The Productive Efficiency of Football Teams in the Italian Serie A.

The relation between Efficiency and Market Value.

Master Thesis

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Abstract

This study investigates the Efficiency of football teams in the Italian Serie A for the 2010-2016 seasons, and analyses the link between these efficiencies and the Market Value of the teams. The efficiencies are produced with the use of the stochastic frontier model, along with an optimal number of points achievable per team per season(Frontier Points).

The Total Shots Rate, Shots on Target, Pass Success, Shots Blocked and the number of Players Used prove to be important influences on the number of points a team can optimally achieve.

The Efficiency analysis shows that the average Efficiency of all teams throughout the dataset is high, that the big clubs in general perform at a higher Efficiency than the smaller clubs, and that Napoli could have been champion of Italy for the 2015-2016 season if they would have performed at average Efficiency. The results additionally suggested a possible impact of Market Value on Efficiency.

Further analysis resulted in proof of an impact of both Efficiency and Frontier Points on the Market Value of a club, where the impact of Frontier Points proved to be bigger than the impact of Efficiency.

Keywords: *Football, Serie A, Efficiency, Frontier Points, Stochastic Frontier Analysis, Market Value.*

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I. Introduction.

It has become a well-known phenomenon in the world of football, a conservative but highly efficient playing style. Over the years, people have enjoyed the attractive football of teams as Barcelona and Bayern Munich. However, these are notably affluent clubs, meaning that they can buy the best players possible to enhance their dominant playing style. Nowadays, for the somewhat smaller clubs with smaller resources, it has become a popular choice to rely on defence first and playing as efficient as possible when possession of the ball is gained.

It is no coincidence that last season, Leicester City became champion of the English Premier League and Atletico Madrid ended at the third place of the Spanish Primera Division, even though Leicester ranked 18th out of 20 (Premier League Team Statistics) and Atletico ranked 10th out of 20 (Primera Division Team Statistics) in their leagues regarding actual possession of the ball.

This shows that possession of the ball has become less important. Meanwhile, the defensive structure of the team and the goals scored with the possession that is acquired, have become a big part of today's playing style. The extent to which in-game-statistics like shots and passes are converted into goals and eventually into points, can be seen as Efficiency. Efficiency has always been, but is becoming an even more important aspect of football.

This paper studies the productive Efficiency of football teams in the Italian Serie A. Economic, and in particular financial models, are applied to a wide variety of sports nowadays (Espitia-Escuer & Garcia-Cebrian, 2004). In these studies, sports players, teams or even coaches are viewed as producers and their results as products (Carmichael & Thomas, 1995). With econometric methods, one can estimate their 'production function', and analyse the Efficiency.

These analyses are relevant for choices as to which player to buy, how to distribute playing time and which aspects of play to focus on with regard to tactics. Furthermore, in a sport where the presence of money is so pronounced, it is interesting to investigate the financial implications of Efficiency.

This study sets out to investigate the productive Efficiency of football teams in the Italian Serie A over the seasons 2009-2010 to 2015-2016, and subsequently looks into the possibility that there is a link between Efficiency and the Market Value of a team.

To do so, this paper formulates a production function soothing for Italian football teams. The approach used in this research is the stochastic frontier model, where the number of points depends on seven in-game statistics including Pass Success and Shots on Goal. The outputs from the frontier model, which are the optimal number of points achievable, are compared to the actual number of points of the football teams to compute the Efficiency. After computing these measures, their link with the Market Value of the clubs is investigated.

Firstly, the literature and methodology on sports' production functions is discussed in Section II. In Section III, background information is provided on the Italian Serie A along with a discussion of the literature on this subject. The stochastic frontier model is presented in the first part of Section IV, while the second part of Section IV clarifies how the link between Efficiency and the Market Value is studied. The results concerning both the Efficiencies of Italian football teams and their relation to the Market Value of these teams are presented in Section V. Section VI holds the conclusion of this paper and points out the implications and possible limitations of this study, along with possible opportunities for further research.

II. Production functions.

The application of production functions on professional sport teams, instead of on economic firms, has become more popular in recent years. Nevertheless, this line of research already originates from the 1960's.

Rottenberg(1956) was the first to come up with the idea that the operations of professional sport teams could be represented as a production function. He performed an economic analysis of the labour market in major-league baseball (Rottenberg, 1956).

The first person to actually estimate a production function that related sports' teams output to a selection of team input variables was Scully (1974). He studied monopsony exploitation in US baseball with a methodology based on forming an average function of production, and his model became the standard model for much of the subsequent work in this area (Scully, 1974). This method will be described later on in this section.

Following these studies, efforts in this area of research increased. For example, Zech (1981) and Chapman & Southwick(1991) estimated production functions in the major league baseball competition. In his paper, Zech tried to identify which factors contribute to team success, empirically estimating the effect of each factor and subsequently constructing a measure of the league's most valuable player (Zech, 1981). Chapman & Southwick(1991) set out to test the job-matching hypothesis offered by (Jovanovic, 1979) and others, in major league baseball (Chapman & Southwick, 1991).

Porter & Scully (1982), on the other hand, focused more on managerial efficiency. They studied managerial efficiency by manager and by firm, managerial marginal revenue product, the rate of change in managerial efficiency over years of experience and relative factor price efficiency for baseball teams over the period 1961-1980 (Porter & Scully, 1982). Studies on production functions of sport teams, also spread towards other sports, including American football.

Atkinson, Stanley & Tschirhart(1988) used data from the National Football League (NFL), to examine how well revenue sharing explained the behaviour they observed in this league (Atkinson, Stanley, & Tschirhart, 1988). In turn, Hoefler & Payne (1996) were the first to investigate efficiency of professional (American) football teams, and present results about how close to their offensive potential teams in the NFL play (Hoefler & Payne, 1996).

In relating the output of sports teams to a variety of inputs, and subsequently measuring the efficiency of these teams, there are several approaches to choose from. These approaches are discussed in the following paragraphs.

Average function of production.

This method involves the estimation of a regression in which the dependent variable is the measure of production/success. In sports, the number of points/wins is often taken for the dependent variable. This dependent variable is affected by a number of other variables that influence the measure of success, like player ability or coaching skills. These variables are the independent variables in the production function.

As previously stated, Scully (1974) provided the foundation for much of the subsequent work on constructing production functions and eventually measuring efficiency. In his study, he formed an average function of production. This production function looked like this:

$$W = W(A_1, A_2, \ldots, A_n, I_1, I_2, \ldots, I_m)$$ (Scully, 1974)

In which W is team success defined as percent wins. This W is related to two vectors of inputs:

- a vector of player skills Ai
- a vector of non-player inputs Ij and more unclear inputs such as team spirit.

This approach was adopted by several authors studying production functions and efficiency for a number of different sports. Ball games involving two teams that can score points in one or more different ways, are very similar to football, (on which this study is focussing). These similar sports are only different to football in the way that points are scored, and the variables that affect them. Schofield(1988), for example, developed this method to estimate production functions for English country cricket for the Country Championship and the John Player League in the seasons 1981-1983, and was the first and still the only one in doing so for cricket (Schofield, 1988). He presented the following multiple equation system:

$$\text{Captaincy } (P_1) = P_1(Z) \quad (1)$$
$$\text{Fielding } (P_2) = P_2(Z, P_1, W) \quad (2)$$
$$\text{Batting } (P_3) = P_3(Z, P_1, W) \quad (3)$$
$$\text{Bowling } (P_4) = P_4(Z, P_1, P_2, W) \quad (4)$$
$$\text{Success } (S) = S(P_1, P_2, P_3, P_4, W) \quad (5)$$ (Schofield, 1988)

Where W is the weather and Z is the set of performance influencing factors like player ability, form, experience and coaching skills.

Carmichael & Thomas (1995) adopted this methodology and translated it to rugby. They formulated a production function for Rugby League Football using performance influencing- and performance related variables as input data (Carmichael & Thomas, 1995).
About six years later, and most relevant regarding this paper, these authors teamed up with Robert Ward and followed the average function of production-methodology to try and estimate a production function for English Premiership football (Carmichael, Thomas, & Ward, 2001). With this study, they tried to move the focus of research on sport's production functions from US-based sports like baseball to football. The introduction of the OPTA-Index provided them with enough data to perform the study, where a shortage of data on football previously prevented researchers to study production functions in this sport. Their multiple equation system looks as follows:

$$\text{PPOINTS} = f\,(\text{total goals scored, total goals conceded}), \qquad (1)$$

$$\text{GC} = f\,(\text{defensive weaknesses, attacking performance by opposition}), \qquad (2)$$

$$\text{GS} = f\,(\text{shot attempts on opposition goal}), \text{ and} \qquad (3)$$

$$\text{SH} = f\,(\text{touch of ball possession}). \qquad (4)$$

(Carmichael, Thomas, & Ward, 2001)

Where PPOINTS is the total number of points achieved during the season as a percentage of the maximum number of points possible. This equation system shows that, in football, points can only be scored in one way (both by the own – and the opposing team). This is the main difference with other ball sports like rugby, where there are various ways of scoring, which can be rewarded by a different number of points per scoring manner.
An interesting conclusion of this study is the finding that the effect of accurate passing on the scoring of goals is of particular significance. Furthermore, the quality of possession in all its manifestations (e.g. passing accuracy, dribble success) is shown to be of greater importance than the quantity of possession (Carmichael, Thomas, & Ward, 2001).

