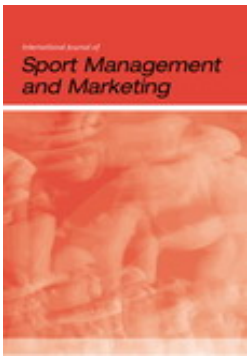


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# This town is not big enough for the both of us: bootstrapped dual-role factor data envelopment analysis of Major League Baseball with two teams in one city

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# This town is not big enough for the both of us: bootstrapped dual-role factor data envelopment analysis of Major League Baseball with two teams in one city

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**Abstract:** This research studies teams in Major League Baseball (MLB) that share the same metropolitan area with another team in the same professional baseball league. This research utilises a special type of data envelopment analysis (DEA), specifically dual-role factor DEA as the method to find the efficiency of teams that share the same market population with one another. Furthermore, the MLB teams were ranked based on efficiency by using cross-efficiency (XEff) to peer rank the teams against each other. A sample taken of several inputs and outputs, both performance-based and financial-based is injected into the DEA model to show the relative efficiencies of teams that share a location with another MLB team. Managerial implications are also discussed.

**Keywords:** data envelopment analysis; DEA; bootstrapped; efficiency; professional baseball; Major League Baseball; MLB; efficiency; cross-efficiency; dual-role factor; two teams in one city; performance-based metrics.

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**Biographical notes:** Justin R. Muñoz is an Assistant Professor of Marketing at the Angelo State University in San Angelo, TX. His current research interests are centred around sports marketing, business-to-business sales, sustainability, and logistics.

## 1 Introduction

For the past century and a half, baseball has been part of the American landscape and has resisted the test of time since the first pitch was thrown in fields of Cooperstown, NY in the summer of 1839 (Rader, 1997). Even during the times when baseball was put on hold because of the major world wars, baseball was never forgotten and came with more fans, bigger stadiums, and higher player salaries year after year. As time marched on, Major League Baseball (MLB), which many saw and continue to see as the top-echelon of playing the game, decided to expand the number of teams playing in the league

(Alexander, 2013; Quinn and Bursik, 2007). Furthermore, team owners were given the freedom to start the process of moving teams to more profitable markets during the 1950 and 1960s (Alexander, 2013). What we have now is an amalgamation of teams in one league that reaches from coast to coast and even across international borders to the north.

What has not been studied after this period of movement and expansion has been the efficiency of teams that have moved or expanded into a location that already has a team present. While many of the teams are profitable, the resources they put into their season may not lead to the results at the end of the season they had hoped for and may lead them to make some changes that will get them to their desired level of efficiency. Efficiency concerns the maximum potential output for a given set of inputs, or in other words, just how successful is each team in getting the most out of what they put into a season (Chen et al., 2021; Guzmán-Raja and Guzmán-Raja, 2021; Pérez-González et al., 2022). This current study uses data envelopment analysis (DEA) as the method to show that these different inputs and the resulting outputs of a professional sports team can affect their operational and strategic initiatives in the near future.

This research takes an in-depth look at the decisions of managers of sports organisations and how it affects the revenue and operations these organisations, including both financial and capacity constraints for each of these teams. The implications from this research can generalised to any sport and to any industry with capacity and output constraints. Some of the main concerns for general managers of professional sports teams, that are included in this study, and can influence organisational success, include the amount spent on the talent on the field, stadium capacity, and overall operations for generating revenue from fan experiences (Coates, 2023; Matheson, 2019). Some famous examples of this include building new stadiums with additional capacity while the current stadium may still be useful for many years to come (Nowland and Sankara, 2024a; Schreyer and Ansari, 2022).

In addition, this research delves into the individual fan and how to further understand how fans engage with and react to team successes and failures. This has been a topic that has intrigued and yet, plagued the full understanding of sports organisations managers in different sports leagues across the world (Huettermann et al., 2022).

The past successes and failures of each individual sports team also has an effect on the fan engagement and the revenue that comes from these fans (Shtudiner et al., 2022). Even more so, this effect can be magnified when a rival team is located withing the same city, maybe only a few miles away (Bradbury et al., 2023; Danielson, 2021). This research studies this affect using the MLB, which is a league that has a rich history in terms of both seasons played and history in movement and placement of teams within the same cities (Cairney et al., 2023).

The model presented uses different types of data including different units of measurement and data from different levels of the organisation. This current research looks at the correct mix of inputs and outputs that drive the efficiency of these teams. However, a novel approach is presented in finding the correct role of a dual-role factor that has been prevalent in previous research (Chen, 2021; Toloo et al., 2021). Therefore, the contribution that this study offers is not only empirical, but also a new methodological view of handling dual-role factors in a (DEA) context. The use of the dual-role factor in this method of analysis also helps to show how one factor of success for a team can be used as in input or output not just in the analysis, but also in the marketing of the team and organisation as a whole. Results in this study were

bootstrapped with 2000 data runs with replacement to help confirm the correct role of the dual-role factor.

When this study and model first materialised, the aim of this model was that the method of analysis, DEA, would be able to handle these various types of data and sporting organisations, whether it be MLB or other sports organisations from soccer and basketball to football and hockey could use this as a steppingstone to fully understanding their customers.

In the case of sports, the customer is unique with a passion for the product and an unwavering support for the success of an organisation that many fans find represents their city. The success of the team is a success for the fan, and managers in the organisation should try to capture this relationship and use it to build a roadmap to creating a lifelong fan with the passion for their team passed on to the next generation of sports fanatics.

### *1.1 A city divided*

Rivalry runs deep within sports of all kinds. The pride that is felt at the successes and the shame of the failures of your city's team is usually passed down from generation to generation (Tamir, 2022). The 2000 MLB World Series saw the New York Mets pitted against the New York Yankees, two teams that are only nine and a half miles from one another (McKee, 2009; Savader, 2012). Yet, there were fans from both sides, each with rich traditions passed down from family members long gone. However, with two teams in the same city, this rivalry may transcend the pride that fans share and may actually affect the financial well-being of the two teams (Di Simone and Zanardi, 2021). These two teams fight over people who will attend their games and buy their merchandise with the hopes that these fans will ultimately develop a strong devotion to the team. What makes this context so unique is that the two teams have a finite population in which to market their game day experience, merchandise, and players (Danielson, 2021; Chen et al., 2022; Bruhn and Rohlmann, 2023). Furthermore, the resources that they put into building their teams for success and for fan interest differ greatly based not only on their past statistics, but also on the financial resources that they put into the team to get a sizeable return out of the team at the end of the season (Ahmed et al., 2018; Chutiphongdech and Kampitak, 2022). This research is meant to begin the conversation by looking into how entities within the same market but with different resources market their products and create efficiency using their marketing and management strategies that have been formed by multiple levels of team management. This research aims to give these managers insight into how they might improve their operations and how they can create an environment that will foster success while competing in a unique setting.

## 2 Theoretical development

Sports have been used in a variety of settings for studying the efficiency of several parts of the organisation. Studies have ranged from studying the front office operations (Lewis et al., 2009; Krautmann, 2019) to actual batting averages and earned runs over the course of a season (Einolf, 2004; Hoffman et al., 2009; Pinheiro and Szymanski, 2022; Wickramasinghe et al., 2021). However, even with a wide range of contexts and settings, most of the studies though have focused on the actual activity in which the organisations take part.

## 2.1 Performance metrics

Research has focused on the performance metrics that sports teams gather throughout the course of a season. Performance metrics are defined as measures gathered from the performance of individual athletes or the team as a whole, depending on the level of analysis (Einolf, 2004; Terner and Franks, 2021). However, even though some studies have extended this definition to the rest of the organisation, including non-athletes (Howard and Miller, 1993), this current study uses the conventional definition set forth by a majority of past studies (Baade and Tiehen, 1990; Einolf, 2004; Sexton and Lewis, 2003). A study by Einolf (2004) used both the metrics of MLB and The National Football League to show that certain players and on-field operations were inefficient and had not been improved over the course of an entire year. A study by Sexton and Lewis (2003) showed that performance metrics can even be used to evaluate the front-office operations of a team through the transitive properties that exist in a two-stage DEA model.

