Why in rugby union "Toulouse" means "to win"? Estimation of a production function of sports results (2011–2016)

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Abstract: The objective of this article is to better understand the determinants of sports performance. To do this, we estimate a production function of sports results that explains the results of the matches of the Toulouse rugby union team expressed as the gap in points between is and its opponents. To the best of our knowledge, this is the first time that a production function has been estimated in rugby union. In addition, it is one of the few production functions specified at the match level. The study confirms the relevance of some variables already identified in the literature such as home advantage, ranking, the role of the referee and the in-match statistics. It also shows the influence of new variables such as weather conditions and the relative strength of fielded teams measured by comparing the teams selected on match day to the ideal teams defined at the beginning of the season.

Keywords: production functions, rugby union, team sports, sports outcomes.
JEL codes: D24, L83, J24.

1. Introduction

Identifying the determinants of sports performance has become an important challenge in recent years. There are several explanations for this trend. Among them, there is an ever greater production of data that permit deeper empirical analyses but also a larger demand for quantitative assessment from various sectors of the public ranging from managers to journalists. The development of the betting industry is also an enhancing factor.

The objective of this article is to build a new model to identify which factors influence sports outcomes, the latter being measured here as the gap in points observed at the end of a

[1] ericduboispro1@gmail.com At the beginning of this article, we benefited from informal discussions with Martial Foucault. We thank *OPTA Sports* for the provision of statistics on the content of games and in particular Florent Chassagne and Thibault Richetta. We also thank Jérémy Fadat and Ludovic Favre from the newspaper *Midi Olympique* for their help. The first version of the article was substantially improved following the comments and suggestions of an anonymous referee of the journal. For terms specific to rugby not defined in this article, one may refer to the glossary available at the following address: https://fr.wikipedia.org/wiki/Lexique_du_rugby_%C3%A0_XV

match between two teams. Specifically, the method used is the estimation of a production function of sports results that links an indicator of sports performance, viewed as an output, with assumed production factors (inputs). Classical references include Scully (1974), Zak et al. (1979) and Schofields (1988).

We focus on rugby union[2] and specifically on the results achieved since 2011[3] by the first team of Stade Toulousain (hereafter "Stade Toulousain"), the main Toulouse rugby union club. Stade Toulousain has the most impressive record in rugby union in France having won 19 first division championships. This is one of the teams that most dominate their sport with a percentage of victories well above the average (63% in the regular phase of the French championship in the last four seasons against an average of 48%). Toulouse also dominates European rugby union with four European cup wins, which again constitutes a record.

This study contributes to the existing literature in three ways. First, it is one of the first, if not *the* first, to focus on rugby union (see Carmichael and Thomas, 1995, for the only existing application to rugby league we know). This helps us to see how certain assumptions developed for other sports are applicable to rugby (such as playing at home, for example). Then, this study is one of the few to focus on the results of a single club and to set the analysis at the match level (see Carmichael et al., 2000, and Leard and Doyle, 2011, for examples of studies at the match level in other sports). In considering this level, this study enables the impact of new potential determinants to be tested, such as the recovery time elapsed since the last game, weather conditions and refereeing. Never before published indicators of the relative strength of the teams are also offered. Finally, new measures are used for variables already present in the literature such as the content of the game.

The rest of the article is organized as follows. Section 2 presents the model. Estimates' results are presented in Section 3. Section 4 concludes.

2. The model

We propose to estimate the following model:

$$GAP = f(\text{context, strength of fielded teams, content of the match})$$

[2] Rugby union is played with 15 players in each team. There are other forms of rugby, the best known are rugby sevens (played with 7 players in each team) and rugby league (played with 13 players in each team).
[3] Some data we use are not available before that year.

2.1. The dependent variable

We selected as dependent variable the gap in points between Stade Toulousain and the opposing team (the number of points scored by Stade Toulousain less the number of points scored by the opposing team; variable noted as GAP). Other choices were available to us but they all had one or more drawbacks. Thus, we could have focused on the points scored by Stade Toulousain alone. However, there may be cases where the Stade Toulousain team scores a lot of points and lose the game (for example, on day 23 of the 2013–2014 season, Stade Toulousain lost despite scoring 28 points). We could also have considered a binary variable equal to 1 for victory and 0 for non-victory (draw or defeat) but this would fail to differentiate between, say a 9-6 victory and a 24-3 victory. Such a binary variable offers little "thickness" and, in the end, little to explain. A similar choice to ours, but in another sport, is made by Carmichael et al. (2000), and explains the difference in goals scored in football.

It now remains to select the competition(s). Over the last five seasons, all competitions mixed up, Stade Toulousain played 186 matches. Table 1 gives their distribution.

[INSERT TABLE 1 HERE]

We chose to focus on the French championship.[4] For this competition, we retain matches played during the regular phase and matches played in the finals as well. Of course, we will check whether the latter exhibit some specificities. We exclude friendly matches (which are mostly pre-season preparation matches or intended to fill an extended period without an official match) and European competition[5] matches. For the latter, important information about the opponent is missing. Table 2 gives some statistical elements about the distribution of the dependent variable.

[INSERT TABLE 2 HERE]

[4] Since the 2004-2005 season, the French championship has had 14 clubs and been called the "TOP 14". During the regular phase, each team meets the 13 others twice in home and away matches. Since the 2009–2010 season, the six top-ranked teams at the end of the regular phase have participated in the finals. The four teams ranked from sixth to third places meet in a play-off match (a kind of quarter of final). The two winners qualify for the semi-finals and face the teams finishing first and second at the end of the regular phase. The two winners of the semi-finals meet in the final for the title. Note that the advantage to be ranked fourth and third is to play the match at home. Semi-finals and final are played on neutral ground.

