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Production, Efficiency and Corruption in Italian Serie A: A DEA Analysis

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Abstract

This paper uses data from Italian Serie A football to analyse the technical efficiency of Italian football clubs, utilising a panel dataset comprising season aggregated match statistics over ten seasons from 2000/01 to 2009/10 inclusive. While there has been considerable research on production and efficiency in most of the major European football leagues, corresponding evidence relating to Serie A is limited. This paper addresses this imbalance, estimating a production function for the league and the relative efficiency of 36 teams, taking into consideration the impact of the Calciopoli corruption scandal in 2006. To achieve this, Data Envelopment Analysis (DEA) models have been used to calculate the frontiers of efficient production. The results highlight how playing style has changed in response to the corruption scandal, emphasizing the importance of attacking play in Serie A.

Key words: Efficiency, DEA, Sports.

1. Introduction

In Italy, professional football has been historically the largest leisure activity, with vast social and economic importance. During the 2012/13 season, professional football registered a cumulative turnover equal to almost €2.7bn with a direct impact on the Italian economy equal to 0.15 per cent of GDP, and a total contribution of €1.03bn in tax revenues (see [1]). Conversely, Italian professional football has declined constantly and slowly commercial since the early 2000s, due to clubs' rising payrolls, accounted for 90 per cent of total costs since the 2004/05 season and spent to attract worldwide football talent, and a slow revenues' growth compared to the other major European leagues (see [2, 3, 4]). Accounting data revealed an increasing trend in net losses equal to roughly €250m per year, with a seven per cent annual growth rate in operational losses. The total debt of Serie A clubs has increased at a nine per cent growth rate per year; i.e. by over 60 per cent since 2006/07. On the revenue side, while in 2011 media revenues steadily represented around 56 per cent of total revenues, gate revenues were decreasing. Consequently, Serie A clubs have been predictably subject to a high mortality rate. Nine out of 37 Serie A teams went bankrupt from 2001 to 2011 (see [4]).

This paper considers the production function of Serie A Italian football clubs, looking at their technical efficiency to analyse their football performance during the last decade. Starting from an already wide literature built around the notions of "sports production function", this analysis assumes that teams, like other enterprises, adopt a production process, with "output", measured as sporting success, combining different playing and non-playing inputs. Since the seminal studies of Rottenberg and Scully [5] on baseball, a vast literature analysing production functions of sport clubs has been carried out by several scholars. From a management perspective, identifying a production function can properly help chairmen, managers and coaches to manage several issues. It estimates the key determinants of team success and how individual players contribute to that success, helping teams in match selection and preparation, besides tactical decisions and changes. A production function can also determine player salaries, along with recognizing those areas in which a team can improve its future performance, including its playing style and the transfer market strategy to strengthen the football squad. While such considerations can affect an individual club's commercial and financial success, and enhance revenue sources, analysing the production function is also relevant for a sport's organizational structure and managerial decision making. Estimating a production function

for any sporting competition assists the ruling body making an attractive and successful product, seen in terms of public interest, media coverage and revenues, and profitable sponsorship agreements.

This paper contributes to the research strand that clearly concentrates on the straight relationships between on-field team success and the aggregate contribution of players' skills and abilities in terms of their football performance. First, whilst production function investigation for Serie A has been limited, this analysis is based on a panel dataset comprising season statistics for Serie A 36 clubs over ten seasons. Second, the time period and the related data include the seasons when Serie A was discredited by the Calciopoli scandal, which allow us to model the effects of clubs' fraudulent behaviour. Finally, this work estimates the production functions using non-parametric techniques with mathematical models, specifically DEA models, that calculate the frontier efficient production for give productive factors. The empirical results obtained differentiate between offensive and defensive production along a period of 10 seasons and explicitly include the Calciopoli scandal. In this way, we can attempt to answer with greater precision how Italian football has changed and what kind of impact corruption has had on it.

Aside from this introductory part, this paper is structured as it follows. First, a brief review of the existing literature on sporting production functions is provided. Then, the league structure of Italian professional football is explained followed by the key features of the Calciopoli scandal. While the forth part describes the dataset and the model specification used for this paper, the fifth part presents the empirical results obtained with DEA analysis - looking at offensive and defensive efficiencies in Serie A over ten seasons and how these were affected by the Calciopoli scandal. Finally, based on the efficiency analysis as a reference, we provide a plausible explanation of the final ranking, followed by final implications and conclusions.

