

Efficiency in European football teams using WindowDEA. Analysis and evolution.

Purpose

The aim of this paper is to analyze efficiency and its evolution in teams that played in the UEFA Champions League (UCL) during nine seasons. The aim is to present a research procedure for determining the most accurate DEA methodology to estimate and compare the efficiency.

Design/methodology/approach

First, we analyzed the existence of a temporal trend using the S statistic. We have calculated the Kruskal-Wallis statistic to verify if there is stability in relative ranks. The results of the aforementioned tests have indicated that window analysis is an accurate methodology to apply to the sample. We have analyzed 94 clubs with a sample of 288 observations, obtaining 768 efficiency ratios. They have been calculated using super-efficiency which enables to discriminate efficient units.

Findings

Results indicate that there is a low efficiency level in the nine seasons observed. There is a strong correlation between sports results and the efficiency of semifinalists. We conclude that improvement in a club's efficiency could enhance its sports results. Finally, as practical implications, we highlight benchmark teams and alternative sports tactics to help clubs become more efficient and achieve better sports results.

Originality/Value

This paper contributes to sports efficiency literature by presenting a research procedure to identify the most accurate methodology to be applied to panel data. To the best of our knowledge, this paper is the first empirical study on international football competitions applying Windows DEA to incomplete panel data.

Keywords

Data Envelopment Analysis, Benchmarking, Performance measurement, Sports, UEFA Champions league.

1. Introduction

The UEFA Champions League (UCL) is one of the most prestigious tournaments in the world and the most important club competition in European football. Nowadays, football, and specially the UCL, has a strong social impact. The Berlin final of the 2014/15 tournament attained extraordinarily high television audience ratings as it aired in more than 200 countries to 400 million viewers. Its social media presence has also exploded. The number of Twitter followers grew 51% during the 2014/15 season, the UCL Facebook page is the world's most popular league or association page on the platform, and during that season, overall page likes increased by 30%, reaching 45.6 million likes ([UEFA](#)).

In the sports field, football is a very competitive sector. As with other organizations, professional football clubs must seek the best use of their resources. The financial-economic restrictions implemented by the FIFA FFP (Financial Fair Play) have made the significance of the optimal use of available resources more apparent. Efficiency is even more essential in the UCL context, because clubs in small leagues must compete with Europe's largest. Consequently, estimating efficiency as a means of analyzing clubs' sports performance is an important approach if they need to consider the resources employed, not just the final sporting result. The assessment of sports performance can also provide useful information to help team managers decide whether to hire players or make more investment on its own reserve of young players, help coaches design playing strategy or tactics, and also help players train and improve their individual technical shortcomings.

Therefore, the main aim of this paper is to estimate and analyze the efficiency and evolution of clubs playing in the UCL using Data Envelopment Analysis (DEA). **The period under study covers 2004/05 to 2012/13, in other words, nine seasons forming a panel data set.** DEA methodology does not need the specification of a production function and allows efficiency calculations in multi-input and multi-output organizations. Our **second** aim is to present a research procedure for determining the most accurate DEA methodology to estimate and compare the efficiency of panel data. The final selection of DEA methodology in this paper is based on the characteristics of the sample under study and not on the literature or research innovation bias. When testing for the existence of a temporal trend in our sample, window analysis emerged as the accurate methodology to analyze efficiency in this paper.

The remainder of the paper is as follows. Section 2 contains a review of the empirical evidence on efficiency in football. Section 3 describes the sample and variables we analyzed. Section 4 explains the research procedure we followed to discover the most accurate methodology and the methodology we applied. The results of the analysis of the

temporal trend, the calculation of efficiency in DEA by means of window analysis and the results of efficiency are exposed in section 5. In section 6 we discuss our results and present our concluding thoughts.

2. Literature review

There is an extensive academic research on efficiency and its implications in the sports field. The efficiency analysis in football leagues is a well-established research line (Barros & Garcia-del-Barrio, 2011). Dawson, Dobson and Gerrard (2000) and Kulikova and Goshunova (2013) provide a comprehensive review of this literature.

From a methodological perspective, two main approaches have been used to measure the efficiency of sports: the econometric or parametric (stochastic frontier analysis, SFA) and the non-parametric frontier methodology (DEA). As Kulikova and Goshunova (2013) observed, DEA is the most popular and it measures technical efficiency. Technical efficiency refers to the ability of an organization or a decision-making unit (DMU in DEA literature) to obtain the maximum potential output from given amounts of factor inputs, or the minimum input required to obtain a given level of output. This concept involves physical quantities and technical relationships (Coelli, Rao, O'Donnell, & Battese, 2005).

