

Research on the Operational Efficiency of NBA Clubs Based on DEA Model

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ABSTRACT

Based on the data of 30 NBA teams in the 2018-2020 season, establish an input-output indicator system. Use the data envelopment analysis method to measure and analyze the efficiency of the team club. The results show that the efficiency of each club in the NBA is quite different; there are more teams at low and medium levels of efficiency; superstars have a greater impact on the efficiency of the team; teams with increasing returns to scale account for the majority. Based on this, NBA teams should expand the scale of investment, improve management efficiency, and strive to pursue superstars.

Keywords: NBA Club, Efficiency, DEA

1. INTRODUCTION

The operating efficiency of a club refers to the relationship between the output and input of the club over a period of time. The National Basketball Association (NBA) is the largest basketball league in the United States and the highest-level professional basketball league in the world. As a commercial sports league, the NBA has achieved great success due to its good operating model and unprecedented attention. According to the latest NBA team valuation published by Forbes, the New York Knicks team is valued at 5 billion U.S. dollars, and other teams are valued at more than 1 billion U.S. dollars. The average operating income of the 30 teams is tens of millions of U.S. dollars. In contrast to China's professional sports, the Chinese Super League has suffered losses for the most part since 2003. At the same time, player costs have continued to rise. Especially in recent years, the sky-high transfer fees and wages of foreign aid have made the Super League one of the most money-burning football leagues in the world [1]. The Chinese Super League team Guangzhou Evergrande lost 312 million yuan in the first half of 2016. In the 2014 and 2015 fiscal years, although the club performed well in the domestic league, the Football Association Cup and the AFC Champions League still lost 482 million yuan and 953 million yuan respectively. It can be seen that there is a serious imbalance between input and output in China's professional sports leagues. The general low efficiency of clubs has caused club efficiency to become a hot topic of public opinion.

At present, the research on club efficiency is mainly concentrated on sports clubs, and it is mainly carried out from the perspective of club investment and operating performance. Foreign research scholars mostly use various models to conduct research from the perspective of input and output. Arlos Pestana Barros and Stephanie Leach [2] used cutting-edge econometric models combined with sports and financial variables to assess the technical efficiency of Premier League clubs from 1998/99 to 2002/03 and concluded that efficiency scores are uneven. Alexander^[3] *et al.* analyzed the impact of the current value and debt level of European football clubs on their performance based on the non-parametric two-stage data envelopment analysis and the 2007-2009 season data from the perspective of on-field and off-field. Halkos George^[4] and others used Simar and Wilson's method to guide the data envelopment analysis score to determine the impact of the current value and debt level of the football club on the efficiency score obtained. The results show that the current value level of football clubs has a negative impact on its performance, indicating that the high value of football clubs does not guarantee the improvement of their performance.

At the same time, empirical evidence shows that the debt level of football clubs does not affect their efficiency levels. Barros^[5] *et al.* used cost function estimation and stochastic frontier models to analyse Brazil's top football leagues from 2003 to 2011. In the covariate, the number of fans in each club and the remoteness of the club are considered. Then it is ranked according to the technical efficiency of the Brazilian clubs during 2000-2011.

Gongbing Bi [6] put forward the output constraint DEA model to evaluate the output and the efficiency of the upper bound production system and used this model to evaluate the efficiency of the Premier League. Shamisudeen [7] *et al.* used DEA to conduct an empirical study on the efficiency of English Premier League football clubs in the 2005-2015 season. Guzmán [8] took Spanish football clubs as a sample, used a performance model based on data envelopment analysis to calculate efficiency measures, and used cluster analysis to analyse the main factors affecting team efficiency. The starting point of domestic research on club efficiency is relatively late. Xu and Liu [9] used data envelopment analysis (the output oriented CCR, BCC and radial super efficiency model of the method) to analyse and evaluate the input efficiency of 16 Chinese Super League teams in 2012. Meng [10] used super the efficiency CCR-DEA model measures operating efficiency of 30 NBA teams in 10 seasons and discusses its external influencing factors; Tan and Yin [11] established a club efficiency evaluation system and used data envelopment analysis Methods The efficiency of the Chinese Super League clubs in the 2015-2017 season was measured, and the problem of investment redundancy was solved through efficiency optimization. Wang [1] selected 30 NBA league clubs in the 2016-2017 season and used the DEA model to measure the operating efficiency of each club and analysis. The current domestic research on club efficiency is not deep enough, and the results are also lacking. Based on the data of 30 teams in the NBA from 2018 to 2020, this article uses the DEA model to measure and analyze the efficiency of the 30 team clubs, with a view to Provide advice on the development of domestic sports league teams.