2. Literature review

From a management perspective, the production function of any organisation is seen as the technical relationship between productive inputs and their relative contribution to output. Rottenberg [6] was the former scholar to conceive that a sports team acts as any other enterprise that offers a product in terms of victory or success, by combining and using different inputs, seen as the skills and other characteristics of the team. Accordingly,

Scully [5] conducted the first empirical study that formally estimated and employed a production function to compare wages and players' marginal revenue product in US Major League Baseball in order to assess the level of monopsonistic exploitation. Since then, this method is recognised as the standard methodology in sporting production function studies (see [7, 8]).

While the early studies involved US-based sports, due to their data-richness with regard to discrete and easily recorded, were able to categorize individual contributions and measurable match play statistics (see, for example, [9, 10, 11, 12, 13, 14, 15, 16, 17]), the relative scarcity of empirical research on other professional sports in different nations is explained by the intrinsic nature of sports that implies significant interaction between teams and complementarity of player contributions within teams, as in the case of rugby and association football(see, for example, [18, 19]). The increased availability and sophistication of quantifiable data, such as the detailed player performance statistics, provide invaluable datasets for analysis. This opportunity has recently favoured the growth of sporting production function studies across sports and continents and the related research strand treating efficiency aspects with various specific applications, particularly featuring the assessment of coaching/managerial efficiency (see [20, 21, 22]).

Sporting production functions can also be distinguished according to selection of output and input measures, the time frame and estimation method. In football, while output is usually measured by points won instead of win percentage (see, for example, [20]), other different measures of output have been utilised including: league position, win rates, and goals or goals difference (see [23, 24, 25, 26]). Regarding match-play inputs, various measures include attacking and constructive plays, aggressive and defensive plays and non-playing aspects, including managerial inputs. Concerning the methods of efficiency analysis, there are two distinct approaches (see, for example, [27]): the econometric stochastic frontier approach based on tools and concepts from regression analysis and the deterministic non-parametric frontier methodology, such as Data Envelopment Analysis (DEA), built on axiomatic properties and mathematical programming techniques.

To summarise, while several studies specifically treating efficiency measurement predominantly examine English and Spanish football (see [23, 24, 25, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39]) with a few using data for Brazil (see [40]), Germany (see [41, 42]) and the US (see [43]), Serie A has been analysed by Boscá et al. [44], who examine efficiency in Italian football over three seasons using DEA, concluding that defensive

efficiency results more significant than offensive efficiency in Serie A. Following Boscá et al. [44], our study incorporates a richer set of direct performance measures that reduces the need to use proxy measures to represent particular aspects, such as defensive performance. Moreover, our dataset focuses on a relatively longer time period, thus includes more observations and clubs involved and covers the seasons when the Calciopoli scandal erupted.

3. The Calciopoli Scandal

Since its establishment in 1898, Serie A represents the top division of Italian football under the supervision of the FIGC, the Italian football association, which manages the operation at professional and amateur levels. Nowadays, Serie A is separately run by Lega Serie A, composed of 20 clubs that compete for the championship title, the so-called "Scudetto". While the Serie A league winner the clubs finishing 2nd and 3rd in the final Serie A table directly take part to the next season's UEFA Champions League, clubs ranked from 4th to 6th places compete in the following season's UEFA Europa League, together with the winner of the domestic knock-out cup competition, the so-called "Coppa Italia".

In 2003 Serie A faced its league restructure (see [45]), when Catania Calcio, a Serie B club, was involved in player eligibility controversy. The dispute led to the expansion of both Serie A from 18 to 20 teams and Serie B from 20 to 22 teams. During the study period from 2000/01 to 2009/10, 33 different clubs in total competed in Serie A and 12 teams achieved a top six position at least once, with four teams featuring in all ten seasons sharing in the championship honours, and three other clubs appearing in the top six on all but one occasion.

Because of poor practice in corporate governance and administration, Italian football has faced numerous major scandals variously linked to doping, fake passports, bribery and match-fixing (see [46, 47, 48, 49]). Arguably the most detrimental and relevant is known Calciopoli in 2006, which erupted shortly before the FIFA World Cup in Germany. Supported by scrupulous investigations, the Italian police discovered a network of close relationships that the involved certain clubs', leagues' and associations' officials influencing the organizational selection and appointment of "amicable" referees for specific matches with the intention of fixing their results (see [45, 50]). Five Serie A clubs - FC Juventus, AC Milan, ACF Fiorentina, SS Lazio and Reggina Calcio - and one Serie B,

AC Arezzo, were involved and received club-level punishments while several officials at different levels were also banned from Italian football for specific periods (see [45]). Amongst the punishments, whilst FC Juventus was demoted to Serie B with a nine point deduction for the following season and retrospectively stripped of its 2004/05 and 2005/06 Serie A titles, AC Milan, ACF Fiorentina, SS Lazio and Reggina Calcio suffered correspondingly eight, 15, 13 and 11 point deductions in the 2006/07 Serie A Season.

