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Technical progress and efficiency changes in football teams participating in the UEFA Champions League

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ABSTRACT

This paper commits to calculate and analyze productivity levels and its components for teams that participated in the UEFA Champions League between 2003 and 2012. It will pursue three objectives: 1) evaluate resources usage, 2) analyze the productivity levels of the football teams and the sports results, and 3) see the influence of participation experience in reference to productivity and sports results. Using Malmquist Productivity Index, the results reflect a lack of consistent progression of efficiency, productivity, and technical change. This competition does not reward the efficient usage of resources and there is not a conclusive relationship between permanence in the competition and productivity.

Keywords: Malmquist Productivity Index, technical progress, efficiency changes, football teams, UEFA Champions League.

RESUMEN

Este artículo pretende calcular y analizar los niveles de productividad y de sus componentes para los equipos que participaron en la Liga de Campeones de la UEFA entre 2003 y 2012. Se persiguen tres objetivos: 1) evaluar la utilización de los recursos, 2) analizar los niveles de productividad de los equipos de fútbol y los resultados deportivos y 3) ver si la experiencia que da la participación influye en la productividad y los resultados deportivos. Usando el índice de productividad de Malmquist, los resultados reflejan una ausencia de evolución constante para la eficiencia, la productividad y el cambio técnico. Esta competición no premia el uso eficiente de los recursos y no hay una relación concluyente entre productividad y permanencia en la competición.

Palabras clave: Índice de productividad de Malmquist, progreso técnico, cambios en la eficiencia, equipos de fútbol, Liga de Campeones de la UEFA.

The fundamental reason that justifies this research is that football clubs are organizations in the economic sense of the term and, as organizations, they manage resources to achieve their objectives. Consequently, the appropriate use of resources can be a criterion for evaluating the performance of football clubs. In the field of economics, the concepts of efficiency and productivity are applicable to all agents and constitute a tool for evaluating the success of management. The industrial productivity is an object of continuous analysis because the success in business and economic competitiveness depends on it.

Level calculations of efficiency and productivity achieved by an organization adhere predominantly to its productive activities. However, the effects of the recommendations that can be drawn from this analysis go beyond production function, since an improvement in efficiency would imply obtaining the same amount of product with fewer productive resources, which in turn would cause costs to decrease and hence profits to increase. Therefore, the conclusions of this analysis should be interpreted initially from a technical viewpoint, but a more general interpretation of the management of the organization is also possible.

In reference to football clubs, the production process consists of training and playing the games in the competitions in which the team participates. The recommendations derived from the levels of efficiency and productivity achieved refers to the plays made during the games; but its ultimate purpose is fundamentally economic (i.e. to make proposals for achieving organizational efficiency).

The aim of this paper consists of three parts. First, it will evaluate the use that football teams have made of the resources available to them, considering that this has an impact on the costs and the profits of the clubs. Secondly, it related to productivity levels calculated here and the sports success of the teams in the sample with the experience acquired through the participation in the competition over a prolonged period. Third, it will determine if there is any relationship between increase in productivity and the sports results of the team for determining whether an adequate use of the factors of production available is necessary to win a competition.

The research sample consists of the football teams that participated in the Union of European Football Association (UEFA) Champions League between the years 2003 and 2012. Since the data available spans several seasons, a dynamic analysis is performed rather than a season-by-season analysis. Due to this, the productivity growth of the football teams is calculated using the Malmquist index and its component parts of technical and efficiency change, will be used to assess which European football teams achieved their sporting results without wasting resources. Nevertheless, the overall activity of the teams is not taken into account. This paper only analyses the variation in productivity of performance on the field, corresponding to the second and final stages of productive process in football teams (Carmichael & Thomas, 1995; Carmichael, Thomas, & Ward, 2000; Schofield, 1988). The remaining sections of this paper are structured as follows: the Malmquist index as a measure of the change in productivity; what could constitute the representative function of the productive activity of football teams; the results obtained from the sample; and finally the most relevant conclusions.

PRODUCTIVITY MEASUREMENT USING THE MALMQUIST INDEX

The analysis and calculation of productivity has been a research topic for a long time leading to several proposals. The easiest way of calculating productivity is by means of the ratio output/input, but it has the inconvenience of showing as an improvement of productivity a substitution of productive resources. Aiming to solve this, the calculations of Total Factor Productivity is proposed. This index maintains the structure of the former productivity ratio because is also calculated as a quotient, but it takes index numbers as measure of the variety of produced outputs and used inputs by organizations. These two ratios provide two different ways of calculation, but they are not concerned about the causes of productivity changes.

According to Grosskopf (1993), productivity growth can be calculated considering that organizations use their resources efficiently (so, technical progress only is at the origin of that growth) or, on the contrary, taking into account the possibility that some inefficiency may exist. Productivity growth is, then, the net change of the amount of output produced due to efficiency change and technical change (this being the second approach and adopted in this research paper from the same author).

In consequence, as a first step to calculate productivity according to the theoretical frame adopted in this paper reference to the methods for evaluating efficiency is needed. Farrell (1957) uses as departure point to calculate efficiency the concept of isoquant established in Economic Theory, designating organizations by the combination of their outputs and inputs, placing those on the isoquant as efficient or those over the isoquant as inefficient.