Studies analyzing football efficiency include papers that observed regular national championships and eliminatory competitions. The main difference between them is that the outcome of eliminatory competitions is more uncertain when compared with regular leagues. The regular national football leagues reward the most stable performance and last longer, because teams usually play two rounds against all the others in the league. In contrast, eliminatory competitions require less time and random results are more likely. Regular competitions are normally leagues played in countries and eliminatory competitions involve nations or clubs in a large territory (i.e. the FIFA World Cup or the UEFA Champions League).

There is more comprehensive empirical literature on regular leagues. The English Premier League (Haas, 2003; Barros & Leach, 2006; etc.) and the Spanish *Liga* (Espitia-Escuer & García-Cebrián, 2004; González-Gómez & Picazo-Tadeo, 2010; etc.) are the most analyzed. Hass (2003), with a small sample size of 20 clubs (2000/01 season), investigated how close the English Premier League clubs play to their potential. Barros and Leach (2006), combining financial and sports variables, applied DEA to measure the efficiency of the teams playing in the Premier League for five seasons (1998/99 to 2002/03) for the 12 clubs that participated in the competition in all the seasons studied. The authors made important recommendations at a managerial level, but, as a limitation, they highlighted the

need for a more extensive panel data set to generalize the conclusions. Espitia-Escuer and García-Cebrián (2004) analyzed the efficiency of Spanish clubs playing in the national league for three seasons (1998/99 to 2000/01) and González-Gómez and Picazo-Tadeo (2010) compared the performance between the Spanish league, the Spanish cup and European competitions for six seasons (2001/02 to 2006/07). Other national leagues have also been analyzed, such as the Italian (Boscá Liern, Martínez, & Sala, 2009); German (Tiedemann, Francksen, & Latacz-Lohmann, 2011); Portuguese (Ribeiro & Lima, 2012); Greek (Barros & Douvis, 2009); Brazilian (Barros, Assaf, & Sá-Earp, 2010); and Mexican (Torres-Dávila & García-Cebrián, 2012).

We would highlight the work by Tiedemann et al. (2011), which analyzed the football players in the German league for seven seasons (2002/03 to 2008/09), due to its different perspective. They found a clear positive relationship between a team's average player efficiency score and its rank in the league table at the end of the season. Their results are corroborated by those of Sala-Garrido, Liern Carrión, Martínez Esteve and Boscà (2009) which highlighted the very nature of football: the performance of the whole team is more important than that of its constituent parts.

The relation between estimated efficiency rankings and sports results is one of the most mentioned in the literature. Barros and Leach (2006) and Torres-Dávila and García-Cebrián (2012) found a statistical correlation between awarded points and estimated efficiency scores. Espitia-Escuer and García-Cebrián (2004) and Haas (2003), however, did not find a significant correlation between efficiency and sports results.

Concerning supranational competitions, the UEFA Champions League is the world's top competition at football club level, and efficiency studies are really scarce in this area (as examples we can find Espitia-Escuer & García-Cebrián, 2010, and Zambom-Ferraresi, García-Cebrián, Lera-López, & Iráizoz, 2017). The fact that the sample comprises an unbalanced panel data set and the limited availability of data could be some reasons for this shortage.

Espitia-Escuer and García-Cebrián (2010) evaluated the efficiency of teams that played in the UCL for four seasons (2003/04 to 2006/07). First, they observed clubs' efficiency season by season, and, in a second analysis, they estimated a frontier for the sample as a whole. The results indicated that in the four analyzed seasons there were no different dominating tactics, which means that there was no technological change in this period. In this case, inefficiency results from wasting resources. Zambom-Ferraresi et al. (2017) analyzed the sports performance of the same competition for ten seasons (2004/05 to

2013/14). They estimated season-by-season efficiency and found high inefficiency levels in the analyzed period, in contrast to the results of Espitia-Escuer and García-Cebrián (2010).

As we have a panel of data in the present paper, our literature revision also focuses on the treatment found in former studies proposing DEA as a method for measuring the efficiency of football teams. Some of them have estimated its efficiency season by season (Tiedemann et al., 2011; Torres-Dávila & García-Cebrián, 2012; Zambom-Ferraresi et al., 2017) and/or have looked at the sample as a whole (Barros & Lech, 2006; Espitia-Escuer & García-Cebrián, 2010; González-Gómez & Picazo-Tadeo, 2010). To the best of our knowledge, only Sala-Garrido et al. (2009) have applied window analysis at a football league scope.