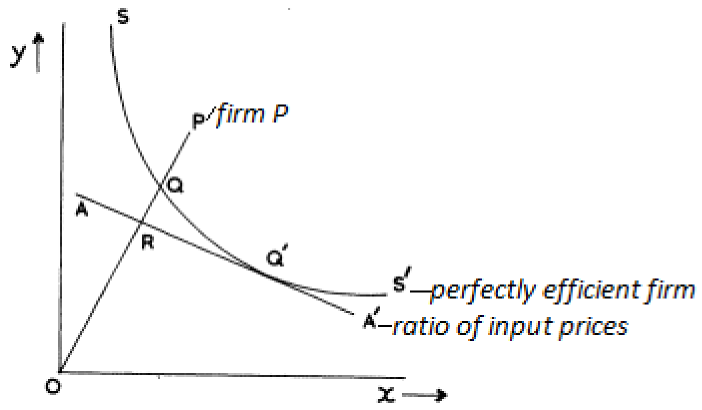
Nonparametric frontier/DEA.

The other methods discussed in this section will be so-called frontier methods. The word frontier comes from the fact that a production function provides the maximum possible output from given quantities of a set of inputs. So there can be points below the production frontier when firms produce less than this maximal possible output, but there can be no points above this production frontier. The amount by which a firm lies below its production frontier can be seen as a measure of inefficiency (Førsund, Lovell, & Schmidt, 1980).

The DEA, or data envelopment analysis, is a method for measuring efficiency of 'Decision Making Units' (DMU's) with linear programming techniques to find optimal input-output combinations. Multiple inputs and outputs can be looked at simultaneously, without having to make assumptions about their distributions. With the DEA-model, efficiency is measured as a deviation in inputs or outputs from the line of optimal input-output combinations. The model can minimize inputs for given levels of outputs, or maximize outputs for certain levels of inputs (Ji & Lee, 2010).

The DEA was originally developed by Farrell (1957). He showed the basics of this model in what he called 'the simple case'. This case considers a firm using two inputs x and y to produce a single unit of output z (one product). He assumes this firm produces under conditions of constant returns to scale. These assumptions allowed him to provide the following isoquant diagram:

Figure 1. Efficiency measures



(Farrell, 1957, p. 254

* *x* and *y* are the two inputs which are used to produce units of output *z*.

Here, point P is the amount of x and y the firm is observed to use to produce one unit of z. The isoquant SS' represents the possible combinations that a perfectly efficient firm would use to produce one unit of output. If such an efficient firm uses the factors x and y in the same ratio as P, it moves to point Q. The figure shows that this firm then produces the same output as P using only OQ/OP of each input, so OQ/OP can be seen as the technical efficiency of firm P.
If AA' represents the ratio of input prices, then the cost of point R is the same as that of the price efficient point Q', and less than the cost of the technically efficient but price inefficient point Q. Therefore, the ratio OR/OQ is the price efficiency of Q. Finally, OR/OP measures total efficiency, because for a perfectly efficient firm (both technically and with prices) the costs would be a fraction OR/OP of what they actually are.

Nevertheless, the mathematical formulation is indicated by Farrel (1957) to be a more important aspect of this method than the graphical isoquant as shown before. Therefore, these mathematical formulations are discussed below for some of the papers that use the DEA method.

Mazur (1994) used the data envelopment analysis method to offer objective rankings of individual baseball player performance (Mazur, 1994), while Anderson & Sharp(1997) used this method to create an alternative to traditional batting statistics called the Composite Batter Index (CBI). These CBI scores were calculated for the years 1901 to 1993 in both the American and National Leagues with the following DEA-formula:

$$\begin{aligned} &\text{minimize} && \Theta, \\ &\text{subject to} && Y\lambda \geq Y_0, \\ & && \Theta X_0 \geq X'\lambda, \\ & && \Theta \text{ free}, \quad \lambda \geq 0. \end{aligned} \qquad (1)$$

(Anderson & Sharp, 1997)

Where Θ is a productivity/efficiency-ranking for each player to indicate their relative efficiency when compared to the rest of the league, between 0 and 1. Input X is the number of plate appearances, output Y is the number of walks singles, doubles, triples and home-runs and vector λ describes the combination of league leaders which do better or as good as the player studied.
In short, a Θ of 0.8 means that there are other hitters in the league who could generate at least the same output in 20% less place appearances (Anderson & Sharp, 1997). The first criterion of this DEA model states that the league leaders, described by vector λ, will have at least as much output Y as the observed player with the same input X. The second criterion states that the player studied, in general, will need at least as much input as the league leaders, to produce the same output.

The DEA approach was also used to measure efficiency in other sports. Fizel & D'Itri(1997), for example, used NCAA Division I college basketball data for the years 1984-91 to construct a measure of the efficiency of coaches/managers in that league using the DEA. By using this measure, they researched the relation between the succession/replacement of coaches and the team performance (Fizel & D'Itri, 1997). Escuer & Cebrian(2004)(, in their study,) applied the DEA methodology to measure the productive efficiency of soccer teams that play in the Spanish First Division from 1998 to 2001 by researching how well teams are converting attacking moves into sporting success during the match. Their basic DEA formula was as follows:

$$\begin{aligned} & \text{Min } \lambda_1 \\ \text{s.t.} \quad & u \leq z\,U \\ & \lambda_1\, x \geq z\,X \\ & z \in R_k^+ \end{aligned}$$

(Espitia-Escuer & Garcia-Cebrian, 2004)

Where λ1 is the overall technical efficiency, u is the vector that represents the production by the firm, U is the matrix that represents production for all firms in the sample, x are the amounts of productive factors used by the observed firm, X is the matrix of the amounts productive factors used by the firms in the sample, and z is a vector of parameters that makes optimal combinations of factors and products.
Again, the criteria imply that the output for firms in the sample, using vector z, will be at least as high as the output for the observed firm with the same level of input. The other way around, the observed firm will need more input to reach at least the same level of output as the firms in the sample.
Their purely technical efficiency(λ2), is subject to the additional criterion $\Sigma z_i=1$. This criterion assumes variable -instead of constant- returns to scale, which makes it possible to compare the efficiency of the observed firms with firms of a similar size. The scale efficiency, ultimately, is said to measure the losses in efficiency due to a wrong choice of firm size and is calculated by λ1/λ2 (Espitia-Escuer & Garcia-Cebrian, 2004).
In their research, Escuer & Cebrian took the number of players used, attacking moves,

possession and shots & headers as input variables. As output variable, they took the number of points achieved in the season. An alternative output possibility, the number of wins, was not chosen because it does not take matches into account that ended in a draw. The number of goals scored was not taken as output variable because of the fact that the league champions have not necessarily scored the most goals, and the last team in the ranking did not necessarily scored the least goals. The main conclusion of this research was that efficient teams do not always finish the highest in the league at the end of the season.

The biggest advantages of the DEA approach, over the econometric approach are that no functional form is required for the inputs and outputs, and that it can cope with multiple inputs and outputs. The biggest limitation is that it cannot make a distinction between noise and inefficiency, which can cause significant problems. In this case, examples of noise can include inaccurate/false observations or even missing or unknown values in the dataset, which lead to deviations from the optimal frontier line.

Parametric/econometric frontiers.

The counterparts of the nonparametric DEA method are the parametric or econometric frontiers. Some advantages of these methods, which are clearly defined in the paper of Barros & Leach (2007), will be discussed.
A big advantage of these econometric frontiers is that there are numerous statistical tests available to investigate the validity of the model. These tests include tests of significance for the inclusion or exclusion of factors, or to verify the functional form of the model. A second advantage is that in the calculation of the efficiency scores, a low or even zero weighting is assigned to variables that are not relevant but are in fact included in the model. This will ensure that the impact of these factors is likely to be negligible. This is an important difference from DEA, where the weights for a variable are usually unconstrained. A third advantage of the econometric frontiers is that it can segregate deviations from the frontier into noise and pure inefficiency (Barros & Leach, 2007). The last part of the DEA-section has shown that the DEA cannot do this and therefore classifies the whole deviation as inefficiency.

In the field of econometric (parametric) frontier approaches, the most pronounced approach is the stochastic parametric frontier, but one could also use a deterministic parametric frontier-approach. Both methods and their implications will be addressed below.

Deterministic parametric frontier.

The deterministic frontier approach can be seen as a predecessor of the stochastic frontier approach.

Zak, Huang & Siegfried(1979) used a parametric frontier to estimate the production frontier for NBA basketball teams. With this frontier, they determined the teams' potential and which factors influenced their performance. They use the following formula

$$Y = F(x) \cdot u.$$ (Zak, Huang, & Siegfried, 1979)

Where Y is the observed output, F(x) is the frontier production function for a vector of inputs x and u is the factor with which Y differs from F(x).
Their study is similar to that of Hoefler & Payne(1997). However, they used a different frontier method, and additionally considered the role of the "home-court advantage".