2. RESEARCH METHODS

Data Envelopment Analysis (DEA) is a non-parametric test method proposed by a famous American operations researcher. DEA selects multiple input and output data of decision-making units (DMU) and uses linear programming to form a “production frontier” with optimal input and output data. By judging whether each DMU is on the frontier of production, Determine the relative effectiveness of DMU [12]. Two common models of DEA are CCR model and BBC model. The basic condition of the CCR model is that the return to scale is unchanged, and the BBC model no longer restricts the return to scale. This article selects the BBC model to evaluate the efficiency of NBA clubs. The BBC model is constructed as follows:

Assuming there are n decision-making units (DMU), the corresponding input and output data are:

where m and s represent the number of input and output indicators respectively. Based on this, the constraint equation set of the BBC model is established:

$$\begin{aligned}
 & \min \theta \\
 & \left. \begin{aligned}
 & \sum_{j=1}^n x_j \lambda_j + s^- = \theta x_0 \\
 & \sum_{j=1}^n y_j \lambda_j - s^+ = y \\
 & \sum_{j=1}^n \lambda_j = 1 \\
 & \lambda_j \geq 0, j = 1, \dots, n \\
 & s^+ \geq 0, s^- \geq 0, \theta \text{ no limit}
 \end{aligned} \right\} s.t.
 \end{aligned}$$

Figure 1

In the formula, θ represents the distance between the decision-making unit and the production frontier. λ_j represents the combined weight of the j-th decision-making unit when an effective decision-making unit DMU_j is formed through the combination of the current decision-making unit [1]. S^+ represents the output slack variable, and S^- represents the input slack variable.

3. NBA CLUB EFFICIENCY EVALUATION

3.1 Construction of NBA Club Efficiency Evaluation System

It can be known from the existing research that one of the most critical steps for efficiency evaluation using the DEA model is to establish reasonable input and output variables [13]. As a commercial organization, the input indicator should measure the resource allocation of the club from the perspective of “cost”, and the output indicator should reflect the club’s “achievement” [14]. When constructing the club efficiency evaluation index system, the selection of the index should satisfy the principle of representativeness and availability. From the perspective of investment, the cost of the NBA team club includes team salary, labor costs, management costs and so on. Considering that the team salary accounts for the vast majority of the cost, it has a strong representativeness, and the team salary is relatively easy to obtain, so the team salary is selected as the input variable. From the perspective of output, the purpose of a team club is to obtain more profits in the capital market, so annual income is used as an output variable. In addition, as the highest-level basketball league in the world, the NBA’s operating efficiency is not satisfactory to judge a team’s operating efficiency from the team’s revenue alone. Taking into account that each team played 82 games in the regular season (the 2019-2020 Covid-19 caused the NBA season to shrink, 30 teams did not play

82 games), so the regular season wins were used as the second output variable.

Table 1. NBA team club efficiency evaluation system

index	meaning	variable
salary	input	x1
wins	output	y1
income	output	y2

It is worth mentioning that only 16 teams in the NBA can enter the playoffs each year, and there is a strong correlation between playoff wins and the team's annual revenue, which will reduce the judgment of the model. Therefore, the playoff wins are not used as an output

indicator. The efficiency evaluation system of NBA clubs is shown in *Table 1*.

3.2 Measure of NBA team club efficiency

According to the above analysis, obtaining the data of each indicator. From HOOPSHYPE (hoopshype.com/salaries), we get 30 team salary x1 for three seasons. Extracting data y1 from the annual revenue of each team published on the official website of Forbes (forbes.com/teams). Then, obtaining the regular season wins y2 of 30 teams in three seasons from the official website of NBA China. The index data is shown in *Table 2*.