3. Data and variables

Considering existing literature, we propose estimating the efficiency of nine UCL seasons. This analysis will be based on DEA, because specifying a production function is unnecessary and it provides easily interpretable results. Our main interest is to know how efficiently teams use their sports resources, turning play styles and tactics into victories. Hence, the input measures are the sports statistics of the main actions on the field and the output measure is the sport result clubs achieve at the end of the competition.

Our sample comprises teams that played nine UCL seasons, from 2004/05 to 2012/13. As the clubs participating in the competition change from one year to the next, there are 32 clubs per season. Some clubs participated in more than one season and some of them participated in all the analyzed seasons. This leads us to have an unbalanced panel data set comprising 288 observations relating to 94 clubs.

In the present paper, we have taken the following variables as representatives of actions on the field: ball recoveries, crosses (open play), corners and total shots. All these inputs have been used in previous works (Sala-Garrido et al., 2009; Espitia-Escuer & García-Cebrián, 2010; Torres-Dávila & García-Cebrián, 2012; Carmichael & Thomas, 2014) and they are the main resources employed by teams to try to score goals and win matches. The aggregated values of the playing statistics over the whole competition are provided by Opta Sports data. Table 1 shows the descriptive statistics of these variables.

The use of ball recovery as an indicator of actions on the field is relatively new and provides a large quantity of information on a team's intention to dominate the game. Even when a team does not have much ball possession, if it tries to get the ball, this variable will measure the purpose of playing actively. The number of ball recoveries could be considered

the outcome of defensive plays or the first step in attack plays (Carmichael & Thomas, 2014; Zambom-Ferraresi et al., 2017).

Crosses and corners are common plays and an important way to get close to the penalty area, where a major part of the plays turns into goals. Carmichael and Thomas (2014) included them in their model. Both inputs are indicators of one characteristic tactic. Crosses can be a quick way to go to the penalty area or a tactic variation that allows opening spaces in the central area. If a team mainly used these plays (crosses and corners), it could be characterized as a tactic style. On the other hand, if a team used them a great deal, but in the same amount as other plays, this could only indicate a variation in the type of play, which is very important to surprise opponent teams.

Insert Table 1 here.

Total shots are one of the most important indicators of actions on the field in football. The main reasonable option to score a goal is shooting. Sala-Garrido et al. (2009), Espitia-Escuer and García-Cebrián, (2010), Torres-Dávila and García-Cebrián (2012) and Carmichael and Thomas (2014) used this input variable to estimate football teams' efficiency.

The output used in this paper is a variable representing sports results during the Championship: the amount of the UCL financial retribution related to sports performance. They are the prizes clubs receive for advancing in the UCL phases. The ranking provided by this variable is the same as the ranking provided by points and played stages, but this output measure will allow us to differentiate between clubs that were eliminated in the same stage but have a different number of victories (Zambom-Ferraresi et al., 2017). For example, in the 2012/13 season clubs received an €8.6 million prize just for participating in the group stage, plus €1 million for each victory and €0.5 million for each draw. The clubs that passed into the round of 16 received €3.5 million more; €3.9 million for playing the quarterfinals, and €4.9 million for playing the semifinals. The runner-up earned an extra prize of €6.5 million and the champion earned €10.5 million. Consequently, the minimum that a club could receive was €8.6 million and if a club won all the matches in the group stage and won the competition, it could receive a prize of €37.4 million for its sports performance. As prizes change every three years and our sample covers nine seasons, we have taken the values of last season's prize as the reference year.

4. Calculation of efficiency using DEA with panel data

Several methodologies have been proposed in the literature to calculate efficiency. One approach is frontier methods, which consider the estimation of isoquant as the sample data envelope. Among frontier methods, deterministic non-parametric and stochastic methods have also been most often used in empirical papers. Deterministic non-parametric or DEA does not specify a functional form for production processes and this is its main advantage. Nevertheless, all deviations from the frontier are classified as inefficient.

Under the assumption of constant returns to scale, DEA proposes the solution to the following linear programming problem for every unit in the sample:

$$\begin{aligned} \text{Min. } & \lambda_i \\ \text{s.t. } & \lambda_i x \geq zX \\ & y \leq zY \\ & z \in R^+ \end{aligned} \tag{1}$$

where x is the vector of consumed inputs by unit i under analysis, X is the matrix of consumed inputs for all units in the sample, y is the vector of obtained output by unit i , Y is the matrix of obtained outputs for all units in the sample, z is a vector of parameters whose values are obtained in the resolution of the problem and λ_i is the ratio of efficiency for unit i . In the orientation to input presented in this problem, λ_i represents the radial reduction to be applied to every input in unit i to become efficient.