[5] The European competitions have existed since 1995. The Champions Cup is reserved for the top six clubs of the previous season (and possibly a seventh after a play-off match against a foreign team) and the Challenge Cup is reserved for the following six clubs and the top two clubs from the second division ("Pro D2").

The table shows that the average outcome of Stade Toulousain matches in the Top 14 over the 2011–2016 period was victory by a margin of 6 points.

2.2. The explanatory variables

We group variables into two blocks: the context of the match and the content of the game.

2.2.1. The context of the match

Our model includes fourteen variables that take into account the context of the match. We distinguish the sports context from the extra-sports context. The latter is taken into account through seven variables.

The first is where the game is played. For a long time researchers have demonstrated an advantage derived from playing a sporting event at home (the so-called "home advantage"; see, among many others, Schwartz and Barsky, 1977, Zak et al., 1979, Carmichael et al., 2000, Goddard and Asimakopoulos, 2004, and Carmichael and Thomas, 2005). Several arguments support such an effect: the crowd supporting the receiving team (through encouragement but also the pressure on the referee as in Greer, 1983), less fatigue due to the lack of travel and familiarity with the environment (better marks). So we introduced a variable denoted as HOME1, which takes the value 1 when the match is played in Toulouse and -1 when the game is played away.[6] This variable is set to 0 when the match takes place on a neutral ground, that is in the semi-finals and in the finals. However, it ignores the fact that a match can be delocalized by the receiving team if they decide to play the game in another, in principle larger, stadium. The effect is uncertain because whilst it certainly can accommodate more spectators, it can also lead to a lack of marks, which can mitigate the supposedly positive effects of playing at home. We have therefore defined HOME2, which takes the value 1 when the match is played in the usual stadium of Stade Toulousain, -1 when the game is played in the usual stadium of the opponent, and 0 otherwise. This variable is included in the regression along with a variable named DELOC which takes 1 when the match is delocalized by Stade Toulousain, -1 when the game is delocalized by the opponent, and 0

[6] In fact, this variable should be considered as the difference between two underlying variables: a variable that is worth 1 when the match is played in Toulouse and 0 otherwise and a variable that is worth 1 when the match is played in the opponent's city and 0 otherwise.

otherwise. Finally, we define HOME3 which takes into account the distance between the two cities. Presumably, the travel time to reach the receiving city may play a role (Goddard and Asimakopoulos, 2004, Nutting, 2010). The travel can be stressful and tiring. We have therefore defined a variable that is the difference between the distance[7] in kilometres travelled by Stade Toulousain and the distance travelled by the opposing team.[8] We can note that, while the majority of trips are made by bus, journeys of more than six hours are generally made by plane. We have therefore converted the distances by taking into account the mode of transportation.[9] The expected sign for HOME3 is negative since farer from Toulouse is the Stade Toulousain, smaller is the home advantage.

The second context variable is the weather.[10] It is often believed that this potential impact is not discriminatory since it affects both teams equally. This view is questionable. Indeed, it is often argued that Stade Toulousain is more disrupted by rain than the opposing team. This is because Stade Toulousain has a game that is more based on handling than other teams that rely more on kicking or rucking. Does this have a foundation? To evaluate handling, we examined the number of passes and the number of offloads[11] per game. Over our study period, the average number of passes for Stade Toulousain was 127 against 99 for its opponents. Similarly, the average number of offloads was 16 for Stade Toulousain and 9 for its opponents. In this context, rain (or snow) would be more detrimental to Stade Toulousain than to other teams. We have introduced a variable equal to 1 when it is rainy (or snowy) and 0 otherwise (variable denoted as RAIN). We have two distinct sources on which to build this variable: the match reports written by the Stade Toulousain website and by the newspaper *L'Equipe*, in its printed version.[12] We chose to use both sources simultaneously. So RAIN is

[7] An alternative possibility was to consider durations and not distances. The journeys are usually made by bus, and we have not been able to find a route planner for journeys using this means of transport.

[8] This variable is well a measure of the home advantage since its value is negative when Toulouse receives (the distance travelled by Stade Toulousain is null) and positive when the opponent receives (the distance travelled by the opponent is null). We note also that the correlation between HOME1 and HOME3 is almost perfect (see Table A3 in annex).

[9] To do this, we took the durations of the trip from Toulouse to Lyon, which is 541 km, by bus and by plane. These times are respectively 8:15 and 2:00 (sources: www.eurolines.fr and www.airfrance.fr). This amounts to a conversion rate of 4.125. Applying this rate, we get distances in "bus equivalent". Thus, the distance between Toulouse and Lyon is no longer 541 km but 131 km.

[10] Note that the impact of weather conditions on sports results has been studied by, among others, Hoffmann et al. (2002a,b). In these studies, however, it is not the climatic conditions at the time of the competition that are under consideration but the usual climatic conditions of the city where the competition takes place.

[11] An offload is a pass made by a tackled player before he falls to the ground. This is a relevant indicator of handling since the tackled player refuses to allow the game to be pulled to the ground and thus prevents an excessive slowdown in the circulation of the ball.