Table 2. NBA team efficiency evaluation index data

Teams	2017-2018 season			2018-2019 season			2019-2020 season		
	Salary	Wins	Income	Salary	Wins	Income	Salary	Wins	Income
Cavaliers	1.377	50	280	1.233	19	302	1.296	19	300
Warriors	1.376	58	359	1.463	57	401	1.293	15	440
Thunder	1.345	48	222	1.449	49	241	1.32	44	258
Heat	1.336	44	253	1.532	39	259	1.2987	44	294
Wizards	1.233	43	222	1.237	32	255	1.213	25	269
Pelicans	1.208	48	204	1.161	33	214	1.179	30	224
Bucks	1.205	44	179	1.31	60	204	1.226	56	283
Rockets	1.199	65	296	1.265	53	326	1.281	44	348
Pistons	1.197	39	221	1.266	41	235	1.045	20	255
Clippers	1.19	42	257	1.18	48	258	1.3105	49	282
Blazers	1.187	49	223	1.303	53	246	1.32	35	287
Hornets	1.173	36	202	1.214	39	213	0.966	23	240
Raptors	1.169	59	250	1.378	58	275	1.225	53	334
Timberwolves	1.16	47	204	1.22	36	223	1.142	19	234
Celtics	1.153	55	257	1.253	49	287	1.178	48	304
Spurs	1.146	47	259	1.216	48	262	1.124	32	285
Grizzlies	1.107	22	206	1.261	33	213	0.985	34	224
Nuggets	1.075	46	202	1.183	54	222	1.287	46	252
Jazz	1.056	48	221	1.138	50	243	1.189	44	258
Knicks	1.054	29	426	1.234	17	443	1.002	21	472
Lakers	1.031	35	371	1.072	37	395	1.187	52	434
76ers	1.008	52	184	1.151	51	268	1.3	43	300
Hawks	0.999	24	209	0.792	29	215	0.856	20	251
Kings	0.996	27	240	1.015	39	263	1.138	31	286
Magic	0.987	25	211	1.144	42	223	1.261	33	244
Nets	0.955	28	273	1.189	42	290	1.189	35	304
Pacers	0.953	48	205	1.107	48	222	1.123	45	243
Suns	0.927	21	218	1.087	19	235	0.985	34	246
Bulls	0.905	27	281	1.126	22	287	1.126	22	301
Maveracks	0.854	24	233	0.867	33	287	1.209	43	307

Note: The salary unit of the input indicator team is 100 million U.S. dollars, and the unit of output indicator team income is millions of US dollars.

3.3 NBA club efficiency evaluation

Using MAXDEA software, select the investment-oriented BCC model, place the data in the model, and calculate the efficiency of each club. The results are shown in *Table 3*.