Besides the short-lived sporting effects of the clubs' punishments, the Caciopoli scandal widely affected Italian football, with particular regard to attendance figures. During the study period, the Serie A average attendance per match was below than 25,000 spectators; the lowest among the top European leagues. Beside high ticket prices and excessive TV exposure of football, Italian football was also negatively affected by numerous episodes of violence and hooliganism occurring in Italian stadia and in their proximity (see [51]). This negative trend might have also been related to corruption issues highlighted by the Calciopoli scandal that strongly accelerated the decline in gate revenues and deteriorated the balance sheets for all the clubs directly involved (see [52]). Consequently, other teams faced a negative spillover on attendance that was partially compensated by rising income from sales of television broadcast rights.

4. Methodological aspects and data

In association football, match specific or cumulative team success over a season or competition depends on winning performances, which is measured by points won by the positive goal difference between goals scored and conceded (see [32, 53]). In any match, goals scored is fundamentally in function of effective attacking moves, also involving passing play and associated ball possession, culminating in shots on goal, along with the opponent defensive performance. Correspondingly, goals conceded are determined by a combination of defensive skills and opponent attacking plays. Based on these assumptions, an estimating model based on a behavioural equation follows as:

$$S_{it} = S_{it}(A_{it}, D_{it})$$

where S_{it} is the league success for the i^{th} team in season t measured by the number of points won as a percentage of the maximum winnable over the season. A_{it} and D_{it} are vectors of attacking play, particularly shot making, and other constructive and defensive play respectively. This approach reveals which technical aspects of football performance

are taken into consideration for football success and, consequently, the reasons one team is more successful than others.

Another assumption is that, although the levels of efficiency and productivity differ between clubs, as their management and organisation structure varies, the levels of technology in terms of football tactics, trainings and physical preparation are similar and homogenous for all clubs. In this context, as argued by Boscá et al. [44], non-parametric methodology, specifically DEA models, is the most suitable optimisation technique, as it provides great flexibility and an absence of specification errors because no particular functional form is needed. Conversely, the disadvantage of being technically deterministic results in the bias of the efficiency results and the attribution of any random shocks to inefficiency due to the presence of atypical observations.

Moreover, our analysis distinguishes between offensive and defensive production to calculate separately offensive and defensive efficiency indicators, as the measurement of output combines offensive productivity (goal-scoring) with defensive efficiency (preventing goals). As a result, we combine inputs as of indicators of each club's offensive and defensive ability in line with their expected signs in the regressions and, then, we calculate the frontier of efficient production. The analysis of offensive and defensive efficiency uses the DEA model[1] that looks at the input-output of the teams with highest outputs per each input, and compares the productivities of the remaining teams with these.

In relation to the choice of the inputs for the analysis of production function and frontiers, the data used in this paper has been supplied by Digital Soccer - the official data supplier of Lega Serie A - and a wide variety of match performance data has been included and used in our analysis of offensive and defensive efficiency of Italian football teams during a period of ten Seria A seasons from 2000/01 to 2009/10. Table 1 summarise the dataset for a varied mix of performance indicators at aggregated club level. As the number of teams participating has changed from 18 to 20 since 2004/05 season, the table shows the average and the standard deviation for the different output and input measures standardised for the number of games played. Nevertheless, despite the ten season data period, the maximum number of observations recorded in any one season is limited to 20 teams.

[1] It is based on GAMS with CPLEX solver.

Table 1: Offensive and defensive inputs in the Italian Serie A (2000-2010)

Variables	*Mean*	*Std. Dev.*	*Min.*	*Max.*
Offensive inputs per game				
Goals	1.303	0.341	0.617	2.236
Shots	13.073	2.076	9.21	19.868
Shots on target	4.94	0.968	2.911	10.342
Assists	0.83	0.256	0.294	1.473
Conattacks	0.014	0.002	0.005	0.02
Cross completed	3.739	0.769	1.921	5.578
Cross rates	0.006	0.0007	0.003	0.008
Crosses	16.79	2.813	10.65	24.41
Passes completed	311.9	54.23	96.02	476.18
Totch	536.65	55.68	399.32	710.71
Useful dribbles	8.348	2.084	3.973	14.91
Defensive inputs per game				
Goals conceded	1.303	0.293	0.558	2.058
Opponents off-sides	3.148	1.044	1.289	6.421
Clearances	4.062	1.007	2.029	8.558
Interceptions	100.94	7.317	81.65	121.39
Anticipations	17.25	3.504	9.947	31.08
Recovered balls	160.18	12.27	132.21	188.79
Gcgksv	0.012	0.002	0.006	0.028
Saves	3.286	0.535	1.617	4.705
Goalkeepers catches	7.204	0.959	4.5	9.382
Tackles	19.806	2.85	12.97	29.08
Yellow cards	2.154	0.433	0.263	3.105
Red cards	0.157	0.0723	0.026	0.5
Fouls committed	19.617	2.563	13.44	27

