Palafox-Alcantar, P.G. & Vargas-Hernández, J.G. (2015). Measuring the efficiency of the 32 franchises in the NFL during the 2014 season. A data envelopment analysis approach. *Journal of Sports Economics & Management*, 5(1), 37-53.

MEASURING THE EFFICIENCY OF THE 32 FRANCHISES IN THE NFL DURING THE 2014 SEASON. A DATA ENVELOPMENT ANALYSIS APPROACH

Medida de la eficacia de las 32 franquicias de la NFL durante la temporada 2014. Una aproximación mediante análisis envolvente de datos

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ABSTRACT: In this paper the Data Envelopment Analysis (DEA) technique has been used to measure de efficiency of the 32 teams' payroll in the National Football League (NFL) in season 2014. The financial structure of the NFL promotes competition and does not favour any franchise, which assures that no team is able to overspend to win. Besides victories, several output variables have been taken into account to measure de statistics of the on-the-field performance, such as points per game and yards per attempt. Finally, the article shows that, not always teams, which make it to the post-season, are the most efficient.

KEYWORDS: data envelopment analysis; DEA; sports; efficiency; NFL

RESUMEN: En este trabajo se utiliza la técnica Análisis Envolvente de Datos (DEA), para medir la eficiencia de los pagos de salarios a jugadores de los 32 equipos de la Liga Nacional de Football (NFL) en la temporada 2014. La estructura financiera de la NFL, incentiva la competencia y no favorece a ningún equipo, lo cual asegura que ninguna franquicia puede gastar excesivamente para ganar. Además de las victorias, se han tomado como variables decisoras de salida estadísticas de desempeño en-el-campo, como los puntos por partido y las yardas por intento. Por último, el artículo muestra que no siempre, los equipos que llegan a la postemporada son los más eficientes.

PALABRAS CLAVE: análisis envolvente de datos; DEA; deportes; eficiencia; NFL

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Introduction

It is of particular interest for the sports fans, how the owners and directives of the teams make decisions about the players recruiting, and how these decisions affect the on-the-field team's performance. When the free agency and the salary cap were introduced, the perspective from which owners and directors assemble their teams has changed substantially. For instance, Einolf (2004) argues that many owners pay incredibly high salaries to veteran players who have proved their high quality over the years, but many are still questioning if these high prices are truly worth it.

There is a linear programming technique, which is able to assess how efficient the payrolls in a sports franchise are, the technique is called Data Envelopment Analysis (DEA). It was introduced by Charnes, Cooper, and Rhodes (1978) and then improved by Banker, Charnes, and Cooper (1984). The DEA has been used extensively in contexts outside sports economics. For example, it has been used to measure the efficieny in hospital management. The DEA has also been used to compare the effects among different strategies used in the airline industry. The technique has even been used to evaluate the effect affecting the uses of information techonologies in firms performance (Wang, Gopal, & Zionts, 1997).

In the sports economics literature, there is abundant material that analyses the sports leagues, their efficiency and their productivity. The majority of these studies focus on how the on-the-field management decisions affect the victories in several sports. However, the DEA technique has also been used inside the sports economics literature. For example, to assess the relative performance of baseball players, also to develop a production frontier function and evaluate the performance of golf players in the Professional Golf Association (PGA). Also to estimate the management efficiency of college basketball coaches. But according to Einolf (2004), measuring exclusively the effects of the decisions in the payroll and on-the-field performance is a new approach.

Background and Definition of the Problem

Inside a sports league, the structures of financial incentives are used to achieve balance between the cooperation and competition among the teams. In other words, franchises compete to generate earnings and also compete to be successful on-the-field, and at the same time they are cooperating to increase the fans or consumers interest. A financial structure, which stimulates inefficient payrolls, may cause the teams, individually, to overspend in salaries at the expense of the entire league, or other teams.

There are also other methods, with which teams obtain monetary benefits. One of the most important is the attendance to stadiums to watch NFL games, the local teams keep 60% of the earnings and the visiting teams receive the remaining 40%. Most of the NFL teams profit comes when the teams locally negotiate the transmission rights with broadcasters, these earning are collected by the league and distributed equally among the franchises in the league. In addition to profit from selling different products during matches, and franchise products throughout the countries. Moreover, teams set restrictions on player contracts to have a share in earnings for players' image. All this prevents a significantly large gap between the large-market and small-market teams. Thus the NFL, has also imposed a salary cap, so big profit franchises do not have great advantage over those of lower profits when it comes to recruiting star players.

Based on the financial incentive structure in the NFL, along with the restrictions and conditions imposed by the NFL, this article studies the next research question, which is also the object of study:

- ¿Which are the football franchises in the NFL, more efficient when they spend more in their players' salaries, both in offense and defense, taking into account that their productivity is measured with the on-the-field performance, in the 2014 season?

It is expected that the football franchises in the NFL are most efficient on-the-field performance, when they have gone further during the regular season. Hence, those which have accumulated more victories and have made it to the post season, in the season 2014.