Table 3. NBA team efficiency and return to scale

Teams	2017-2018 season				2018-2019 season				2019-2020 season			
	e	te	se	rs	e	te	se	rs	e	te	se	rs
76ers	0.952	1.000	0.952	Irs	1.000	1.000	1.000	Cos	0.742	0.834	0.889	Irs
Pacers	0.929	1.000	0.929	Irs	0.963	0.984	0.978	Irs	0.881	0.984	0.895	Irs
Maveracks	0.774	1.000	0.774	Irs	1.000	1.000	1.000	Cos	0.800	0.897	0.891	Irs
Bulls	0.859	1.000	0.859	Irs	0.692	0.770	0.898	Irs	0.630	0.800	0.787	Irs
Kings	0.708	0.878	0.806	Irs	0.929	0.942	0.986	Irs	0.664	0.848	0.783	Irs
Lakers	0.989	1.000	0.989	Irs	1.000	1.000	1.000	Cos	1.000	1.000	1.000	Cos
Hornets	0.623	0.770	0.809	Irs	0.732	0.781	0.937	Irs	0.631	0.915	0.690	Irs
Grizzlies	0.535	0.771	0.694	Irs	0.624	0.678	0.921	Irs	0.771	1.000	0.771	Irs
Pistons	0.665	0.769	0.865	Irs	0.748	0.776	0.963	Irs	0.585	0.822	0.712	Irs
Rockets	1.000	1.000	1.000	Cos	0.986	1.000	0.986	Drs	0.780	0.856	0.910	Irs
Nuggets	0.789	0.879	0.898	Irs	1.000	1.000	1.000	Cos	0.787	0.867	0.907	Irs
Jazz	0.843	0.920	0.916	Irs	0.982	0.989	0.992	Irs	0.819	0.921	0.889	Irs
Blazers	0.761	0.827	0.921	Irs	0.904	0.905	0.998	Drs	0.604	0.759	0.796	Irs
Celtics	0.890	0.929	0.958	Irs	0.908	0.911	0.997	Drs	0.907	0.967	0.938	Irs
Clippers	0.749	0.812	0.922	Irs	0.923	0.931	0.991	Irs	0.826	0.877	0.942	Irs
Nets	0.810	0.947	0.856	Irs	0.860	0.862	0.998	Drs	0.690	0.845	0.816	Irs
Hawks	0.619	0.855	0.725	Irs	0.911	1.000	0.911	Irs	0.706	1.000	0.706	Irs
Thunder	0.663	0.723	0.917	Irs	0.757	0.765	0.989	Irs	0.737	0.829	0.889	Irs
Spurs	0.826	0.877	0.941	Irs	0.900	0.905	0.994	Irs	0.678	0.866	0.783	Irs
Raptors	0.931	0.951	0.979	Irs	0.937	0.973	0.964	Drs	0.963	0.975	0.987	Irs
Magic	0.641	0.869	0.737	Irs	0.831	0.871	0.954	Irs	0.590	0.774	0.763	Irs
Knicks	1.000	1.000	1.000	Cos	0.974	1.000	0.974	Drs	1.000	1.000	1.000	Cos
Wizards	0.681	0.763	0.892	Irs	0.659	0.684	0.964	Irs	0.558	0.747	0.747	Irs
Cavaliers	0.737	0.766	0.962	Irs	0.665	0.726	0.915	Irs	0.527	0.685	0.769	Irs
Heats	0.677	0.729	0.929	Irs	0.613	0.624	0.982	Irs	0.757	0.844	0.898	Irs
Timberwolves	0.747	0.818	0.914	Irs	0.696	0.740	0.941	Irs	0.496	0.750	0.662	Irs
Suns	0.651	0.921	0.707	Irs	0.587	0.748	0.785	Irs	0.777	1.000	0.777	Irs
Pelicans	0.733	0.789	0.929	Irs	0.679	0.736	0.923	Irs	0.574	0.804	0.714	Irs
Bucks	0.674	0.777	0.867	Irs	1.000	1.000	1.000	Cos	1.000	1.000	1.000	Cos
Warriors	0.899	1.000	0.899	Drs	0.954	1.000	0.954	Drs	0.722	0.759	0.952	Irs
Mean	0.778	0.878	0.885		0.847	0.877	0.963		0.740	0.874	0.842	

Note: The calculation result retains three decimal places. Among them, e stands for comprehensive efficiency, te stands for technical efficiency, se stands for scale efficiency, and rs stands for scale return. Irs stands for increasing returns to scale, Cos means constant returns to scale, Drs stands for diminishing returns to scale.

According to the previous literature, it is generally considered that the efficiency value falls into [0,06) as inefficiency, [0.6,0.8) as low efficiency, [0.8,1) as medium efficiency, and 1 as high efficiency [11]. According to the data in Table 3, the overall average efficiency of the 30 teams was the highest in the 2018-2019 season, reaching a medium efficiency of 0.847. The

efficiency of the other two seasons fell into the [0.6, 0.8) range, which is low efficiency. Among them, the 2019-2020 season has the lowest average efficiency value, which is 0.107 lower than the efficiency of the previous season. To facilitate the overall analysis, we make the NBA team efficiency clustering table for the 2018-2020 season, as shown in *Table 4*.