Scully, in his 1994 study, used both the deterministic parametric frontier and the stochastic parametric frontier in his study on the relationship between coaching performance and the efficiency of this coaching. He studied three different sports, namely basketball, baseball and American football (Scully, 1994).
Hadley et al.(2000) focused solely on American football to evaluate the collective performance of each football team against its potential for US NFL teams during the seasons 1969/70–1992/93 (Hadley, Poitras, Ruggiero, & Knowles, 2000). They start from the formula

$$w = g(X) + \varepsilon,$$ (Hadley, Poitras, Ruggiero, & Knowles, 2000)

Where ε is the difference between the observed and predicted number of wins (w and G(X), respectively). However, econometric estimation of this formula produces a two-sided residual that cannot be directly interpreted as a measure of inefficiency. (Greene, 1993) showed that this can be solved by adjusting the estimated intercept, so that predicted wins are equal to or larger than the observed wins. This leads to the formula

$$f(X_i) = g(X_i) + v,$$ (Hadley, Poitras, Ruggiero, & Knowles, 2000)

Where v is the largest positive residual from the starting formula.

Deterministic models, on the other hand, are models where the properties are well known. The output of these models are fully determined by the parameter values and the initial conditions. Stochastic models, on the other hand, have random properties with a uniform or normal distribution which fit the real world better. In conclusion, stochastic models can handle uncertainty in the inputs within the model, where for deterministic models these uncertainties are external to the model.

Stochastic parametric frontier.

The stochastic parametric frontier methodology was initially developed by (Aigner, Lovell, & Schmidt, 1977). The standard form of the formula behind this frontier is shown best by the following formula

$$Y_i = \mathbf{X}_i\boldsymbol{\beta} + v_i + u_i \quad i = 1, \ldots, n$$ (Hoefler & Payne, 1997)

Where Xi is a row vector of production influencing characteristics, β is a column vector of regression coefficients and $Y_i=X_i$ β is the output or production of firm i in a 'perfect' world without error and inefficiency. Furthermore, *v* is a stochastic component that describes random shocks, and *u* is what this study is actually about. The stochastic parametric frontier analysis assumes that firms, in general, are not perfectly efficient. This means that these firms produce less than they might under optimal conditions, due to a degree of inefficiency. This inefficiency is measured by *u*. From the formula it becomes clear that, in this specific case, $u \leq 0$.

Hoefler&Payne (1997) used the stochastic production frontier methodology to estimate production functions for professional basketball teams and to compare the actual performance of the teams to their potential. They used a non-frontier production function and a frontier production function. Their non-frontier function was represented by

$$Y_i = \boldsymbol{X}_i \boldsymbol{\beta} + v_i \quad i = 1, \ldots, n$$ (Hoefler & Payne, 1997)

When they added the random error term u, they came to the standard stochastic frontier function we discussed earlier. Their choice of output is the number of wins by a team in the 1992-1993 NBA season, and the measure of inefficiency they used was the percentage of frontier output that was really attained. In other words, for a certain team, they would have an output from the frontier function (the optimal number of wins), and the actual number of wins of that team during the season. By dividing the actual number of wins by the optimal number of wins (and multiplying by 100), they ended up with a percentage of efficiency.

In 2006, Hoefler & Payne performed a similar study to investigate how closely NBA teams play up to their potential (Hoefler & Payne, 2006). The method used was the stochastic production frontier again with panel data on NBA clubs for the years 2001–2002.

Finally, some studies on football that used the standard stochastic parametric frontier as was previously shown in this section, will be addressed. Dawson, Dobson & Gerrard published two papers in (the year of) 2000. In both papers, they focused on the coach as the unit of study, while using the stochastic production frontier method. In the first of these two papers, the authors tested the robustness of estimates of coaching efficiency to changes in estimation methods, the definition of team performance and playing talent inputs (Dawson, Dobson, & Gerrard, 2000a). They developed a measure of player quality based on the transfer value of those players, and their results were shown to be minimally affected by different measures of team performance. Concerning the estimation methods, their results are highly sensitive to ex post financial input measures. Ex ante input measures as predicted transfer values are recommended on both theoretical and empirical grounds (Dawson, Dobson, & Gerrard, 2000a).

In the second paper, they provided estimations of technical efficiency for a panel of coaches in the English Premier League for the period 1992 to 1998, with team quality used as input (Dawson, Dobson, & Gerrard, 2000b). This study stands out from similar studies in estimating the efficiency at the level of individual managers rather than the club. Their main

conclusion is that managerial efficiency has fallen over their sample period.
A more recent study using the stochastic parametric frontier on football was written by Barros & Leach(2006). These authors evaluated the technical efficiency of English Premier League clubs from 1998/99 to 2002/03, combining sport and financial variables. They, however, used a stochastic cost frontier (Barros & Leach, 2006). They concluded that the football clubs in their sample have different efficiency scores, and that more investigation on this subject is needed.

Within the stochastic frontier analysis, there are several different ways to specify the inefficiency-term *u*, and the random shock-term *v*. To separate the two, the random shock-term is assumed to have a symmetric distribution, while the inefficiency term is assumed to have a strictly nonnegative distribution. Frontier analysis provides three models in which *v* is assumed to be normally distributed with $N(0,\sigma^2_v)$ and to be independent of u_i (Kumbhakar, 2000).
The basic models differ in their assumption of the distribution of the inefficiency term u_i. The inefficiency term can be distributed in three ways, which can be found in the paper by Hoefler & Payne (1997).

(a) a 'half-normal' distribution where *u* is independently distributed with $N(0,\sigma^2_u)$ and truncated at zero.
(b) *u* is exponentially distributed with variance σ^2_u.
(c) a 'truncated normal' distribution where *u* is independently distributed with $N(\mu,\sigma^2_u)$ where μ does not equal zero and truncated at zero.

The present view on these choices is that the first two choices are poorer than (c), because their modal values would be nearly zero, which underestimates the size of the inefficiencies (Hoefler & Payne, 1997).

Given the pros and cons of all models researched in this section, the choice in this paper fell on using the stochastic frontier approach. These stochastic models have clear advantages over the nonparametric/DEA models and the deterministic models. The frontier model used in this study will assume the random shock term v_i to be normally distributed with $N(0,\sigma^2_v)$ and to be independent of $u_{i,}$ while assuming *u* to be normally distributed with $N(\mu,\sigma^2_u)$ and truncated at zero. The exact stochastic frontier model and variables used in this study, will be explained in the methodology- section.

Efficiency and Value.

Several studies are discussed in this section to give an insight in how Efficiency might influence Market Value,
No existing literature was found studying the specific relationship between Efficiency and Market Value. However, a number of studies researched the effect of winning/losing football matches on the stock price of football teams. This is similar to the relation studied in this paper since Efficiency is basically about how close to their potential clubs perform in terms

of points achieved and winning matches. Stock price and Market Value are the same thing since the Market Value of a listed team is the total stock value of that team.

Stadtmann (2006), used stock market data for Borussia Dortmund, one of the leading German football clubs, for an application of the news model. Their most important finding is a close link between sporting success and following changes in the stock market. Won matches have a significant positive impact on stock returns, while lost matches have a significant negative impact on stock returns (Stadtmann, 2006).

Scholtens & Peenstra (2009) examined the link between football match results and stock returns further. They analysed matches of eight teams in the national and European competition between 2000–2004 and, like Stadtmann (2006), found that the stock market response is significant and positive to victories and negative to defeats. Additional conclusions are a significantly stronger response in the case of defeat, and the finding of a stronger response for matches in the European competition than for those in the national competition. Furthermore, unexpected results were found to have a stronger impact than expected ones for European matches, but this is not the case in the national competition (Scholtens & Peenstra, 2009).

In that same year, Benkraiem et al.(2009) examined the impact of football match results on abnormal returns and trading volume around the dates of matches. Their main finding is that sporting results of listed football clubs affect both the abnormal returns and the trading volume around the dates of matches. The movement of the impact and the time when the impact occurs depend on the nature of the result(win/loss/draw), and the match venue (home or away) (Benkraiem, Louhichi, & Marques, 2009)

Lastly, Bell et al. (2012) found some support for the notion that stock prices are affected more by the results of important matches than matches of lesser importance. The difference between the number of points achieved by the game and the number of points expected to be achieved, is also found to affect (its) stock price (Bell, Brooks, Matthews, & Sutcliffe, 2012).
This last finding is particularly interesting for this paper, since the difference between points achieved and points expected to be achieved can be seen as a form of Efficiency. The finding that this factor affects stock price may imply a relation between Efficiency and Market Value.

This paper chose to investigate the relation between Efficiency and Market Value rather than stock price. The most important reason behind this is the fact that only three Italian teams are listed on the stock exchange. Market Value is relatively easy to find for all teams in the Italian Serie A over multiple years. This will ensure a more reliable analysis.

III. Italian Serie A.

Before deep-diving into the ins and outs of Italian top league football, this section will briefly explain some basics of football which are relevant to this study.

