Measuring Efficiency of Football Clubs: DEA approach

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Abstract. Professional football clubs have a special characteristic and that is a combination of sports and financial performances. Currently, performance analysis of football clubs is a useful tool to help managers with evaluation and feedback with respect to the real context of the market. The aim of the presented paper is to use data envelopment analysis (DEA) to calculate efficiency and then evaluate and compare the efficiency of selected European football competitions. For comparison, two European competitions with the potential for similarity were selected from the football environment. They are the Czech Fortuna:Liga and the Danish 3F Superliga. Both competitions are the highest professional football competitions in their countries and were chosen on the basis of the same game model and similar placement in the UEFA league coefficients. The researched period are the seasons 2015/2016 to 2019/2020. The data used were obtained from the official databases of both examined sports competitions and subsequently supplemented with private databases of companies from the football environment. In terms of results, some implications for the management of football clubs are discussed and suggestions for increasing efficiency in inefficient clubs are made.

Keywords: sport management, football, DEA, efficiency, performance factors

JEL Classification: C10, L83, C67, C44
AMS Classification: 90B90, 90C90

1 Introduction

At present, football is one of the most important sports, and at the same time a business of high economic importance. Every sport organization strives to evaluate its performance: its weaknesses and strengths. Nowadays, success in the professional football league goes hand in hand with successful coaching and leading the entire team. In the real world, team leadership always requires not only evaluating one's own performance, but also monitoring the activities of competitors. So it is often a crucial condition to learn from your own mistakes and from your competitors' innovations. However, evaluating performance is not an easy task at all.

Football is a global phenomenon that prevails mainly in Europe. The football industry has changed significantly over the last two decades. Economic survival has become increasingly important in recent years as the more restrictive future forces football clubs to rethink the amounts they pay for players and their wages. Based on this outlook, the technical efficiency analysis appears to be an important tool for evaluating the activities of clubs and their sports performance. The aim of this paper is to contribute to previous research and to evaluate and compare the efficiency of selected European football competitions using data envelopment analysis. The presented research evaluates the performance of professional football clubs that participated in five seasons (2015/16 to 2019/20) of the highest football competitions in the Czech Republic and Denmark.

2 Literature review

Sports statistics and performance appraisal are currently more and more frequently used words. There are several peer-reviewed journals looking for innovative methodologies for data analysis in sports, and several major conferences are dedicated each year to presenting statistics in sports research. As in many other fields, there is currently an influx of large amounts of available sports data, creating an opportunity for advanced statistical analysis. The following part of the paper briefly summarizes selected authors who apply various statistical and mathematical methods in their research to evaluate the performance of various sports disciplines.

Tunaru et al. [18] use contingent claims methodology and standard techniques in stochastic calculus to develop a framework for determining the financial value of professional football players to prospective-acquiring clubs. In

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their research, they use the Opta Index to model the uncertainty of players' performance, including possible injuries. They also consider uncertainty about the club's income, player income, club image, fan loyalty and so on. Kirschstein and Liebscher [11] use robust analysis techniques to examine the extent to which a player's market value depends on his football skills. In their research, they analyze a data set comprising 28 performance metrics and the market value of 493 players from the 1st and 2nd Bundesliga. Kim et al. [10] use several techniques (for example, regression analysis or cluster analysis) to propose an approach for classifying and evaluating footballers based on their performance and transfer fee. Lee and Harris [13] examine factors that could affect Major League Soccer players' salaries. By applying four different methods of regression analysis, they revealed these three key determinants affecting players' salaries: the number of goals, the number of assists and the minutes in the game. Simmons [16] examines the relationship between a player's salary and his performance in two major sports: American football and European football.