In order to utilise the dataset more efficiently, the number of independent variables is reduced by creating composite variables to reflect implicitly latent and unobserved aspects of overall playing performance, thereby decreasing degrees of freedom and eventually reducing problems linked to multicollinearity that could lead to instability in the parameters' estimates. Traditionally, researchers have used their knowledge of the sport in question, but this approach certainly implies an element of subjective judgement in the weighting of the components. In our case, we have included objective technical indicators that offer the most accurate idea of the teams' quality, structure and game style. Our choice of attacking and defensive inputs has been based on careful considerations and justifications. First, all the selected inputs were correlated and statistically significant with the relevant output measure accordingly. Secondly, those inputs that were highly correlated with other similar inputs were discarded. Thirdly, we also eliminated those potential inputs that are subject to randomness, hazard or luck. Then, we ran regressions using the equations in function of the remaining and respective offensive and defensive inputs. The selected inputs are generally (but not necessarily) statistically significant (at uni- and multivariable analyses) and positively correlated with the relevant offensive and defensive output measures. Finally, similar input measures were used in other studies that estimate parametric football production functions. Following these criteria, the chosen inputs reasonably resemble well the attacking

or defending collective and/or individual quality of football teams. Five offensive inputs and five defensive inputs were chosen respectively: shots, counter attacks, crosses completed, passes completed, and useful dribbles; saves, anticipations, tackles, clearances and opponents' offside.

5. Offensive and defensive efficiency and classification

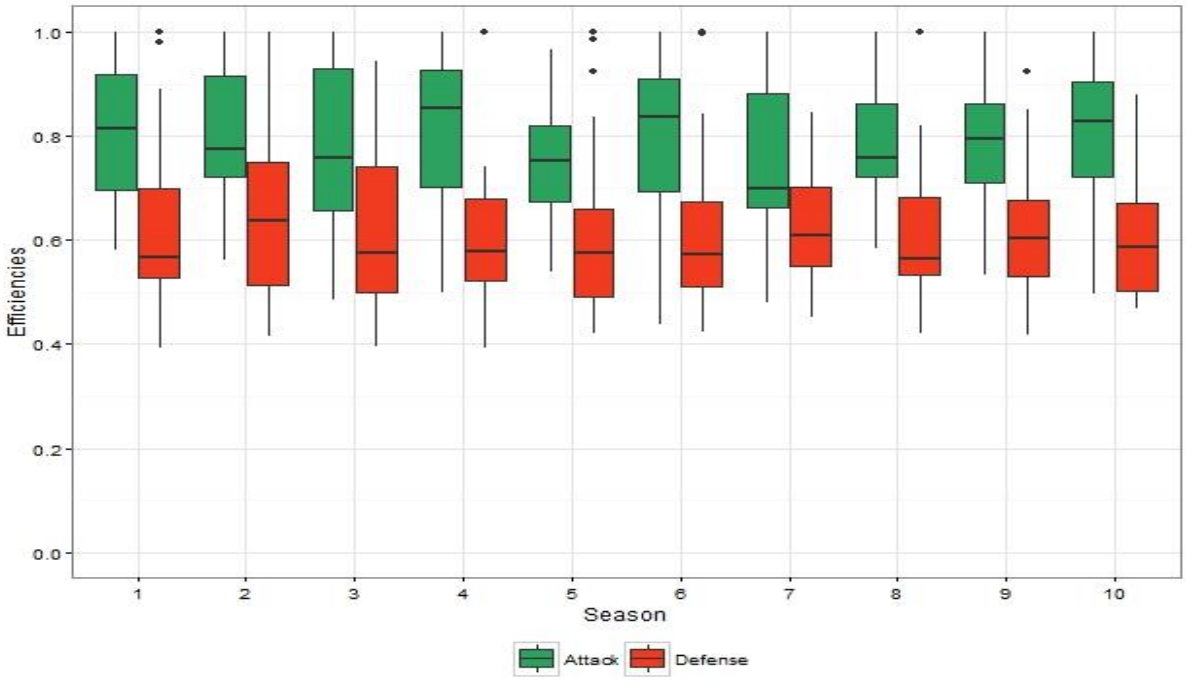
In this part, we present the results obtained with the DEA models on offensive and defensive efficiencies based on the inputs and outputs selected. In Table 2 below, we provide the mean and standard deviation of offensive and defensive efficiencies for each season and some preliminary findings can be extrapolated, and Figure 1 display the box plots over the 10 seasons.