Within a football team, a distinction can be made between a number of different roles. In general, players are categorized as either a goalkeeper, defender, midfielder or attacker. The primary function of the goalkeeper is to save goal scoring attempts from the opposing team. Furthermore, a game is characterized by different moves in open play. The moves that are part of the attackers' skillset involve running or dribbling with the ball, passing the ball to teammates, creating goal-scoring chances and shooting at goal, among other things. Defenders mostly are blocking and intercepting opposition passes and shots, tackling opponents, and clearing the ball from pressure situations. Midfielders are considered the (most) all-round players in football, because they both attack and defend. However, to a certain extent, every field player is involved in all aspects of the game. The most important aspect is of course scoring goals, while preventing the opposing team from scoring. A match can end in a win, a loss, or even a draw. In most professional football competitions, a win is awarded with three points, a draw is awarded with one point and a loss means no points are earned by the specific team. The total number of points achieved at the end of the season determines the final position in the league table.

Serie A.

The Italian Serie A is the highest Italian professional football league and was officially founded in 1898. From this year onto the 1929-30 season, the league had regional and interregional rounds. From the 1929-30 season onwards, the competition was changed to a single-tier league or "round-robin tournament". This concept will be explained later on in this section. The Italian competition has been organized by Lega Calcio until 2010. Since that season, however, the new Lega Serie A was created.

The Serie A is regarded as one of the strongest football leagues in the world. According to the International Federation of Football History and Statistics (IFFHS), the Serie A is the second-strongest national league in the world (the strongest league in the world 2015, 2016). The top-ranked teams in the league ensure themselves from playing in the continental competitions, among which the European Champions Cup is the most prestigious and the Europa League is the inferior of the two. The Serie A has produced the most European Cup finalists, together with the Spanish Primera Division (Uefa Champions League, 2016). Furthermore, the Serie A is the fourth ranked European competition according to the UEFA associations' club coefficients rankings, behind the Spanish, German and English competitions (UEFA rankings for club competitions, 2016)**.** These coefficients are based on the results of each competition's clubs in the five previous UEFA Champions League and UEFA Europa League seasons. The rankings, in turn, determine how many places are allocated to each competition in next year's European competitions.

Teams and format.

The three most famous teams in the Serie A are Juventus, Milan and Internazionale, other well-known teams are Roma, Fiorentina, Lazio and Napoli . These seven teams are known as the Seven Sisters of Italian football[1], although originally Parma was considered one of the seven and Napoli was not included. Juventus has become champion of Italy most frequently with 32 titles in total. They have also been the reigning champions for five years now.

Most of the Serie A seasons were played with 16 or 18 clubs, but since 2004 there have been 20 club teams competing in the competition. The league covers the period from August to May where each team plays every other team twice, once at home and once away. Each team plays a total of 38 games during the season. This format is widely used and is called a round-robin format. During the first half of the season, every team plays each other team once. In the second half of the season, the teams play every other team again in the same exact order. At the end of the season, the top three teams qualify for the UEFA Champions Cup where the first two are qualified directly and the third has to play a qualification round. The teams that became fourth and fifth qualify for the UEFA Europa League, as well as the winner of the Italian National Cup (Coppa Italia). The bottom two teams are relegated to the Serie B, the second division of Italian football.

With regard to the clubs' finances, three Italian teams are listed on the stock exchange, namely Juventus F.C., S.S. Lazio and A.S. Roma (5 Football Clubs Listed on the Stock Exchange, 2014).

Studies.

about a number of studies have been conducted on the Italian Serie A. Baroncelli and Lago, for instance, studied the financial crisis in Italian Football in their 2006 paper. This crisis had caused bankruptcy for some clubs and strong downsizing for others. At the end of the 2002-2003 football season, the aggregate net loss for Serie A was larger than €400 million, more than one third of total turnover. In the article, the authors analysed data from Italian football, discussed the reasons for the financial crisis, and proposed some remedies (Baroncelli & Lago, 2006).
In 2011, Baroncelli teamed up with Caruso in a study intended to briefly analyse the fundamentals of the organization of Italian top football and its economic aspects. Furthermore, they review the evolution of the financial situation in this area, attempt to find causes for the evident underperformance and research the management of TV-rights, the most important source of funding for Italian Football (Baroncelli & Caruso, 2011).

In 2009, Rampirini et al. took a different approach and focused primarily on the strictly sportive performance of teams in the Italian Serie A. They examined the changes in technical and physical performance between the first and second half during official matches of Italian Serie A league, and compared this performance of players of the more successful teams with

[1] (Le 7 sorelle dell'Italcalcio tornano a spendere all'estero, 2013)

the players of the less successful teams from the same league. Their study showed a decline in technical and physical performance between the first and second half, and that both physical performance and technical skills were different between players from more successful and less successful teams (Rampirini, Impellizzeri, Castagna, Coutts, & Wisløff, 2009).

Vigne et al. (2013) performed a study that is similar to the study by Rampirini et al. (2009), in that it examines physical performance of a successful Italian Serie A team of more than 3 consecutive seasons. This study showed how for 3 consecutive seasons a Serie A team of successful players reduced their distances performed at submaximal speeds, and increased ball possession, while maintaining the high-intensity activities and the number of points at home. A reason for this finding can be a better understanding of roles, tactics and team organization after multiple seasons, which reduces unnecessary energy expenditure during the game (Vigne, et al., 2013).

IV. Methodology and data.

In this study, the Efficiency of football teams will be measured by the application of the stochastic parametric frontier methodology.

Stochastic frontier model.

The stochastic frontier model was originally developed by (Aigner, Lovell, & Schmidt, 1977) to focus on production and its Efficiency. By focussing on football instead of business firms, these terms become more difficult to interpret. For the purpose of this study, production will be represented by the number of points acquired by a team. The frontier will produce the maximum number of points a team can acquire given their inputs and the Efficiency shows us how close a team performs to its potential.
Kumbhakar & Lovell(2000), in their book on stochastic frontier analysis, provide a detailed derivation of the basic stochastic frontier model. The basic steps of this derivation are shown in the section below.

In a perfect world, without error or inefficiency, production would solely depend on the production-influencing factors. A firm i would then produce:

$$Y_i = f(X_1, \dots, X_n)$$

The stochastic frontier model, however, acknowledges that in reality many firms produce less than this because of inefficiency. The firm will then produce:

$$Y_i = f(X_1, \dots, X_n)\varepsilon_i$$

Where ε_i is the level of Efficiency and $0< \varepsilon_i \leq 1$. If ε_i=1, the firm is achieving the optimal output given its resources.
Production is also influenced by random shocks depicted by v. The formula will then become:

$$Y_i = f(X_1, \dots, X_n)\varepsilon_i exp(v_i)$$

Where exp(v_i) represents e to the power v_i.
Taking the natural log of both sides results in:

$$ln(Y_i) = ln\{f(X_1, \dots, X_n)\} + ln(\varepsilon_i) + v_i$$

A more widely used expression of ln(ε_i) is u_i. The formula then becomes

$$ln(Y_i) = ln\{f(X_1, \dots, X_n)\} + u_i + v_i$$

(Kumbhakar, 2000)

Note that, because u_i is the natural log of ε_i and $0< \varepsilon_i \leq 1$, u_i will be negative and only zero in the case of optimal Efficiency ($u_i \leq 0$). The term u_i in fact measures inefficiency in terms of a

loss of production.
In this study, the random shock term v_i is assumed to be normally distributed with $N(0,\sigma^2_v)$ and to be independent of u_i. Furthermore, this study assumes u to be normally distributed with $N(\mu,\sigma^2_u)$ and truncated at zero.
The start values needed in order to estimate the parameters of the stochastic frontier model, are coming from the initial OLS estimates.

The production model used in this study is in a Cobb-Douglas- form and is

$$ln(Y_i) = c + \sum_{i=1}^{6} \propto_i \ln(X_i) + \propto_7 \ln(X_7) + u_i + v_i \qquad i = 1, \ldots, n$$

And

Y= Points= the number of points acquired by a team,
X_1=TSR= Total Shots Rate(+),
X_2=PS= Pass Success(+),
X_3=SoT= Shots on Target(+),
X_4=SB= Shots Blocked(+)
X_5=ST= Successful Tackles(+)
X_6=DS= Dribble Success(+)
X_7=PU= Players Used(-),
With the expected signs in parentheses.

Much of the data on these variables in the Italian Serie A is owned by OPTA (OPTA Sports). Since OPTA requires a payment to provide their data, the data had to be collected from websites that publish OPTA-stats like Squawka, WhoScored or the FOX Sports website. In the end, almost all the data needed could be found in the Italian Serie A-section of the website of WhoScored (Serie A Team Statistics).