The following is a brief summary of selected authors who apply the DEA method in their research. This method has been applied successfully to measure efficiency in different cases as well as in sport. In his research, [12] applies the non-parametric DEA method to the evaluation of hockey teams in the NHL. Using this method, each team receives an efficiency score and is then compared to other NHL teams. The salaries of goalkeepers, defenders and attackers were chosen as inputs to the model. League points in the base season model and winnings in the play-off model were chosen as outputs. Halkos and Tzeremes [7] evaluate the career performance of 229 professional tennis players using the DEA methodology. Gutierrez and Ruiz [5] evaluate the game performance of 24 teams participating in the 2011 Men's Handball World Championships in Sweden using the DEA and the cross-efficiency evaluation. Espitia-Escue and García-Cebrián [3] measure the efficiency of professional football teams playing in the Spanish First Division. The timeline of the study covers three seasons from 1998 to 2001. To this end, they apply the DEA methodology, taking into account players used, attacking moves, the minutes of possession of the ball, and the shots and headers as input variables. They consider the achieved number of points as an output. Palafox-Alcantar and Vargas-Hernández [14] measure the wage efficiency of 32 football teams in the National Football League in the 2014 season using data analysis. Halkos and Tzeremes [8] use the DEA method to compare the current level of value of football clubs and their performance. The research concluded that the current level of value of football clubs has a negative effect on their performance, which suggests that the high value of football clubs does not guarantee their higher performance. Zambom-Ferraresi et al. [19] have employed DEA to estimate the technical efficiency of English football teams playing in the Premier League. The researched period are the seasons 2012/13 and 2014/15. They consider sports results measured by the total number of points achieved in the league, revenues, attendance, and fans impact on social media as the outputs. The input variables include the amount of the team's salary, the market value and the plays performed during the match. In their research, [6] apply an input-oriented efficiency model to Spanish football clubs. They use staff costs and other expenses such as inputs and turnover and points won as outputs. Their model of analysis mixes economic and sport performance, and so a non-economic additional output, such as points won in competitions, was also considered to calculate efficiency scores.

From the above, it can be stated that for football clubs, there is no agreement on the input and output variables that should be used in the DEA model, each study uses different combinations of inputs and outputs. Some works consider only sports variables (shots on goal, minutes of control over the ball, points obtained), while others also include economic factors (rotation, personnel expenses) in the research. Some papers combine both types of variables. The literature also discusses what type of inputs better explains the performance of sports clubs. On the one hand, several contributions analyzed the performance of sports clubs using so-called ex-post inputs (e.g. wages). On the other hand, some authors criticized the use of these ex-post inputs and recommend the use of ex-ante inputs such as the market value of players. In the presented paper, an approach was chosen that uses both economic and non-economic variables. In terms of input variables, an ex-ante approach was used.

2.1 Data Envelopment Analysis

To calculate efficiency, two methodological approaches are possible [15]: parametric models and non-parametric models, which use the conditions that must be met by the set of production possibilities. The advantage of the non-parametric approach is its flexibility to adapt to multi-product and lack-of-price environments, although it has the disadvantage of being deterministic in character, so that any deviation from the efficiency frontier is considered to be inefficient behavior of the evaluated unit. In this paper, a non-parametric method of data envelopment analysis will be used. It is very often utilized to evaluate the technical efficiency of production units. The DEA technique is a linear and parameter-free programming method. DEA is especially suitable for determining the technical efficiency of units that are comparable to each other. The method analyzes and calculates the relative efficiency of the DMUs from multiple inputs and output factors. The units are compared with each other and

it is determined which of them are efficient and which are inefficient. In the case of inefficient units, depending on the type of model, it can be determined how the inefficient unit should reduce/increase its inputs/outputs to become efficient. There are many DEA models that can be used in different situations.

One of the frequently used models is the CCR model which works under the conditions of constant returns to scale and which enables the calculation of overall technical efficiency score (ET_{CCR}). The second alternative is the BCC model, which is based on variable returns to scale and calculates the so-called pure technical efficiency score (TE_{BBC}). The efficiency frontier defines the maximum combinations of outputs that can be produced for a given set of inputs. Assuming a set of n scenarios as DMUs, each DMUj (j = 1, ⋯, n) uses m inputs x_{ij} (i = 1, 2, ⋯, m) to produce s outputs y_{rj} (r = 1, 2, ⋯, s). The input-oriented envelopment models with constant returns of scale, can be formulated in equation (1) to minimize the inputs while keep the outputs at their current levels.

$$\begin{gathered} min\ \theta - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_i^+\right) \\ s.t. \sum_{j=1}^{n} \lambda_j\, x_{ij} + s_i^- = \theta x_{ip} \quad i = 1,2,\dots,m \\ \sum_{j=1}^{n} \lambda_j\, y_{rj} - s_r^+ = y_{rp} \quad r = 1,2,\dots,s \\ \lambda_j, s_i^-, s_r^+ \geq 0,\ j = 1,2,\dots,n.\ \theta\ unrestricted\ in\ sign. \end{gathered} \tag{1}$$

The technical efficiency of the unit is measured in relation to the other analyzed units using the efficiency score. The overall technical efficiency rate (ET_{CCR}) takes values in the range from 0 to 1. Technically efficient units achieve an efficiency rate of 1, for inefficient units the efficiency rate is less than 1.