In fact, inefficient organizations are wasting inputs because they are using them in higher quantities than necessary and they have the opportunity of saving resources moving to the isoquant. Next, Farrell (1957) proposes the estimation of the isoquant as the frontier of real values of production and input consumption of a sample composed by several organizations.[1]

Using the proposal of Grosskopf (1993), measuring productivity falls within the frontier methods for measuring efficiency, she states that efficiency changes are changes in the distance between an observation and the technology frontier over time and the technical change could be interpreted as the change in the location of the frontier itself over time.

Among the various approaches in existence for calculating efficiency using frontier methodology from real sample data, this study has opted for the Data Envelopment Analysis (DEA). This analysis has the advantage of not requiring specification of the production function, and calculates the efficiency ratio of the units that make up the sample to be studied by solving the following linear programming problem:

$$
\begin{aligned}
\text{Min.} \quad & \lambda_i \\
\text{s.t.} \quad & \lambda_i * x \geq u * X \qquad (1) \\
& y \leq u * Y \\
& u \in R^+
\end{aligned}
$$

where: λ_i is the efficiency ratio obtained by solving the problem and is related to the distance among the combination of inputs and outputs of unit i and the frontier representative of the isoquant;

x is the vector of the quantities of n inputs used by the unit i;

y is the vector of the quantities of m outputs obtained by the unit i;

X is the matrix of the quantities of n inputs used by the k sample units;

Y is the matrix of the quantities of m outputs obtained by the k sample units;

u is the vector of coefficients as a result of the problem.

The formulation of the problem (1) assumes constant returns to scale and has adopted an input orientation whereby l_i is interpreted as the rate at which the amounts of all productive resources used by the unit under analysis should be reduced, such that it could be situated on the isoquant or frontier and could be classified as efficient. If the sample under study is composed by k organizations, problem (1) has to be solved k times, one for each unit in the sample. Therefore, all those units in the sample whose l_i takes on a value equal to unity will be classified as efficient, and they are placed on the isoquant, while those which have a value for the ratio l_i lower than one, will be inefficient because they are over the isoquant. The justification for knowing the efficiency ratio of the organizations is to propose actions that will allow the inefficient ones to situate them on the isoquant and thereby produce the actual quantity of product, but with a reduced consumption of resources, reducing their costs.

Problem (1) allows the efficiency value of a unit to be calculated in a given period taking into consideration the data of the entire sample for the same period. The efficiency of an organization can also be calculated for one period using as reference a different period. This would allow us to calculate the Malmquist index using the following expression:

$$M_0\ (x^{t+1}, y^{t+1}, x^t, y^t) = \left[\frac{\lambda^t(x^{t+1}, y^{t+1})}{\lambda^1(x^t, y^t)} * \frac{\lambda^{t+1}(x^{t+1}, y^{t+1})}{\lambda^{t+1}(x^t, y^t)}\right]^{1/2} \quad (2)$$

The superscript accompanying λ represents the period from which the input and output values of the pooled sample have been taken to form the efficient frontier that will serve as reference for the efficiency calculation. Moreover, *x* and *y* represent, respectively, the quantities of inputs used and outputs obtained by the unit under study, and superscripts indicate the period to which they refer.

With the aim of measuring the productivity growth of an organization, Grosskopf (1993) proposes the use of the geometric mean of two Malmquist indexes by means of the calculation of the following expression:

$$M_0(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{\lambda^{t+1}\ (x^{t+1}, y^{t+1})}{\lambda^t\ (x^t, y^t)} * \left[\frac{\lambda^t(x^{t+1}, y^{t+1})}{\lambda^{t+1}(x^{t+1}, y^{t+1})} * \frac{\lambda^t(x^t, y^t)}{\lambda^{t+1}\ (x^t, y^t)}\right]^{1/2} \quad (3)$$

According to Grosskopf (1993), breaking down the Malmquist index as presented in (3) allows the two components, to be calculated: the term outside the brackets would be the efficiency change and the bracketed term, the technical change.

Since the Malmquist index calculation requires efficiency using the data of the sample units from a different period in time as reference, it no longer supports that these efficiency values are bounded by unity, therefore it should come as no surprise that some of them have values greater than one. Both the efficiency and technical changes may take on values less than, equal to, or greater than, one. An efficiency change value less than unity means that the efficiency of the organization under study has decreased over time since its value is lower at period t+1 with respect to period t, therefore, in period t, this organization has been closer to the frontier than in period t+1. The interpretation is the opposite in the case of a value greater than one, and a ratio equal to one means that there has been no change in efficiency.