The performance metrics that are used in this current study are overseen by two complementary theoretical views. One of these is Organisational Theory that states that all types of organisations have the need to accomplish a common goal for all members of that organisation and that all members of the organisation are responsible for this success (Daft and Armstrong, 2021; Likert and Bowers, 1969). In this case, the goal would be to have higher wins, attendance, and revenue in sports organisations. In addition, there is also Organisational Performance Theory, which states that the overall success of an organisation is influenced by individuals of that organisation (Akpa et al., 2021). Both organisational theory and organisational performance theory drive the measures to have more success and ultimately greater efficiency than their league rivals that they compete against over the course of a season. There have been several studies that have included performance metrics that have ranged from financial measures to changing market dynamics to drive the success of the entire organisation (Malina and Selto, 2004; Richard et al., 2009). There is a broad range of both inputs and outputs that can encompass both team and individual decisions that can have an effect on how efficient their team is both after and season and over the long-run.

In this study, performance metrics are used as both inputs and outputs depending on the stage of the model or the outcomes currently under study. Therefore, there can be no restriction to whether performance metrics are held to be inputs and outputs in the model. However, in the current study, these metrics are constrained to either inputs or outputs from the theory from previous literature. However, following the same theorising by Sexton and Lewis (2003), multiple studies show that historical successes including historical championships is not constrained solely by theory and has been used as either an input or an output to find the efficiency scores (Baade and Tiehen, 1990; Kang et al., 2007; Lewis, 2014; Sueyoshi et al., 1999).

Along with performance metrics, several other studies have used measures of the organisation that have to do with non-athletic performance. These metrics are either capacity or financially based measures that are part of the landscape of a professional baseball organisation and how they can put these resources into their season year after year (Howard and Miller, 1993; Jacobsen, 2023). This view on the resources that each team possesses and puts into their season is seen through the theoretical lens of the Resource-based View (RBV). This theory focuses on the importance of an organisation's resources and capabilities as sources of competing in the market for success on the field and for fan engagement (Barney, 2001; Wernerfelt, 1984; Pianese, 2021). In addition to

these capacity and financial resources, past events such as previous championships and other reputational resources also increase the ability of sports teams to compete and achieve success (Ahmed et al., 2018; Chutiphongdech and Kampitak, 2022). This supports the dual-role factor that is discussed in later sections and how it can create higher chances of success for sports organisations. In the case of this current study, the success would be a high efficiency relative to other teams, especially ones in close adjacency.

Some contributory resource-based measures include how the use of human resources have contributed to the success of teams while also showing that performance metrics only tell part of the overall success story of teams (Smart and Wolfe, 2003; Smart et al., 2008). Others include how the compensation of supporting staff for teams also affects the outcome of team success after a season (Shin et al., 2023). Financial measures have included the length of contracts and the economic gain brought on by the productivity of players over the course of long-term contracts (Solow and Krautmann, 2020). Others include how teams win and how this can affect revenue for profit-maximising teams in MLB (Ehrlich and Potter, 2021).

## *2.2 Influential capacity-based measures*

Let's first start with the capacity-based measures. A study by Noll (1974) lays out several of the most influential variables that are used to make the case for a successful team using both DEA measures and non-DEA measures. In this study, his famous equation in the sports literature world for his study on attendance and price setting in baseball actually creates a regression equation with the variables that significantly contribute to the model of understanding how team success is calculated and even predicted. The predictor variables in the regression equation and the ones that will be used for this study include market characteristics such as the years operating in the city, stadium capacity, and the payroll of each team included in the analysis. This model has been empirically tested and shows that these variables contribute to understanding the financial success of the team (Bi, 2021; Lewis, 2014; Noll, 1974). Noll (1974) also goes on to mention that the predictor variables are correlated with the output variables that will be discuss shortly in which these can be used in a variety of contexts. The number of years operating in the current location, stadium capacity, and payroll have withstood the test of time with subsequent studies strengthening their use and making a stronger case for their use in this study as well (Baade and Teichen, 1990; Butler, 2002; Christopoulos, 1988; Howard and Miller, 1993; Lewis, 2014; Wang et al., 2021).

## *2.3 Fans and the team*

A major part of any sports league concerns how to keep the organisation profitable. With this effort comes the fact that fans should be willing to buy tickets, merchandise, food and beverage, and even team experiences (Shtudiner et al., 2022). More so, the fans of the team need to keep this willingness to engage with the team over the long-term (Huettermann et al., 2022). This is where teams try to create lifetime customers and pass this passion on to future generations. This identification with a sports team is based on the theory of social identity. This theory encompasses both psychological and sociological aspects and according to this theory, people differentiate between an in-group to which they belong and an out-group to which they do not belong (Hogg,

2016). In this case, the group to which the fans belong is the team that they support and the team that they keep this engagement with throughout the years (Kural and Özbek, 2023). Team managers try to increase this identification level in which a fan feels a psychological connection to the team (Lintumäki and Koll, 2024). This psychological connection creates an 'extension of self', where a fan can perceive their team's wins as personal successes (Ma and Kaplanidou, 2021). This then creates loyalty to the team which is the ultimate goal of managers, since it is one of the only ways to compete against other teams vying for fans, especially with another team so close in vicinity (Fathy et al., 2022; Lintumäki and Koll, 2024). This competition for fans includes how to create the ultimate fan experience that will allow these fans to share not only in the gameday activities but also in the success of 'their' team. However, if a fan feels that their team is losing ground in competition through lower amounts spent on players or even subpar facilities, then this loyalty to the team may diminish quickly, ultimately causing the fan to switch to a nearby team. Famous examples of this have recently taken place with rival teams increasing their spending on players to become contenders for championships and creating new and bigger stadiums for teams to shine and welcome in fans (Barden and Choi, 2021; Nowland and Sankara, 2024b).

## *2.4 Inputs*

### *2.4.1 Number of years operating in current location*

The number of years operating can have a significant effect through the lens of how established teams have differences in both output factors with the team and the fans alike, such as revenue and attendance as compared to teams that are less established (Lewis et al., 2009). The number of years operating in a current city helps for the team to develop a following from the fans in that location as well as develop a history that can have a significant effect on how the team is viewed going forward from the current and past seasons. The history of previous seasons can significantly affect fans through attendance and revenue, including revenue per fan (Wann et al., 2017). The longevity of the operations present in a location significantly affects the total revenue for teams that have been established for years and have brought in stable revenue over time (Chacar and Hesterly, 2004; Gustafson and Hadley, 2007). Location of the operation has had a significant effect on fans attending games relative to other choices that they have for entertainment (Lim et al., 2019). A major part of influencing consumer choices is the management of the organisation that comes from decision-makers that ultimately affects how the team operates in a certain location with the resources they have at their disposal. Even recent case studies have used team operations including using a strategic view of how differences in location coupled with personnel decisions can have a significant effect on the team and their ability to win a championship the following season and having the fans and revenue that follow that success (Braunstein-Minkove and Kim, 2023; Cialone and Newland, 2023; Horowitz, 2000; Lim et al., 2019).

### *2.4.2 Payroll*

Another measure concerns the payroll that is paid to each employee, which in this case would be the players. Studies by Baade and Tiehen (1990), Howard and Miller (1993), and Regan (2012) have used payroll within their models. The assertion is made that

payroll amount is indicative of the quality of player that you possess and therefore the calibre of team that you have to compete with at the highest level. However, as seen in the results discussion, this is not always the case. Performance and salary usually are correlated with each other and are used in past research as inputs and outputs in DEA analysis. Even in pop culture, through the study of Major League Manager Billy Beane as the manager of the Oakland Athletics, the salary for the players was directly linked to quality of player, only by perception (Lewis, 2004). In the end, the higher payroll was shown to be inefficient at generating wins for expensive teams (Armstrong, 2012; Waller and Fawcett, 2013).