3 Data and methodology

The aim of the research is to use DEA to calculate the degree of technical efficiency and then evaluate and compare the efficiency of selected European football competitions. Two European competitions with the potential for similarity were selected for comparison from the football environment. They are the Czech Fortuna:Liga and the Danish 3F Superliga. The evaluation of efficiency is based on the indicators such as number of players, total squad market value and total points in the season. Due to the availability of data in both countries, the efficiency was analyzed in the seasons 2015/16 to 2019/20. The research process can be divided into the following stages.

1. Selection of sports competitions – for the needs of the research, two sports football clubs were selected from the total number of 55 UEFA member associations – the Czech Fortuna:Liga and the Danish 3F Superliga. The similarity of these competitions is based on the same game model and similar placement in the UEFA league coefficients. A close ranking in the UEFA league coefficient table indicates relatively similar qualities of the best units of each competition. These and other similarities are a prerequisite for making comparisons. After the 2019/20 season, Denmark was two places ahead of the Czech Republic in the UEFA league coefficient. The Czech top football competition called Fortuna:Liga is attended by a total of 16 teams from Bohemia, Moravia and Silesia. A total of 12 teams take part in Denmark's highest football competition called the 3F Superliga.

2. Collection of the data – the data used for the purposes of the research come from the official databases of both examined sports competitions and are supplemented by private databases of companies from the football environment. The core of the research are data from InStat [9], which analyzes the performance of athletes and sports teams. They are supplemented by the database of the Transfermarkt.com server [17] and the databases of the Czech Fortuna:Liga [4] and the Danish 3F Superliga [1]. The research period was limited by InStat's data for Denmark's highest competition when the oldest possible sports data are for the 2015/16 season.

3. Definition of inputs and outputs – another important step is to choose the appropriate number of inputs and outputs. Bowlin [2] set the rule that the number of DMUs should be at least three times as high as the number of the inputs and outputs reasoned. A large amount of data was available to evaluate the performance, the selection of the most suitable variables was then performed using correlation analysis. Number of players and total squad market value were used as inputs; total points in the season were outputs.

4. Construction of DEA model and determination of the ET_{CCR} score – an input-oriented CCR model was used to measure the performance of football clubs. The CCR model measures overall technical efficiency (ET_{CCR}), by aggregating pure technical efficiency and scale efficiency into a single value. All calculations were made using the OSDEA-GUI software.

5. Comparison of the performance of football clubs in both countries – a Kolmogorov-Smirnov test was used to compare the performance of selected sports competitions. A non-parametric test was chosen because using the Shapiro-Wilk test, it was proved that the values of the individual variables do not have a normal distribution. Statistical testing was performed at a significance level of 5% using STATGRAPHICS Centurion XVIII.

4 Research results

Applying an input-oriented CCR efficiency model, the performance levels achieved by Czech football teams for seasons 2015/16 to 2019/20 are reported in Table 1. The analysis thus shows how clubs convert the inputs into points gained within competition tables. The values refer to the current members of the season.

The CCR-I model described 2 to 3 football clubs as efficient each year. This means that the size of these clubs is optimal, they have chosen the appropriate sports tactics and at the same time the clubs are able to efficiently transform the inputs into outputs. The most efficient club in the researched period of five seasons in the Czech highest competition is Viktoria Plzeň. A total of three times out of five seasons, Viktoria Plzeň has become efficient from the point of view of ET_{CCR}. Prague's Slavia and Ostrava's Baník achieved an efficient score twice. However, in the 2015/16 season, when Baník descended from the highest competition, it also achieved the lowest score from the totals of the given season. The fact that a total of 39 different players in the Baník Ostrava jersey intervened in the matches in the 2015/16 season has a significant influence on this fact. This is the highest number of the whole observations. The FC Viktoria Plzeň club achieved an average ET_{CCR} score of 0.9560 in the monitored period and became the most efficient club in terms of long-term observation. The SK Slavia Praha club, which achieved an average ET_{CCR} score of 0.9130, took the second place. Far beyond expectations in terms of efficiency remains the historically most successful football club of the Czech highest competition, the AC Sparta Praha team. In the monitored period, the club playing its home matches at Prague's Letná achieved an average ET_{CCR} score of 0.6294. This result corresponds to the fact that, according to the Transfermarkt.com server, the value of the Sparta Praha team, together with Slavia Praha, is one of the utmost in the entire Czech highest competition every year. Unlike its biggest rival from the other side of the Vltava River, however, Sparta failed to transfer the high value of the team and the number of players into an adequate points gain. Specific levels of the ET_{CCR} value found according to the CCR-I method lower than 1 show that inefficient clubs should have had a lower level of inputs to achieve the given point gains, represented by a lower number of players and a lower team value. If their technical inefficiency were caused only by scale inefficiency, it could be stated that the size of these clubs is not optimal and inappropriate sports tactics was chosen.