[12] Note that it is not climate data but a subjective assessment by the person in charge of writing the report.

worth 1 when the Stade Toulousain website or the printed version of *L'Equipe* indicates that the weather was rainy,[13] and 0 otherwise.[14] The question of the wind, whose presence is very annoying for playing rugby, also deserves to be mentioned. However, with teams changing sides at half-time, we can consider the negative effect of the wind to be cancelled out.

The third variable is the identity of the referee.[15] Of course, the purpose here is not to hypothesize that some referees deliberately advantage or disadvantage Stade Toulousain.[16] But one may believe that the way of arbitrating some phases of the game varies from one referee to another and this may influence the final outcome. We have no theoretical basis for saying that a particular referee has a particular way of arbitrating a particular phase of play. Our approach here is therefore inductive. We build one variable for each referee who officiated at least three times during a match featuring Stade Toulousain in our sample.[17] For privacy reasons, these variables are anonymous and are simply named REFEREE1, REFEREE2, etc. So REFEREE1 is worth 1 when Referee 1 arbitrates Stade Toulousain, and 0 otherwise. A total of 14 referees have officiated in at least three matches featuring Stade Toulousain since 2011.

The following three variables are calendar-related variables. The fourth variable takes into account the fact that the game takes place just before a European cup match (variable named BEFORE_EC). One may indeed think that there will be a rise in power of the team that will also wish to store trust. Conversely, we may also think that the coach will rotate his team in order to have it in better shape for the European cup match. The fifth variable takes into account the fact that the game takes place right after a European cup match (variable named AFTER_EC). The effect here seems clearer: the coach may wish to rest his leader players. BEFORE_EC (respectively, AFTER_EC) is worth 1 when the match precedes (respectively,

[13] We could only use one source and test the other for robustness purposes but *L'Equipe* stopped reporting the weather conditions in 2015.

[14] This variable is not expressed in terms of gap, which means that only Stade Toulousain is advantaged or disadvantaged by the weather. Of course, other teams that had the same set of features as Stade Toulousain would also be advantaged or disadvantaged. Unfortunately, it turned out to be too complicated to identify these teams. Indeed, we do not have the statistics for passes and offloads for all teams that have faced Stade Toulousain over our entire study period.

[15] In his study of the results of national football teams, Torgler (2004) introduced two variables measuring the geographical and cultural (linguistic) proximity between each team and the referee.

[16] It is often stated that home advantage and refereeing are linked and that a referee bias actually exists (see the seminal article of Greer, 1983, and also, among many other, Moskowitz and Wertheim, 2011). The story is a little bit different here since there is a bias for two referees whether they refer at home or not. Even when they refer Stade Toulousain at home, they disadvantage it.

[17] The case of a referee who refereed Stade Toulousain once or twice is problematic because the associated dummy would be a catch-all variable that captures all non-observed effects in a particular game and not only arbitration.

follows) a European cup match, and 0 otherwise.[18] The sixth variable deals with recovery. This is the number of additional recovery days in favour of Stade Toulousain. Specifically, it is the number of days elapsed since the last Stade Toulousain match minus the number of days elapsed since the opposing team's last game (variable denoted as RECOVERY). For the first game of the season, the last game is the last friendly match.

The seventh variable is the relative level of the two teams. One can expect that the gap in points will be smaller when the level of the teams is close. To reflect this, we build a variable that is the gap in the ranking at the end of the previous day (RANKING). The more the differential is negative, the more the gap in points will be positive (and vice versa). For the first four days, we take the ranking after the last day of the previous season.[19] Indeed, it takes a few matches for the ranking of the current season to make sense because of the great variability of positions, which fluctuate greatly with the smallest defeat or victory. Preliminary simulations showed that it was necessary to use the ranking of the previous season for the first four days of the current season. Note that using the ranking is common in studies to assess the relative strength of the teams. Thus, Torgler (2004) and Paul and Mitra (2008) use the FIFA rankings in their study of the results of national football teams.

The eighth variable reflects what is at stake in the game.[20] Indeed, in the last matches of the regular phase, one of the two teams, or both, may not be concerned by either the possibility of reaching the finals or the possibility of dropping into Pro D2 (lower league). Conversely, one of the two teams, or both, may sees its participation in the finals or its relegation to Pro D2 as assured.[21] The STAKE variable is worth 1 if the match has a stake for Stade Toulousain only, -1 if the match has a stake for the opponent only, and 0 otherwise (stake or lack of stake for both teams[22]). For example, before the day 26 of season 2011-2012, Stade Toulousain was ranked 1st with 83 points. There was no stake for Stade Toulousain since the team ranked 3rd has 69 points.[23] Stade Toulousain was therefore sure to be qualified for the semi-finals. So the value of STAKE for Stade Toulousain is zero. This day, its opponent, Montpellier, was ranked 4th with 66 points. A direct qualification for the semi-

[18] These variables, however, ignore the possibility that the opponent of Stade Toulousain also plays in the European cup.
[19] If the opponent is one of the promoted teams, we considered its ranking to be 15 if it finished first in Pro D2, 16 if it finished second, etc.
[20] See Goddard and Asimakopoulos (2004) for the use of a stake measurement.
[21] Note, however, that in the event that participation in the finals is assured, as we have seen, the ranking still matters.
[22] In the finals, since there is at stake for both teams, STAKE is worth 0.
[23] We recall that a maximum of 5 points can be gained (4 points for the victory and 1 point in case of 3 tries more than the opponent scored).

finals was impossible to reach since the team ranked 2nd has 82 points. But Montpellier was threatened by two teams, ranked 5th and 6th with 65 and 63 points respectively. It implies that in case of a defeat of Montpellier and a victory of the team ranked 5th, Montpellier losses its 4th rank and so will play away in the first match of playoffs. So the value of STAKE for the opponent is 1. Therefore, after taking the difference, the overall value of STAKE is -1.