If technical change shows a value less than one, it means that the isoquant representing technology in period t+1 is farther from the coordinate origin than in the preceding period; this indicates that more quantities of resources are needed for reaching the same quantity of output, so there has been a technical regress. It is also possible that it exhibits a value greater than unity, which would have the opposite interpretation, while a value equal to one would indicate that no technical change has taken place. Nevertheless, the interpretation of the values resulting from the calculation of technical change requires an additional comment. In the case of efficiency change, maybe not all sample units under study are in the same situation in reference to the technical change experienced. In the first case, however, this should not seem strange nor require additional explanation, when this occurs for the technical change values indicate that some of the units in the sample have experienced technical progress, while others have regressed. Given that the technical change is related to the variation of the position of the isoquant relative to the coordinate axes, a priori this contradiction should not arise. The explanation is, when within the sample there are organizations that have experienced both technical progress and regress, the technology isoquants for the periods studied intersect. However, the fact that all of the organizations in a sample show the same type of technical change for a given period does not necessarily mean that the isoquants do not cross, but it may indicate that when represented on a graph of the isoquants, the units studied are situated in a space where intersection does not occur.

Finally, the Malmquist index may exhibit values less than, or equal to, one. If the Malmquist index for an organization in the sample is less than one, the interpretation is the organization's productivity has decreased, if it is greater than one, it has increased, and has not changed for those cases where the index is equal to unity. Each one of these three possible values may be the result of the combination of different efficiency and technology change values, which, as shown in the figure below, would have a different interpretation.

Figure 1. Possible Malmquist index values and its components

a) Malmquist index not equal to 1:

Technical change		
	The organization has not improved the utilization of its resources as well as the sample since it is farther from the isoquant that in the previous period. <u>Malmquist index value undetermined</u>	There has been technical progress and the organization has improved the utilization of their resources better than the sample since also been located closer to the isoquant. <u>Malmquist index greater than 1</u> <u>Improved productivity</u>
1	There has been technical regress and the organization is farther from the isoquant. The use of its resources has worsened in relation to the sample. <u>Malmquist index less than 1</u> <u>Lower productivity</u>	There have been technical regress, but the organization is better situated with respect to the isoquant. <u>Malmquist index value undetermined</u>
0	1	Efficiency change

b) Malmquist index equal to 1:

Technical change = 1	**Technical change = 1 / Efficiency change**	
Efficiency change = 1	**Technical change <1**	**Efficiency change <1**
The isoquant does not move with respect to the origin of coordinates and the efficiency of the organization does not change with respect to the previous period.	The technical regress is offset by increased efficiency.	The decrease in efficiency is offset by technological progress.

Source: Own elaboration

Over time, an organization that has made suitable use of its resources will always be located on the isoquant, which would classify it as efficient for all of the periods analyzed, and besides, this isoquant would approach the coordinate origin experiencing technical progress. Therefore, as far as the values of the indices considered in this paper are concerned, the efficiency change of the organization would exhibit a value equal to unity[2] and the Malmquist index would be greater than one and would coincide with the value of technical progress for the entire period. If the productivity change calculations for a sample over several periods do not yield these consistent results, one could conclude that the organizations being analyzed have not employed their resources appropriately. For example, with an orientation toward input such as has been adopted by this study they could have obtained the same volume of product using lesser amounts of their factors of production[3] and, therefore, they could have reduced their costs.

THE PRODUCTION FUNCTION OF FOOTBALL TEAMS[4]

Since the Data Envelopment Analysis is a tool for estimating the isoquant that represents the production function of the organizations that make up the sample under study, the choice of the input and output variables used in the analysis should be those considered as such in the production process for the analyzed sector.

The initial studies dedicated to Sports Economics established that it is an industry with certain peculiar attributes and part of the research focuses on establishing what their product and the resources that it begins with are. Neale (1964) establishes that the league can be considered a company with many plants, meaning the games. Meanwhile, Carmichael and Thomas (1995), Hadley, Poitras, Ruggiero, and Knowles (2000) and Dawson, Dobson, and Gerrard (2000) use measures of success or game wins as the output of sports teams and variables related to the characteristics and performances of the players as inputs, which is the option adopted in this paper.

Concerning the selection of variables representing output, in the case of the Champions League, holding an eliminatory competition, the number of games played by the teams is an indirect indicator of success, since playing more games indicates that the team has been surviving the knockout rounds. The choice of the number of games as an output variable follows the proposal of Rottenberg (1956), which states that the product of a football team is the game. Brook (2005), who presents a discussion concerning which is the variable that best represents the output of the sports teams and, after analyzing several alternatives, concludes that the game itself should be taken as such. In this paper, the number of played games will represent output obtained by football teams participating in UEFA Champions League.

Schofield (1988), Carmichael and Thomas (1995) and Carmichael, Thomas, and Ward (2000) state that the production process of sports teams can be broken down into two stages; the team's victories depend on the performance of the players on the field and this, in turn, depends on their physical fitness, experience, skills, coach, among others. Therefore, concurring with these authors, we can formulate that the production function of the football teams consists of two stages, each with their particular resources and outputs: First stage, the physical (facilities) and human (staff and players) resources convert, through training, into plays on the field. Second stage, the plays made during the games are transformed into victories, measured in different ways, depending on the type of competition being held.