	Season					
Club	**2015/16**	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**Avg.**
1. FC Slovácko	0.8481	0.8940	0.8748	0.7188	0.8462	**0.8364**
1. FK Příbram	0.5160	0.7058	-	0.7421	0.4954	-
AC Sparta Praha	0.6867	0.6265	0.5521	0.6594	0.6223	**0.6294**
Bohemians Praha 1905	0.6354	0.7596	0.8537	0.8246	0.7605	**0.7668**
FC Baník Ostrava	**0.2268**	-	0.7077	**1.0000**	**1.0000**	-
FC Fastav Zlín	0.6912	0.9941	0.5762	0.8484	0.5360	**0.7292**
FC Hradec Králové	-	0.9572	-	-	-	-
FC Slovan Liberec	0.8515	**0.5972**	0.6251	0.7078	0.7151	**0.6993**
FC Viktoria Plzeň	**1.0000**	0.7807	**1.0000**	0.9994	**1.0000**	**0.9560**
FC Vysočina Jihlava	0.6527	0.8934	0.7008	-	-	-
FC Zbrojovka Brno	**1.0000**	0.8682	0.5479	-	-	-
FK Dukla Praha	0.6560	0.8333	0.7866	**0.4763**	-	-
FK Jablonec	0.7008	0.8503	0.8098	0.8286	0.8557	**0.8090**
FK Mladá Boleslav	0.8657	0.8357	**0.4613**	0.5371	0.6093	**0.6618**
FK Teplice	0.5125	**1.0000**	0.5952	0.6306	0.6652	**0.6807**
MFK Karviná	-	0.8909	0.7956	0.5604	**0.4432**	-
SFC Opava	-	-	-	**1.0000**	0.6483	-
SK Dynamo Č. Budějovice	-	-	-	-	**1.0000**	-
SK Sigma Olomouc	0.5327	-	**1.0000**	0.6849	0.7297	-
SK Slavia Praha	0.9663	**1.0000**	0.7024	**1.0000**	0.8961	**0.9130**
Avg.	**0.6559**	**0.8429**	**0.7243**	**0.7637**	**0.7389**	**x**

Table 1 ET_{CCR} score of Czech clubs playing Fortuna:Liga

Applying an input-oriented CCR efficiency model, the performance levels achieved by Danish football teams for seasons 2015/16 to 2019/20 are reported in Table 2. The analysis thus shows how clubs convert the inputs into a point gain within competition tables. The values refer to the current members of the season.

According to the CCR-I model, in the first to the fourth monitored seasons, two teams were always efficient. In the last fifth season, the number of efficient teams doubled. We can observe that the clubs that achieved the lowest ET_{CCR} score in the season either decreased or reached the efficient ET_{CCR} value in the following season. This also applies to Silkeborg IF, which after the 2019/20 season descended to the second highest Danish football competition. On average, the most efficient team of the Danish league in the monitored period was FC Copenhagen, which due to the less efficient examined third season reached the average value of ET_{CCR} "only" 0.8862. Other clubs in terms of ET_{CCR} value are Aalborg BL (0.8511), SonderjyskE Fodbold (0.8500) and FC Midtjylland (0.8075). SonderjyskE Fodbold reached the efficient ET_{CCR} value in the first monitored season, FC Midtjylland in the last season. Despite the fact that it was not efficient in any of the monitored seasons according to the ET_{CCR} value, the Aalborg BL club steadily maintained a score of around 0.8.