The number of Points is a total per team per season. Pass Success is the percentage of passes that were successful against all passes that were sent during the season, and Shots on Target is the ratio of shots that were on target of a team against all shots fired by that team. Shots Blocked is the ratio of blocked shots against total shots conceded and Successful Tackles is the percentage of tackles where possession was taken from the opponent's player by the tackler. Dribble Success is the percentage of dribbles where the player outplayed their opponent, and the Total Shots Rate was calculated separately with the following equation.

$$TSR = \frac{Shots\ for}{(Shots\ for + Shots\ against)}$$

Where the shots against (conceded) were only to be found per game. This was easily rectified by extrapolating the per game-statistics to data per season. The data was modified by simply multiplying the per game-data times the number of games each team played

during the season, which is 38.
The only data that could not be found on the WhoScored-website were the data regarding the number of Players Used for each team per season. These data were therefore collected from the website of Transfermarkt, in the 'Players Used'- section of the Italian Serie A (Players Used). All data collected are from the 2009-2010 season until the 2015-2016 season.

The dependent variable in this study is the number of points achieved by each team during the regular season in the Serie A. Total Shots Rate and Shots on Target are expected to positively influence the number of points per team. This expectation is due to the fact that these variables measure the dominance of a team during the season in terms of shots and the quality of shooting of that team in that season, respectively.
Pass Success and Dribble Success are also expected to have a positive impact on a team's points, because better passing and dribbling will lead to more and better chances on scoring goals, while preventing the opposition from gaining possession and scoring.
Shots Blocked and Successful Tackles are expected to have a positive impact on a team's points as well, because these variables resemble solid defending. Good defending prevents the opponent from scoring goals, leading to more games won and more points.
The only variable which is assumed to have a negative impact on the number of points is the number of Players Used by a team during a season. When a team uses more players, this team is expected to have changed their starting eleven and their formation more often. Keeping a consistent formation and squad is assumed to benefit the number of points because the players then become accustomed to each other and the tactics. This can be seen as a sort of synergy that improves a team's effectiveness. This is why using more players is expected to have a negative impact on the number of points.

The sign and significance of the seven different variables on the number of points achieved, can be of great interest for the clubs, their coaches and even the scouts. If the impact of Shots on Target or the Total Shots Rate turn out to be significant, coaches can adapt their tactics to shoot more and be more dominant in terms of shooting. If Pass Success or Dribble Success proves significant in predicting Points achieved, the coach may be inclined to focus on the quality of passing/dribbling by reducing risky passes/dribbles. Moreover, a significant impact of Shots Blocked and Successful Tackles may possibly increase the focus on the training on defensive tasks while a negative influence of Players Used may persuade the coach to work with a fixed core of players which is not that big.
Furthermore, the scouting may use the outcomes of the frontier analysis in their search for new players. A player who scores high on different statistics that have a significant impact on the number of Points achieved, can prove to be a welcome addition to the team.

In the end, the frontier model will produce a yearly inefficiency (*u*) for each team in the dataset. This inefficiency can then be easily converted into an Efficiency, from where the optimal number of points achievable can be derived(more about this later).

The resulting Efficiencies can be of use for the teams as well. From this number, the teams can derive how close to their potential they performed. If the Efficiency turns out to be relatively low, a team can assume that it has substantial growth potential.
The number of points achievable (Frontier Points from now on) is of great interest to teams as well. This number depicts the maximum number of points a team could achieve, if they would perform at 100% Efficiency. A high number of Frontier Points means that the team has shown great dominance in terms of the seven statistics in the frontier model. This measure says a lot about a team's performance in terms of statistics, while the Efficiency shows how efficient teams are in converting these statistics into goals and points. A low number of Frontier Points could be caused by low values for one or more of the statistics taken into account. A club can use this outcome to try and improve areas of play in which it fell short, by training more on these areas or maybe even buy players who excel in these areas.
For both Frontier Points and Efficiency, improving one while keeping the other constant will improve the actual number of points a club collects in a season. With the outcomes of the frontier analysis, teams are given valuable insights in the possibilities of improving performance.

Efficiency and Market Value.

This research takes the stochastic frontier model and production functions, concepts from the financial world, and translates it to the world of football. As a result, this model will produce yearly Efficiencies and a number of Frontier Points, for every club in the database. The next step is then to translate these values back to a financially relevant subject.

In this step, the relation of the Efficiency and Frontier Points with the Market Value of a club will be analysed. The total Market Value of a club, in this case, is the total value of all the players that are in the selection of this club.

First, the correlation between Efficiency, Frontier Points and Market Value will be studied. This will be done by constructing a basic correlation matrix where all correlations and their significance are inspected.

The correlations between both Efficiency and Frontier Points, and the Market Values are expected to be substantial and positive. The reason behind this is that the Market Value of all players in the selection of a club, resembles the quality of those players. On the transfer market, exceptional players are worth more than less talented players. With better players on the pitch, a team is expected to be more dominant in terms of the variables that affect the number of Frontier Points. Therefore, higher Market Value will result in a higher number of Frontier Points, and vice versa.
A higher Efficiency indicates a season where the specific club played close to their potential. A good season will normally increase the value of the players that realised this accomplishment, as well as the total Market Value of the club due to a higher income

through possible price money, TV-rights and better sponsor deals. Therefore, Efficiency and Market Value are expected to be positively correlated.
The correlation between Frontier Points and Market Value is expected to be higher than the correlation between Efficiency and Market Value, since Market Value is assumed to display player value and therefore player quality. Players of better quality will result in more dominance during the games, higher measures for the statistics included in the frontier model and a higher number of Frontier Points. Efficiency describes how close to the potential number of Frontier Points, a team performed. Therefore, this is assumed to be less influenced by Market Value.

As an extra test of the influence of Efficiency and Frontier Points on Market Value, the total Market Value is regressed on these values. The total Market Value is chosen as the dependent variable since this is total value of the club.
This Market Value is regressed on Efficiency and Frontier points separately, as well as on the both of them combined to capture their individual and combined influence on the Market Value.

To do this, the following three regressions will be conducted,

$$Y = c + \propto_1 X_1 \qquad \text{(A)}$$

$$Y = c + \propto_1 X_2 \qquad \text{(B)}$$

$$Y = c + \propto_1 X_1 + \propto_2 X_2 \qquad \text{(C)}$$

Where
Y= Market Value
X_1=Efficiency (+)
X_2=Frontier Points (+)
Expected signs in parentheses.

Again, for the same reasons as described earlier in this section, Efficiency and Frontier Points are expected to have a positive impact on Market Value.

Positive correlations or coefficients of Efficiency and Frontier Points with/on the Market Value of a team can be interesting for football teams in the sense that these teams then know that in order to raise Market Value, they can try and raise their Efficiency and/or Frontier Points. They can naturally do this by improving any of the variables that turn out to be significant influence on Points achieved in the frontier analysis.
Additionally, proof of relations between these variables can open up a whole new area of research since the relation between Market Value and Efficiency or Frontier Points has not been thoroughly researched before.

The total Market Values were retrieved from the Serie A-section of the Transfermarkt website (Clubs of the Serie A). These values are in millions of dollars.
The Efficiencies and Frontier Points naturally result from the frontier model, where the Efficiencies are in percentages, and Frontier Points are rounded to whole points.

V. Results.

In the first part of this section, the stochastic frontier analysis will be conducted, producing a yearly Efficiency and number of Frontier Points for every club in the dataset. In the second part, the relation of the resulting Efficiency and Frontier Points with the average Market Value will be analysed.

Efficiency analysis with frontier model.

The start values needed in order to estimate the parameters of the stochastic frontier model, are derived from OLS estimates. In the OLS- step, the natural logarithm of the number of points achieved, is regressed on the seven independent variables that were presented in the previous section. The OLS-step is presented in the following table, to clarify the process followed in this study.

Table 1. OLS step of frontier model, dependent variable is number of points (P).

Variable	*Coëfficiënt*	*t-ratio*
Constant	-9.496	-3.86
Total Shots Rate	0.694	6.00
Pass Success	1.558	3.37
Shots on Target	0.516	2.35
Shots Blocked	0.628	4.08
Successful Tackles	0.230	0.90
Dribble Success	0.037	0.27
Players Used*	-0.018	-3.49
R^2		0.716
Adj R^2		0.701
F(7,132)		47.48
n		140

*All variables are in natural logarithms, except Players Used. The rest of the variables are ratio's, and this variable is not.

The most important things to look at in the OLS-step are the (adjusted) R-squared, and the F-statistic of the model. The (adjusted) R-squared shows us that there is a serious relation between the number of points and the seven independent variables. This model explains more than 70 percent of the variation in the number of points. The F-statistic of this model is high and does therefore display an overall significance of the model.

To test for heteroscedasticity, a White's test was conducted. This test provides P-values for heteroscedasticity in three possible ways (heteroscedasticity, kurtosis and skewness) as well as a total P-value for overall heteroscedasticity. For these tests, the null hypothesis is one of homogeneity, which means no heteroscedasticity. This implies that (with a significance level of five percent) a P-value below 0.05 indicates a rejection of homogeneity and hence proof of heteroscedasticity. The outcomes show that there is no significant heteroscedasticity and kurtosis (P-values of 0.53 and 0.41), but there is significant skewness in the data sample with a P-value of 0.01. The total P-value, however, is 0.14. This is big enough to not reject the null hypothesis of homogeneity. Furthermore, the variance inflation factors indicate that there are no collinear relationships between the variables. VIFs of more ten are considered worrisome (O'Brian, 2007), but the mean VIF of all seven variables in this model is only 1.65.