In the original DEA formulation, efficient units present a ratio equal to 1 and their ratio for inefficient units is less than one. This supposes that efficient units in a sample show the same value of efficiency and it is impossible to discriminate among them. To solve this inconvenience, Andersen and Petersen (1993) proposed the calculation of super-efficiency, which consists of calculating efficiency ratios on the basis of the aforementioned problem, but taking the whole sample except the unit under analysis as a comparison sample. Consequently, inefficient units present the same ratio of efficiency as solving the original DEA problem, but efficient units do not have their efficiency ratio limited by 1, so they can present ratios above this value and we can order them by the criteria of the highest value. Therefore, the efficiency ratios calculated for football clubs in the sample under study have been calculated using super-efficiency.

In empirical work aiming to discover the efficiency of units forming a sample, the availability of information in the form of panel data is an improvement to be taken into

consideration. Of course, calculations can be repeated in every single period in the time horizon, but the treatment of pooled data can be taken advantage of as a whole. If a researcher has panel data, several analysis possibilities exist. Tulkens and Vanden Eeckaut (1995), Asmild, Paradi, Aggarwall, and Schaffnit (2004) and Cullinane and Wang (2006) propose four different calculations of efficiency using DEA from a panel data set:

- Contemporaneous approach: efficiency is calculated for every DMU taking only the input and output data of DMUs in the same period as a reference set. As many efficiency ratios as periods in the whole sample are calculated for each DMU, each of them with a different frontier.
- Sequential: efficiency is calculated for every DMU in one period taking input and output data of DMUs in the same period and all the precedents as a reference set.
- Intertemporal: efficiency is calculated for every DMU in one period taking input and output data of DMUs in the whole time of the sample as a reference set. Efficiency is calculated taking all the data from the panel in a pooled manner. As many efficiency ratios as periods in the whole sample are calculated for each DMU, all of them with the same frontier.
- Window analysis: efficiency is calculated for every DMU in one period taking input and output data of DMUs in the periods forming the window length as a reference set. Researchers should decide on window length depending on the characteristics of each empirical work. DMUs forming each window vary because the first period is suppressed to add the following one to form the next window.

The choice of methodology requires taking their characteristics into account. Following Tulkens and Vanden Eeckaut (1995) concerning changes in production technology, it could be argued that if the contemporaneous method is chosen, the efficient frontier is considered to change from period to period. Concerning the technology available at each moment, it is assumed that, with the sequential method, the way of producing in the past will be also available in the future; therefore, only shifts in the frontier reflecting technical progress are assumed. If the intertemporal frontier is chosen, it is assumed that no shift occurs.

If there is no temporal trend, the efficiency calculated year by year only considers DMU data in the same period as a reference sample and some organizations could be qualified as efficient, even though they could be qualified as inefficient if they were compared with the same units' performance in different periods. In this case of no temporal trend, the best way of exploiting information provided by panel data is to estimate an intertemporal frontier and calculate efficiency by taking it as a reference set. In fact, Brockett, Golany and Li (1998) establish that the use of a single efficiency frontier assumes that no technological changes affecting productive efficiency have occurred over the time periods. Wang, Wang, Huang,

Wu, and Liu (2014) explain that, in the presence of technical change, evaluating efficiency using an intertemporal frontier formed by many periods can deem that DMUs observed in the technical improvement periods are efficient. Therefore, DMUs of periods with no technical improvement and considered inefficient would be recommended to become a benchmark impossible to reach given their technological context.

Where a temporal trend is detected, the year-by-year calculation of efficiency can lose information: it is difficult to analyze improvements in efficiency because the sample changes every year. In this case, two different situations can be applied. If the temporal trend is in fact the realization of an event at a single and recognizable moment that drastically changes technological conditions, efficiency could be calculated with two intertemporal frontiers, one before that event and the other afterwards. Brockett et al. (1998) propose a procedure in the event of no drastic changes. These authors quoted that these trends can develop slowly, only in a few DMUs (they are not generalized), and can go unnoticed by managers. Brockett et al. (1998) also remarked that efficiency results calculated across time in contrast to year-by-year results are more useful to managers as they avoid the influence of extraordinary events in a single period.

Proposing recommendations that fit with the technological evolution in the sample under study require verification of this evolution before starting the efficiency calculation. Consequently, Brockett et al. (1998) suggested an intertemporal calculation of efficiency and the running of several tests on the obtained efficiency ratios. For the study of the eventual existence of trends in performance over time, following Brockett et al. (1998) and Ross and Droge (2002), we have used the S statistic proposed by Brockett and Kemperman (1980). For the analysis of stability in relative ranks, we have used the Kruskal-Wallis statistic, proposed by Brockett et al. (1998) and Sueyoshi and Aoki (2001). All these previous process have enabled us to choose the most accurate methodology considering the characteristics of our sample.