Another area in the payroll landscape is the ability of teams to pay players to participate fully in the team's quest to win the championship at the end of the year. In addition, the payroll for the players needs to be at a level that allows them to perform to their highest abilities to help achieve that end goal for the team (Szymanski, 2003). With these resources in place, the players can fully contribute to the end goal of team success including wins, championships, and contributing to the revenue for the organisation, rather than individual success at the end of the season (Bradbury, 2019; Leeds et al., 2022). Therefore, payroll is included as a variable that influences the overall model. In the model, this variable will be labelled as payroll to stay in line with the currently used terminology in recent literature.

### *2.4.3 Stadium capacity*

Fans have been a cornerstone of sports teams from the onset of professional sports long ago. Even home-field advantage has been a significant help in the home team winning their games because of the fans that are there to cheer the team to victory. Even more significantly, the number of fans that are in attendance has made a significant difference in the chances of a team winning their games and having success throughout their season. A study by Smith and Groetzinger (2010) shows that a one standard deviation increase in attendance results in a 4% increase in the likelihood of a win by the home team. In addition, if stadium capacity increases by 48%, the home team's run differential would increase by one run (Smith and Groetzinger, 2010).

A further study also shows that as stadium capacity and the number of fans that root for the home team has changed and increased over time, there is a change in competitive balance that has decreased the disparity of 'rich' and 'poor' teams, or teams with varying resources to spend on players (Schmidt and Berri, 2001).

Another recent study by Lim et al. (2019), places stadium capacity in conjunction with other factors such as payroll, location of operations, quality of the team, start players, and ticket prices. These factors had a significant influence on outcomes such as attendance, the competitive success of the team, and the total revenue over the course of an entire season.

Stadium facilities are also responsible for increases in economic activity for the team and the surrounding areas in which the team resides. This means that as stadiums are built in certain geographic locations, there are certain neighbourhood effects such as increases in the total revenue gained in the surrounding areas (Matheson, 2019). Even the value of other business entities have an increase in economic health and stadiums promote so much more than just direct revenue through ticket sales, including an increase in the value of surrounding real estate and business valuations (Feng and Humphreys, 2012, 2018; Rosentraub, 2014). As this valuation increases there are added reverberations that

affect the fans of a team and their identification with their sports team. As one economist put it 'an economically healthy area provides a local identity, promotes the city's image, enhances civic pride, and serves as a melting pot for different races, ethnicities, and socio-economic classes (Rosentraub, 2008). This means that as the team tries to increase their connection with their fans through their social identity, stadiums can also play a role in capturing and keeping this fan over many years.

So, indeed, stadium capacity is a significant factor that can lend itself to analysing the success of an MLB organisation with other factors included besides just the amount spent on players and personnel. Instead, there are a myriad of different input factors that can lead to differences in how efficient teams are managed around the Major Leagues, and even more so with two teams in close proximity to one another.

## *2.5 Outputs*

### *2.5.1 Average attendance*

Average attendance has been used as the dependent variable in multiple studies with the predictor variables described above as the predictors for average attendance and has been used as an outcome variable in different studies with varying methods (Han et al., 2010; Kim et al., 2017; Lewis, 2014). Average attendance has also led to interesting results as a function of stadium capacity at team ballparks (Noll, 1974; Kalist, 2010). Therefore, average attendance will be treated as an outcome of the model in the current study. Attendance has been significantly affected by the relative location of another team in the same area such as in the study by Winfree et al. (2004). Attendance changed based on the stadium location with a reduction in attendance for teams that had another team close to it in proximity. One team might 'steal' the fans from the other team, especially dependent on the current success of the teams in relation to one another (Winfree et al., 2004). This may have some significant effects in the current study when there are two teams with fans in close proximity to each other.

Another study by Ahn and Lee (2014) claims that as time has passed from the dawn of MLB, there have been significant changes in the drivers of attendance. In the early years of MLB (1904–1957), the wins were the only factor that drove attendance. In the later years (1958–2012), there are other factors such as stadium quality and the how the team operates that can lead to changes in fan attendance at games (Ahn and Lee, 2014).

### *2.5.2 Total wins*

Most of the studies use wins in addition to the revenue that are generated by the team over the course of a year. Multiple studies have used wins in their studies as the aggregate measure of performance and as a measure that is highly correlated with championships, which in this study, is the dual-role factor (Porter and Scully, 1982; Scully, 1974; Wang et al. 2021). In the current research, championships is used as a dual-role factor that can influence both the input and output functions of the DEA model due to the fact that we are looking at how wins can influence how fans respond to the rich history of the team going forward or if fans may need a winning record above other teams at the end of every season to keep supporting the team after the season has ended. A great example of wins would be the New York Yankees. Currently, they have won more than 10,600 games from the 1903 season through the 2023 season, a win rate of 0.569, which

is one of the highest in professional baseball, and at the time that I was conducting this research, they were on the verge of clinching a spot in the playoffs and making another deep run towards another World Series title (Karpin, 2023; Klink et al., 2023). They have the highest revenue out of all major league teams in MLB. We might be quick to call this efficient. However, when compared to revenue per fan, the Yankees are near the bottom when compared to the rest of the teams. Since this is a function of market population, we can assume that the Yankees and their wins may not be enough to keep their fans interested and coming back. Marketing their products and successes may require a change to be as efficient as possible. It is only through the DEA analysis that we can empirically see the efficiency of this team taking other factors into account.

### *2.5.3 Revenue per fan-market and total revenue*

The same study by Noll (1974) and Quinn and Bursik (2007) also deal with league expansion. These studies are the same context as this current this study from the perspective of a team commencing operations after another team has already been operating for a few years. Revenue per fan is seen as a good metric to use to find the marketing effectiveness and how much money the team is pulling in from fans on average. This measure is included in the current study as a measure that encompasses the total revenue and the average revenue per person. In other words, revenue per fan is a function of the total revenue spread out over the market population. In these studies mentioned, there is a difference between resident and non-resident fans and the amount that they spend on the team. This can be used to study the population in which the teams are marketing their products. I keep only the resident market population in the current study in order to decipher and control for the difference between geographical areas in the same city.

In addition to the revenue per fan, most of the studies mentioned above use revenue as an outcome measure of the overall financial success of the organisation. Revenue is an aggregate approach that has also been used as an output in addition to the performance metrics used above (Butler, 2002).

The resource constraints that many teams have also affect their ability to generate revenue. This view that comes from the resources that teams currently possess helps to take an in-depth view of how teams are able to compete with what they have to use. The revenue generated from multiple areas including ticket sales, merchandise, and gameday fan spending allows for competition in the marketplace (Nielsen and Storm, 2017). In addition the introduction of other factors such as total wins and championships works in culmination with generating revenue and helps to hedge against financial collapse (Sandy et al., 2004). Many sports economists have used team successes in different contexts and sports to show that optimising financial, (i.e., payroll, stadium capacity) and non-financial, (i.e., total wins, championships) decisions can lead to optimising revenue over the course of a single season and multiple seasons as well (Garcia-del Barrio and Szymanski, 2009).

### 2.6 Dual-role factor

#### 2.6.1 Historical championships

Previous literature within the context of baseball has modelled both the inputs and outputs presented above in mainly the same fashion with certain factors fixed as either inputs or outputs (Baade and Tiehen, 1990; Cairney et al., 2023; Einolf, 2004; Sexton and Lewis, 2003). However, the use of historical championships within these same studies have shown that historical championships has been used as both an input and as an output, making the case that historical championships could be a dual-role factor that is not fixed as either an input or an output (Cook et al., 2006). This has been used in both baseball and other sports where championships are seen as a driving factor of team efficiency (Bi, 2021; Kim et al., 2024) In other words, for some teams, historical championships have driven the outputs in the way that the more historical championships a team claims, the greater the future attendance, revenue, and other factors that are part of the outputs of a team's season. In other cases, the inputs into a team's season, such as the stadium and payroll capacity, among other inputs helps to drive outputs with the help of a championship claimed at the end of the season. Therefore, this study finds the optimal method to use the historical championship factor as either an input or an output for each team [decision making unit (DMU)].