This paper will focus on the second of these two stages. Due to this, no physical or human resources will be found among the inputs placed under consideration the efficiency and productivity calculations. Furthermore, in studies that use the Data Envelopment Analysis to calculate the efficiency of companies whose productive function can be divided into various stages. Lovell, Walters, and Wood (1994), Keh and Chu (2003), Sexton and Lewis (2003), Lewis, Lock, and Sexton (2009), Chen, Cook, and Zhu (2010), Kao and Huang (2008, 2011), and Medina-Borja and Triantis (2011), human resources show as input only in the first stage, and later the inputs are considered outputs of the previous stage.

Given that the efficiency of the games will be analyzed, the variables representing the productive resources should be related to the plays made during the games. Specifically, the six offensive variables provided by the Opta Sports database will be used as inputs in this paper: assists, crosses into the box, corners kicks, arrivals to the box, penalty shots awarded and shots on goal.

The reasons that only offensive plays are taken into consideration are as follows. First, the calculation of efficiency and productivity using Data Envelopment Analysis involves estimating the representative isoquant of the production function of the sector under consideration and, in all production functions, the relationship between the amounts of the inputs and outputs must be positive. Therefore, when applying this concept to football teams, the two types of plays made during the games must be taken into account (offensive and defensive). Only the offensive plays have a positive relationship with the output (more offensive plays are related with more goals, more wins and more stages passed in the case of eliminatory competitions, such as the UEFA Champions League), while defensive plays have no such positive correlation. In the extreme case of a match in which both teams only defend, the initial scoreless tie would be only the result assured.

Secondly, a group of defensive plays that do affect a team's outcome and those are the plays made by the opposing team. However, the team under consideration has no influence over them, and the ability to decide upon the quantities of inputs to be used is another condition that must be met in the specification of production functions.

Finally, unlike other areas, the process of the transformation of resources into products, which constitutes the second stage of the football team's production process, is done publically and observed as a series of plays; however, the overall activity should not lead towards the belief that all actions are inputs to the production function. It is evident that teams have to make defensive plays and that those plays consume resources; therefore, it is necessary to acknowledge they are not to be considered productive resources of the games played by football teams. The team's defensive plays serve to impede the success of the opponent, therefore, as a business strategy, they are an adaption to the environment and the resources used here are never included among the variables in an efficiency study, limited to the sphere of production.

Results

For the calculations performed in this study, the sample was composed of all of teams participating in the UEFA Champions League during that year. As calculation of efficiency by means of DEA does not need a specification of production function this method of calculation is chosen in this paper due to the lack of evidence proving that the transformation of plays in field into sport results could adjust to one of the often proposed functions as Cobb-Douglas.

The sample composed by teams participating in the UEFA Champions League in one season is used to calculate efficiency applying problem (1) for each team for the season in question. For those teams that played the previous year, and for those that played the following year, with the purpose of obtaining the efficiency ratios to be used in the calculation of the Malmquist index and its components. This study considered the number of games played during the UEFA Champions League competition as the only output. Due to this, an input orientation was deemed more appropriate, since it makes more sense to recommend reducing the consumptions of inputs than obtaining increases in output, as the latter would imply inefficient teams should increase the number of games they play and values that this variable can take are determined by the system of the competition.

Despotis (2002) establishes that the degrees of freedom are sufficient to calculate efficiency using Data Envelopment Analysis if the following rule is complied:

$k \geq \max. \{m*n, 3*(m+n)\}$

where: k is the number of observations in the sample (32 in our case);
m is the number of outputs employed in the production function for the organizations in the sample (one output selected for football teams in the sample studied in this paper);
n is the number of inputs to the production process (six inputs represent the resources used by football teams in this paper). Therefore, the number of inputs and outputs used in the present work complies with the condition set by Despotis (2002).

Few teams in the sample participating in the Champions League during every season included in this study as well as teams that participated during the first years and others that have emerged in seasons that are more recent. Under these circumstances, and given that at least two consecutive observations are needed to calculate the Malmquist index, results will not be obtained every season for all of them for.

In the context of football, an improvement in efficiency shown by a team can be interpreted as the team reduced the distance to the isoquant form period t to period t+1 and it used less plays in field to obtain its results. The opposite would represent a change in efficiency less than one. A technical pro gress consisting in a shift in isoquant approaching to the coordinate origin means, in the football clubs case, that tactics and plays developed by efficient teams (those locate on the isoquant) have allowed to obtain their sport results in period t+1 with less quantities of inputs than those used by teams on the isoquant in period t. An adverse situation reflects a technical regress.

For an initial analysis of the results, the average technical, efficiency, and productivity change could be used for each season as presented in Table 1.