Then, in the next section, there is the theoretical framework and a brief review of the relevant literature for the research. Several studies have been important and relevant to this work, which have served as a guide and reference for the progress of this study.

Reference Framework and Brief Review of the Literature

There have been several studies related to sports Economics, some of which have used the DEA technique to evaluate the efficiency and productivity of sports leagues and players, as well as teams and managers, including administrative decisions of the league. Some examples which will be discussed in this section are: professional tennis players, the efficiency of football soccer players in the Bundesliga, the budget efficiency from Formula 1 builders, teams in England's Premier League, the assessing of cycling teams on the Tour de France, and finally a comparison between the Major League Baseball (MLB) and NFL. All these researches have used the DEA technique or its derivatives. Next, the brief recensions of these articles are presented.

Moreno and Lozano (2015) have performed an assessment of the change in the productivity of the National Basketball Association (NBA) teams during the last seven seasons. In the meantime in 2011-12 a collective bargaining agreement was ratified to end a 161-day lockout. The authors used the Malmquist Productivity Index to measure the total factor productivity whilst they used de DEA input-oriented technique to calculate the distance of each team to the productivity frontier. In their results they show that the best practices are improving and most teams are reducing their payrolls to keep up with this practices. And they found that changes in number of victories depend more on the scale efficiency change than on budget or efficiency changes.

The paper realized by Ruiz, Pastor, and Pastor (2013), evaluates the performance of professional tennis players from the perspective of efficiency of their game using DEA, which authors argue that their study provides additional information to ranking the Association of Tennis professionals (ATP), which deals with their competitive performance. The model provides an index of overall performance of the players by adding the ATP statistics related to the different aspects of the game. Their “benchmarking” analysis of DEA allowed them to identify the strengths and weaknesses of each game player. Finally for the players’ ranking, the authors used cross efficiency evaluation, which assesses players in a peer with different aspects of the game.

The article published by Tiedemann, Francksen, and Latacz-Lohmann (2011), presents a new model for evaluating the performance of football soccer players on-the-field. Which is based on DEA, they used an approach of concave metafrontier to be allowed to estimate the results of efficiency of players under the relevant considerations of their player positions. The model is applied to a data set of players in the German Premier League covering the seasons from 2002/03 until 2008/09. Their results revealed clear, positive relationship between the average team efficiency result of a player and his position in the league table at the end of the season. In addition, the metafrontier approach is used to identify the optimal game position of a player in the team, and to quantify the increase in performance when moving to that position.

Another study of special interest for this research is the article by Gutiérrez and Lozano (2014), where their research assesses the relative efficiency of the participating teams in the World Championship Formula 1 Constructors. The non-parametric used method was based on the DEA tchnique. The objective is to measure the performance of each builder, compare their relative efficiency with that of all other competitors participating. The study uses financial and performance data to assess the proximity to the frontier of best practices. The analysis has been made considering the results of the F1 season in 2003, 2006, 2008, 2010 and 2011. In order to create a parsimonious DEA model, a varaiable selection method was used to reduce the dimensionality. The results indicated that, in general, a substancial reduction should be imposed on the budget of competitors throughout the seasons, in order to be efficient in comparison to the identified reference points. Furthermore, the scale efficiency revealed that most manufacturers operate below its full scale production capacity.

Guzmán and Morrow (2007) focused on their research on evaluating the efficiency and productivity of teams in te English Premier League. Professional football soccer clubs are unusual firms, its performance is judged on and off-the-field. Information from the financial statements of clubs is used as a measure of corporate performance. To measure changes in productivity and inefficiency, the Malmquist non-parametric technique was used. This technique is derived from linear programming approach DEA wih Canonical Correlation Analysis (CCA) which was used to ensure the cohesion of the input-output variables. The paper concluded that while clubs operate near the efficiceny levels for the model evaluated, there is limited technological progress in their performance in terms of displacement of the technology frontier.

The publication by Rogge, Van Reeth, and Van Puyenbroeck (2013), relates to using DEA robust approach (of order *m*) to evaluate the efficiency of cycling teams in the Tour de France. Because there are mutliple ways in which this event can be successful for a cycling team, it is taken into account that managers face strategic decisions of inputs, which concerns the team and the characteristics of the cyclists. In particular, it distinguishes between ranking teams, speed teams, and mixed teams and calculate each team a score of efficiency as was done to the relative performance of the teams ranked similarly, and a score of efficiency that results from the type of team. Finally, the authors found that the ranking teams are generally more efficient than other types of cycling teams.

And finally, the main and most important paper for this study, which has served as the basis at various points, it makes reference to the article by Einolf (2004). It addresses the efficiency and productivity of MLB and NFL, of the United States of America, between the period of 1981 and 2001. In his article, Einolf (2004) found that there are great differences in inefficiencies between both leagues. The MLB inefficiency is significant and is given primarily by the little profit sharing and there is no salary cap in this league. In the same way, it shows that the enormous costs of the MLB and its inefficiency are related. The study also shows that the efficiency on the NFL has improved significantly since the salary cap was introduced in 1994. However, this paper has the objective to evaluate both leagues fully in the course of time and compare them, but for this study's main interest is to assess and evaluate the teams together, on the played season in 2014.