Table 4. NBA teams' efficiency clustering

efficiency	meaning	Teams		
		2017-2018 season	2018-2019 season	2019-2020 season
[0,0.6)	inefficiency	Grizzlies,	Suns	Pistons, Magic, Wizards, Cavaliers, Timberwolves, Pelicans,
[0.6,0.8)	low efficiency	Maveracks, Kings, Hornets, Pistons, Nuggets, Blazers, Clippers, Hawks, Thunder, Magic, Wizards, Cavaliers, Heats, Timberwolves, Suns, Pelicans, Bucks	Bulls, Hornets, Grizzlies, Pistons, Thunder, Wizards, Cavaliers, Heats, Timberwolves, Pelicans,	76ers, Pacers, Bulls, Kings, Hornets, Grizzlies, Rockets, Nuggets, Blazers, Nets, Hawks, Thunder, Spurs, Heats, Suns, Warriors
[0.8,1)	medium efficiency	76ers, Pacers, Bulls, Lakers, Jazz, Celtics, Nets, Spurs, Raptors, Warriors,	Pacers, Kings, Rockets, Jazz, Blazers, Celtics, Clippers, Nets, Hawks, Spurs, Raptors, Magic, Knicks, Warriors,	Maveracks, Jazz, Celtics, Clippers, Raptors,
1	high efficiency	Rockets, Knicks	76ers, Maveracks, Lakers, Nuggets, Bucks,	Lakers, Knicks, Bucks,

It can be seen from the *Table 4* that in the 2018 season, 1 team was inefficient, 19 teams were low efficiency, 10 teams were medium efficiency, and 2 teams were high efficiency. In the 2019 season, 1 team is inefficient, 10 teams are low efficiency, 14 teams are medium efficiency, and 5 teams are high efficiency. In the 2020 season, 6 teams are inefficient, 16 teams are low efficiency, 5 teams are medium efficiency, and 3 teams are high efficiency. It can be seen that the teams in the low and medium efficiency range account for the majority, and nearly 50% of the teams in the 2018-2019 season are in the medium efficiency range. There are fewer teams in the inefficiency zone, only Grizzlies in the 2017-2018 season, Suns in the 2018-2019 season, the Pistons, Magic, Wizards, Cavaliers, Timberwolves, and Pelicans in the 2019-2020 season. To a certain extent, it reflects the inefficient management of NBA teams and clubs. There are also relatively few teams that fall into the high efficiency range. There were only 2 teams, 5 teams and 3 teams in the 18th, 19th, and 20th seasons. The impact of the Covid-19 in early 2020 on NBA teams and clubs is also huge. The 76ers have fallen from the high efficiency of the 2019 season to the lower efficiency of the 2020 season, and the Magic has fallen from the medium efficiency of the 2019 season to the inefficiency of the 2020 season. According to *Table 3*, the vast majority of clubs have been affected by Covid-19, resulting in less revenue growth than last season. According to *Table 4*, in the context of the Covid-19, only five teams have achieved positive growth in

efficiency. They are Grizzlies, Raptors, Knicks, Heat, and Suns. The side reflects that despite the impact of the Covid-19, the operations of these five teams are successful.

The combined efficiency of Rockets and Knicks reached 1 in 2017-2018 season, indicating that these two teams have maximized their output based on the limited scale of input elements. Among them, Rockets won the first place in the regular season and almost overturned Warriors in the playoffs and won the championship. Although Knicks' results in the regular season are not satisfactory, their good geographical location and the team's higher operational management efficiency have made Knicks the highest-paid team in the league. However, Rockets did not get the first place in the regular season in the next two seasons, so they did not reach the DEA effective. Although Knicks' regular season results are as usual, but due to their high income, the efficiency value has always been at the forefront of the league. According to the input and output of Knicks, it needs to be reinforced in order to enter the playoffs and even the finals. The Cavaliers' operating efficiency has declined for two consecutive seasons, which is related to the departure of superstar LeBron James. LeBron James left the Cavaliers in 2018 and switched to the Lakers, which directly led to the bleak regular season results of the Cavaliers in the 2018-2019 and 2019-2020 seasons and did not enter the playoffs. It is worth mentioning that the revenue of the Cavaliers in the 20th season is the only team with negative growth among the 30 teams. This can