## 3 Methodology

### 3.1 Data envelopment analysis

DEA is a powerful non-parametric method that is used to find the relative efficiency of DMUs. A DMU is a single separate entity, such as in this case, each baseball team, that will be studied on the basis of the outputs that are generated as a result of the inputs that managers put into the team over the course of a season. DEA was first introduced in 1978 by Charnes, Cooper, and Rhodes as a method to find the efficiency of each DMU assuming constant returns to scale. A later model by Banker et al. (1984) assumed that there were variations in the returns to scale as part of the DEA model and choose to present a DEA model assuming variable returns to scale. DEA has been used in a variety of contexts and settings including education performance (Bougnol and Dula, 2006; Morgan et al., 2010) and labour productivity (Ablanedo-Rosas et al., 2010; Deprins et al., 1984). Table 1 shows the MLB teams and their abbreviations for those that have two teams in one city.

DEA is used to transform inputs into outputs so that the efficiency of DMUs can be determined. In the model proposed by Charnes et al. (1978) (CCR model), efficiency scores were bound in the range between 0 and 1. DMUs with an efficiency score of 1 were considered to be 'efficient' while DMUs with a score below 1 were considered to be 'inefficient'. As time went on, there were other derivations of DMU models that were used in literature in a variety of settings. However, one of the most innovative models developed looked at the role of a 'dual-factor' or the possibility that a factor in a traditional CCR model could play the role of an input for one DMU and the role of an output for another DMU in determining the optimal efficiency score for each individual DMU (Cook et al., 2006). This is the model that is adopted to find whether the factor

'historical championships' plays an input or output role for each DMU. Table 2 shows the inputs, outputs, and dual-role factor for the model.

**Table 1** DMUs-MLB teams (two teams in one city)

| *Abbreviation* | *Team name* |
|---|---|
| LAD | Los Angeles Dodgers |
| LAA | Los Angeles Angels |
| OAK | Oakland Athletics |
| SFG | San Francisco Giants |
| CHC | Chicago Cubs |
| CHW | Chicago White Sox |
| NYY | New York Yankees |
| NYM | New York Mets |

I follow the model of dual-factor roles presented by Cook et al. (2006) in which a factor is not reduced to either an input or an output, but rather is allowed to work through the model to find the true role that the factor plays for each DMU. The proper form to model dual-role factors is shown through the following:

$$\max \left( \sum_{r=1}^{R} \mu_r y_{ro} + \gamma \omega_o - \beta \omega_o \right) \Big/ \left( \sum_{i=1}^{I} v_i x_{io} \right)$$

$$\text{subject to}: \sum_{r=1}^{R} \mu_r y_{rk} + \gamma \omega_k - \beta \omega_k - \sum_{i=1}^{I} v_i \gamma_{i_k} \leq 0,$$

$$k = 1, ..., K,$$

$$\mu_r, v_i, \gamma, \beta \geq 0.$$

The linear programming form of the above function is:

$$e_o^* = \max \sum_{r=1}^{R} \mu_r y_{ro} + \gamma \omega_o - \beta \omega_o,$$

$$\text{subject to}: \sum_{i=1}^{I} v_i x_{io} = 1,$$

$$\sum_{r=1}^{R} \mu_r y_{rk} + \gamma \omega_k - \beta \omega_k - \sum_{i=1}^{I} v_i \gamma_{i_k} \leq 0, \quad (6)$$

$$k = 1, ..., K,$$

$$\mu_r, v_i, \gamma, \beta \geq 0.$$

One of three possibilities exists in regard to the sign of $\hat{\gamma} - \hat{\beta}$, where $\hat{\gamma}, \hat{\beta}$ are the optimal values from problem (6); $\hat{\gamma} - \hat{\beta} > 0, = 0$ or $< 0$.

**Table 2** Inputs, outputs, dual-role factor

| *Inputs* | *Outputs* | *Dual-role factor* |
|---|---|---|
| Years operating in current location | Average attendance | Historical championships |
| Payroll | Total wins | |
| Stadium capacity | Total revenue | |
| | Revenue per fan-market | |

### *3.2 Bootstrapping – the role of the DMU*

The current research uses bootstrapping to confirm the role of the dual-role factor in each DMU. This new approach is not only a contribution to the sports literature, but also to the DEA literature as it is an extension of the dual-role modelling proposed by Cook et al. (2006). Previously, there have been no other studies that have bootstrapped a dual-role model to confirm the role of the factor. Therefore, significant contributions were made to the literature on dual-role factors by using bootstrapping to find the true nature of the dual role as it applies to each DMU (team).

I utilise the bootstrapped DEA approach introduced by Simar and Wilson (1998) to examine the efficiency scores of each team generated not by conventional DEA. The key assumption is that the bootstrap distribution will mimic the original distribution. The bootstrap process will therefore generate values that mimic the original distribution after 2000 bootstrap samples have been generated. The bootstrap approach is based on the DEA estimators themselves by drawing with replacement from the original estimates of theta. Assuming n branch observations $[(x_i, y_i), i = 1, \ldots, n)]$ that use multiple inputs $x$ to produce multiple outputs $y$, a summary of the Simar and Wilson's (1998, 2000) methodology to estimate the dual-role efficiency of the sample observations is described in the following steps (Aggelopoulos and Georgopoulos, 2017; Simar and Wilson, 2007):

1 For each branch observation $[(x_k, y_k), k = 1, \ldots, n)]$, I compute $\hat{\theta}k$ as solution to the cross-efficiency linear program formula:

$$
\begin{aligned}
& e_o^* = \max \sum_{r=1}^{R} \mu_r y_{ro} + \gamma\omega_o - \beta\omega_o, \\
\text{subject to}: & \sum_{i=1}^{I} \upsilon_i x_{io} = 1, \\
& \sum_{r=1}^{R} \mu_r y_{rk} + \gamma\omega_k - \beta\omega_k - \sum_{i=1}^{I} \upsilon_i x_{i_k} \le 0, \quad (6) \\
& \qquad\qquad k = 1, ..., K, \\
& \mu_r, \upsilon_i, \gamma, \beta \ge 0.
\end{aligned}
$$

2 I use bootstrap via smooth sampling from $\hat{\theta}1, ..., \hat{\theta}n$ to obtain a bootstrap replica $\theta^*1, \ldots, \theta^*n$. I draw with replacement (bootstrap) from $\hat{\theta}1, ..., \hat{\theta}n$ to generate $\beta^*1, \ldots, \beta^*n$. I smooth the sampled estimates using the following formula:

$$\tilde{\theta}_i^* = \begin{cases} \beta_i^* + h\varepsilon_i^*, & if\ \beta_i^* + h\varepsilon_i^* \le 1 \\ 2 - \beta_i^* - h\varepsilon_i^*, & otherwise \end{cases}$$

I correct the variance of the bootstrap estimates using the following formula:

$$\theta_i^* = \overline{\beta}^* + \frac{\theta_i^* - \overline{\beta}^*}{\sqrt{1 + h^2/\sigma_{\hat{\theta}}^2}}$$

$\overline{\beta}*$ is the average of $\beta*1, \ldots, \beta*n$ and $\hat{\sigma}2\hat{\theta}$ is the sample variance of $\hat{\theta}1, ..., \hat{\theta}n$.