In the next section the method to be used, as discusses above is the DEA, is described in detail, its introduction and further improvement, as well as the approach it was given to this work. Likewise, the justification of the use of this method is stipulated, its advantages and limitations over the traditional linear regressions.

Methods and Model

This paper compares how efficient are the football teams in the NFL, and how these teams use their inputs to produce outputs. The salaries of the players, the team's biggest expense, are used to represent these inputs, while the performance statistics on-the-field (including number of victories) are used to measure the products of the team. These data are used because they are accurate and available from the played season in 2014.

To measure the efficiency the technique called DEA will be used, which was introduced to measure the relative efficiency in Decision Making Units (DMU) for which inputs and outputs vary. This model is a linear programming technique to compare the levels of inputs and outputs from a DMU with the rest of the DMUs. The DMU which produce the most with respect to their inputs used are the ones called efficient, and these DMUs form a linear frontier in sections. The surface of this frontier is a hyperplane with as many dimensions as there are inputs and outputs. All efficient DMUs are evaluated according to the surface of efficiency (Charnes, Cooper, & Rhodes, 1978).

The purpose of the input oriented DEA model introduced by Charnes, Cooper y Rhodes (1978), which will be called from now on CCR, is to minimize inputs using while satisfying minimum known levels of outputs. Using linear programming, the model compares each of the DMUs with the rest of the DMUs. The program searches the data to determine whether a linear combination of similar DMUs, uses lower level of inputs to produce at least the same amount of outputs than the DMU analyzed.

It is assumed mathematically, that there exists n DMUs to analyze. Each DMU uses m inputs and produces s outputs. X is an m x n matrix which contains all the DMUs inputs (the element in the matrix, x_{ij}, is the value of the input i for the DMU j). Y is an s x n matrix which contains all the products of the DMUs (the element of the matrix, y_{ij}, is the value of the output i for the DMU j). x_o represents a vector of 1 x m inputs for the DMU tested, and y y_o represents a vector of de 1 x s outputs for the DMU analyzed. The linear program finds the θ efficiency factor. This is the factor with which the analyzed DMUs are equally and proportionately reduced to emulate a linear combination of paired DMUs. The program also finds λ, a vector of n x 1 size of multipliers which develop a linear combination of the paired DMUs. The CCR model is formulated as follows:

$$\text{Minimize } \theta \quad (1)$$

Restricted to:

$$\theta x_0 - X\lambda \geq 0, \quad (2)$$

$$Y\lambda \geq y_0, \quad (3)$$

$$\lambda \geq 0, \quad (4)$$

To explain the CCR model, the context considered is in which the efficiency of sports franchises is measured using a variable input (team payroll payments) and a variable output (number of matches won). Figure 1 shows how the model establishes the efficiency frontier and measures the relative inefficiency of DMUs not found in the border. The team B has the best practice standard with more wins per dollar paid in the payroll. The DEA model described in equations (1) to (4) is built on the assumption of constant returns to scale. Which means, if any combination of input/output (x, y) is on the efficient frontier, then for any t positive constant, the combination of input/output (tx, ty) is also on the efficient frontier. Hence, the team B victories per payroll ratio define the efficient frontier. When the linear program computes the team B efficiency factor (θ_B), it is unable to reduce the level of team B payroll to which any combination of wins from other teams as many as team B con a total lower payroll. Therefore, the program sets $\theta_B = 1$, *i.e.*, franchise B is efficient (Einolf, 2004).

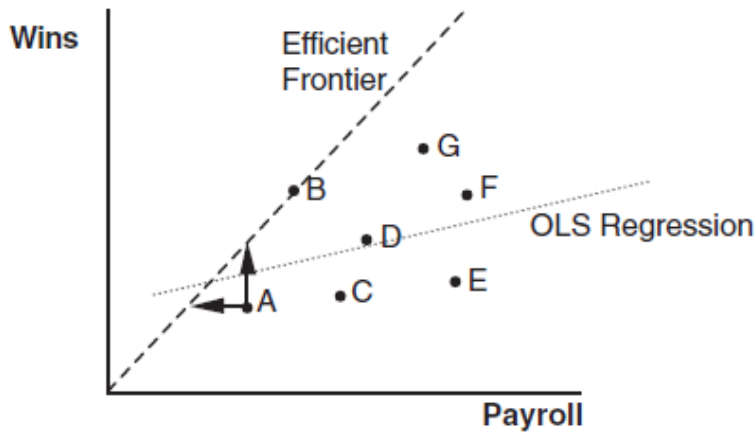

Figure 1. The efficient DEA frontier compared to the Ordinary Least Squares (OLS) regression
Source: Einolf (2004, p.134)

In Figure 1, franchise A is inefficient. If the input-oriented approach is used, the linear program measures the percentage of the A payroll which should be required to obtain the wins in the A team, if A had been operating efficiently. Hence, $\theta_A < 1$, and the input reduction is presented in Figure 1 with the horizontal arrow pointing to the left (Einolf, 2004).