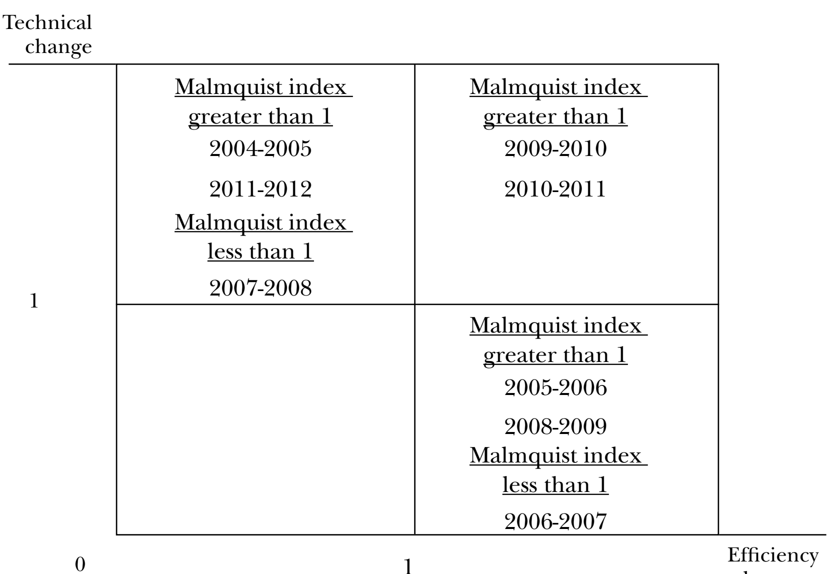
Table 1

Average Malmquist index and its components for the seasons analyzed

Season	Technical change	Efficiency change	Malmquist index
2004-2005 over 2003-2004	1.2312	0.8750	1.0739
2005-2006 over 2004-2005	0.8907	1.1412	1.0158
2006-2007 over 2005-2006	0.8549	1.1456	0.9701
2007-2008 over 2006-2007	1.1395	0.8241	0.9386
2008-2009 over 2007-2008	0.9896	1.0366	1.0253
2009-2010 over 2008-2009	1.0304	1.0809	1.1093
2010-2011 over 2009-2010	1.0671	1.0964	1.1684
2011-2012 over 2010-2011	1.1355	0.9485	1.0525

Source: Own elaboration

Figure 2. Position of the seasons analyzed according to the average value of the components of the Malmquist index.



Source: Own elaboration

Figure 2 shows there is a decrease in productivity in only two of the seasons analyzed, attributed to a decrease of only one of its components: a technical regression in the 2006-2007season and decreased efficiency in 2007-2008. In the rest of the seasons, productivity has increased, but only in seasons 2008-2009 and 2010-2011 there is, in average terms, a simultaneous increase in efficiency and technical progress over the previous seasons. Nevertheless, the analysis of average values hides individual results that may be of interest, as shown in Table 2.

First, the results obtained from the calculation of the Malmquist index and its components point to an on-going situation of wasted resources. At no time in the period studied, or for any of the teams that make up the sample analyzed, there is a stable situation of an efficiency change equal to unity and a Malmquist index value greater than one that coincides with that of technical progress.

Secondly, the technological change presented in the results in Table 2 should be highlighted. In the 2004-2005 and 2007-2008 seasons, all teams show technical progress (i.e. the isoquant has shifted toward the origin and fewer resources are necessary to obtain the product), while in 2005-2006 and 2006-2007 the opposite occurs. For the other seasons there is no unanimous tendency of technical change (which would indicate that the isoquants intersect), while in the 2008-2009 season the teams experiencing technical regression were predominant, in the other seasons the majority of them showed technical progress.

The efficiency changes are more erratic, none of the seasons present an evolution common to all of the teams. Nor is there a relationship between the two components of the Malmquist index, since there are observations with increased efficiency coupled with both technical progress and regress and the same applies to the cases of decreased efficiency. As a result, the Malmquist index value does not reveal a clear trend for the sample studied in this paper.

In Table 2, the two finalists of the competition for each season are also highlighted, allowing the relationship between the evolution of technology and efficiency and sports success to be commented on. Only in the last three seasons has an increase in productivity, caused by an increase in efficiency and technical progress, been observed for the champion or the runner up. In the previous seasons, a Malmquist index value greater than unity among the finalists is observed, but due to the increase of only one of its components, and there are finalists who have experienced a decline in their productivity. Moreover, only in the season 2009-2010 is the champion team the one that shows a highest Malmquist index value of the participants in the competition, but several teams have a higher index than the runner-up. For the rest of the seasons studied there are teams that experience a greater productivity change than the two finalists.