3 I generate a pseudo-dataset given:

$$x_{ib}^* = \frac{\hat{\theta}_i}{\hat{\theta}_{ib}^*} x_i$$

4 I solve the DEA program to estimate theta using the following formula:

$$\hat{\theta}_{k,b}^* = \min\left\{\theta\ subject\ \theta x_k \ge \sum_{i=1}^{n} z_i x_{ib}^*;\ y_k \le \sum_{i=1}^{n} z_i y_i;\ \sum_{i=1}^{n} z_i = 1,\ z_i \ge 0\right\}$$

5 I repeat steps 2–4, 2,000 times to obtain the set of bootstrap estimates. Results are discussed later in this research for the eight MLB teams without and with the bootstrapping to confirm the role of the dual-factor central to this study and to the teams' overall efficiency score.

### *3.3 Cross-efficiency (XEff)*

One of the main contributions of this overall study is to find how each of the teams that share a common city compares to each other. Furthermore, the ranking of the cities to show how they fare amongst each other is of integral importance. This ranking is a relative ranking that takes into account the inputs and the outputs of each of the teams along with the optimal placing of the dual-role factor that will give the optimal efficiency score for each team. The model for this study is provided by Lee and Saen (2012) to find the cross-efficiency in a dual-role factor setting. The following linear programming model helps to analyse the different teams and will give the rankings discussed earlier. At the beginning of the study, I tried using VRS and CRS but those two methods did not give any useful information or the information that I needed to find the differences in the baseball teams. Both VRS and CRS are low on the power to discern between DMUs.

$$\text{Max} \sum_{j=1}^{n} d_j$$

s.t.

$$\sum_{r=1}^{s} u_r \left( \sum_{j=1}^{n} y_{rj} \right) + \sum_{i=1}^{m} v_i \left( \sum_{j=1}^{n} x_{ij} \right) = n$$

$$\sum_{r=1}^{s} u_r y_{rk} + y w_k - \beta w_k - \theta_j^* \sum_{i=1}^{m} v_i x_{ik} = 0,$$

$$\sum_{r=1}^{s} u_r y_{rj} + y w_j - \beta w_k - \theta_j^* \sum_{i=1}^{m} v_i x_{ij} + d_j = 0,\ j = 1, ..., n$$

$$\sum_{r=1}^{s} u_r y_{rj} + y w_j - \beta w_j \geq 0,\ j = 1, ..., n$$

$$\gamma, \beta, u_r, v_i, d_j \geq 0, \text{ for all } r, i, j.$$

There is a missing constraint that does not allow the comparison of the DMUs against one another. I add the constraint of:

$$\sum_{r=1}^{R} \mu_r y_{rk} + \gamma \omega_k - \beta \omega_k \geq 0.$$

This constraint guarantees that an efficiency score can be calculated for peer DMUs. Hence, the cross-efficiency score can be determined (Aggelopoulos and Georgopoulos, 2017). In this way, I am now able to show a ranking and find where each team falls relative to the other. In tune with the overall research questions for this study, with this methodology, we can find how different teams within the different cities rank relative to each other in efficiency. We can then make the case that one team in a certain location is ranked higher in efficiency than the other team in that location, even when taking into account a factor that is not constrained as either an input and an output at the beginning of analysis.

## 4 Empirical results

### *4.1 Historical championships – results without bootstrap*

Cross-efficiency is a technique that helps to give peer rankings based on the set of DMUs in the consideration set (Lee and Saen, 2012; Lu et al., 2023). This means that the eight different teams are ranked against one another so that they can be compared among their strengths and weaknesses. What makes this research so innovative is that cross-efficiency is used to evaluate teams against one another without constraining the role of historical championships as an input or an output. Furthermore, bootstrapping is used to confirm the role of historical championships for each of the teams. Novel statistical methods are used to analysed each team using real world, empirical data from MLB.

Table 3 shows a comparison between CRS-DEA (Charnes et al., 1978) and the cross-efficiency model that was used to break the ties among the eight teams in the study. In other words, we need XEff to make sure that we are getting the information that we need for both the current research question and to get a sound analysis that will help to discriminate between the efficiency of teams. With XEff we are able to get a ranking that we can use for results and decision making. Table 4 shows the results of the XEff process with only one data run using the method by Lee and Saen (2012).

**Table 3** Cross-efficiency

| *DMU* | $\theta_k$ | $\theta_k$ *rank* | *XEff* | *XEff rank* |
|---|---|---|---|---|
| LAD | 1 | 1 | 0.5883 | 3 |
| LAA | 1 | 1 | 0.6997 | 1 |
| OAK | 1 | 1 | 0.4998 | 4 |
| SFG | 1 | 1 | 0.6034 | 2 |
| CHC | 1 | 1 | 0.4764 | 6 |
| CHW | 1 | 1 | 0.3543 | 7 |
| NYY | 1 | 1 | 0.3417 | 8 |
| NYM | 0.9762 | 8 | 0.4935 | 5 |

**Table 4** Cross-efficiency ranking

| *Role* | *XEff* | | *LAD* | *LAA* | *OAK* | *SFG* | *CHC* | *CHW* | *NYY* | *NYM* |
|---|---|---|---|---|---|---|---|---|---|---|
| Input | 0.5883 | LAD | 1.0000 | 0.0377 | 0.1706 | 0.7458 | 0.7515 | 0.7932 | 0.2076 | 1.0000 |
| Input | 0.6997 | LAA | 0.9979 | 1.0000 | 0.0316 | 1.0000 | 0.7558 | 0.7695 | 0.0430 | 1.0000 |
| Output | 0.4998 | OAK | 0.1666 | 0.4337 | 1.0000 | 1.0000 | 0.0085 | 1.0000 | 0.3698 | 0.0196 |
| Output | 0.6034 | SFG | 0.7729 | 0.3855 | 0.2583 | 1.0000 | 0.6831 | 0.4845 | 0.3699 | 0.8729 |
| Input | 0.4764 | CHC | 0.3890 | 0.0518 | 0.0970 | 0.2437 | 1.0000 | 0.8931 | 0.1368 | 1.0000 |
| Input | 0.3543 | CHW | 0.2122 | 0.0265 | 0.1757 | 0.1852 | 0.5315 | 1.0000 | 0.1431 | 0.5598 |
| Output | 0.3417 | NYY | 0.0000 | 0.0000 | 0.8479 | 0.8855 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| Input | 0.4935 | NYM | 0.7795 | 0.1216 | 0.0649 | 0.4754 | 0.7576 | 0.6830 | 0.0925 | 0.9734 |

The input and the output role is also shown on the left-hand side of the chart. Table 5 shows the gamma ($\gamma$) and beta ($\beta$) scores. When $\gamma$ is 0 then the role of historical championships is an input. When $\beta$ is 0, then the role of historical championships is an output (according to Lee and Saen, 2012).

**Table 5** Gamma and beta of historical championships

| *DMU* | $\gamma$ | $\beta$ |
|---|---|---|
| LAD | 0.0000 | 0.4530 |
| LAA | 0.0000 | 0.2456 |
| OAK | 0.9934 | 0.0000 |
| SFG | 0.5807 | 0.0000 |
| CHC | 0.0000 | 0.7565 |
| CHW | 0.0000 | 0.6600 |
| NYY | 1.1391 | 0.0000 |
| NYM | 0.0000 | 0.8296 |

From the results, there is a mix of input and output roles for historical championships, meaning that this factor truly is a dual-role factor (Cook et al., 2006). For some teams it will be a help presenting the previous successes as a way to get more people to back the team. For other teams, all the inputs they put into a season will be aimed at winning the final game of the season or otherwise known as the World Series Championship. Within

these two scenarios, this mix of inputs and outputs, along with whatever role historical championships plays, will give the best efficiency of each team compared to the others. We can even see the rank of each team from the Los Angeles Angels as number 1 to the poorly efficient New York Yankees as number 8. The reasons that this is the case are discussed later in this research.