The next step is to come up with the actual maximum likelihood estimates of the stochastic frontier model. The table below lists these estimates, along with the estimates of several parameters, a log-likelihood and a LR-test.
The log-likelihood of the model has no real meaning in itself, but can be used in tests to compare different models, like the LR-test (Stata Annotated Output, Logistic Regression Analysis).
This LR-test tests the stochastic frontier model against a model where there the inefficiency effects are absent, where the null hypothesis presumes no inefficiency component (Battese & Coelli, 1995). When the null hypothesis is true, the model becomes an OLS model with normal errors. For the truncated-normal model used in this study, Coelli (1995) derived a one-sided test for the presence of an inefficiency term (Coelli, 1995).

Table 2. Stochastic frontier model, dependent variable is number of points (P).

Variable	*Coëfficiënt*	*t-ratio*
Constant	-8.221	-3.91
Total Shots Rate	0.657	6.44
Pass Success	1.474	3.60
Shots on Target	0.525	2.82
Shots Blocked	0.521	3.63
Successful Tackles	0.109	0.49
Dribble Success	0.077	0.63
Players Used*	-0.017	-3.56
μ**	-0.573	-0.40
$\ln(\sigma^2)$**	-1.942	-1.37
Ilgt(γ)**	2.587	1.82
Log likelihood		54.745
LR-test ***		-2.809
n		140

* Again, for the same reason, all variables except Players Used are in natural logarithms.
** μ = the mean of the truncated-normal distribution, $\ln(\sigma^2)$ is the optimization of $\sigma_S^2 = \sigma_V^2 + \sigma_U^2$ and ilgt(γ) is the inverse logit of γ which is the optimization of $\gamma = \sigma_U^2/\sigma_S^2$.
*** Likelihood ratio test of OLS vs stochastic frontier model, H_0=no inefficiency component. Z-distribution.

This table shows that the Total Shot Rate, Pass Success, Shots on Target-ratio and Shots Blocked all have a significant positive impact on the number of points. This was expected because a team's Total Shot Rate represents the dominance of that team in terms of shots, Pass Success will positively impact the chances created by a team while preventing the opposing team from capturing the ball and creating chances, and the Shots on Target-ratio will increase the chance of scoring a goal through more accurate shooting. Shots Blocked, on the other hand, will reduce the number of shots on goal from the opposing team, thereby reducing the number of goals conceded by the own team.

The coefficients for Shots on Target and the Total Shots Rate indicate that in order to collect more points during the season, a team can try to shoot more (on target). More shots will result in a higher measure of the TSR while more shots on target naturally results in a higher measure for Shots on Target, in turn leading to more Points achieved. This can be done buying 'good shooters', training more on shooting or simply by implementing a more opportunistic playstyle.
The significant positive coefficient for Pass Success can, in turn, lead to a more conservative playstyle since a higher percentage of successful passes can result in a higher number of Points achieved. A more conservative playstyle will make sure that less risk is taken with respect to passing the ball, resulting in more successful passes and thereby improving the measure for Pass Success.
Lastly, the significance of Shots Blocked depicts the importance of the defensive organization of a team. Teams could improve this measure by simply training on defensive structure and by filtering possible defensive transfer targets on their shot blocking-statistics.

The results show that Successful Tackles and Dribble Success do not significantly improve the number of points achieved by a team. This seems plausible, because (of the fact that) the area on the field where the successful dribble/tackle takes place is very important. For instance, successful tackles near the opposing goal can have a big impact on the number of goals scored, positively influencing the number of points. Unsuccessful tackles near the own goal can have a big impact on the number of goals conceded hereby reducing the number of points, while successful tackles in this area will reduce the number of goals conceded and increase the number of points. In short, the specific area on the field in which the (un)successful tackle/dribble takes place is an important factor of these variables. Unfortunately, data on the areas in which the tackles and dribbles take place are not provided by the (available) websites used in this study. However, this can explain why these variables are not significantly influencing the number of points.

The coefficients for Successful Tackles and Dribble Success therefore do not provide football teams with clear guidance on how to improve the number of points they collect during the season. However, the fact that the area of the field in which the Dribble or Tackle took place was not included in this study offers a possibility for further research. Researchers who have access to the specific statistics needed about the areas of Dribbles or Tackles can include these statistics in their analysis and possibly find significant coefficients for these variables.

Lastly, the number of Players Used by a team shows to have a significant negative impact on the number of points achieved by a team. Using more players was expected to have a negative impact on the number of points and using fewer players therefore was expected to have a positive impact on the number of points.
One of the reasons, as previously stated in this paper, may be that keeping a consistent formation and squad can benefit the number of points because the players then become accustomed to each other and the tactics. Another reason can be that more players used

could possibly be the result of compulsory changes in the team due to injuries or suspensions of the initial players. If one of the important starting players is injured or suspended, the substitute player in general is inferior to the player who is normally starting. These changes result in both more players used and less points achieved by the team due to the inferior abilities of substitute players.

A team can have a strong core of more than eleven players, which they use in a rotating manner to reduce fatigue and injuries, and create competition within the squad. This will however only be done to a certain extent. The number of players used in a rotating manner will come down to a maximum amount of about twenty players, after which the extra substitutions are of inferior capability and will result in less points achieved as explained before. The range of players used throughout the dataset is between 22 and 38 players in one season. Assuming that no team in the world has a core of more than 22 players of equal ability, the negative impact of Players Used on the number of points is expected.

The significant negative coefficient for Players Used may persuade coaches to try and use fewer players during the season. A capacious core of players is definitely needed in order to avoid fatigue and injuries, but the coach might try to reduce changes outside this core group of players in order to decrease the number of Players Used and collect more points with the team. To reduce the number of Players Used, a club can also try to prevent injuries by hiring good medical staff and building in rest periods for the players to reduce fatigue.

Another important part of this table is the value for the Likelihood Ratio-test (LR-test). This value is -2.809 with a p-value of 0.002, so the null hypothesis of no inefficiency component is rejected here, and the stochastic frontier model suffices.

After estimating the frontier model, the inefficiency term *u* was stored as a separate variable in the dataset for each team per season. Because *u* is measuring inefficiency, the Efficiency is obtained by the following simple calculation

$$Efficiency(\%) = (1 - |u|) \times 100\%$$

Furthermore, the optimal number of points that could be achieved for each club per season, according to the frontier model, is calculated by the equation:

$$Frontier\ Points = \frac{Actual\ number\ of\ points}{Efficiency}$$

Below, there is a summary of the Efficiency and the optimal number of points, from all throughout the dataset.

Table 3. Summary of Efficiencies.

Variable	*n*	*Mean*	*Min*	*Max*
Number of points*	140	52.00	19.00	102
Optimal number of points*	140	61.00	29.00	114**
Efficiency(%)	140	84.38**	44.81	96.87

*The actual and optimal number of points is rounded to the nearest whole number.
**The maximum optimal number of points that came out of the frontier model was 121 points, this applied to Napoli in the 2015/2016 season. However, the optimal number of points that teams are able to acquire in one season of 38 games is 38*3=114 points. This affected the mean Efficiency as well (went from 84.35% to 84.38%).

From this table, it becomes clear that the mean Efficiency over all seven seasons is 84.38%. This shows us that the teams are highly efficient in converting their game-specific factors into points. The least efficient team in the dataset was Cagliari in the 2014-2015 season, with an Efficiency of only 44.81%. In this season, they achieved a disappointing 34 points out of a possible 76 according to the frontier model. The most efficient team reached an Efficiency of 96.87%. This was Roma in the 2009-2010 season where they achieved 80 points out of an optimal number of points of 83. Furthermore, Juventus achieved the most points in a single season with 102 points in the 2013-2014 season, while Livorno achieved the least number of points in a season with 29 points in the 2009-2010 season.

To test if the (in)efficiencies that followed from the frontier model are correct, two specific team-season combinations in the dataset will be checked.

The first observation that is checked, is the Efficiency of Internazionale during the 2009-2010 season. This observation was chosen because during this season, Internazionale became champion of Italy, won the Italian Cup and won the Champions League. Intuitively, in such a good season where almost everything was won, the Efficiency of Inter is expected to be high. Furthermore, during that specific season, José Mourinho was the head coach of Internazionale. Followers of football commonly associate this coach with a defensive, conservative but highly efficient style of play. This adds to the expectation of a high Efficiency for Inter during the 2009-2010 season. Another interesting aspect about Internazionale in the 2009-2010 season is that their Market Value was the highest of all teams in the serie A (309 million dollar). As was stated in the previous section, higher Market Value indicates higher individual player value and (hence) better players. Having better players in the team might improve the Efficiency of that team.
When this observation is checked, it becomes clear that the Efficiency of Internazionale during the 2009-2010 season is 95.7%. This is indeed highly efficient, as was expected.

To see if the model computes correct Efficiencies during bad seasons as well, the Efficiency of Parma is checked during the 2014-2015 season. At the end of this season, Parma was relegated to the Serie B after ending last in the competition with only 19 points. During this season, Parma was in big financial trouble, and after the season the club faced bankruptcy.