The four following variables are season dummies. They are worth 1 in a particular season, and 0 otherwise. We have therefore SEASON11-12, SEASON12-13, SEASON13-14, and SEASON14-15, the season 2015-2016 being the benchmark. Since the composition of the league is different each year with two promoted teams and two relegated teams, it could be the case that the level of the league is higher or lower in mean than other season. It could also be the case that all the other teams have a better or a worse team, depending on, for example, financial constraints. If these cases, Stade Toulousain can have a systematic advantage or disadvantage on a particular season.[24]

The thirteenth variable is a dummy that takes into account that the match is a play-off match (variable noted PLAYOFF). Indeed, unlike regular season matches, this kind of matches are direct elimination match. The team which loss the match is eliminated and cannot continue the competition. This generates a particular stress and usually this kind of matches are more close. We can therefore expect a smaller gap for these matches.

The fourteenth and last variable is the strength of fielded teams. The purpose here is to measure the actual composition of the teams on match day and to take into account the constraints that the coach is faced with. In particular, the coach does not have her/his entire squad at her/his disposal at every game, for various reasons: players selected for national teams, players injured or out of form, players suspended, etc.[25] For the coach, the reason for absence is irrelevant, what matters is that the players are not available. The coach may also choose to rotate the team.

How should we measure the composition of a team and how can we determine whether this is a strong team? It is necessary here to have a reference, an ideal team that consists of the 15 holders of each position.[26] The concept of ideal team may appear irrelevant in rugby.

[24] Other factors may play a role as a change of rule for example but it is not obvious why it could impact Stade Toulousain performance only.
[25] For a study on the impact of having injured players, see Drawer and Fuller (2002).
[26] Other variables can account for the fielded team's strength, such as the average age, the total number of international caps, the total number of Top 14 matches, the weight of the pack, etc. (see in this regard Carmichael and Thomas, 1995). In some studies, the relative strength of the teams is taken into account through

Indeed, unlike other sports, the turnover is much more important. In rugby union, eight replacements can be made during an official match and so 53% of the starting team can be changed. In football, for example, the ratio is only 27%. This should lead us to be cautious about the ideal team concept. One could, for example, say that for the same position, and after consultation between the players and the coach, there are really "two holders" sharing the playing time. There are very few sources for obtaining the ideal teams. Over our studied period, the only source we found was the bi-weekly *Midi Olympique*, which publishes in the weeks before the start of the championship a series of articles called "Saga". Each club is presented and a "probable XV" is proposed. From there, we calculate the number of ideal team players absent in the starting 15 (i.e. not holders) during a given match (STRENGTH1) and the number of ideal team players absent from the sheet match (holders or substitutes) in a given game (STRENGTH2). It is likely that the presence of an ideal team player as a substitute is less damaging than his complete absence. Both variables are expressed as a difference between Stade Toulousain and its opponent. These two variables, however, have two major limitations. First, they ignore the fact that one or several ideal team players may be on the match sheet but get injured during the match, and possibly early in the game, which makes them virtually absent. Second, these indicators do not reflect the relative quality of the absent players. Thus, a missing Stade Toulousain international holder is put on the same level as a missing non-international opponent holder. STRENGTH1 and STRENGTH2 are therefore split in two by distinguishing international players from non-international players. INTER is the difference between the number of players in the ideal team of Stade Toulousain selected for the national team and the number of players in the ideal team of the opponent selected for the national team. NONINTER is built the same way for non-international players. Finally, INTER and NONINTER are indexed by 1 and 2 to be in line with the definition of STRENGTH1 and STRENGTH2.

2.2.3. The content of the game

Despite a favourable context and a strong line-up, Stade Toulousain may "not turn up" and deliver a bad performance. Conversely, a weak team may play above itself, notably to challenge the hierarchy for certain positions, and ultimately deliver a high-quality

specific dummies (Carmichael et al., 2000) or past results (Goddard and Asimakopoulos, 2004) for each opponent team.

performance. We must therefore consider the content of the game. For this, we use statistics tracing the course of the match and the actual performance of the players on the field.[27] First, we obtained a set of 25 statistics available on the *Midi Olympique* website: (number of) tries, metres run with the ball in hand, runs with the ball in hand, defenders beaten, line breaks, passes, offloads, turnovers, tackles (total), missed tackles, kicks from hand, conversions, successful penalties, missed penalties, successful drop goals, missed drop goals, rucks won, rucks lost, own line-outs won, own line-outs lost, own scrums won, own scrums lost, penalties conceded, yellow cards, red cards. Unfortunately, these statistics are available for the 2014–2015 season only. They were in fact provided by *Opta Sports* as part of an ephemeral partnership. We contacted *OPTA Sports* who provided us with the statistics for three other seasons, 2011–2012, 2012–2013 and 2013–2014. That is why our sample starts in 2011. Data for the season 2015–2016 are taken from the espn.co.uk website. It seems that once again the ultimate source for these data is *Opta Sports*.