### *4.2 Historical championships – results with bootstrap*

After running 2,000 bootstraps following the method provided by Simar and Wilson (1998), I found that the efficiency scores and the rankings from each of the teams changed slightly. However, I was also able to show that the role of the dual-role factor of historical championships was used as an input and an output by various teams. With some teams however, it was shown in equilibrium. Table 6 shows the XEff comparison before and after the bootstrap process.

**Table 6** Bootstrapping comparison

| *DMU* | $\theta_k$ | $\theta_k$ *rank* | *Without bootstrap* | | *With bootstrap* | |
|---|---|---|---|---|---|---|
| | | | *XEff* | *XEff rank* | *XEff* | *XEff rank* |
| LAD | 1.0000 | 1 | 0.5883 | 3 | 0.7036 | 3 |
| LAA | 1.0000 | 1 | 0.6997 | 1 | 0.8016 | 1 |
| OAK | 1.0000 | 1 | 0.4998 | 4 | 0.5001 | 6 |
| SFG | 1.0000 | 1 | 0.6034 | 2 | 0.7240 | 2 |
| CHC | 1.0000 | 1 | 0.4764 | 6 | 0.5186 | 5 |
| CHW | 1.0000 | 1 | 0.3543 | 7 | 0.3705 | 8 |
| NYY | 1.0000 | 1 | 0.3417 | 8 | 0.3841 | 7 |
| NYM | 0.9762 | 8 | 0.4935 | 5 | 0.5735 | 4 |

The efficiency of each of the teams increased after the 2,000 data runs. This is a better overall estimate of the efficiency for each team that comes from both a small sample and the resampling process with replacement that was undertaking during the bootstrapping process (Simar and Wilson, 1998). The Los Angeles Angels are still the most efficient among the set of teams, but the New York Yankees are no longer in last place. The bootstrapping process gave overall better estimates that was received from one data run using XEff.

Table 7 shows the new role of the dual-factor historical championships. There is a mix of input, output, and equilibrium. However, after taking 2,000 resamples with replacement, Table 7 makes a strong case for the role of the dual-factor (Simar and Wilson, 1998). This means that we have been able to place the role of the dual-factor role by running the analysis multiple times to find the optimal solution. Therefore, we now know where the dual-factor should fall for each team. Table 8 shows how many times the data runs fell in each of the three role categories. From this data, hypothesis testing will show that each role with a majority of the data runs is statistically different from the other roles.

Table 9 shows the following characteristics for $\gamma$ and $\beta$ for each DMU when looking at the linear form of the equation for cross-efficiency. This is consistent with the previous theorising on $\gamma$ and $\beta$ that I made before the bootstrapping was performed. Therefore, out

results are uniform and consistent with the linear form of the cross-efficiency DEA model.

**Table 7** Cross-efficiency results with bootstrapping

| *Role* | *XEff* | | *LAD* | *LAA* | *OAK* | *SFG* | *CHC* | *CHW* | *NYY* | *NYM* |
|---|---|---|---|---|---|---|---|---|---|---|
| Equilibrium | 0.7036 | LAD | 1.0000 | 0.1307 | 0.7458 | 1.0000 | 0.7515 | 0.7932 | 0.2076 | 1.0000 |
| Equilibrium | 0.8016 | LAA | 0.8448 | 1.0000 | 1.0000 | 1.0000 | 0.7558 | 0.7695 | 0.0430 | 1.0000 |
| Output | 0.5001 | OAK | 0.4718 | 0.5957 | 1.0000 | 0.5356 | 0.0085 | 1.0000 | 0.3698 | 0.0196 |
| Equilibrium | 0.7240 | SFG | 0.8773 | 0.5040 | 1.0000 | 1.0000 | 0.6831 | 0.4845 | 0.3699 | 0.8729 |
| Input | 0.5186 | CHC | 0.3555 | 0.0705 | 0.2437 | 0.4495 | 1.0000 | 0.8931 | 0.1368 | 1.0000 |
| Input | 0.3705 | CHW | 0.2201 | 0.0499 | 0.1852 | 0.2740 | 0.5315 | 1.0000 | 0.1431 | 0.5598 |
| Output | 0.3841 | NYY | 0.4336 | 0.2181 | 0.8855 | 0.5356 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| Input | 0.5735 | NYM | 0.7009 | 0.1531 | 0.4754 | 0.7525 | 0.7576 | 0.6830 | 0.0925 | 0.9734 |

**Table 8** Data runs (equilibrium, input, and output)

| | *Count E* | *Count I* | *Count O* |
|---|---|---|---|
| LAD | 1,631 | 369 | 0 |
| LAA | 1,928 | 72 | 0 |
| OAK | 396 | 11 | 1,593 |
| SFG | 1,837 | 163 | 0 |
| CHC | 127 | 1,873 | 0 |
| CHW | 0 | 2,000 | 0 |
| NYY | 612 | 0 | 1,388 |
| NYM | 0 | 2,000 | 0 |

**Table 9** Gamma and beta characteristics for each DMU

| | $\gamma$ | $\beta$ |
|---|---|---|
| LAD | 0 | 0 |
| LAA | 0 | 0 |
| OAK | > 0 | 0 |
| SFG | 0 | 0 |
| CHC | 0 | > 0 |
| CHW | 0 | > 0 |
| NYY | > 0 | 0 |
| NYM | 0 | > 0 |

## *4.3 Hypothesis testing: T-test among roles*

One of the main contributions of the current research is finding the correct role that the dual-role factor plays in the overall DEA structure in each of the DMUs. I want to say with high certainty that the role that was found for each of the DMUs after bootstrapping is statistically different than the opposite role or from equilibrium. After the 2,000 bootstraps, I found that a majority of the results for the role of the dual-role factor fell

into one of three categories: input, output, or equilibrium. The reason for the bootstrapping procedure is that it runs the data more times to be certain that the dual-role factor belongs in either one of the three categories (Simar and Wilson, 2007). With this method, we can separate the majority category of the dual-role factor and the two other minority categories of the dual-role factor. In the analysis, the category where the majority of data runs for historical championships fall is called the 'role' while the two minority categories, grouped together, are called the 'non-role' group. They can vary based on the majority role for each DMU. For instance, when looking at Table 8, the role category for LAD is equilibrium while the other two categories, input and output, are the non-role category. In the same way, for NYY, the role category would be the majority, so for this DMU the role category in the t-test analysis is output while input and equilibrium are grouped together as the non-role category.

There is a significant difference between the majority placement and the placement in the other two categories with a small number. A t-test was run on the categories to empirically show that there is a statistically significant difference between the role and the non-role of the dual-role factor for each DMU. The results of the t-test that show there is a significant difference between the role and the non-role categories ($p < 0.001$). This means that we can say, with 95% confidence, that the category where a majority of the data runs resulted for the dual-role factor is the correct role given that DMU. I now move on to analyse what this means with a dual-role factor that has been strongly supported by both the bootstrapping procedure and the t-test. Table 10 shows the paired sample statistics and Table 11 shows the results of the paired samples test.

**Table 10** Paired samples statistics

| *Paired samples statistics* | | | | | |
|---|---|---|---|---|---|
| | | *Mean* | *N* | *Std. deviation* | *Std. error mean* |
| Pair 1 | Role | 1,781.25 | 8 | 220.850 | 78.082 |
| | Non-role | 218.75 | 8 | 225.850 | 78.082 |

**Table 11** Paired samples test

| *Paired samples test* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Paired differences* | | | | | | | | | |
| | | *Mean* | *Std. deviation* | *Std. error mean* | *95% confidence interval of the difference* | | *t* | *df* | *Sig. (2-tailed)* |
| | | | | | *Lower* | *Upper* | | | |
| Pair 1 | Role-non-role | 1,562.500 | 441.700 | 156.165 | 1,193.229 | 1,931.771 | 10.005 | 7.000 | 0.000 |

## *4.4 The outcome-teams with two cities*

At the beginning of the study, I had the notion that the story of the efficiency of the teams would be told based on how long the team had been in operation in MLB, along with how much money is spent on both the team and facilities. In fact, mostly anybody who is involved in the sports world would say that to have success, you need to spend money, and lots of it (Ozanian and Teitelbaum, 2024). However, after conducting this study, I

can now say that that is not the case. In fact, this current research is groundbreaking because it allows the scrutiniser of sports teams to rethread their mindset into thinking that there may be other factors that they can control that will give the most success to their team. We move away from the old method of thinking that success is dependent on the dollars spent on teams and toward a new way of showing empirically that there are many facets of teams within the control of management and other organisation leaders that will allow that team to compete with others, especially the team right down the street.