Table 2

Malmquist index values and components

	2004-2005 over 2003-2004			2005-2006 over 2004-2005			2006-2007 over 2005-2006			2007-2008 over 2006-2007		
	Technical change	Efficiency change	Malmquist index	Technical change	Efficiency change	Malmquist index	Technical change	Efficiency change	Malmquist index	Technical change	Efficiency change	Malmquist index
Ajax	1.2006	0.7882	0.9463	0.9070	1.2783	1.1593						
Arsenal	1.2094	1.1302	1.3669	0.8614**	1.0638**	0.9164**	0.9113	0.7597	0.6924	1.2091	0.9875	1.1941
Atlético de Madrid												
Basilea												
Bayern München	1.3096	0.7708	1.0094	0.8695	1.1308	0.9832	0.8188	1.3266	1.0863			
Benfica							0.8671	1.0859	0.9416	1.1356	0.6000	0.6814
Celtic	1.3055	0.8321	1.0864							1.0896	0.8966	0.9770
Chelsea	1.2976	1.1619	1.5078	0.8338	1.2989	1.0830	0.9192	0.7091	0.6518	1.1706**	0.7895**	0.9241**
CSKA Moscu										1.1061	0.7682	0.8497
Deportivo de La Coruña	1.2572	1.0248	1.2884									
F.C. Barcelona				0.9380*	1.3374*	1.2545*	0.8110	1.5179	1.2310	1.1188	0.6261	0.7005
F.C. Dynamo Kyiv	1.2007	0.9971	1.1973							1.1617	0.7494	0.8706
F.C. Porto	1.1737	0.7783	0.9134	0.9565	0.8687	0.8309	0.8207	1.2462	1.0228	1.1940	0.7732	0.9231
Fenerbahçe				0.8866	0.9815	0.8702						
Fiorentina												
Girondins												
G. Rangers												
Inter	1.2551	1.0298	1.2925	0.8806	0.8995	0.7921	0.9193	1.4422	1.3258	1.1069	0.6844	0.7575
Juventus F.C.	1.2456	0.5682	0.7078	0.8539	1.2838	1.0962						
Lille							0.9069	0.8773	0.7956			
Liverpool	*	*	*	0.8323	0.8204	0.6828	0.8765**	1.2293**	1.0775**	1.1869	0.8023	0.9522
Lyon	1.2115	0.8702	1.0543	0.9486	1.0752	1.0200	0.7971	1.2717	1.0137	1.1156	1.0490	1.1702
Manchester United	1.3117	0.7941	1.0417	0.8587	1.1419	0.9806	0.8041	1.0040	0.8073	1.1470*	0.7756*	0.8896*

Table 2 (continued)

Malmquist index values and components

	2004-2005 over 2003-2004			2005-2006 over 2004-2005			2006-2007 over 2005-2006			2007-2008 over 2006-2007		
	Technical change	Efficiency change	Malmquist index	Technical change	Efficiency change	Malmquist index	Technical change	Efficiency change	Malmquist index	Technical change	Efficiency change	Malmquist index
A.C. Milan	1.3188**	0.7718**	1.0178**	0.8649	1.1745	1.0158	0.8304*	0.9936*	0.8251*	1.1642	1.0548	1.2280
Monaco	1.2181	1.1131	1.3559									
Olimpiakos Piraeus	1.0850	1.2013	1.3034	0.9375	0.7169	0.6721	0.8010	1.3289	1.0645	1.1296	0.9216	1.0410
O. Marseille												
Panathinaikos	1.0898	1.0000	1.0898	0.8932	0.9300	0.8306						
PSV Eindhoven	1.3387	0.6314	0.8452	0.9279	1.5838	1.4695	0.9144	1.0000	0.9144	1.1429	0.8889	1.0160
Real Madrid	1.2374	0.8161	1.0099	0.9316	0.8862	0.8256	0.7839	1.4572	1.1423	1.1235	0.8114	0.9116
Roma										1.1355	0.7199	0.8175
Rosenborg BK				0.8298	1.1890	0.9866						
RSC Anderlecht	1.2443	0.6424	0.7994	0.9076	1.6192	1.4695	0.9664	0.8397	0.8114			
Rubin Kazan												
Shakhtar Donetsk												
Sparta Praha	1.1141	0.5789	0.6450	0.8531	1.4104	1.2033						
Sporting de Lisboa												
Steaua Bucarest										1.0739	0.9412	1.0107
Valencia C.F.										1.1034	1.0039	1.1077
Werder Bremen				0.9326	1.2755	1.1895	0.7851	1.3865	1.0885	1.1758	0.6375	0.7496

Table 2 (continued)

Malmquist index values and components

	2008-2009 over 2007-2008			2009-2010 over 2008-2009			2010-2011 over 2009-2010			2011-2012 over 2010-2011		
	Technical change	Efficiency change	Malmquist index	Technical change	Efficiency change	Malmquist index	Technical change	Efficiency change	Malmquist index	Technical change	Efficiency change	Malmquist index
Ajax										1.1758	0.6960	0.8183
Arsenal	0.9532	1.0313	0.9831	1.1616	0.8543	0.9923	1.0894	1.3715	1.4942	1.0386	1.0398	1.0799
Atlético de Madrid				1.029	0.8379	0.8623						
Basilea										1.0052	1.2956	1.3023
Bayern München				1.0223**	1.0357**	1.0587**	1.0723	0.9337	1.0012	1.2890**	0.8788**	1.1328**
Benfica										1.0393	1.0057	1.0452
Celtic	0.9321	0.9344	0.8710									
Chelsea	0.9914	1.1836	1.1735	0.9967	0.9651	0.9619	1.1345	0.9719	1.1026	1.1653*	1.0055*	1.1717*
CSKA Moscu												
Deportivo de La Coruña												
F.C. Barcelona	1.0019*	0.9407*	0.9425*	1.0353	0.9710	1.0052	1.0706*	1.5816*	1.6932*	1.4939	0.6527	0.9751
F.C. Dynamo Kyiv	0.9954	1.5833	1.5761	1.0689	0.9542	1.0200						
F.C. Porto	0.9852	1.1351	1.1184	1.0265	0.9634	0.9890						
Fenerbahçe	0.9954	1.3383	1.3321									
Fiorentina				1.0171	1.4300	1.4545						
Girondins				1.0165	0.7843	0.7973						
G. Rangers							1.0007	1.1801	1.1809			
Inter	0.9765	0.7667	0.7486	0.9979*	1.8088*	1.8050*	1.1155	0.9906	1.1050	1.2916	0.6997	0.9038
Juventus F.C.				1.0288	1.0771	1.1080						
Lille												
Liverpool	0.9864	1.0673	1.0527	1.0385	0.9503	0.9869						
Lyon	1.0073	0.7269	0.7322	0.9864	1.1256	1.1103	1.0229	0.7420	0.7590	1.0285	1.0304	1.0597
Manchester United	0.9988**	0.8547**	0.8537**	0.9934	1.2967	1.2881	1.1556**	1.0132**	1.1708**	0.9918	0.8602	0.8532