In reviewing the list of statistics, we can make a first selection and disregard some of them because using them amounts to explaining the score by the score. This is the case with the number of tries, the number of successful conversions, the number of successful penalties and the number of successful drop goals. Indeed, the points scored by a team are mechanically deduced from these statistics: number of points = (number of tries scored x 5) + (number of successful conversions x 2) + (number of successful penalties x 3) + (number of successful drop goals x 3).

Then, some statistics are meaningful only if they are expressed in relative terms. One thus defines five variables. First, SCORERSSUCCESS is the percentage of successful placed kicks by the scorer(s) of a team. More specifically, it is the number of successful penalties plus the number of successful conversions over the number of attempted penalties plus the number of attempted conversions.[28] Similarly, TACKLES, RUCKS, LINEOUTS and SCRUMS are, respectively, the number of missed tackles, lost rucks, lost line-outs and lost scrums expressed as a percentage of the total. DEFENDERSBEATEN, LINEBREAKS, TURNOVERS and PENALTIES are left as they are.

[27] Statistics on the content of matches or "in-match statistics" are used in the production functions, for example, by Zak et al. (1979), Carmichael et al. (2000), Torgler (2004) and Carmichael and Thomas (2005).

[28] This variable takes into account success of the scorers but also their fails. In doing so, it shows what happened but also what did not. Scoring some penalties is obviously important but it is also important not to miss too much of them.

Similarly, one may question a priori the relevance of statistics such as the (number of) metres run with the ball in hand, runs with the ball in hand, passes, offloads or kicks from hand, because it is not clear how they reflect a good or a bad game. Indeed, they may be associated or not with points scored according to the team's effectiveness. The variables constructed from these statistics will nevertheless be tested (the variables METRES, RUNS, PASSES, OFFLOADS and KICKS, respectively). It is assumed that these statistics positively influence the gap in points, a team that advances being more likely to score points.

Finally, two statistics require special treatment: the number of yellow and red cards.[29] On the one hand, yellow cards conceded late in the game can penalize teams by less than ten minutes. On the other hand, red cards penalize teams for the remainder of the game. For these reasons, we have built an indicator called OUTNUMBER, which is the number of minutes Stade Toulousain played with fewer players than its opponent. OUTNUMBER13 accounts for the special event when Stade Toulousain played with 13 players. For these two variables, we considered possible playing time beyond the 80th minute. The sign for these two variables is uncertain because an outnumbered team can tighten its defence, and its players, knowing they have one fewer, can be more focused. The impact of cards in other sports has been studied, especially by Ridder et al. (1994) and Carmichael et al. (2000).

All the 16 variables that we have just defined are, as before, expressed in the gap between Stade Toulousain and its opponent.

3. Estimation of the model and results

The sample contains 138 observations. For 6 of them, some data are not available. In the end, the model will be estimated on 132 observations. Thirty different variables are considered and, given their different possible definitions, 51 variables have to be tested. Table 3 recalls the name of these variables and the expected sign for each of them.

[INSERT TABLE 3 HERE]

[29] A yellow card results in a temporary exclusion of 10 minutes and a red card results in a permanent exclusion. A second yellow card during the game to the same player automatically leads to a red card.

Since we have a relative small sample regarding the number of variables to include, we estimate the two blocks separately in a first step. Table 4 displays the estimates of block 1 (context of the match).[30]

[INSERT TABLE 4 HERE]

At this stage, it is dangerous to interpret the size and the significance of all the coefficients since a lot of control variables are missing. We will therefore restrict to compare estimates between them to tackle two issues.

The first one for this block is the home advantage. Playing at home provides a clear advantage. HOME1 is found to be significant at the 1% threshold (see column 1). Its coefficient, equal to 7.50, indicated that, other things being equal, the gap in points in favour of Stade Toulousain increased by about 8 points when Stade Toulousain was playing at home. Results are not better when including HOME2 and DELOC (see column 2). While both variables are significant at the 1% threshold, they come with broadly the same coefficient, indicating that delocalizing has no sportive impact on the match. Of course, other (extra-sportive) advantages can be found in delocalizing as to permit more people to see the match and, linked to that, obtain additional financial resources. HOME3 is also strongly significant and confirm the existence of a clear home advantage (see column 3). In addition, the travelled distance by both teams play a role. Indeed, when Stade Toulousain receives a team from a city located 100 km away (by bus), it has an advantage of about 3 points. Thus, when receiving Montpellier, a city located 242 kilometres from Toulouse, Stade Toulousain has an advantage of about 7 points. However, the estimate including HOME3 is not superior in terms of R^2 or adjusted R^2, so we decided to keep HOME1, the most straightforward measure of the home advantage in the remaining of the article.

The second issue regarding the context of the match deals with the strength of fielded teams. Our indicator of the composition of teams modeling their relative strength is clearly relevant. The coefficient of STRENGTH1 is indeed significant at the 10 % threshold (see column 1). It is also negative, as expected: absences of players from the ideal team are detrimental. Each missing player costs about 0.8 points for his team. An interesting point here

[30] The sources of data, descriptive statistics and correlations are presented in the appendixes. For all the estimates in the article, the heteroskedasticity is corrected by applying the White correction and the Jarque-Bera test is performed to check that the residuals are normally distributed (the p-value is reported below each estimate in the table).

is that STRENGTH2, which takes into account the fact that one or more players of the ideal team may be present but substitutes, is not significant (see column 4). It implies that only the full absence of players matters. If they are present as substitutes, there is no impact on the game. But the most surprising point here is that splitting STRENGTH1 or STRENGTH2 to make a distinction between international and non-international players provides no additional explanatory power (see columns 5 and 6). Unlike journalists often say, having missing players du to their convocation in the national team has no impact on the match outcome. It is most likely that these absences are already taken into account through the STRENGTH variable.