Table 2: Average offensive and defensive efficiencies in the Italian Serie A (2000-2010)

Season	*Offensive efficiency*		*Defensive efficiency*	
	Mean	*Std. Dev.*	*Mean*	*Std. Dev.*
2000/01	0.816	0.128	0.636	0.175
2001/02	0.802	0.138	0.656	0.176
2002/03	0.782	0.159	0.617	0.159
2003/04	0.803	0.176	0.614	0.174
2004/05	0.753	0.113	0.623	0.177
2005/06	0.789	0.157	0.618	0.163
2006/07	0.743	0.133	0.631	0.115
2007/08	0.785	0.128	0.610	0.135
2008/09	0.785	0.136	0.615	0.135
2009/10	0.807	0.141	0.605	0.117

Firstly, on average, the indicators for defensive efficiency among Italian teams are lower than those for the offensive efficiency along the ten seasons, implying that the "average team" was closer to the frontier of offensive efficiency than to that of defensive efficiency. However, the standard deviation of defensive efficiency created greater differences between Italian teams than offensive efficiency. These results are in line with Boscá et al. [44]. Secondly, over the ten season period both offensive and defensive efficiencies have fluctuating trends. In other words, we see a change in clubs' efficiencies in Italian football. Thirdly, season 2006/07 after the Calciopoli scandal registers the lowest levels of offensive efficiency with the standard deviation of offensive deficiency higher than defensive efficiency. This might lead to the argument that clubs became less offensive efficient, taking into consideration the point deductions of some clubs and the relegation of FC Juventus, the most successful team in Serie A.

Figure 1: Offensive and defensive efficiencies' box plot in the Italian Serie A (2000-2010)



To support our DEA analysis about the relative average behaviour of teams in Italian football, Table 3 provides simple correlations between offensive and defensive efficiencies, between offensive efficiency and points, and between defensive efficiency and points. We use the number of points won as a percentage of the maximum winnable over the season, POINTS%, as since the season 2004/05 Serie A expended from 18 to 20 clubs.

Table 3: Pearson correlation coefficients between points and indicators of offensive and defensive efficiencies in the Italian Serie A (2000-2010)

Season	*Offensive efficiency and defensive efficiency*	*Offensive efficiency and points*	*Defensive efficiency and points*
	ρ	ρ	ρ
2000/01	0.262	0.595^{***}	0.753^{***}
2001/02	0.587^{*}	0.592^{***}	0.651^{***}
2002/03	0.557^{**}	0.777^{***}	0.823^{***}
2003/04	0.346	0.673^{***}	0.799^{***}
2004/05	-0.119	0.349	0.620^{***}
2005/06	0.529^{**}	0.808^{***}	0.802^{***}
2006/07	0.408^{**}	0.766^{***}	0.773^{***}
2007/08	0.460^{**}	0.782^{***}	0.747^{***}
2008/09	0.500^{**}	0.825^{***}	0.676^{***}
2009/10	0.129	0.673^{***}	0.619^{***}

Note: ***, **, *, statistically significant with p<0.001, <0.01 and <0.05, respectively.

An interesting point found in the table above is that the correlations between offensive and defensive efficiency have been generally found positive in all but one season (2004/2005): in five season the correlation coefficient was statistically significant at p<0.05. This indicates that, in general, those Serie A teams that are relatively efficient offensively are also efficient defensively and vice-versa. This is also confirmed by the correlation between

indicators of efficiency and points won in all the season (0.69 for attack efficiency, 0.72 for defensive efficiency, both statistically significant at $p<0.001$). However, we can notice that, while at the beginning of the last decade, the greatest correlations were scored between points won and the indicator of defensive efficiency, an opposite scenario is found at the end of decade, when the correlation between points won and the indicators of offensive efficiency have been generally higher since season 2005/06. This finding might reveal that, in Italy, there has been a change of tactical paradigm within the top league Serie A, where a good attack has become a necessary condition to obtain the greatest number of points, indicating that a team has to be more offensively, rather than defensively, efficient to win the Italian championship, or avoid relegation to Serie B.

It is possible to use regression analysis to further explain the points obtained by teams during a season with different efficiency indicators and we can attempt to understand with greater precision how Italian football changed in the last decade and the impact of Calciopoli scandal in terms of defensive and offensive efficiencies.