Table 2 (continued)

Malmquist index values and components

	2008-2009 over 2007-2008			2009-2010 over 2008-2009			2010-2011 over 2009-2010			2011-2012 over 2010-2011		
	Technical change	Efficiency change	Malmquist index	Technical change	Efficiency change	Malmquist index	Technical change	Efficiency change	Malmquist index	Technical change	Efficiency change	Malmquist index
A.C. Milan							0.9573	1.3477	1.2902	1.0194	0.9468	0.9652
Monaco												
Olimpiakos Piraeus												
O. Marseille	1.0234	0.7857	0.8041	0.9954	1.1907	1.1853	1.1144	0.7332	0.8171	0.9801	1.4335	1.4051
Panathinaikos												
PSV Eindhoven	0.9919	0.7318	0.7259									
Real Madrid	1.0007	0.8150	0.8156	1.0718	1.0492	1.1246	1.0984	1.4030	1.5411	1.3061	0.6912	0.9028
Roma	0.9870	1.3279	1.3107									
Rosenborg BK												
RSC Anderlecht												
Rubin Kazan							0.9737	0.8887	0.8653			
Shakhtar Donetsk	0.9831	1.3791	1.3557									
Sparta Praha												
Sporting de Lisboa	0.9968	1.2284	1.2245									
Steaua Bucarest	0.9954	0.9650	0.9606									
Valencia C.F.										1.0729	1.0434	1.1194
Werder Bremen	1.0011	0.8995	0.9004									

*Season champion
**Finalist

Source: Own elaboration

Since there are some teams that have participated in the competition during all of the seasons analyzed in this study, it was considered appropriate to comment on the influence that the experience gained by these particular teams. First, concerning the possible relationship between experience and sports results, it should be noted that teams positioned as finalists in at least one of the seasons and the teams that have participated in all, or all but one, of the competitions, practically coincide. Lyon and Real Madrid have participated in all of them and have not reached any of the finals during the years covered by this study. Liverpool and A.C. Milan are the only teams in the sample that have won or been runners up in the competition that have been absent from the competition for more than two of the seasons during this period.

Table 3

Average Malmquist index for the teams in the simple for the period studied

Ajax	0.9746	Liverpool	0.9504
Arsenal*	1.0899	Lyon*	0.9899
Atlético de Madrid	0.8623	Manchester United*	0.9856
Basilea	1.3023	A.C. Milan	1.0570
Bayern München	1.0452	Monaco	1.3559
Benfica	0.8894	Olimpiakos Piraeus	1.0203
Celtic	0.9781	O. Marseille	1.0529
Chelsea*	1.0721	Panathinaikos	0.9602
CSKA Moscu	0.8497	PSV Eindhoven	0.9942
Deportivo de La Coruña	1.2884	Real Madrid*	1.0342
F.C. Barcelona*	1.1146	Roma	1.0641
F.C. Dynamo Kyiv	1.1660	Rosenborg BK	0.9866
F.C. Porto	0.9663	RSC Anderlecht	1.0268
Fenerbahçe	1.1011	Rubin Kazan	0.8653
Fiorentina	1.4545	Shakhtar Donetsk	1.3557
Girondins	0.7973	Sparta Praha	0.9241
G. Rangers	1.1809	Sporting de Lisboa	1.2245
Inter*	1.0913	Steaua Bucarest	0.9857
Juventus F.C.	0.9707	Valencia C.F.	1.1136
Lille	0.7956	Werder Bremen	0.9820

*Teams that have participated in all, or all but one, of the seasons analyzed.
Source: Own elaboration

One could also study the existence of a possible relationship between productivity changes and the experience of the teams in the UEFA Champions League. For this reason, Table 3 exhibits the average Malmquist index for all of the teams in the sample. In reality, these calculations represent the average of the index for the teams and not the index value if the first and last seasons considered were consecutive, since this was the case for only nine of the teams. The results obtained from this study appear to show a higher percentage of teams with an average Malmquist index greater than one for those teams participating in all seasons than among the rest.