The cross-efficiency scores after the bootstrapping show a significant margin between the efficiency scores for the teams in one city. In Los Angeles, the Angels rank highest of all the eight teams and higher than the Los Angeles Dodgers that ranked number 3. This means that the Angels were much more efficient than the Dodgers. This is due to the revenue that they pulled out from fans (Cialone and Newland, 2023; Ehrlich and Potter, 2021). From the raw data from each team, we can see that the Angels pulled out more money per fan than any other teams. This means that through their operations, they were able to still have fans that spent more money on merchandise, food, and gameday festivities than their counterparts. The dodgers were deficient on this and were not able to get much revenue out of their fans. In fact, the Angels were able to get more than nine times the amount of revenue per fan than the Dodgers. This may have been the deciding factor, when paired with the rest of the inputs and outputs that gave the Angels an edge over their competition. Even though the Dodgers have more championships than the Angels, the analysis shows that the role of this factor is in equilibrium for both teams, telling us that this factor does not drive the efficiency of the Dodgers over the Angels as we would expect from such a margin in championship seasons.

In the bay area, the San Francisco Giants were ranked higher in efficiency than then Oakland Athletics. The Giants were ranked 2nd behind the Angels and the Athletics were ranked 6th. However, in this case, the Giants and Athletics had very similar revenues per fan that they were able to achieve over the 2017 season. This means that there was another factor that may have played a bigger role in creating the discrepancy among the efficiency scores. The analysis shows that the role of historical championships was an output role for the Athletics. The Athletics do have more championships than the Giants, but only by one. When compared with the other inputs and outputs in the analysis, there is a major discrepancy between the payroll that the Giants are able to use as compared to the payroll that makes up part of the Athletics inputs into a full season. This may be the driver between the efficiency score since championships plays an equilibrium role for the Giants, meaning that the championships in the past will not solely tell the story of success for the Giants, but rather through the rest of the mix of inputs and what was taken out from the season. In this way, while both the Athletics and the Giants have experienced success, there are other factors that can also cause a mix for the teams and cause a difference of efficiency scores. However, one of the drivers for the Athletics were championships, but only in the sense that the Athletics need to have more successes each year to truly feel the effects of historical championships as an output.

The story with the teams in Chicago tells a similar story. The only difference in these teams is that the least efficient team in this city and the entire data set for that matter has a smaller stadium than their counterparts only a few miles away. There are some discrepancies between the inputs that the Cubs have put into the season as opposed to the resources that the White Sox have put into the season. The Cubs have a higher payroll and higher revenue per fan. These are all drivers of efficiency that were discussed

previously. What is novel and interesting about this setting is the fact that historical championships plays the role of an input for both the teams. What is even more interesting is that both teams have won three championships each. This is something that is under the control of both the team and management for both teams. The more championships that are won by either team and the better off each team may be in terms of efficiency, holding all the rest of the inputs constant (Cook et al., 2006). Therefore, both teams should try to compete for more success on the field, in the true spirit of rivalry. They have control over their success and hard work on the field may pay off in the management offices after a long 162-game season.

The three previous locations have given a glimpse into different settings into which the dual-factor plays the role of both an input, output, or is in equilibrium, meaning that it can play both an input or output role. The fourth and final location, New York, gives insight into how historical championships plays an input for one team and an output for the other. The New York Yankees and the New York Mets are two very distinct teams, even though they are only separated by nine and a half miles. The Yankees have won three times as many championships as the next team in the entire data set, the Oakland Athletics and have almost 14 times as many championships as their Met counterparts. However, for the Yankees, there success on the field is applicable as being an output rather than an input. In other words, instead of having high efficiency due to their past success because of their fan base or because of people who value success going back to the mid 1900s, the Yankees need to keep winning more championships rather than sitting on the 27 they have now. Speaking to several Yankee fans, they only believe that the team is valuable when they win the final game of the season, meaning that they win the World Series and add another trophy to their list of accolades. Without a championship to show for each season, the fans, revenue, and eventually efficiency will continue to drop (Kensinger and Schacter 2006; Shonk and Weiner, 2021). This shows in their efficiency score as the Yankees are actually one of the worst teams when it comes to being efficient (ranked 7th out of 8 teams). The Yankees have not won a championship since 2009, bringing the dry spell of no success up to eight years (Ozanian and Teitelbaum, 2024; Zimbalist, 2018).

This leads to the next point in the discussion of the Yankees as compared to the Mets. The Mets are actually ranked highly in the data set at number 4 even with their low number of championships. For them, championships are an input rather than an output. This means that their past success actually counts for much of their success in the present time. However, the reason they are ranked so much higher than the Yankees when it comes to efficiency is because the Mets have a payroll that is much lower than the Yankees. This means that the Yankees themselves are spending astronomical amounts of money for no success while the Mets have their payroll under control and are riding the wave of two previous World Series titles into financial success. This has been a criticism of the Yankees for quite some time and through their managers as well. The question is can this change to help the team move up the rankings of efficiency?

## 5 Application to other sports organisations

This research helps to present two different types of measures, which are both monetary and capacity-based measures. The nature of the inputs and outputs helps this model to be used in a multitude of different contexts and different sports. Other leagues can place

their years operating, payroll, stadium capacity, attendance, wins, revenue, revenue per fan, along with historical championships to find their efficiency and how to use their success to market and position their team with fans and potential fan involvement that they might be able to capture.

The use of the method, DEA, also aids in further dissection of sports organisations in that this method can handle different types of data that may slightly vary from sport to sport. An aim of this model and this current study is not only just to show the efficiency of teams, but also to make that comparison of teams with close proximity to each other as is the case with many of the teams in other leagues, such as the English Football League where most of the teams are within miles of each other with the closest teams being only 0.8 miles from each other (Forrest and Simmons, 2006). Other examples include basketball in the USA where the closest teams are only 5 miles from each other (Brooklyn Nets and New York Knicks) or the Los Angeles Lakers and Los Angeles Clippers which previously shared the same arena but are now only 13 miles from each other (Humphreys and Nowak, 2017; Kim et al., 2024). The same goes for hockey where the two closest teams (New York Islanders and New York Rangers) are only 14 miles from each other and the Los Angeles Kings and Anaheim Ducks are only 34 miles apart, but still considered part of the same metro area (Teed et al., 2009). This model helps to create a blueprint for managers of sports teams to follow to increase their knowledge and understanding of what drives their business success.

## 6 Managerial significance

The empirical results give some new paths for managers to follow that previous research has not discussed. These managerial implications are not only meant for baseball teams, but can be generalised to any sport and to any industry with capacity and output constraints. Managers should first turn their attention to getting the most revenue out of their customers. This means that operations should be focused on serving customers and at the same time making sure that the organisation is allowing customers to spend in multiple ways, including tickets, merchandise, food and beverage, and in each part of the gameday fan experience. This spending is synonymous with businesses that have consumer experiences as part of their business model for revenue generation. This can be comparable to the gameday spending that happens each day in the 30 Major League ballparks around the USA and Canada. This is not limited to just the MLB. These same experiences can be generalised to multiple sports in that fans who partake in the gameday activities are ones that drive the revenue generation for the teams. Even the fans who are not immediately at the game can also partake in the games through their social identification with their favourite team. This social identification can also be heightened as team success in the form of championships continues to increase and helps to ‘cement’ fans as part of their teams that keeps achieving this success. This increase in social identification between fans and the team that will also allow for greater fan engagement and spending on the team in the multiple ways previously mentioned including tickets, merchandise and the like. From the results and from the data, revenue per person or in this case per fan was one of the outcomes that was higher for those teams that had more efficiency. Therefore, if a team wants to be more efficient, then their management would want to look into how to increase their revenue both for gameday experiences and even for fans not physically present but still engaged with the team.