	Season					
Club	**2015/16**	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**Avg.**
Aalborg BK	0.8312	0.8966	0.8728	0.8694	0.7853	**0.8511**
Aarhus GF	0.6158	0.5834	0.6716	**0.5666**	**1.0000**	**0.6875**
AC Horsens	-	0.8648	0.8773	0.9062	**1.0000**	**0.9121**
Brondby IF	0.6436	0.9814	**1.0000**	0.8029	0.7432	**0.8342**
Esbjerg fB	0.4140	**0.5324**	-	0.9161	0.5022	**-**
FC Copenhagen	**1.0000**	**1.0000**	0.5057	**1.0000**	0.9254	**0.8862**
FC Helsingor	-	-	0.7112	-	-	**-**
FC Midtjylland	0.6677	0.6798	0.6991	0.9911	**1.0000**	**0.8075**
FC Nordsjaelland	0.4382	0.6155	0.7787	0.5890	0.6142	**0.6071**
Hobro IK	**0.3887**	-	**1.0000**	0.6626	0.6796	**-**
Lyngby Boldklub	-	**1.0000**	0.6875	-	**1.0000**	**-**
Odense BK	0.5352	0.8518	0.7451	0.9720	0.6670	**0.7542**
Randers FC	0.7211	0.7618	**0.4531**	**1.0000**	0.8795	**0.7631**
Silkeborg IF	-	0.8815	0.7644	-	**0.4640**	**-**
SonderjyskE Fodbold	**1.0000**	0.9590	0.8027	0.7371	0.7510	**0.8500**
Vejle Boldklub	-	-	-	0.5993	-	**-**
Vendsyssel FF	-	-	-	0.6315	-	**-**
Viborg FF	0.7062	0.6846	-	-	-	**-**
Avg.	**0.6635**	**0.8066**	**0.7549**	**0.8031**	**0.7865**	**x**

Table 2 ET_{CCR} score of Danish clubs playing in the 3F Super League

In the last lines of Tables 1 and 2, the average ET_{CCR} scores of the clubs that participated in a given season are calculated. In both professional competitions, the highest average ET_{CCR} score was achieved in the 2016/17 season, which followed the season when, on the contrary, the lowest average ET_{CCR} score was achieved. The development of the values of the average ET_{CCR} score was very similar in both competitions. The performed non-parametric Kolmogorov-Smirnov test also confirmed that there are no significant differences between the two competitions at the level of significance of 5%.

5 Conclusion and discussion

In this article, we have measured the efficiency of the professional football clubs playing in the Czech Fortuna:Liga and Danish 3F Superliga. To that end, we have taken the time span of the five seasons from 2015/16 to 2019/20. Efficiency of football clubs was measured using non-parametric DEA method. Total squad market value and number of players were chosen as club inputs. Output was measured by total points in the season. This particular specification proved to be suitable for this application, but it can also be applied to efficiency analysis of team sports other than football.

Given the current economic and financial situation of football clubs, there is an increasing need to know how efficiently a club uses its resources. In addition, this analysis is also important for evaluating the club's sports performance. Based on the analyzed period, the first conclusion of the research can be reached: the winner of Fortuna:Liga was, with the exception of the 2019/20 season, always marked as efficient and the club with the lowest ET_{CCR} value mostly descended. Similar conclusions apply to Danish clubs: the winner of the 3F Superliga

has always been described as efficient and the club with the lowest ET_{CCR} value has either dropped or been considered efficient the following season. With the help of the research, it was possible to state the second conclusion: in the five seasons analyzed, no Czech or Danish club was able to maintain efficiency throughout the observed period. It is important to note that the clubs and resources used are constantly changing from season to season, just as the opposing teams are changing. So when an efficient club uses the same resources in the same way in previous seasons, it is not enough to be efficient in the coming seasons. Furthermore, it can be stated that there are no significant differences between Czech and Danish clubs. It is also possible to discuss the sources of clubs inefficiency. The first source of clubs inefficiency is related to the waste of resources. To achieve the same output, clubs should only need a lower value of inputs (i.e. a lower total squad market value or a lower number of players). The second source of inefficiency could be determined by calculating the scale efficiency. The problem is not only how they use their sports resources, but what sports tactics they use. These clubs should seek to develop a medium and long-term strategy to develop new and different tactics. The purchase of players should also take place in the context of the development of these new sports tactics. There are also clubs that suffer from both sources of inefficiency (the BCC model should be applied in further research to assess the sources of inefficiency in detail). In this case, clubs should reduce their resources and, in terms of size, find out how efficient clubs are developing sports tactics.

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