To check this possibility, Table 4 present the results of linear regressions for the ten league champions in Italy that explain the points obtained by teams during a season in relation to the different efficiencies. There are several general points that should be highlighted, inthat the general tendencies for the Italian league have changed. By looking at the regressions' results, we can confirm that, to explain points won along the ten seasons, the difference between coefficients associated with general defensive efficiency and general offensive efficiency moves from positive to negative. In particular, this is notable since the season 2004/05 when Serie A expanded from 18 to 20 clubs and the coefficient associated with general offensive efficiency of 1.47 (95% CI [0.41; 2.53]) is roughly similar to that of defensive efficiency of 1.41 (95%CI [0.73; 2.08]). Since then, the trend of offensive efficiency has become higher than the trend of defensive efficiency. An increase in defensive efficiency by 10 per cent will imply a gain ranging between 0.140 and 0.217 points per game, depending on the concrete championship we look at. These figures range between 0.101 and 0.194, if we look at the coefficients estimated for the general offensive efficiency variable. Thus, for an Italian team, the popular maxim, the best attack begins with a good defence, does not hold.

Table 4: Points and efficiency indicators in the Italian Serie A season by season (OLS estimates)

	Dependent variable: Points%									
	2000/01	*2001/02*	*2002/03*	*2003/04*	*2004/05*	*2005/06*	*2006/07*	*2007/08*	*2008/09*	*2009/10*
Constant	-0.752*	-0.213	-0.512**	-0.843***	-0.650	-1.64**	-1.378***	-0.960***	-0.809**	-1.050***
Offensive efficiency	1.391**	1.010	1.212***	1.297**	1.470**	1.676***	1.820***	1.784***	1.946***	1.647***
Defensive efficiency	1.528***	1.158*	1.481**	1.878***	1.407***	1.685***	2.176***	1.493**	1.063*	1.792***
R^2	0.737	0.489	0.825	0.817	0.597	0.867	0.842	0.803	0.774	0.741
Number of observation	18	18	18	18	20	20	20	20	20	20

Note: ***,**,*, statistically significant with p<0.001, <0.01 and <0.05, respectively.

However, if we look at these results in more detail, we can see that there remain some interpretative problems. For example, in the regression to explain Italian points won in the 2006/07 season, a general coefficient of defensive efficiency of 2.17 is obtained, resulting in the highest level along the ten years. This peculiar result can be linked to the fact that the season 2006/07 was when the Calciopoli scandal decisions were inflicted as we test in the next part.

6. Evaluation of football technical efficiency

To assess the impact of the Calciopoli scandal, we hypothesize that the relationship between underlying performance and success should be less well captured in an estimation that incorporate the points deducted in the 2006/07 season in the dependent variable as a result of the scandal, as this measure of success is in some sense artificial. Following Carmichael, et al. [54], we estimate additional versions of the previous regression equation along the ten seasons with the aim to examine whether clubs' performance was at all affected by their punishment for 2006/07. In particular, to take account of the team effects we have used a mixed model with a random intercept for team as shown in Table 5.

Estimations 1 and 2 are the specifications that assess the impacts of Calciopoli through a transformed dependent variable. In estimation 2, is Points% (with deduction) is the dependent variable and the results are very similar to those in estimation 1. The larger absolute size of the coefficient on the attacking measure relative to the measure of defensive performance suggests that attacking play results important determinant of league success overall in both estimations

Table 5: Multilevel linear regressions between points and indicators of offensive and defensive efficiencies in the Italian Serie A (2000-2010)

	Dependent variable 2000/01-2009/10	
	Points% (1)	*Points%* (with deduction) (2)
Offensive efficiency	1.185***	1.157***
Defensive efficiency	1.146***	1.126***
2001/02	0.039	0.035
2002/03	0.084	0.078
2003/04	0.052	0.048
2004/05	0.088	0.083
2005/06	0.085	0.080
2006/07	0.130*	0.072
2007/08	0.062	0.056
2008/09	0.090	0.085
2009/10	0.058	0.053
LR test	57.10***	54.94***
Number of observations	192	

Note: ***, **, *, statistically significant with p<0.001, <0.01 and <0.05, respectively.

However, in estimation 2, both coefficients of the efficiencies decrease, but this is stronger for the offensive efficiency than for the defensive efficiency. In other words, the points deductions had a higher impact on offensive efficiency than on defensive efficiency. Accordingly, the overall significance of the estimation is weaker, according to the Wald statistics. This is consistent with the hypothesis that the transformed variable, incorporating as it does the artificiality of the points deduction, provides a less accurate representation of performance.

We use our results to rank the Serie A clubs in terms of their offensive and defensive efficiency performance in the league over the ten seasons. These rankings, showed respectively in Table 6 and Table 7 below, help us to explain teams playing behaviour in relation to the league final classification. If a team is very efficient offensively and defensively, then it usually obtains a high final league ranking as the table shows. Although the strong correlation between the two rankings is pretty robust, as we also highlighted in Table 3, there are some interesting cases in the rankings. For example, Roma in season 2008/09 and Livorno in season 2004/05 appear not to have made more efficient use of its defensive resources than its average league rank. Conversely, Parma in season 2000/01 was highly efficient defensively compared to the other teams present in the ranking. Interestingly, Chievo in season 2001/02 appears to have had their defensive and offensive potential to achieve a higher overall ranking than other top Italian clubs along the decade.