Figure 1 also shows a simple linear regression which passes through the data. This line measures el *average* of won games per dollar payroll. Franchise E will bring this *average* down significantly. DEA technique provides additional information which is not available in regular regression techniques. For instance, a benefit from DEA over the standard regression analysis is that it measures the best-practice frontier and assesses the deviation of all the other points of data from this frontier. DEA does not compare each team with the average of *all* the teams. Instead, DEA compares an inefficient team with the efficient teams which are similar to it (Charnes, Cooper, Devine, Ruefli, & Thomas, 1989).

The CCR model explained in equations from (1) to (5) was improved to allow characteristics such as variable returns to scale (Banker, Charnes, & Cooper, 1984), this model will be called BBC hereafter. This is an important and powerful improvement in this context, because possibly, the productive outputs of a sports team show decreasing returns to scale in high payrolls. The BCC model differs from the CCR model only in the addition of the restriction: *e* represents a row vector of 1 x *n* with all elements equal to 1,

$$e\lambda = 1, \quad (5)$$

$$(\text{hence}, e\lambda = \sum_{j=1}^{n} \lambda_j = 1)$$

Figure 2 shows the efficiency frontier using the BCC model with the single-input, single-output example. The additional restriction (equation 5) imposes a condition of convexity on the admissible ways the franchises may be combined in the linear program. Hence, the team A cannot be compared with any combination of the (*t*x, *t*y) constant of B. The requirement of constant returns to scale is now relaxed. Therefore, the team A is efficient and the efficient frontier and yields increasing returns to scale along the segment from A to B. The team G is also efficient, since de BCC model allows decreasing returns to scale along the segment from B to G. In this example, the constant returns to scale are only found in the point B, where the transition from increasing to decreasing returns to scale occurs. The inefficient teams are now assessed from the BCC frontier. As a general rule, the BCC efficiency factors (θ) are equal or larger to the CCR efficiency factor, due to the feasible region is now a subset of the CCR feasible region (Einolf, 2004).

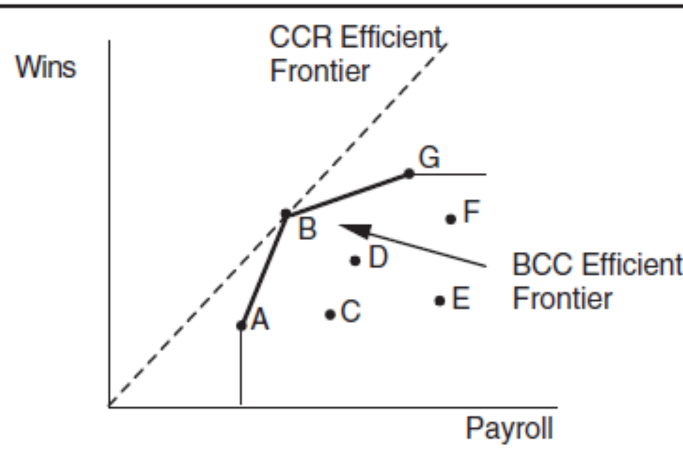

Figure 2. The efficient frontier by de Banker, Charnes, and Cooper (BCC) (1984)
Source: Einolf (2004, p.135)

It is important to metion a few other methods used to measure efficiency and productivity in the sports economics literature. The method entitled the Stochastic Frontier Production (SFP) was used by del Corral, Maroto, and Gallardo (2015) to analyze the efficiency of coaches in the Top Spanish Basketball League and the determinants of this efficiency. Their most important proposed determinants was if the coach is from Spain and wether he is an ex-professional player. In their results they demonstrate that foreign coaches are more efficient.

As well, Fort, Lee, and Berri (2008) used SFP estimates of team win production, to calculate the technical efficiency of African-American and white NBA coaches and examine the difference in retention among these two types of coaches. In their findings, they assure that there is no difference in technical efficiency by race of the coach, also coaches are retained based on their technical efficiency.

In summary, this paper analyzes the efficiency from sports franchises, specifically football teams in the NFL, which transform inputs, such as player salaries, into on-the-field productive outputs. The payroll efficiency is measured using two inputs, and five outputs with the BCC model analysis of DEA as described in the above equations form (1) to (5). This model is attractive because it follows a multidimensional production function, and it does not require an assumed restriction of constant returns to scale

Data and Parametric Estimation

In summary, and as a simple way to present the proposed variables, which will be explained in detail further ahead, Table 1 is introduced. Using the BCC model, product-oriented and using decreasing returns to scale, since according to Einolf (2004) the outputs of a sports team show decreasing returns to scale in high level of payroll, and the payrolls in the NFL teams are considered as one of the highest in the world in all sports.