The second managerial recommendation is one that comes from the heart of this research itself. Past success is handled differently in different situations by different organisations. The first action that managers should take is to find how past successes affect the organisation. Does past success allow you to have a rich tradition or do past successes cause fans and customers to want more every year and without any success, face declining efficiency as compared to other organisations? This research has used MLB teams as the setting to show how a dual-role factor can play different parts and yet, be confirmed in the correct role by use of robust statistical methods. Finding the right role is what managers need to work on whether it be past success or any other role that they feel might be playing a dual part in the overall efficiency and success of the organisation.

## 7 Research implications

The use of the dual-role factor in the model is novel in that it helps organisations to know how to treat this factor of their operations. In this case of using historical championships, knowing the way to treat this factor could lead to more of a strategic understanding on how to generate revenue and capture that revenue from individual fans.

In the case of baseball, older teams with a long and storied history of winning championships can use success to their advantage. While newer and less experienced teams may not be able to use these past successes but can also create an atmosphere of 'being in the hunt' for championships at the end of the season (Losak and Halpin, 2024). This has been seen recently as newer teams have had more success and have come closer to winning that coveted championship trophy at the end of the year. The case with the San Diego Padres, who have limited success, now market their team in the same fashion and much of their efforts and strategic initiatives treats this championship as an output that they are hoping to achieve in the next few years (Nightengale, 2024). This dual-role factor, when used as either an input or an output, will shape the marketing strategy of the organisation and will also change their marketing communications (static, social media, etc.) and overall marketing message to reflect this use of championships (Keenan, 2024; Perrin, 2024).

The use of this dual-role factor in the model can be extended to other types of sports, especially ones with a long history. For example, the English Football league in Europe is considered one of the top levels of soccer and has been around since 1863 (Plumley et al., 2018). In that time, each of the 68 teams in that league have different claims to the number of championships won over the last century and beyond. This current research can help to place these successes at the forefront of how these teams position their 'product' that they offer to fans and customers of the sport. This dual-role of historical championships can be used as an input and an output, but through this current model that is presented, each team can find just how to use their successes on the field to market themselves off the field.

## 8 Limitations

One of the limitations of the study that can be helped by future research is that the amount of inputs and outputs in this model are limited. This is mainly due to the previous research on these inputs and outputs and the limited study on how each of these can affect

different sports organisations. Many of the previous studies also cannot be generalised to other contexts due to the specific definitions of each input and output that have been used in previous literature. However, this current study expands on the definition of the inputs and outputs to try to generalise to different contexts and presents an overall view of how this model can be used to study the efficiency of teams from different sports leagues around the world. This model, though, could benefit from an expansion of inputs and outputs and dual-role factors that could tell more of an overall story with this use of other factors that may influence team efficiency going forward. After all, the dual-role factor itself can be a major part of the decisions to be made to shape the marketing repertoire for sports organisations (Joonas et al., 2024).

Another limitation concerns the definition of success of different sports leagues. In the case of this study with the MLB as the focus, the success at the end of the season is winning the World Series. However, the success in other leagues for other sports may be winning multiple championship titles during a certain season as could be the case with European soccer teams that play in multiple leagues at the same time (Ponce-Bordón et al., 2024). Other successes could mean also winning championships with an international focus that encompasses teams from different locations around the globe as opposed to teams within the same country (Winfree et al., 2024). This differing view on success is something that need further refinement in terms of the definition of success for each type of sport and sports league.

## 9 Future research

In the dynamic setting of sports, there is always future research that can be done to gain a better understanding of the operations of professional sports teams. One of these ways is to expand on the inputs and outputs that are a part of this study that may affect the overall efficiency of teams. For example, professional sports are moving more towards the event being an 'experience' instead of a game for fans (Jeong, 2024). A new input could be the hospitality for fans including suite prices, food quality, food prices, and beverage availability. It is assumed that a better overall hospitality scenario for fans would translate into better revenue per fan and may be able to draw fans away from another team in close geographical proximity. Another example could be the connection between the team and city as an input. In the MLB there is a new initiative to create 'City Connect' jerseys and merchandise that have a high significance with the city that the team represents (Sheanin, 2024). This city connection may be a part of the overall marketing landscape for a team that could translate into higher attendance and total revenue over the course of season. In either scenario, the expansion of inputs and outputs might help to more thoroughly understand the underlying dynamics of these teams and sports leagues. However, research on these different areas of sports mentioned also needs to be present in subsequent literature.

Future research could also take a look at how the current model can be used in leagues with a promotion and relegation style of play (Renfree et al., 2024). When teams move up or down a league, there will be some differences in their opponents and their geographic proximity, along with changes in payroll resources, attendance and revenue. This will ultimately change the efficiency of teams and this style of changing leagues after success or collapse may lead to changes in how owners and general managers both market and manage their teams.

An area of future research for this context of teams in a close vicinity to each other would be the changing populations and specifically the increasing populations that may further blur the lines between team locations and fan demographics in that area. In 2024, population is growing at a staggering rate in cities with professional sports teams (Giri et al., 2024). It will be a major task for each of these teams to capture these new and potential fans. This also includes capturing younger fans as more and more decisions on attending sporting events and purchasing merchandise are made by children and teens and heavily influence their parents and other siblings (King-White et al., 2024). This could also be an additional input and or output where teams study how to market to younger people and their parents and create lifelong fans from an early age.

## 10 Conclusions

Overall, the results of the current study are very intriguing because multiple scenarios are presented depending on how a dual-role factor behaves. In this context, teams within the same geographic area are always competing to see which is better than the other not only on the field, but in the front offices as well (Kensinger and Schacter, 2006). However, even teams separated by less than 10 miles have different histories and structures that lead to different efficiencies.

Altogether, managers should be focused on serving customers and allowing customers to spend through multiple avenues, including tickets, merchandise, food and beverage, and in each part of the gameday fan experience. The social identification between fans and the teams can also be heightened as team success in the form of championships continues to increase and help establish fans as their team succeeds.

The research showed the use of the dual-role factor in the model is unique in that it can help sports organisations in their operations. Knowing how to treat historical championships leads to more of a strategic understanding on how to create income for the team and can help in their market positioning and how to use their successes to market themselves to potential fans.

As with any research, there are some limitations. Team efficiency could be altered as more inputs, outputs, and dual-role factors are explored by further theory and supporting literature. The definition of success is another concern with different sports leagues. The success in other sports may be winning multiple championships or even just being promoted to a higher tier league. The differences in what a sports league determines is success may also influence the efficiency when studying teams in close proximity.

Future research could look into hospitality for fans including suite prices, food quality, food prices, and beverage availability. A better hospitality scenario for fans could translate into better revenue per fan and fan identification with the team. Additionally, teams with a close vicinity to each other can be affected by changing demographics of populations within the city.

As we see the current movement of teams from not only baseball, but from other sports such as professional hockey, soccer, and basketball as well as the expansion for more teams, it is hopeful this research will shed light on the internal dynamics of what makes a professional sports team tick and have success. After all, organisations play to win and teams play for championships with everyone involved. As the great Babe Ruth said “The way a team plays as a whole determines its success. You may have the greatest

bunch of individual stars in the world, but if they don't play together, the club won't be worth a dime" [Ruth, 1939; Sobol, (1974), p.87].

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