5. Results

5.1. Analysis of the existence of temporal trend

We are going to verify the two aspects proposed in Brockett and Golany (1996) and Brockett et al. (1998): analysis of the existence of a temporal trend in the whole sample and of stability in relative ranks.

Concerning the analysis of a temporal trend in the whole sample, Brockett et al. (1998) and Ross and Droge (2002) use the S statistic proposed by Brockett and Kemperman

(1980). These authors have a complete panel in their analysis. In our case, we have unbalanced panel data because not all the teams in the sample have played in the UCL throughout the entire period under analysis. Nevertheless, it is possible to apply the S statistic because observations are accumulated by period and 32 teams play in the UCL every season. As we have previously obtained super-efficiency in our calculations, we have avoided ties in the application of the test. As we obtained a statistic value equal to 3830, we found that we can reject the null hypothesis of no temporal trend with a significance level of 5%.

To analyze the stability in relative ranks, Brockett et al. (1998) and Sueyoshi and Aoki (2001) propose the use of the Kruskal-Wallis statistic. Brockett and Golany (1996) also quote this method. Brockett et al. (1998) and Sueyoshi and Aoki (2001) have a complete panel again, but the original paper of Kruskal and Wallis (1952) considers the possibility of a different number of observations for each individual in the statistic calculation. We have calculated this statistic for our sample using super-efficiency ratios, again to avoid ties, and we have obtained a value for the statistic equal to 101.66; therefore, we have accepted the null hypothesis of equivalent distribution of efficiency ranking with a level of significance of 5%.

To sum up, we have detected a temporal trend and teams have not maintained their relative positions over time. Therefore, intertemporal analysis cannot be conducted with our data to determine which teams are efficient because a temporal trend exists. The contemporaneous approach is also incomplete because the technical changes in football (players and coaches) are usually gradual and it is possible to find similar contexts in two consecutive periods. Although Brockett et al. (1998) do not use window analysis, they quote this method in their paper referring to it as a way of introducing new temporal data in the DEA calculation. These authors mention that studies applying WDEA do not use statistical tests, an issue that we try to solve in our paper. Furthermore, window analysis provides knowledge of robustness in efficiency ratios. This helps to identify really reliable results and, as a consequence, to identify which DMUs can be used as an efficiency benchmark. Due to statistically equivalent distribution of efficiency positions, we would not expect efficient teams to be the same throughout the period studied in this paper.

5.2. Calculation of efficiency in DEA using window analysis

Window analysis consists of calculating efficiency rates using DEA but forming the sample with data collected from a number of consecutive periods. This sample extracted from the whole panel is called a window, and the number of periods in a window is called the width of the window. Calculations are repeated by eliminating the data corresponding to the

first period in the window and adding data for the following period (season in our case) after the last in the window. This process is repeated as many times as the length of panel provides data. Window analysis enables us to assess the robustness of the efficiency ratios and to come to more reliable conclusions on the evolution of efficiency.

As we have previously highlighted, only Sala-Garrido et al. (2009) have applied window analysis methodology to the sports field. Traditionally, apart for a methodological approach (Tulkens & Vanden Eeckaut, 1995; Sueyoshi & Aoki, 2001), studies considering window analysis have been applied to various economic sectors: banking (Yue, 1992; Asmild et al., 2004); air forces (Charnes, Clark, Cooper, & Golany, 1985); brewing industry (Day, Lewin & Salazar, 1994); carbonated beverage industry (Charnes, Cooper, Golany, Learner, Phillips, & Rousseau, 1994a); container port (Cullinane & Wang, 2006); semiconductor manufacturer (Chung, Lee, Kang, & Lai, 2008); telecommunications firms (Yang & Chang, 2009); science park (Sun & Lin, 2009); and coffee sector (Suárez & Mejía, 2010), for instance. Recent works have also applied window analysis to calculate efficiency. For example, Detotto, Pulina and Brida (2014) analyzed the productivity of the hospitality sector in Italian regions; Wang et al. (2014) and Epure and Lafuente (2015) study efficiency in banking. Mariano, Sobreiro and do Nascimento Rebelatto (2015) present a revision of the literature on the application of DEA to analyze efficiency in human development processes and window analysis appears as one of the extensions of DEA if panel data is available.