Table 6: Offensive efficiency ranks (2000-2010)

Team	*Season*	*Top 10*	*League position*	*League points*	*Team*	*Season*	*Bottom 10*	*League position*	*League points*
Inter	2007/08	1.000	1	91	Treviso	2005/06	0.438	19	21
Roma	2003/04	1.000	2	71	Torino	2006/07	0.481	16	40
Chievo	2001/02	1.000	5	54	Torino	2002/03	0.484	18	21
Milan	2008/09	1.000	3	74	Livorno	2009/10	0.496	20	29
Milan	2005/06	1.000	2	88	Empoli	2003/04	0.498	17	30
Roma	2000/01	1.000	1	75	Modena	2003/04	0.518	16	30
Juventus	2007/08	1.000	3	72	Ancona	2003/04	0.519	18	13
Inter	2006/07	1.000	1	97	Lecce	2005/06	0.528	18	29
Juventus	2008/09	1.000	2	74	Siena	2008/09	0.533	14	44
Inter	2002/03	1.000	2	65	Reggina	2008/09	0.547	19	31

Table 7: Defensive efficiency ranks (2000-2010)

Team	*Season*	*Top 10*	*League position*	*League points*	*Team*	*Season*	*Bottom 10*	*League position*	*League points*
Inter	2007/08	1.000	1	91	Bari	2000/01	0.391	18	20
Roma	2003/04	1.000	2	71	Brescia	2003/04	0.392	11	40
Chievo	2001/02	1.000	5	54	Reggina	2002/03	0.394	14	38
Milan	2003/04	1.000	1	82	Ancona	2003/04	0.407	18	13
Juventus	2001/02	1.000	1	71	Udinese	2001/02	0.415	12	38
Juventus	2005/06	1.000	1	91	Roma	2008/09	0.419	6	63
Milan	2004/05	1.000	2	79	Parma	2007/08	0.421	19	34
Parma	2000/01	1.000	4	56	Livorno	2004/05	0.421	9	45
Juventus	2000/01	0.982	2	73	Perugia	2003/04	0.423	15	32
Juventus	2002/03	0.943	1	72	Sampdoria	2005/06	0.423	12	41

To better analyse the behaviour of the clubs involved in the Calciopoli scandal, Table 8 and Table 9 compare respectively the offensive and defensive efficiency rankings of the sub-set of 20 teams that competed in season 2005/06 and season 2006/07. Apart from Reggina Calcio, all the other teams involved in the Calciopoli scandal scored higher level of offensive efficiency in season 2005/06 than in season 2006/07 as shown in Table 8. While in the 2005/06 season ACF Fiorentina and AC Milan were the most efficient teams defensively and Lazio was ranked 6th, the same teams had a worse offensive efficiency performance the following year when the points deductions were inflicted. Only Reggina Calcio registered an increase of offensive efficiency that was the highest achieved along the ten seasons. Being always involved in the battle to avoid relegation, the club might have understood that the best strategy was to adopt a more highly offensive playing style to recover the points deduction.

In Table 9, we see an opposite scenario. Except for AC Milan, all the clubs involved in the scandal improved their defensive efficiency in the season after the Calciopoli scandal. In particular, these clubs also registered the highest level of defensive efficiency along the ten seasons period.

Table 8: Offensive efficiency ranks (2005-2007)

Club	Offensive efficiency 2005/06	Club	Offensive efficiency 2006/07
Juventus	0.916	Inter	1
Milan	1	Roma	0.936
Inter	0.851	**Lazio**	0.892
Fiorentina	1	**Milan**	0.692
Roma	0.942	Palermo	0.821
Lazio	0.909	**Fiorentina**	0.891
Chievo	0.954	Empoli	0.692
Palermo	0.734	Atalanta	0.890
Livorno	0.832	Sampdoria	0.742
Parma	0.844	Udinese	0.704
Empoli	0.842	Livorno	0.685
Ascoli	0.745	Parma	0.647
Udinese	0.682	Catania	0.736
Sampdoria	0.644	**Reggina Calcio**	0.880
Reggina Calcio	0.865	Siena	0.613
Cagliari	0.790	Torino	0.408
Siena	0.698	Cagliari	0.595
Messina	0.572	Chievo	0.667
Lecce	0.528	Ascoli	0.688
Treviso	0.438	Messian	0.604

Note: The teams are ranked according to their final league ranking. In bold, teams involved in Calciopoli scandal.