Table 1. Summary of Model to Analyze for the NFL 2014 Season.

Description	**X (Inputs)**	**Y (Outputs)**	**Information**
National Football League (NFL)	Offense Players' Salaries	Wins (+) Points Scored per Game (+) Yards Advanced per Attempt (+)	* Including Playoffs -Based on 16 matches in 2014 season
	Defence Players' Salaries	Points Allowed per Game (-) Yards Permitted per Attempt (-)	- Based on 16 matches in 2014 season

Note 1: Including post-season

In the model, and in Table 1, the payed salaries only to the team's players, excluding managers and administrators, are separated into offensive players' salaries and defensive players' salaries; these are the two franchise inputs. The output variables in the franchise of

NFL model include: number of total matches won (including playoffs), points scored per game (PSG), yards advanced per attempt (YAA), points allowed per game (PAG), and yards permitted per attempt (YPA). The teams will be analyzed separately by salaries of offense players and defense players.

The YAA are a well-known statistic in the NFL. It is the number of yards obtained in average when the quarterback steps back to pass the ball, o run it with the different runners. This statistic has been used for a long time as a main offensive statistic in the NFL to measure the performance of a team. According to Table 1, a team with a high number of PSG and YAA, and a low number of PAG and YPA, tend to have a higher number of victories in games.

For the variables PAG and the YPA, in the DEA model it is required a monotony assumption in its output variables, so PAG and YPA were marked inverse, by subtracting the effectiveness of each team, plus a unit to avoid values in zero because it would cause problems in the software to run the models, from the highest effectiveness in the study, *i.e.*:

$$PAG = (PAG^{*} + 1) - PAG_i, \tag{6}$$

$$YPA = (YPA^{*} + 1) - YPA_i. \tag{7}$$

Where PAG^{*} are the highest scored points by match in the simple and PAG_i is the scored point per game of each franchise. Likewise, YPA^{*} are the highest yards permitted per attempt in the simple and YPA_i is each franchise yards permitted per attempt.

The sample data is considered for the regular season in 2014. Data from salaries of players on offense and defense was obtained from the website Spotrac (2015), and were obtained in current US dollars. Wins data (including postseason) were obtained from the official website of the NFL (2015). And finally, the data of points per game, both scored and allowed, and yards per attempt, both advanced as permitted were obtained from the website FootballDB (2015).

Results

In the model, the franchises were compared using a multidimensional measure of on-the-field performance; they were analyzed separating offense from defense. An NFL franchise is named as inefficient in offense only when another franchise in the league (or a linear combination of franchises) is able to produce more victories, a higher average of points scored per game, a higher average of advanced yards per attempt, using a lower level of player salaries on the offense. And it is inefficient in defense only when another NFL franchise (or a linear combination of franchises) can produce a lower average of point allowed per game, and a lower average of yards permitted per attempt, using a lower level of player salaries on the defense.

The software called Stata IC/12.0 was used to compute the statistics of the BCC model. The efficiency factor θ_j of each team was calculated for the 2014 season. There were computed a total of 64 efficiency factors, and each franchise was compared against its peers, in separate in offense and defense to determine if it should have reached a higher or equal on-the-field performance with players' salaries in offense and defense. When the model presented a factor $\theta_j = 1$, then the team was efficient. This means that there is not a linear-convex combination of other franchises that performed better with fewer inputs. When the model yielded an efficiency factor $\theta_j < 1$, the team was inefficient. A linear-convex combination of other franchises existed so the input vector of the inefficient franchise, X_j, should be reduced to θX_j.

The teams that made the playoffs in 2014 and are expected to be efficient are the following: Arizona, Baltimore, Carolina, Cincinnati, Dallas, Denver, Detroit, Green Bay, Indianapolis, New England, Pittsburgh and Seattle.

According to the results obtained with the software STATA/IC 12.0, which can be consulted in Appendix 1, the efficiency factors indicate the following offensively efficient teams: Arizona, Atlanta, Baltimore, Denver, Detroit, Green Bay, Indianapolis, New England, New Orleans, Philadelphia, Pittsburgh, Seattle, San Francisco, Tennessee and Washington as the efficient DMUs in their offense payroll. Hence, it is demonstrated that 9 of the 12 teams who entered the playoffs in 2014, reached efficiency in offense players payroll. Carolina (CAR), Cincinnati (CIN) and Dallas (DAL), despite being teams that made the postseason in 2014 did not reach offensive efficiency, and are in the efficiency ranking in number 25, 18 and 17 respectively. And however, it is observable that Washington (WAS) is the superefficient DMU, since it has the greater number of references for improving the other DMUs, which is surprising since it has been one of the teams that failed to reach the playoffs and also has one of the lowest number of victories in the season.

