsburgh Pirates	2	9	6	11	10	**36**	**8**
St. Louis Cardinals	1	8	17	9	8	**42**	**9**
Cleveland Indians	2	10	8	13	15	**46**	**10**
New York Mets	2	12	9	12	17	**50**	**11**
San Francisco Giants	1	22	17	1	11	**51**	**12**
Texas Rangers	1	11	17	10	14	**52**	**13**
Minnesota Twins	2	14	10	16	12	**52**	**14**
San Diego Padres	2	16	7	17	13	**53**	**15**
Seattle Mariners	2	13	11	15	18	**57**	**16**
Atlanta Braves	2	15	13	14	16	**58**	**17**
Chicago Cubs	1	18	17	19	9	**63**	**18**
Colorado Rockies	2	17	12	18	19	**66**	**19**
Los Angeles Dodgers	1	19	17	20	20	**76**	**20**
Milwaukee Brewers	2	20	14	21	22	**77**	**21**
Cincinnati Reds	1	21	15	22	26	**84**	**22**
Detroit Tigers	1	24	17	23	23	**87**	**23**
Arizona Diamondbacks	2	23	16	24	25	**88**	**24**
Philadelphia Phillies	1	25	17	26	21	**89**	**25**
Los Angeles Angels	1	28	17	28	24	**97**	**26**
Baltimore Orioles	1	27	28	25	27	**107**	**27**
Chicago White Sox	1	29	29	27	28	**113**	**28**
Washington Nationals	1	26	27	30	30	**113**	**29**
Toronto Blue Jays	1	30	30	29	29	**118**	**30**

DISCUSSION

The results of this study tended to run contrary to the majority of other studies reviewed. Other studies had determined that higher-paying teams tended to outperform lower-paying teams (Cameron, 2012a; Cameron, 2012b; Garcia, 2012; Hasan, 2008; Lewis & Sexton, 2004;). While this may have been true when only using wins as an output, when considering other equally

important factors to management such as popularity and revenue generated, results show that more efficient teams do not spend the most money. When the emphasis is placed only on wins in head-to-head competition, a definite trend of overspending when two opposing forces compete appears (Sexton & Lewis, 2012). When the concepts from that paper are applied to the MLB, one can see that, since the teams tend to constantly engage in head-to-head competition the need to compete can result in inefficiency in areas such as player salary.

The major managerial implication of this research is that higher spending does not lead to a higher level of relative efficiency when one considers combined inputs such as salary, runs against, and the population of the host city and compares them to outputs such as wins, revenue, and popularity. This suggests that MLB owners and general managers should ignore the idea that only high-spending teams can find success. The results of this paper show statistical evidence that teams do not have to spend excessive amounts of money in order to find organizational success. One can see this by just looking at the relative efficiency scores. Some MLB teams may view winning as the only goal of the organization, but that view, if allowed to be the only desired output, has the potential to lead to a level of organizational inefficiency.

CONCLUSION

This study sought to find the relative efficiency scores of the thirty MLB teams from the inputs of player salary, population of the host city, and runs against and the outputs of revenue, popularity, and wins. Using the DEA model, results showed the relative efficiency score of MLB teams using three different DEA model variants: Bilateral CCR-I, BCC-I, SBM-C, and SBM-V models. Each model was tested twice with the emphasis being shifted between inputs and outputs.

Results indicate that when measured using the inputs and outputs of this study each MLB team paying a lower salary to its players will increase relative efficiency beyond that of higher-paying teams. The implications of this have the most importance to the management and owners of MLB teams. This questions the idea that teams have to spend a lot of money on players in order to be successful. A team can obtain relative efficiency by keeping the payroll low while making smarter player and location decisions. While the measure of success may vary from team to team, this measurement shows that spending less money tends to indicate a higher level of relative efficiency of the organization.

This study is limited by the relatively low amount of information officially available from MLB teams. While one can easily obtain payroll information for comparison since it is reported to MLB with similar rules, information on front-office spending is not so easily found and is not as comparable due to different ways of computing such costs. This information could help future studies by providing additional insight about the situation as an input in a DEA model for MLB teams.

Though MLB does not have a salary cap, MLP does implement a luxury tax that is intended to curb talent disparities caused by high value contracts. Further research may explore effects of the luxury tax. The American League's designated hitter rule is assumed to generate more scores than the National League. Therefore, DEA modeling within each league is suggested to avoid such score bias. Future studies could also compare league efficiency as well as league efficiency with

inputs and outputs more customized to the desire of that division or league. For example, player performance in outdoor stadiums or indoor stadiums may be more appropriate when comparing divisional efficiency based on the type of stadium in which specific teams most often played. Also, an analysis of multi-year data per each team may generate interesting pattern and trend. With the information available at this time, this paper has made a contribution to the sports management and business analytics literature with empirical evidence.

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