When applying window analysis, one important decision is to establish the width of windows, which depends on assumptions about changes in the frontier (Tulkens & Vanden Eeckaut, 1995). Several approaches have been proposed in the literature. Papers by Boussofiene, Dyson, and Thanassoulis (1991), Day et al. (1994), Ross and Droge (2002), Sala-Garrido et al. (2009), and Suárez and Mejía (2010) state that it is a decision taken by an analyst. Nevertheless, to provide some criteria, Paradi, Vela and Yand (2004), Asmild et al. (2004), Charnes et al. (1994a) and Yang and Chang (2009) suggest that windows should be wide enough to have the necessary degrees of freedom and narrow enough to maintain the same context. Finally, more formal suggestions are those by Cooper, Seiford and Zhu (2004), Charnes, Cooper, Lewin and Seiford (1994b, 60), who propose the trial and error method, and Cooper, Seiford and Tone (2000), who propose a formula.

Following the formulae provided by Cooper et al. (2000), we should have used a width of five seasons in the present paper. Nevertheless, Sala-Garrido et al. (2009) suggest that most teams change either players or their coaches from one season to another, which means there is no sense analyzing windows of more than three seasons for football clubs. Regarding this consideration, we have also employed a width of three seasons, as this

period is consistent with the average time coaches, players and teams remain in the championship.

Before exposing the efficiency results, it is important to remember that we do not have a complete panel of data. In this paper, efficiency for each team in each window is calculated with the sample formed by teams playing in some of the three seasons forming the window, although some of them did not participate in all three seasons.

The overall results of efficiency (WDEA) are presented in table 2. Due to a shortage of space, table 2 is organized by season. For seasons that belong to more than one window, we present the efficiency scores for all the respective windows (two or three). The differences between the efficiency scores for the same season in different windows give us an idea of the robustness of the results. The coefficient of variation (CV) between efficiency scores is added to help observe robustness whenever there is more than one window. The results are sorted by the clubs' sporting performance. The lines separating clubs in the results table represent the final stage in which clubs are ranked in each season. From top to bottom, these are final (champion and runner-up), semifinals, quarterfinals, knockout round and group stage. The results highlighted in gray are efficient observations and results underlined are not considered robust.

To interpret the results, it is important to remember that observations with an efficiency score of less than one are inefficient and of one or more are efficient. For general results, a coefficient of variation above 10% was considered to mean substantial differences in efficiency values and not robust. On the other hand, all those observations that present a $CV < 10\%$ had estimated robust efficiency scores. As we have used super-efficiency in our calculations, efficient units present ratios above one, independent of the exact ratio value. We will, therefore, consider efficient teams robust if the ratios in all the seasons in the same window are above one, even if their CV is above 10%. Consequently, efficient teams at least once with CV less than 10% or with CV above 10%, but efficient in all seasons in a window, will be considered robust efficient clubs and will be used as reference units and benchmarking for the inefficient clubs in the sample.

The first highlighted result concerns the low efficiency level of the UCL for the 2004/05 to 2012/13 seasons. This result agrees with those found by Zambom-Ferraresi et al. (2017). Our sample comprises 288 observations and, due to the repetition in calculating efficiency in Window DEA, we have 768 different ratios and only 6% of the entire sample is efficient. Looking at windows separately, these results are similar. On the one hand, the window with more efficient observations is window 3, with nine efficient observations. On the other, window 4 had only three efficient observations.

Insert table 2 here.

Clubs that had robust efficient scores in their respective windows will be a reference for the rest of the sample. Internazionale 2009/10 and Barcelona 2010/11 are the best benchmarking observations. Both clubs were champions and had relative technically efficient scores when compared with other teams that played in window 4, 5 and 6 and 5, 6 and 7, respectively. Apoel's 2011/12 performance is an example and must be a reference for all the small and medium clubs in the sample. This club reached the quarterfinals of the UCL by being efficient when compared with the performance of the other clubs in the two periods before and after. The performance of Slavia Prague 2007/08, Apoel 2009/10 and BATE Borisov 2012/13 is also worthy of note. These clubs did not advance past the knockout round, but as they did not waste their sports resources, they can be qualified as efficient. These robust efficient clubs achieved good sports results on the basis of the inputs they employed.

If we also take into account teams with at least one ratio above 1 in one window and with CV below 10%, robust efficient units are found in all the stages and over the entire time horizon studied in the present paper. After eliminating observations only present in one or two windows, these cases are: Liverpool 2006/07, Internazionale 2006/07, CSKA Moscow 2006/07, Manchester United 2007/08, Celtic 2007/08, Anorthosis 2008/09, Ranges 2010/11, Bayern Munich 2012/13, Borussia Dortmund 2012/13, Barcelona 2012/13, Valencia 2012/13 and CFR Cluj 2012/13.