An analysis of the disaggregated results presented in Table 2 shows that teams with a Malmquist index greater than unity did not participate in the competition the following season (Celtic in 2004-2005, Ajax in 2005-2006, Bayern München in 2006-2007, A.C. Milan in 2007-2008, Fanerbahçe in 2008-2009, F.C. Dynamo Kyiv in 2009-2010 and Bordeaux in 2010-2011, among others). Findings show teams with only one Malmquist index for the period studied being greater than one (Deportivo de La Coruña, Monaco, Fiorentina, G. Rangers, Shakhtar Donetsk, and Sporting de Lisboa). Conversely, teams with extensive experience in the UEFA Champions League frequently show Malmquist indices less than unity for the seasons studied (Arsenal in 2005-2006, 2006-2007, 2008-2009, and 2009-2010; Chelsea in 2006-2007, 2007-2008, and 2009-2010; Barcelona in 2007-2008, 2008-2009, and 2011-2012; Inter in 2005-2006, 2007-2008, 2008-2009, and 2011-2012; Lyon in 2008-2009 and 2010-2011; Manchester United in 2005-2006, 2006-2007, 2007-2008, 2008-2009, and 2010-2011; and Real Madrid in 2005-2006, 2007-2008, 2008-2009, and 2011-2012). Consequently, a decisive relationship between productivity changes and permanence in the competition is missing; there appears to be evidence that productivity increases do not guarantee the presence of an inexperienced team in the following season. However, if the teams manage to maintain their presence in the UEFA Champions League competition over time, decreases in productivity do not affect the continuity of the teams in the competition. Since access to the tournament depends on the team's results in the domestic competition of the previous season, productivity in the domestic competition could be determining the presence of the teams in the UEFA Champions League for the following season. If the permanence effect originates in the national competition, no association will be observed between productivity and results in the UEFA Champions League.

CONCLUSIONS

In this study, we have calculated the efficiency, technology, and productivity changes of game play by the teams participating in the UEFA Champions League between 2003 and 2012. Although this is a labor intensive industry that performs a physical activity besides, the purpose of this article was not to assess the physical performance of the players, but to adopt a purely economic perspective. The teams that in one season have experienced increases in productivity have been able to obtain the same output as in the previous one, but using fewer resources and, thus, by reducing the consumption of inputs, increase profits.

First, from the results obtained from the study it follows that, both on average and individually, neither productivity nor efficiency or technical change show a consistent progression. Therefore, no team has reached the state of absence of waste where it would be consistently located on the isoquant and productivity would increase by the same percentage as the technical progress. Consequently, in view of this situation of excess use of resources, it could be said that the UEFA Champions League is a competition in which teams bear the cost of those excess resources and there is a potential savings for all of them in their utilization.

Secondly, it has been found that the finalists of the competitions studied in this paper do not coincide with those with the highest Malmquist indices for the season, and do not even exhibit index values greater than unity in all of the seasons. Therefore, one could conclude that the UEFA Champions League is a type of competition that does not reward the efficient use of resources. However, the finalists with Malmquist indices greater than unity could indicate the case in which teams wasted resources largely than their rivals with a higher value as well as the contrary. Since the index and its components measure changes in productivity, efficiency, and technology, and very productive and very efficient teams have little room for improvement, that would be reflected in values higher than one in the three ratios calculated in this study, but lower than those of the other teams with greater possibilities to improve the use of their inputs. However, none of the finalist teams in the sample studied had achieved an efficient use of resources while taking full advantage of the technical progress.

Finally, given that the teams participating in the UEFA Champions League are not the same every season, a study was undertaken to determine whether prolonged permanence in the competition and the experience derived thereof may have some effect on both the sports results achieved by those teams and on their productivity. On one hand, evidence of the relationship between experience and success was found considering almost all of the teams that have been finalists in the seasons analyzed participated in all of them. On the other hand, there are no conclusive findings of a relationship between permanence in the competition and productivity. It is not enough for teams with a brief history in the UEFA Champions League to have a Malmquist index greater than one to stay in the competition for another season, while those that have participated for several years, have quite frequently had seasons in which their productivity declined. In short, the influence that the experience acquired through the on-going participation in the UEFA Champions League has on the issues raised in this paper requires more in-depth research, which, on one hand, should take into account that the teams that play in this competition were the highest ranked in their national competitions the previous season. Therefore, the number of seasons that they participate in European competition depends on their success in other tournaments; on the other hand, it may be worthwhile to ascertain whether there is a relationship between experience and productivity changes and which of these two variables influences the other.

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NOTES

[1] This is the reason because the methodology used to estimate isoquants initiated by Farrell (1957) is known as frontier models.

[2] An efficiency change value equal to one could also occur in the event that an organization were inefficient with the same value of λi for all years of the period studied. To determine which of the two possible situations would correspond to an eventual efficiency change equal to unity, it is recommended that the efficiency of the organization under study be calculated for each period.

[3] Values greater than unity for both efficiency and technology change reveal an improvement in the utilization of resources, however, if over the various periods that make up the time horizon these results are combined with Malmquist indices below unity, it would be interpreted as there has not been constant and permanent good use of productive resources.

[4] In the present paper, election of inputs and outputs, choice of returns to scales and so on, are based on the works of Sexton, Silkman and Hogan (1986), Golany and Roll (1989), Triantis (2004) and Cook, Tone and Zhu (2014).