We turn now to the second block of explanatory variables dealing with the content of the match. Table 5 displays the estimates.

[INSERT TABLE 5 HERE]

As for table 4, we do not interpret the size and significance of coefficients. Table A3 in annex exhibits however some quite high pairwise correlations. This can lead to severe multicolinearity problems. In order to overcome this potential problem, we perform auxiliary regressions: we regress each explanatory variable over all other remaining explanatory variables. We apply after the Klein's rule: if the R^2 of the auxiliary regression is larger than the overall R^2 (R^2 of the complete regression; column 1), the dependent variable of the auxiliary regression may cause severe multicolinearity problems and should be dropped. Columns (2) to (6) displays the auxiliary regression for which the R^2 is larger than the overall R^2, implying that METRES, RUNS, PASSES, DEFENDERSBEATEN, and TACKLES should be removed from the analysis.[31] Estimates of column 7 are obtained.

The last step consists in characterizing the final estimation. To do this, we blended estimates of column 1, Table 4, and column 7, Table 5. We then perform the stepwise regression method with backward elimination: at each step, we remove the variable with the lowest Student t and we rerun the estimation. We stop when the Akaike criterion is minimal. e final estimation results are displayed in Table 6.

[INSERT TABLE 6 HERE]

[31] Results of the 11 other auxiliary regressions are available from the author upon request.

Overall, the goodness of fit of the model to the data is relatively good with a R^2 of 76%. Thus, the model explains 76% of variance of the gap in points between Stade Toulousain and its opponent.

As noted before, playing at home provides an advantage. HOME1 is found to be significant at the 10% threshold. Its coefficient, equal to 1.70, indicated that, other things being equal, the gap in points in favour of Stade Toulousain increased by about 1.70 points when Stade Toulousain was playing at home. This effect is quite lower than the one enlightened by Table 4 what is not surprising since that it is now controlled by other factors.

As expected, the coefficient of RAIN is negative and strongly significant. When it rains, the gap in favour of Stade Toulousain is reduced by about 4.6 points.

Similarly, referees have a non-neutral influence on the gap in points. So when Referee 7 referees the game, the gap in favour of Stade Toulousain decreases by about 7 points. A similar effect is found with Referee 11 but in a lesser extend. Is this an artefact and do these variables actually capture anything other than the single influence of the arbitration? Presumably not. Indeed, Referee 7 and Referee 11 refereed Stade Toulousain respectively 12 and 10 times in our sample. It can therefore hardly be a coincidence. As we said earlier, it is not a matter for us to cast aspersions upon these referees and believe that they knowingly favour or disadvantage Stade Toulousain. We think it is more their way of arbitrating that plays a role. For example, it is likely that Referee 7 blows more for forward passes. In doing so, this unwittingly assists Stade Toulousain, whose game relies very much, as we have seen, on passing.

The ranking of the two teams before the game plays a very important role. Indeed, the RANKING coefficient is negative and strongly significant. When Stade Toulousain is ranked ahead of its opponent, each rank increases the gap in points by about 0.4 points. For example, if Stade Toulousain is ranked first and its opponent sixth, RANKING is worth 1-6 = -5 and the impact on the gap will be -5x-0.44 or 2.2 points.

Stake matters with an additional gap of 11.6 points in absolute value when nothing is at stake in the match for one team.

Finally, among the four SEASON dummies, only SEASON11-12 turned to be significant. During the season 2011-2012, Stade Toulousain appeared to have a systematic advantage. As noted when this variable was presented, this effect is not so easy to explain. A first element is

a potential weakness of the league this particular year. We examined some indicators[32] but failed to indentify a special profile for the season 2011-2012. A second hint could be the fact that Stade Toulousain was champion the previous year. This may have impressed the opponent teams and gave the Stade Toulousain a kind of premium. We note however that even if Stade Toulousain was champion in 2012, SEASON12-13 did not turn to be significant.

Other context variables turned out to be non-significant (BEFORE_EC, AFTER_EC, RECOVERY, PLAYOFF). Having more or fewer days off does not have an influence.[33] With regard to the dummy variables for the matches played just before and just after the European cup, it might be that their influence is potentially captured by other variables such as the composition of teams or statistics on the content of matches.

Our indicator of the composition of teams modelling their relative strength is also relevant. The coefficient of STRENGTH1 is indeed clearly significant. It is also negative, as expected: absences of players from the ideal team are detrimental. One ideal player more than the opposing team missing will result in 0.7 fewer points.

Finally, we have to examine the results for the variables for the content of the game. Of the 11 variables tested (since five variables were dropped to avoid multicolinearity problems), eight turned out to be significant and all have the expected sign.

The coefficient of KICKS indicates that two kicks more than the opponent increases the gap in points by about 1 unit. This is consistent with our hypothesis that the team that advances more scores more points.

Two attack variables is significant: LINEBREAKS and TURNOVERS. Thus, one line break more increases the gap in points by about 1.3 units and two balls lost decreases the gap in points by about 1 points.

As regards set pieces, SCRUMS and LINEOUTS are both significant with two coefficients of comparable size. If Stade Toulousain loses one out of 10 of its own lineouts or of its own scrums when the opposing team loses none, the gap in points is reduced by about 1 points.