The club also failed to pay the wages of players throughout the season, which resulted in a total deduction of seven points[2]. The extremely bad season, but mostly the deduction of seven points, lead to the expectation that the Efficiency of Parma for the 2014-2015 season is really low. The seven points-deduction is an external event to the frontier model. This means that, if the model is working correctly, the optimal number of points that could be achieved by Parma is still the same as it would be without the deduction (with 26 points).This should lead to a low Efficiency because the number of points achieved fell with approximately 27%, while the optimal number of points that could be achieved stayed the same.
The Efficiency of Parma over the 2014-2015 season is a mere 47%, which is in line with the expectations.

In table 4, the mean Efficiency per team is computed for each of the 31 teams in the dataset. In order to place these Efficiencies in perspective, the number of seasons in which a team was active out of seven seasons is also included in the following table (depicted by #).

Table 4. Mean Efficiency by team over all 7 seasons, ranked by Efficiency.

	Team	*Eff (%)*	*#**		*Team*	*Eff (%)*	*#**
1	Carpi	93.35	1	**17**	Napoli	83.25	7
2	Frosinone	92.11	1	**18**	Bologna	82.68	6
3	Inter	91.31	7	**19**	Verona	82.24	3
4	Roma	90.16	7	**20**	Udinese	81.79	7
5	Catania	89.97	5	**21**	Robur Siena	78.60	3
6	AC Milan	89.62	7	**22**	Novara	78.37	1
7	Chievo	89.13	7	**23**	Cagliari	77.00	6
8	Juventus	88.55	7	**24**	Empoli	76.69	2
9	Sassuolo	88.11	3	**25**	Pescara	76.41	1
10	Genoa	87.92	7	**26**	Lecce	76.28	2
11	Lazio	87.58	7	**27**	Torino	75.26	4
12	Atalanta	87.47	6	**28**	Cesena	71.16	3
13	Sampdoria	87.15	6	**29**	Bari	70.56	2
14	Palermo	85.60	6	**30**	Livorno	57.20	2
15	Fiorentina	85.26	7	**31**	Brescia	54.14	1
16	Parma	83.40	6				

* # is the number of seasons in which a team was active out of the total seven seasons studied.

One thing stands out in this table. It shows that teams with only one or two seasons in the Serie A over the last seven years, are mostly located either on top or at the bottom of this table. This is easily explained, considering that one very good (bad) season for these teams will result in a very good (bad) mean Efficiency as well with no other seasons to restore the balance. When we focus on teams with a decent amount of seasons in the dataset, Cagliari is the only team with an Efficiency below 80%. A big factor in this 'low' Efficiency can very well be their catastrophic 2014-2015 season, after which they were relegated to the Serie B.

[2] (Parma: Serie A club deducted point by Italy FA, 2014), (Parma hit with two-point deduction for failure to pay wages, 2015), (Parma deducted another four points for breaching financial regulations, 2015).

Torino, with four seasons, are fairly well represented in the dataset. They achieved a mean Efficiency of 75.26%, which is the fifth worse out of the entire sample. There is no noticeable trend perceivable regarding improving, declining or constant Efficiencies of teams over the years. The Efficiencies are yearly measures and are therefore independent of inputs from previous seasons. Several teams perform at higher Efficiency now than they did before, other teams' Efficiency stayed relatively constant and some teams perform worse than before. There is no sign of a clear trend in how the Efficiency is moving over the years.

Furthermore, the usual 'top competitors' in the Italian Serie A are really efficient in using their abilities to achieve points. Inter, Roma, AC Milan and Juventus all reached an Efficiency between 88 and 92%, which means that these teams are competing close to their potential. One team that is relatively new at the absolute top of the league in Italy is Napoli. Over the last three seasons, they ended third, fifth and second in the Serie A. However, looking at their mean Efficiency over the last seven seasons, they are performing at a reasonable 83.25% of their potential. This is below the mean Efficiency of 84.38%, which indicates that Napoli has the most growth potential out of the 'Big five'[3].

The high Efficiency of big clubs could in part be caused by the fact that the bigger clubs are usually the richest clubs. Richer clubs tend to have better players in their team, who might be superior in converting dominance in terms of game-statistics into goals and points. However, the quality of teams is assumed to be taken into account by the dominance during games, and therefore by Frontier Points. The lower Efficiencies for teams with less money can come from a lower Frontier Points for those teams. If a team with a Frontier Points of 50 loses one more match instead of winning is, these three points will lower Efficiency with six percent. For a richer team with better players, the Frontier Points might be around 100. Here, losing a match instead of winning it only results in a lower Efficiency of three percent.

To show that the teams with the most (least) points are not necessarily the teams with the highest (lowest) Efficiency, and to see if the richest teams indeed have the highest Efficiencies, the Efficiencies of all twenty teams over the 2015-2016 season are listed in the table below. The Efficiencies are represented along with the actual and optimal number of points, the ranking in the league table at the end of the season and the Market Value of the teams in millions of dollars.

[3] With 'Big five', this study refers to Juventus, Inter, AC Milan, Roma and Napoli. The five biggest clubs in Italy in terms of supporters (Top five best supported Serie A clubs , 2015).

Table 5.All teams active in 2015-2016 season, ranked by Efficiency.

	Team	*Points*	*Optimal #points*	*Efficiency%*	*MV*	*Ranking*
1	Chievo	50	52	95.67	37.42	9
2	Roma	80	84	95.01	270.26	3
3	Atalanta	45	48	94.61	64.11	13
4	Palermo	39	41	94.24	53.17	16
5	Inter	67	72	93.53	250.67	4
6	Sassuolo	61	65	93.39	65.71	6
7	Carpi	38	41	93.35	55.93	18
8	Frosinone	31	34	92.11	36.25	19
9	Juventus	91	101	90.50	335.18	1
10	Lazio	54	60	89.94	145.20	8
11	Bologna	42	47	89.14	69.51	14
12	Genoa	46	52	88.76	106.21	11
13	AC Milan	57	66	86.60	198.60	7
14	Empoli	46	54	84.82	32.11	10
15	Sampdoria	40	48	83.92	114.62	15
16	Fiorentina	64	83	76.72	143.10	5
17	Napoli	82	114	71.93	214.37	2
18	Udinese	39	57	68.90	81.94	17
19	Torino	45	74	61.06	69.42	12
20	Verona	28	46	60.31	49.92	20
	Mean	**52**	**62**	**85.23**	**119.69**	

This table clearly shows that the ranking in the league table does not directly follow from the place in the 'Efficiency ranking', and vice versa. The table does show that the worst performing team in terms of Efficiency, achieved the fewest points in the league as well. The second and third worst teams in terms of points achieved, however, had Efficiencies of around 92% and 93%, respectively. This shows that these two teams (Carpi and Frosinone) just did not have the abilities to capture a place in the top half of the ranking. Frosinone, for example, would have ended up at the 19th position even when they would have performed at 100% Efficiency. If Verona had performed at average Efficiency for the league, they would have ended up around the 16th position in the league, instead of 20th and last.

At the top of the league, Juventus became champions of Italy with a comfortable lead of nine and eleven points on Napoli and Roma, respectively. However, even though Roma performed highly efficient, Napoli had the potential to become league champions. The optimal number of points that Napoli could have achieved according to the frontier was an immense 114 points, against 102 potential points for Juventus. This means that Napoli was performing at a disappointing Efficiency of around 72%. If they would just perform at the average Efficiency for the whole league they would have ended up with 97 points, six points above Juventus at the first place as champions of Italy. Keep in mind, this does not mean that Napoli should have been champions of Italy. The ability to convert a high potential in a high number of points, is a quality in itself.

With regard to the effect of Market Value on Efficiency, there is no clear proof of one for the 2015-2016 season. The team with the highest Market Value (Juventus) ended ninth in the Efficiency ranking, while Roma and Inter ended second and fifth in this ranking with the highest Market Values behind Juventus. However, the team with the highest Efficiency was Chievo with the third lowest Market Value of the league. Furthermore, the average Market Value of the top ten teams in terms of Efficiency is approximately 131 million dollar, while the average Market Value of the bottom ten teams is about 108 million. This implies that there might be a small effect of Market Value on Efficiency, but it is not clearly noticeable in this season. The effect is mainly noticeable for the three richest clubs, who were all in the top ten regarding Efficiency.
Nevertheless, the Market Value was previously expected to have a bigger effect on Frontier Points than on Efficiency. The average Market Value of the ten most Efficient teams over the 2015-2016 season indeed is high with 177 million. The average Market Value of the bottom ten teams is 62 million.

The results show that the effect of Market Value manifests itself more in the number of Frontier Points of a club than in its Efficiency, over this specific season. The relations between Efficiency/Frontier Points and Market Value will be studied more thoroughly in the next section.

Efficiency and Market Value.

This section analyses the relation of the Efficiencies and Frontier Points found in the Efficiency analysis, with the average Market Value.

To do so, first the correlation between Efficiency, Frontier Points and Market Value will be analysed. The correlations, with their significance levels, are displayed in the table below.

Table 6. Correlation matrix Efficiency and Market Value.