directly reflect that there is a strong relationship between a team's superstar and team efficiency. Therefore, the Cavaliers need to carry out reasonable trading operations to free up the team's salary space and enhance the team's combat effectiveness. Turn to Lakers. As a veteran giant, Lakers have always been at the forefront of the league in terms of team revenue and team efficiency. But after getting LeBron James in the summer of 2018, the comprehensive efficiency was 1 for two consecutive seasons, and the team's income has increased significantly, and it won the NBA championship in the 2019-2020 season. The input and output of the Lakers are more reasonable. The Warriors' income in the 18th and 19th seasons and regular season results are among the best in the league, but the reason for not reaching the effective DEA is its high salary. In the 20th season, due to the injury of two core players, Curry and Thompson, the regular season results plummeted, changing from a championship-winning team to a big-bodied team. The Warriors should reasonably reduce their salary and wait for the return of the two core players during the period to improve the team's combat effectiveness. Mavericks's comprehensive efficiency reached 1 in the 2018-2019 season but has changed to 0.8 in the 2019-2020 season. The reason is that there is redundancy in investment. The 2019-2020 season's salary increased by about 40 million US dollars compared with the 19 seasons, but the team's record and income did not have a large increase compared with the previous season. Therefore, Mavericks should reduce the pressure on the team's salary through trades and improve the overall strength of the team.

3.4 Analysis of NBA Club's Return to Scale

There are three types of returns to scale: increasing, constant, and diminishing. Increasing returns to scale means that when all factors of production change by the same percentage, the output level changes by a larger percentage; diminishing or constant returns to scale means that when all input factors change according to a certain proportion, the output level changes in a smaller or constant proportion. When the production unit is in the stage of diminishing returns to scale, decision makers should consider increasing production input and expanding the scale of production; if the production unit is in the stage of diminishing returns to scale, the producer should reduce the amount of production input and scale of production to save resources^[15]. From Table 3, there is 1 team with diminishing returns to scale in the 18th season, 2 teams with constant returns to scale, 27 teams with increasing returns to scale; 7 teams with diminishing returns to scale in 19 seasons There are 5 teams with constant returns to scale and 18 teams with increasing returns to scale; there are no teams with diminishing returns to scale in the 20th season, and 3 teams with constant returns to scale, with increasing returns to scale There are 27 teams. The majority of

league teams are in increasing returns to scale, indicating that most NBA clubs are in a state of "unsaturated" investment. Did not invest more funds to recruit excellent players, which also restricted the efficiency of the club. The club should expand the scale of investment to improve efficiency. For clubs with diminishing returns to scale, it shows that their investment has reached a relative redundancy, and the investment scale should be further adjusted, and resources allocated rationally. It is worth mentioning that the Warriors, as the only team with diminishing returns in scale for two consecutive seasons, reflects on the one hand the high salaries of the Warriors in recent years, and on the other hand, it also shows that although the Warriors have been a favorite in recent years The team, but its resource allocation still has certain problems.

4. CONCLUSION AND ENLIGHTENMENT

Efficiency is essential to the operation of professional sports clubs. Based on the data of 30 NBA teams in the 2018-2020 season, this paper establishes an NBA club efficiency evaluation system. It uses MAXDEA to measure the efficiency of the team clubs. Based on this analysis, the following conclusions are drawn: The average efficiency of the 18 season is relatively high. Low level, the league's overall efficiency in the 19 season is the highest, reaching a medium level. The new crown epidemic has a greater impact on the NBA, and the average efficiency of the league in the 20th season has reached the lowest value. Each season has the largest number of teams at the lower and middle levels, and the number of teams falling into the range of high efficiency and inefficiency is relatively small. The existence of superstars has a great impact on the efficiency of the club; the efficiency level of the teams in the east and west divisions is not as expected, and the situation of "high in the west and low in the east" will appear. On the contrary, the average efficiency of the eastern teams is in the 18 and 20 seasons. Both surpassed the Western Conference team. Most NBA teams are in a state of increasing returns to scale, and only a few teams have diminishing returns to scale. The Warriors are the only team with diminishing returns on scale for two consecutive seasons. The redundancy of NBA investment is not obvious, and most teams should expand their investment scale.

Based on the above, NBA teams should rationally arrange capital investment and effectively allocate their resources during the development process. Team clubs can pursue superstars on the market through operations and at the same time strengthen the training of their own players.

ACKNOWLEDGMENTS

This research is supported by the National Social Science Foundation of China, number:20&ZD127. And thanks to Professor Qingmei TAN, Director Institute of

Regional Economy & Director Institute for Technoeconomic and Innovation Management, College of E&M, Nanjing University of Aeronautics and Astronautics for the assistance that greatly improved our manuscripts.

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