Finally, efficient teams are not the same throughout the entire time horizon in this paper, as expected after the statistical acceptance of null hypothesis of the equivalent distribution in efficiency ranking. This lack of continuity in efficient teams is not only due to the existence of teams not playing in all the seasons under study, as some of the efficient teams have a continuous presence in the UEFA Champions League.

5.3. Evolution of efficiency and sports results

Given that WDEA was employed, we can draw more accurate conclusions about the evolution of efficiency. By observing the relation between DMU efficiency in the first season of a window and the variation in its efficiency during the window period we can observe interesting issues. The following figures (1A to 1G) are easy to interpret and help us to analyze the evolution of efficiency. The clubs on the right side of the horizontal axis have showed positive efficiency changes, and the clubs on the left side have had negative changes during the window cycle. Clubs in the top left quadrant are efficient in the first season of the windows,

but cannot maintain this efficiency in the next two seasons. We find nine observations with this performance and four of them are the champions of the competition in the first season of the respective window (w): Barcelona 2005/06 (w 2) and 2010/11 (w 7), Internazionale 2009/10 (w 7) and Liverpool 2004/05 (w 1).

Insert Figures 1A - 1G here.

In the seven windows we studied, no case was found in the top right quadrant, which means that no clubs were capable of maintaining efficiency for three seasons. These results corroborate those found by Zambom-Ferraresi et al. (2017), where teams had many problems maintaining their efficiency during the seasons.

In the bottom left quadrant, we can see those clubs that were inefficient in the first season of the window and cannot improve on this inefficiency during the window cycle. The most highlighted cases are Lyon and Manchester United, which are inefficient and do not change in five out of seven analyzed windows. Real Madrid was found in the same case in four out of seven of the observed windows and this team is present in all of them. In contrast, Porto participated in the UCL in four out of these seven windows and was inefficient in all the seasons in which they played.

Porto's situation captures our attention. In the last decade, exactly the period analyzed here, Porto was known as one of the best clubs at the time for hiring (mainly) and training young, talented and unknown players. This means that, when hiring players, Porto [1] presents a satisfactory performance, but its resources on the field were used inefficiently. Pursuing efficiency in all areas is essential for medium clubs like Porto, which is competing on the field with the largest clubs in Europe.

Finally, the bottom right quadrant includes clubs that improved their efficiency scores during the window cycle, but their improvement did not suffice to be efficient when their performance is compared with all the clubs in the window. The clubs in this situation are Arsenal, Chelsea and Internazionale, four times out of the seven possible. Barcelona and Real Madrid also improved their efficiency three times during the seven observed windows. We could see that these are major clubs that participated in the UCL in all or almost all the analyzed windows. In some performances they had good sports results, but they wasted their resources, e.g. Arsenal reached the 2008/09 semifinal and Chelsea was the 2011/12 champion. Sometimes clubs present very poor sports results considering the number of inputs they employed and, in these cases, their inefficiency is evident. This is the case of

Real Madrid in windows 4, 5, and 6.

The relation between sports results and efficiency can be observed in figure 2. Most observations are inefficient, which explains the few observations on the right side of the axis of the efficiency score. The observations of the first two competition stages (group and knockout) are very crowded, as was expected, because both concentrate the largest part of the sample. The highest sports prizes for these two groups could be 14.6 and 18.1 (million euros), respectively. A growing trend in figure 2 can only be observed in the final stages of the competition.

Insert Figure 2 here.

After analyzing the correlation between sports results and the efficiency score of all the 768 ratios in the sample in table 3, we have found a positive and significant correlation of almost 40% of the sample. However, the importance of efficiency is obvious when we look at the correlation for the clubs that reach the semifinal stage. The correlation between efficiency and the sports results in this phase is 72%. By observing these results, we can conclude that for all kinds of club, whether large or small, efficiency is significant, positive and highly correlated with reaching the final phases of the UCL.

Insert Table 3 here.

Individually, one of the most highlighted performances when observing both efficiency and sports results was Internazionale in the 2009/10 season (calculated in windows 4, 5 and 6); a team characterized by Jose Mourinho's stamp, playing mostly in counter attack, using one of the simplest and most known tactics in football, the numerical superiority of players. In a decade characterized by an ornate play style of the victorious Barcelona and Spanish selection, the ball possession style was considered one of the main outcomes of football. However, it is important to note that ball possession is not an important outcome. At the end of the match, it does not matter if a team has had a high percentage of ball possession if the team loses the match. Although fans would undoubtedly prefer to see their team controlling ball possession, they would obviously rather win the match. Internazionale and its coach proved that "alternative" tactics could and must be employed (including for major clubs) to surprise and win competitions. Based on the results calculated and obtained by means of DEA, Internazionale won the competition that season without wasting its resources. Looking

for other performance indicators (not included in our model) of this team in 2009/10, we could confirm a different style of play: only 45% of ball possession; the team that committed the most fouls and received the most yellow cards in the season; and also the one with more offsides. All these characteristics are the opposite of the norm in recent years. Most teams have tried to imitate Barcelona, and it is undeniable that they had a beautiful style of play. Fans have enjoyed watching Barcelona, especially as the team was winning. This seemed the perfect tactic, but it is not available to everyone. José Mourinho has noted this and made an intelligent and efficient use of this information and its resources.