Variable	*MV*	*Eff*	*FrontierPoints*
Market Value**	*1*		
Efficiency	*0.276* (0.00)*	*1*	
Frontier Points	*0.713* (0.00)*	*0.110* (0.194)	*1*

Note: significance level (P>|t|) in parentheses
*Significant at 1% level.

The correlation between Frontier Points and Market Value stands out in this table. This correlation is highly significant and remarkably high with 71%. Frontier Points was expected to have a positive correlation with Market Value because both values reflect player talent, a correlation of 71% can however be seen as high.
Efficiency is significantly, positively correlated with Market Value as well with a correlation of 28%. However, the correlation is smaller than that between Frontier Points and Market

Value. Again, this positive correlation was expected given the fact that a high Efficiency indicates a successful season, resulting in a rise of the Market Value. Nonetheless, a correlation of 28% indicates a rather small connection between Efficiency and Market Value.

The correlation analysis displays a significant relation of both Efficiency and Frontier Points, with Market Value. As an extra test, the Market Value is regressed on Efficiency(A) and Frontier Points(B) separately, and on both of them combined(C). The outcomes of these regressions are displayed in the following table.

Table 7. Regressions of Market Value on Efficiency and Frontier Points.

*Market Value***	***A***	***B***	***C***
Constant	*-50.375*	*-105.124*	*-216.895*
	(-1.03)	(-5.56)*	(-5.85)*
Efficiency	*1.943*	-	*1.405*
	(3.38)*		(3.46)*
Frontier Points	-	*3.580*	*3.496*
		(11.97)*	(11.98)*
R^2	0.076	0.510	0.549
Adj R^2	0.070	0.506	0.543
F	11.41	143.39	83.40
n	140	140	140

Note: t-statistics in parentheses.
*Significant at 1% level.

From the regression of Market Value on both Efficiency and Frontier Points, it becomes clear that the effect of Frontier Points on Market Value is highly significant. The effect of Efficiency on Market Value is significant as well, although less pronounced in both significance and magnitude. The R-squared of this regression is relatively high(55%), taken into account that there are only two independent variables included in the regression. The model, which regresses Market Value on both Efficiency and Frontier Points together, explains approximately 55 percent of the variation in the total Market Value of the club. The F-statistic of this model is high, this represents that the model itself is significant.

To see which part of the explanatory power is contained by Efficiency and Frontier Points, we look at the individual regressions A and B. The coefficient and its significance for Frontier Points does not differ greatly from the combined regression. For Efficiency, on the other hand, the coefficient rises with about 40% while the significance drops slightly.
However, the most important aspects of these regressions are the R-squared and the F-statistics. Just by looking at these values, it becomes clear that the explanatory power largely originates from Frontier Points. The R-squared of the regression on Frontier Points alone is around 51%, while that of the regression on Efficiency is just 8%. Moreover, the F-statistic of the regression on Frontier Points is exceedingly high, with a value of 143. The F-statistic for Efficiency is much lower, around 11.
These findings imply a significant impact of both Efficiency and Frontier Points, on the

Market Value of a club. From these two variables, Frontier Points exhibits by far the biggest explanatory power.

The biggest reason for the distinct relation between Frontier Points and Market Value is the underlying player quality. High Market Value reflects valuable players and players who are worth most money are ordinarily the best players. With better players, a team is presumed to be dominant during games and would therefore be expected to have a higher number of Frontier Points. This works both ways, high Frontier Points reflects better players who are worth more money, resulting in a higher Market Value.
Player quality, to a lesser extent, influences Efficiency as well. Efficiency basically shows the ability of teams to convert for instance Shots on Goal and Pass Success into goals scored and games won. This ability comes down to player quality. A world class striker will need less Shots on Goal to eventually score than another, less-talented striker. On the other hand, preventing the opposing team from scoring also increases Efficiency. Therefore, good defenders and particularly a keeper who saves plenty of shots fired by the opponent are Efficiency-influencing factors. These specific qualities that influence Efficiency, also have an impact on Market Value in the same way as player quality.

Assuming that the variables influencing Efficiency and Frontier Points are known in the 'football-world', it seems logical that higher transfer values are assigned to those players that are specialized in these aspects. For instance, a higher transfer value might be assigned to a player who is extremely accurate in his passing, than to a player who is gifted at dribbling with the ball.
That the importance of Efficiency is well-known in the world of football is shown by the fact that the focus of most of the teams is on scoring goals. Gifted strikers are generally worth more than superior defenders, for the simple reason that strikers provide teams with goals. With their talent for converting shots, dominance and possession into goals, world class strikers are the ultimate form of Efficiency for football teams.

The results in this section show that clubs and coaches can effectively improve the Market Value of their club by raising its Efficiency or Frontier Points. Scouting on talented goal-scorers is an important aspect of increasing Efficiency, while Frontier Points can also be improved by good tactics, attractive/dominant football and a moderate number of players used in the season. Interestingly, the observation that Frontier Points has a bigger impact on Market Value than Efficiency, indicates that, to a certain extent, attractive and dominant football has a bigger effect on Market Value than efficient football. However, a healthy mix of the two is the ultimate combination for both increasing Market Value and performance.

Finally, this section of the study provides an interesting foundation for further research on the relation between Efficiency and Market Value. Little research on this relation has been done before. This study kept its focus on the specific relations between the factors, not taking possible control variables into account. More extensive research on these relations would be an interesting addition to the existing literature about Efficiency in football.

VI. Conclusion.

The aim of this study was to investigate the Efficiency of football teams in the Italian Serie A for the 2010-2016 seasons, and to find out if there is a link between these Efficiencies and the market value of the teams. The Efficiencies were produced with the use of the stochastic frontier model, along with an optimal number of points achievable per team per season (Frontier Points).

The Total Shots Rate, Shots on Target, Pass Success, Shots Blocked and the number of Players Used proved to be important influences on the number of points a team can optimally achieve -where Players Used is the only factor that negatively affects Points Achieved . To increase Points Achieved in the season, coaches can train on these specific aspects, change their tactics or even buy new players who excel in one or more of these aspects. Regarding Players Used, coaches could be persuaded to use fewer players during the season. This can be done by working with a fixed core of players, reducing injuries by hiring good medical staff, and building in rest periods for the players.

Furthermore, this study has provided some interesting results regarding the Efficiencies of the clubs. First of all, the average Efficiency all throughout the dataset is 84.38%, which shows that the teams in the Italian Serie A are highly efficient in converting their game-specific factors into points.
When the Efficiency was analysed per team, the results showed that the 'big clubs' (Internazionale, Roma, Milan and Juventus) are highly efficient in using their abilities to achieve points (88-91% Efficiency), while Napoli has the biggest growth potential out of the top competitors (83.25% Efficiency). These results indicated a possible effect of how rich clubs are (Market Value) on their Efficiency.
Subsequently, the Efficiencies over the previous season were studied. This showed us that Napoli could well have become champions of Italy in the 2015-2016 season, if they would just have performed at average Efficiency for that season instead of their disappointing 72% Efficiency. The effect of Market Value on Efficiency showed to be small and hardly recognizable, while the effect of Market Value on Frontier Points turned out to be more pronounced.

The relation of Efficiency and Frontier Points to the Market Value of the club was studied deeper in the next section. The results showed that Efficiency has a significant positive correlation with the Market Value of 28%, as well as a significant coefficient when the Market Value was regressed on Efficiency. The explanatory power of Efficiency however was quite low with an R-squared of 8%.
Frontier Points was shown to have a large significant correlation with Market Value of 71%. In the regression of Market Value on Frontier Points, its coefficient was highly significant as well as the explanatory power with an R-squared of 51%.
These results show significant relations between Efficiency and Market Value, as well as between Frontier Points and Market Value.

The underlying reason behind these relations is player quality. Player quality is assumed to be related to Market Value given the fact that better players are worth more money. With regard to Frontier Points, higher player quality will result in more dominant play and will therefore raise Frontier Points. Regarding Efficiency, specific qualities are important in converting dominant play in actual goals and points. Focussing on buying or training players that possess the quality needed to raise dominance or Efficiency, is the way to increase Market Value. Accurate passers have a positive impact on Frontier Points, while superior goal scorers are of great importance for increasing Efficiency.
The results have shown that, to a certain extent, attractive and dominant football has a bigger effect on Market Value than efficient football. However, both aspects are needed in order to get the desired results and raise Market Value.

This study was restricted in some way due to data limitations. For the Italian Serie A, data on in-game statistics was only to be found for the past seven seasons. Combined with a number of twenty teams per season, this resulted in 140 observations. With more data, the results would have possibly been more reliable.
Furthermore, this study included seven statistics as independent variables in the frontier model. As there are various statistics influencing the number of points achieved by a team, other variables could be taken into account to enhance the reliability of the results.

This research provides useful opportunities for further research. Predominately the relation between Efficiency and Market Value is interesting to analyse further. This study kept its focus on the specific relations between the factors, not taking possible control variables into account. More extensive research on these relations would be an interesting addition to the existing literature about Efficiency in football.
Concerning the Efficiency itself, it might be interesting to look at the Efficiency of teams in international tournaments like the Champions League or even the World Cup for national teams.

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