Similarly according to the results by the STATA/IC 12.0 software, this can be viewed in Appendix 2, the efficiency factors show as the defense efficient teams as follows: Arizona, Denver, Detroit, New York Jets, Oakland, Seattle, Tennessee and Washington as the efficient DMUs in their defense payroll. Hence, only 4 of 12 teams that made the postseason in 2014, reached the efficiency in defense players' salaries. It is observed that Denver (DEN) and Detroit (DET) are both superefficient teams on the defense, since they have the most number of references for improving other DMUs. This is consistent as both teams advanced to the 2014 playoffs. Even DEN reaching the Super Bowl or final title game.

Conclusions and discussion

The analysis has yielded two important results. First, most of the teams that made the postseason in 2014, have reached the efficiency in the offense players payroll. Second, only 4 of 12 teams that reached the playoffs in 2014 achieved the efficiency in the defense players' salaries. A possible explanation is that franchises overspend on their payrolls in defense players, which represents a waste of funds and damages their efficiency defensively.

It is of great interest that teams as WAS and TEN, which have been among the worst teams ranked in the 2014 season, have managed to be efficient in both aspects, even WAS becoming superefficient to the offense. This may have an explanation in the salaries they pay their players both offensively and defensively, are below the league average. Furthermore, in the BCC model it was proposed that the number of regular season wins is not the only output of franchises. For example, in the amount of YAA and YPA, these two franchises are above and below, respectively, the average in the league.

The salary cap imposed in 1994, keeps the franchises from spending too much on salaries even if they have larger profits than other teams. This increases the competitiveness of the league and allows all teams to access and hire, or retain, star players and veterans who have proven their high quality on-the-field, ensuring these teams have greater possibilities to achieve efficiency and productivity on-the-field. Also the financial structure of the NFL shows that it does not favour any of the franchises. Certainly all the teams attempt to win, but none has the possibility of overspending to win, even when they have the monetary resources to do so.

It is imperative to mention that this study performed the analysis of the NFL for the 2014 season only, which represents a constraint, it is suggested and recommended in the future to make an analysis with a larger number of seasons, so the context would be clearer about the teams that have managed to be efficient and inefficient on-the-field throughout the seasons.

Finally, according to the object of study that was presented above, it was mentioned that most efficient franchises are those, which have made it to the postseason. However, with the DEA analysis and output-oriented BCC model, it shows that it is not always as it was mentioned. Offensively, it is accepted, as most of the efficient teams made it to the 2014 postseason. But only a third of the playoff teams, managed to be defensively efficient.

References

Banker, R. D., Charnes, A., & Cooper, W. W. (1984). Some models for the estimation of technical and scale inefficiencies in data envelopment analysis. *Management Science*(30), 1078-1092.

Charnes, A., Cooper, W., & Rhodes, R. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research, 2*, 429-444.

Charnes, A., Cooper, W., Devine, D., Ruefli, T., & Thomas, D. (1989). Comparisons of DEA and existing ratio and regression systems fo efficiency evaluation of regulated electric cooperatives in Texas. *Research in governmental and nonprofit accountign*, 187-210.

Del Corral, J., Maroto, A., & Gallardo, A. (2015). Are former porfessional athletes and native better coaches? Evidence from spanish basketball. *Journal of Sports Economics*.

Einolf, K. (2004). Is Winning Everything? A Data Envelopment Analysis of Major League Baseball and the National Football League. *Journal of Sports Economics, 5*(2), 127-151.

FootballDB. (2015). *FootballDB team stats*. Retrieved Mayo 23, 2105, from http://www.footballdb.com/stats/teamstat.html?lg=NFL&yr=2014&cat=T&group=O&conf=&sort=teamname

Fort, R., Lee, Y., & Berri, D. (2008). Race, Technical Efficiency, and Retenttion: The Case of NBA Coaches. *International Journal of Sport Finance, 3*(2), 84-97.

Gutiérrez, E., & Lozano, S. (2014). A DEA Approach to Performance-Based Budgeting of Formula One Constructors. *Journal of Sports Economics, 15*(2), 180-200.

Guzmán, I., & Morrow, S. (2007). Measuring efficiency and productivity in professional football teams: evidence from the English Premier League. *Central European Journal of Operations Research*(15), 309-328.

Moreno, P., & Lozano, S. (2015). Estimation of Productivity Change of NBA Teams from 2006-07 to 201-13 Season. *International Journal of Sport Finance, 10*, 217-241.

NFL. (2015). *NFL team stats*. Retrieved Mayo 23, 2015, from http://www.nfl.com/stats/categorystats?seasonType=REG&offensiveStatisticCategory=null&d-447263-n=1&d-447263-o=2&d-447263-p=1&d-447263-s=TOTAL_POINTS_GAME_AVG&tabSeq=2&season=2014&role=OPP&Submit=Go&archive=false&conference=null&defensiveStatisticCategory=

Rogge, N., Van Reeth, D., & Van Puyenbroeck, T. (2013). Performance Evaluation of Tour de France Cycling Teams Using Data Envelopment Analysis. *International Journal of Sport Finance*(8), 236-257.

Ruiz, J., Pastor, D., & Pastor, J. (2013). Assessing Professonal Tennis Players Using Data Envelopment Analysis (DEA). *Journal of Sports Economics, 14*(3), 276-302.