Table 9: Defensive efficiency ranks (2005-2007)

Club	Defensive efficiency 2005/06	Club	Defensive efficiency 2006/07
Juventus	1	Inter	0.795
Milan	0.843	Roma	0.788
Inter	0.998	**Lazio**	0.796
Fiorentina	0.717	**Milan**	0.474
Roma	0.589	Palermo	0.679
Lazio	0.660	**Fiorentina**	0.844
Chievo	0.603	Empoli	0.638
Palermo	0.493	Atalanta	0.483
Livorno	0.732	Sampdoria	0.548
Parma	0.523	Udinese	0.575
Empoli	0.512	Livorno	0.552
Ascoli	0.573	Parma	0.543
Udinese	0.515	Catania	0.451
Sampdoria	0.423	**Reggina Calcio**	0.578
Reggina Calcio	0.535	Siena	0.624
Cagliari	0.505	Torino	0.685
Siena	0.579	Cagliari	0.671
Messina	0.478	Chievo	0.592
Lecce	0.573	Ascoli	0.562
Treviso	0.505	Messian	0.479

Note: The teams are ranked according to their final league ranking. In bold, teams involved in Calciopoli scandal.

A plausible explanation to the case of AC Milan is that the club received the highest points deduction and it was also competing for the UEFA Champions League. In this situation, the club was aware that its chance for the Serie A title was almost null and that the only ambition for the season was to qualify for the next UEFA Champions

League. Thus, out of the five Serie A teams implicated in Calciopoli, ACF Fiorentina, Reggina Calcio and SS Lazio appeared to have accrued points more efficiently in defense in 2006/07 than they did along the other seasons and this might be indicative of the impact of the points deductions. These results corroborate the main finding of our analysis. In the Italian top professional football league, we have assisted to a change of playing style.

7. Summary and conclusions

This paper has focused on the on-field performance of Serie A football clubs to analyse their production function and technical efficiency over the last decade. Based on DEA methods of optimization, which calculate the frontier of efficient production given available productive factors, attacking and defensive playing performance were modelled as inputs in the production of league level success. For this reason, the empirical results have been obtained distinguishing between offensive and defensive production. The analysis included those seasons scarred by the Calciopoli scandal to assess the impact of points deductions on the production and efficiency of the implicated clubs in the estimating model. Specifically, the impact of the Calciopoli scandal was modelled by creating an alternative dependent variable.

Some of the most interesting results are summarised here. Firstly, our results partially confirmed Bosca et al.'s [44] results that in Italy an efficient defence was the best way to obtain the most points. However, since the 2005/06 season, this trend has not remained stable along the ten seasons analysed. In fact, according to our estimations, increasing offensive efficiency pays more than increasing defensive efficiency. Our study suggests that to obtain a high ranking in the league, it is much more important to be offensively, rather than defensively, efficient in Italy, as the contribution of offensive performance is of greater significance than that of defensive performance.

The efficiency terms extrapolated from the DEA were also used to evaluate Serie A clubs in terms of their efficient conversion of performance into points. If we look at these results, the punishments imposed on the implicated clubs in Calciopoli do appear to have affected actual defensive and offensive performance. At least three of these clubs – Reggina, Lazio and Fiorentina – appear to have outperformed defensively relative to season 2005/06, where they were judged to have cheated, and subsequent seasons. Conversely, Reggina was the only club to increase its offensive efficiency, while AC Milan underperformed both defensively and offensively compared to the previous season. This evidence suggests that

these clubs took short-term decisions away from their usual tactical behaviour and presumably they adopted different playing strategies to compensate for the impact of the points deductions.

Looking at our results we might argue that many Italian clubs, which were used to spending so much money on good offensive and defensive players, might have also faced the loss of competitive advantage, that Serie A benefited in the past, at expenses of other European leagues. This might have also affected the transfer market strategies of Italian clubs and consequently their playing style. The above results might suggest a rigorous cost-benefit analysis of this change and the temptation of adopting corruptive behaviour in professional football. Clubs such as Juventus and AC Milan have budgets that are usually several times larger than any medium or small club and their player transfer market continues to expand these differences in the relative values of defending and attacking players. If we include these financial gaps between clubs, relative differences might be greater than those measurable by any indicator of offensive and defensive efficiency. This aspect can be related to how costly the adoption of fraudulent behaviour can be to individual clubs and the league as whole, as the increasing costs associated with relegation, or the loss of competing in European cups, might have relevant impact on clubs' financial stability and this might provide incentives to adopt fraudulent behaviour.

To conclude, further research should expand its horizon to include more European leagues. This comparative approach might provide interesting findings and better explain how clubs' strategies and tactics vary league by league, as we always assume that football in each country is inspired and affected by different social, cultural and economic factors.

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