Insert figures 3A – 3G here.

Figures (3A–3G) show results from the relation between the evolution of efficiency scores and the evolution of sports results. The evolution is calculated on the basis of the difference between the last and the first season of each analyzed window. Regular windows in this paper are composed of three seasons, so they contain 96 efficiency ratios. As we mentioned above, several clubs could not participate in the UCL on an ongoing basis. Therefore, we merely analyzed the evolution of those clubs that played in all three years in each window. From an overall view of all seven analyzed windows, we can see a clearly positive trend, except for windows 1 and 5. This trend means that clubs that improve their efficiency enhance their sports results and vice versa.

6. Discussion of results and conclusions

The aim of this paper is to analyze efficiency and its evolution in teams that played in the UEFA Champions League taking advantage of the panel data we have for nine sport seasons. This paper contributes to sports efficiency literature by presenting a research procedure to identify the most accurate methodology to be applied to panel data. First, we analyzed the existence of a temporal trend using the S statistic proposed by Brockett and Kemperman (1980). We have calculated the Kruskal-Wallis statistic to verify if there is stability in relative ranks. **Our efficiency ratios have been calculated using super-efficiency (Andersen & Petersen, 1993), which enables us to discriminate efficient units among them.**

The results of the aforementioned tests have indicated that window analysis is an accurate methodology to apply to the UCL sample. **In comparison with other papers as Zambom-Ferraresi et al. (2017) and Espitia-Escuer and García-Cebrián (2010) which also calculated efficiency for football teams playing UCL, WDEA can be considered a superior**

methodology because it is the best adapted to the temporal evolution in ratios verified by statistical tests. Besides, this methodology enables us to assess the robustness of efficiency ratios to detect the best benchmark clubs.

To the best of our knowledge, this paper is the first empirical study on international football competitions applying WDEA to incomplete panel data. Previously, only Sala-Garrido et al. (2009) have applied this methodology to eight seasons of the Spanish league, from 2000/01 to 2007/08. Nevertheless, to obtain a complete panel data, the authors only considered the most regular teams, those with a good performance.

Our general results show a low efficiency level in the analyzed sample: only 6% of the teams under analysis can be considered as efficient (with a efficiency ratio above one) and they can be proposed as benchmarks for inefficient clubs. We have also found robust efficient teams in all stages in the championship, which opens the possibility of evaluating teams not exclusively from a sport success standpoint, but taking a combination of resources and sport results into account.

We have verified the existence of a temporal trend in efficiency. This means that technical changes occurred between the 2004/05 and 2012/13 seasons that led to changes in the efficiency frontier. The best example was Internazionale's sports performance and efficiency in 2009/10. Additionally, in our study, teams did not maintain their relative efficiency. This means that, over time, efficient units have changed. This is corroborated by the analysis of efficiency evolution in a window and efficiency in the first period of the window. We have identified that it is hard for clubs to maintain their efficiency during their time in the UCL environment. In fact, we have not found any club capable of maintaining its efficiency.

In all the stages in the competition we have found a positive and significant correlation between sports results and efficiency. However, the most remarkable, significant, positive and strong correlation between estimated efficiency scores and sports results was found in those teams that reached the semifinals of the UCL. This is an important finding for the top best teams in Europe: some simple changes in technology may represent an improvement in efficiency. This finding may assume greater significance if we consider other important findings, namely that an improvement in efficiency could also be an improvement in sports results. Even better is that this improvement could happen without the need for more inputs, which are very scarce nowadays in a football scope.

Although the correlation between efficiency and sport results is weak in teams playing in only the first stages of the championship, the observation between the evolution of efficiency and the evolution of sports results in the majority of the windows indicates that if teams

improve their efficiency, they could enhance their sports results. Consequently, even though pursuing efficiency is essential for all kinds of clubs, it seems crucial for small and medium clubs competing in the field with the largest clubs in Europe. The most remarkable benchmarking observation in this regard was attained by Apoel 2011/12.

Finally, if efficiency is positively correlated with sport results, teams could successfully change their style of play without using more resources. And the lack of continuity in efficient teams adds emotion to the championship.

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