Spotrac. (2015). *Spotrac*. Retrieved Mayo 21, 2015, from http://www.spotrac.com/nfl/cash/2014/

Tiedemann, T., Francksen, T., & Latacz-Lohmann, U. (2011). Assessing the performance of German Bundesliga football plaers: a non parametric metafrontier approach. *Central European Journal of Operations Research*(19), 571-587.

Wang, C., Gopal, R., & Zionts, S. (1997). Use of data envelopment analysis in assessing information technology impact on firm performance. *Annuals of Operations Research*(73), 191-213.

Appendix 1: Table of efficiencies from STATA/1C 12.0 NFL teams, Input: offense players' payroll

city	team	offense salaries	wins	PSG	YAA	dmu	rank	theta	ref_ARI	ref_ATL	ref_DEN	ref_GB	ref_IND	ref_NWO	ref_PIT	ref_SEA	ref_WAS	is_offense	os_wins	os_PSG	os_YAA
ARI	Cardinals	6.70E+07	11	19.4	5.2	ARI	1	1	1											0	
ATL	Falcons	9.20E+07	6	23.8	5.8	ATL	1	1		1										0	
BAL	Ravens	8.10E+07	11	25.6	5.7	BAL	1	1												0	
BUF	Bills	5.90E+07	9	21.4	5	BUF	32	0.8280271					0.1109463		0.4563013	0.1495265	0.111253			0	
CAR	Panthers	5.60E+07	8.5	21.2	5.2	CAR	25	0.8834658					0.2099499		0.1686741	0.1895869	0.315255			0	
CHI	Bears	7.10E+07	5	19.9	5.2	CHI	24	0.8876684		0.0815478	0.0058528			0.4345963			0.3656716		0		
CIN	Bengals	5.50E+07	10.5	22.8	5.5	CIN	18	0.93068					0.1471368		0.1573213	0.43518	0.1910419			1.26E-08	
CLE	Browns	6.40E+07	7	18.7	5.1	CLE	22	0.8950825	0.1171279	0.0766419						0.2446491	0.4566635			1.03E-08	
DAL	Cowboys	5.40E+07	13	29.2	6.1	DAL	17	0.9972124				0.6787888	0.1540766		0.0427023	0.1216445				1.91E-08	
DEN	Broncos	6.40E+07	1	30.1	6	DEN	1	1			1								0		
DET	Lions	7.00E+07	11	20.1	5.2	DET	1	1												0	
GB	Packers	5.80E+07	13	30.4	6.2	GB	1	1				1									0
HOU	Texans	5.60E+07	9	23.3	5.2	HOU	30	0.8604525			0.0464457		0.28334		0.4496381		0.0810286			3.84E-09	
IND	Colts	3.70E+07	13	28.6	5.9	IND	1	1					1					0		0	0
JAC	Jaguars	5.00E+07	3	15.6	4.7	JAC	16	1					0.0827215				0.9645752		1.719324	0	
KC	Chiefs	6.30E+07	9	22.1	5.3	KC	27	0.8764029		0.0118109					0.5386325	0.170034	0.1559255			0	
MIA	Dolphins	6.80E+07	8	24.3	5.4	MIA	26	0.8831193		0.1250554	0.1265869	0.0884171			0.5430598				0		
MIN	Vikings	5.40E+07	7	20.3	5.1	MIN	28	0.8749585					0.2985332		0.1021172	0.0098547	0.4644535			0	
NWE	Patriots	6.30E+07	15	29.3	5.5	NWE	1	1													0
NWO	Saints	7.40E+07	7	25.1	6	NWO	1	1						1						0	
NYG	Giants	6.80E+07	6	23.8	5.4	NYG	23	0.8926504			0.2211096			0.2875945	0.3185634		0.065383			0	
NYJ	Jets	6.50E+07	4	17.7	5	NYJ	29	0.8658966			0.0385155			0.0731067	0.0618057		0.6924688			0	
OAK	Raiders	5.90E+07	3	15.8	4.5	OAK	31	0.8304356			0.0189324		0.0393845				0.7287785		0.4460447	0	
PHI	Eagles	7.40E+07	10	29.6	5.6	PHI	1	1													0
PIT	Steelers	6.50E+07	11	27.3	6.2	PIT	1	1							1				0		
SEA	Seahawks	5.50E+07	14	24.6	5.9	SEA	1	1								1		0		0	
SND	Chargers	5.90E+07	9	21.8	5.4	SND	20	0.9111159					0.0778355		0.2721448	0.2750003	0.2861353			4.43E-08	
SNF	49ers	7.40E+07	8	19.1	5.2	SNF	1	1												0	
STL	Rams	7.20E+07	6	20.3	5.3	STL	21	0.9079663		0.2916821					0.1659137	0.0623375	0.388033			3.52E-08	
TB	Bucaneers	6.30E+07	2	17.3	5	TB	19	0.9255753		0.518949	0.1686102								1.266436		0
TEN	Titans	6.40E+07	2	15.9	5.3	TEN	1	1											0		
WAS	Redskins	6.30E+07	4	18.8	5.7	WAS	1	1									1			0	

Source: Self elaborated with data from: FootballDB (2015), Spotrac (2015) and NFL (2015) and software STATA/IC 12.0.