The success of the scorer(s) is also very important. As shown by the coefficient of the SCORERSSUCCESS variable, every additional percentage point of success leads to a gain of

[32] Number of points of the team ranked 1st at the end of the regular phase, gap in points between this team and the team ranked 14th, number of points necessary to qualify for the playoffs, number of points necessary to stay in TOP 14, etc.

[33] This does not change if we impose an upper bound on the values of this variable and consider a maximum of 3 days, 2 days or 1 day for a resting time of at least 4 days.

0.14 points. Thus, when the scorers for Stade Toulousain are successful in one penalty out of two and the scorers of the opposing team miss all their attempts, the gap in points is higher by seven points.

Finally, discipline plays a very important role. Each penalty given against Stade Toulousain reduces the gap in points by about 0.5 points and each minute spent with 14 players by Stade Toulousain decreases the gap in points by about 0.2 points (i.e. 2 points for a yellow card received in the middle of the match). A red card received by Stade Toulousain in the 50th minute leads to a loss of 6 points. An additional penalty from playing with 13 players could not be demonstrated.

Conclusion

The aim of this article was to better understand the determinants of sports performance. For this, we estimated a production function of sports results by choosing as application the outcomes of the matches of the Toulouse rugby union team expressed in gap in points between it and its opponents. This application to rugby union was original since, to the best of our knowledge, no other academic study has used a similar methodology dedicated to this sport. Furthermore, by locating the analysis at the match level (the finest level since it is constituent of more aggregated results such as the ratio of wins in a season, for example), we identified new potential determinants. Some proved to be relevant (such as weather), others not (such as recovery). We have also proposed new indicators for variables already used in the literature. We believe the real novelty lies here in the measurement of the relative strength of fielded teams by comparing teams set up on match day to ideal teams.

The model is estimated on the 132 championship games that have been played by Stade Toulousain since 2011. The main results are as follows. With regard to the context, the gap in points in favour of Stade Toulousain is higher when it plays at home, when it is ranked higher than its opponent and when it does not rain. What is at stake also matters. More surprisingly, the gap in points varies according to the identity of the referee, which suggests that the manner of arbitrating influences the score. The positioning of the game compared to the European cup and the number of days of recovery have, as measured here, no impact on the performance. As regards the relative strength of fielded teams, this is clearly influenced by the absence of players belonging to the ideal team. The absence of international players in turn does not lead to any additional penalty. Finally, variables accounting for the content of the

game have a crucial impact on the outcome. Of the 16 variables tested, eight were in fact proven to be relevant in explaining the gap in points, and each sheds a specific light depending on it accounts for an overall domination, a better attack, a better defence, a better conquest and a greater discipline. In particular, we note the importance of kicks, line breaks, scrums, line-outs, scorer(s) success, penalties conceded and time spent outnumbered.

Beyond these conclusions, future research may be considered. First, it would be desirable to ensure that the model is valid for one or several other teams, in France or abroad. Given the amount of work involved, in particular in the building of the strength of fielded teams, the assessment of external validity could not be performed here. However, we are confident because the proposed model is of general application and has no factor really specific to the chosen team. Then we believe that the proposed model can be applied to other sports. In particular, we believe that it would be very interesting to apply our measure of the relative strength of fielded teams in sports such as football, where the number of possible substitutions is more limited, which makes the absence of players composing the ideal team relatively more costly. Finally, we advocate the development of studies at the game level. In some sports, this would allow new determinants to be explored. We are thinking here in particular about the playing system, which, if it does not make sense in rugby, is extremely important, for example, in football (4-4-2 versus 4-3-3, for example).

References

Carmichael, F. and Thomas D. (1995) Production and efficiency in team sports: An investigation of rugby league football, *Applied Economics*, **27**, 859–69.

Carmichael, F. and Thomas D. (2005) Home-field effect and team performance evidence from English premiership football, *Journal of Sports Economics*, **6**, 264–81.

Carmichael, F., Thomas, D. and Ward, R. (2000) Team performance: The case of English premiership football, *Managerial and Decision Economics*, **21**, 31–45.

Drawer, S. and Fuller, C. W. (2002) An economic framework for assessing the impact of injuries in professional football, *Safety Science*, **40**, 537–56.

Goddard, J. and Asimakopoulos, I. (2004) Forecasting football results and the efficiency of fixed-odds betting, *Journal of Forecasting*, **23**, 51–66.

Greer, D. L. (1983) Spectator booing and the home advantage: A study of social influence in the basketball arena, *Social Psychology Quarterly*, **46**, 252–61.

Hoffmann, R., Lee, C. G. and Ramasamy, B. (2002a) The socioeconomic determinants of international soccer performance, *Journal of Applied Economics*, **5**, 253–72.

Hoffmann, R., Lee, C. G. and Ramasamy, B. (2002b) Public policy and Olympic success, *Applied Economics Letters*, **9**, 545–8.

Leard, B and Doyle, J. (2011) The effect of home advantage, momentum, and fighting on winning in the National Hockey League, *Journal of Sports Economics*, **12**, 538–60.

Moskowitz, T. J. and Wertheim, L. J. (2011) *Scorecasting: The hidden influences behind how sports are played and games are won*. New York: Crown Archetype.

Nutting, A. (2010) Travel costs in the NBA production function, *Journal of Sports Economics*, **11**, 533–48.