Appendix 2: Table of efficiencies from STATA/1C 12.0 NFL teams, Input: defense players' payroll.

city	team	defense salaries	PAG	YPA	dmu	rank	theta	ref_DEN	ref_DET	ref_NYJ	ref_OAK	ref_SEA	ref_TEN	ref_WAS	is_defense s	os_YPA	os_PAG
ARI	Cardinals	6.30E+07	1.3	10.5	ARI	1	1									0	
ATL	Falcons	5.60E+07	1	3.1	ATL	32	0.4653346	0.2589119	0.0553856	0.151037							4.95E-09
BAL	Ravens	6.60E+07	1.9	10.3	BAL	14	0.8389623		0.453436			0.3789581			0	0.0449544	
BUF	Bills	6.60E+07	2.2	11.1	BUF	10	0.9428009	0.0975572	0.490822			0.3544217			0		
CAR	Panthers	4.30E+07	1.7	5.8	CAR	11	0.8915675	0.0827274	0.2528522	0.555988							1.36E-08
CHI	Bears	5.90E+07	1.1	1.6	CHI	28	0.6264867	0.1097727		0.0980322	0.4186817						2.12E-08
CIN	Bengals	6.50E+07	1.7	7.7	CIN	22	0.7270525	0.2313411	0.3149898			0.1807215			8.74E-10		
CLE	Browns	6.80E+07	1.9	8.1	CLE	18	0.8019559	0.3499948	0.2329675			0.2189935			4.88E-08		
DAL	Cowboys	4.70E+07	1.3	7.2	DAL	26	0.6719329		0.6047303			0.0139194			0	0.0652052	
DEN	Broncos	6.80E+07	2.4	7.1	DEN	1	1	1									
DET	Lions	5.10E+07	2.2	11.6	DET	1	1		1						0		
GB	Packers	7.80E+07	1.8	7.4	GB	17	0.834168					0.5129129	0.2644234	0.0568317			6.18E-10
HOU	Texans	5.90E+07	1.9	10	HOU	16	0.8345302	0.0077054	0.6185175			0.2083074			0		
IND	Colts	6.90E+07	1.7	6.1	IND	24	0.710901	0.5178496	0.0848921			0.1081593			0		
JAC	Jaguars	5.20E+07	1.6	3.4	JAC	12	0.8646166	0.2235097		0.3780563	0.2630506						
KC	Chiefs	5.90E+07	1.9	11.6	KC	9	1		0.6645756			0.2925506			0	0.2934429	
MIA	Dolphins	6.30E+07	1.8	5.9	MIA	21	0.7788086	0.5911324	0.124465	0.0632113							0
MIN	Vikings	6.70E+07	1.7	7.8	MIN	23	0.7216814	0.2144159	0.2758727			0.2313928			0		
NWE	Patriots	5.90E+07	1.8	9.6	NWE	19	0.7996818		0.5909145			0.2064205			0	0.0160631	
NWO	Saints	5.10E+07	1.1	2.7	NWO	29	0.5688232	0.2008123		0.2923296	0.0756813						
NYG	Giants	6.10E+07	1.1	4.2	NYG	31	0.4772136	0.2783507	0.187783	0.0110799							1.96E-08
NYJ	Jets	3.60E+07	1.7	4.1	NYJ	1	1			1					0		0
OAK	Raiders	6.20E+07	1.6	1	OAK	1	1				1						0
PHI	Eagles	5.60E+07	1.7	4.2	PHI	13	0.8412406	0.4072571		0.2820939	0.1518896						
PIT	Steelers	6.70E+07	1.1	6.2	PIT	30	0.5076808		0.2445608			0.2528643			0	0.0701943	
SEA	Seahawks	8.60E+07	2.5	13.3	SEA	1	1					1			0		
SND	Chargers	5.60E+07	1.6	7.4	SND	25	0.7075899	0.186998	0.5009167			0.0196753			9.95E-09		
SNF	49ers	5.70E+07	1.9	8	SNF	15	0.8378219	0.3427479	0.4715582	0.023516							0
STL	Rams	5.90E+07	1.5	7.1	STL	27	0.6565555	0.1475122	0.4221255			0.0869179			1.61E-08		
TB	Bucaneers	6.30E+07	1.6	3.6	TB	20	0.7803128	0.4319142		0.0596809	0.2887178						
TEN	Titans	6.40E+07	1.7	1.8	TEN	1	1						1				
WAS	Redskins	7.20E+07	1.2	1.8	WAS	1	1							1		0	0

Source: Self elaborated with data from: FootballDB (2015), Spotrac (2015) and NFL (2015) and software STATA/IC 12.0.