Paul, S. and Mitra, R. (2008) How predictable are the FIFA Worldcup football outcomes? An empirical analysis, *Applied Economics Letters*, **15**, 1171–6.

Ridder, G., Cramer, J. S. and Hopstaken, P. (1994) Estimating the effect of a red card in soccer, *Journal of the American Statistical Association*, **89**, No. 427, 1124–7.

Schofield, J. A. (1988) Production functions in the sports industry: An empirical analysis of professional cricket, *Applied Economics*, **20**, 177–93.

Schwartz, B. and Barsky, S. F. (1977) The home advantage, *Social Forces*, **55**, 641–61.

Scully, G. W. (1974) Pay and performance in Major League Baseball, *American Economic Review*, **64**, 915–30.

Torgler, B. (2004) The economics of the FIFA football Worldcup, *Kyklos*, **57**, 287–300.

Zak, T. A., Huang, C. J. and Siegfried, J. J. (1979) Production efficiency: The case of professional basketball, *The Journal of Business*, **52**, 379–92.

Appendixes

Table A1. Data sources

Variables	Sources
GAP	www.lequipe.fr and www.rugbyrama.fr
HOME1	www.lequipe.fr and www.rugbyrama.fr
HOME2	www.lequipe.fr and www.rugbyrama.fr
DELOC	www.lequipe.fr and www.rugbyrama.fr
HOME3	www.lequipe.fr, www.rugbyrama.fr and www.mappy.fr
RAIN	Newspaper L'Equipe (printed version) et www.stadetoulousain.fr
REFEREE1 to 14	www.lequipe.fr and www.rugbyrama.fr
BEFORE_EC	www.lequipe.fr and www.rugbyrama.fr
AFTER_EC	www.lequipe.fr and www.rugbyrama.fr
RECOVERY	www.lequipe.fr and www.rugbyrama.fr
RANKING	www.lnr.fr
STAKE	www.lnr.fr
SEASON11-12	www.lnr.fr
SEASON12-13	www.lnr.fr
SEASON13-14	www.lnr.fr
SEASON14-15	www.lnr.fr
PLAYOFF	www.lnr.fr
STRENGTH1	Newspaper Midi Olympique (printed version), www.lequipe.fr et www.rugbyrama.fr
STRENGTH2	Newspaper Midi Olympique (printed version), www.lequipe.fr et www.rugbyrama.fr
INTER1	idem STRENGTH1 plus various Internet sources
INTER2	idem STRENGTH2 plus various Internet sources
NONINTER1	idem STRENGTH1 plus various Internet sources
NONINTER2	idem STRENGTH2 plus various Internet sources
METRES	Opta Sports, www.midi-olympique.fr and www.espn.co.uk
RUNS	Opta Sports, www.midi-olympique.fr and www.espn.co.uk
PASSES	Opta Sports, www.midi-olympique.fr and www.espn.co.uk
KICKS	Opta Sports, www.midi-olympique.fr and www.espn.co.uk
LINEBREAKS	Opta Sports, www.midi-olympique.fr and www.espn.co.uk
DEFENDERSBEATEN	Opta Sports, www.midi-olympique.fr and www.espn.co.uk
OFFLOADS	Opta Sports, www.midi-olympique.fr and www.espn.co.uk
TURNOVERS	Opta Sports, www.midi-olympique.fr and www.espn.co.uk
RUCKS	Opta Sports, www.midi-olympique.fr and www.espn.co.uk
TACKLES	Opta Sports, www.midi-olympique.fr and www.espn.co.uk
SCORERSSUCCESS	Opta Sports, www.midi-olympique.fr and www.espn.co.uk
SCRUMS	Opta Sports, www.midi-olympique.fr and www.espn.co.uk
LINEOUTS	Opta Sports, www.midi-olympique.fr and www.espn.co.uk
PENALTIES	Opta Sports, www.midi-olympique.fr and www.espn.co.uk
OUTNUMBER	Opta Sports, www.midi-olympique.fr and www.espn.co.uk
OUTNUMBER13	Opta Sports, www.midi-olympique.fr and www.espn.co.uk

Notes: These are primary sources. Raw data taken from these sources were then reworked by the author to build the variables finally used for the estimations.

Table A2. Descriptive statistics (part 1)

Variable	Minimum	Maximum	Mean	Median	St. Deviation
GAP	-30.00	51.00	5.73	3.00	15.92
HOME1	-1.00	1.00	0.03	1.00	0.99
HOME2	-1.00	1.00	0.05	0.00	0.88
DELOC	-1.00	1.00	-0.01	0.00	0.44
HOME3	-422.00	422	-6.03	-83.00	222.41
RAIN	0.00	1.00	0.22	0.00	0.42
REFEREE1	0.00	1.00	0.05	0.00	0.22
REFEREE2	0.00	1.00	0.08	0.00	0.27
REFEREE3	0.00	1.00	0.09	0.00	0.29
REFEREE4	0.00	1.00	0.03	0.00	0.19
REFEREE5	0.00	1.00	0.03	0.00	0.19
REFEREE6	0.00	1.00	0.03	0.00	0.17
REFEREE7	0.00	1.00	0.09	0.00	0.28
REFEREE8	0.00	1.00	0.11	0.00	0.31
REFEREE9	0.00	1.00	0.08	0.00	0.27
REFEREE10	0.00	1.00	0.03	0.00	0.17
REFEREE11	0.00	1.00	0.07	0.00	0.26
REFEREE12	0.00	1.00	0.02	0.00	0.14
REFEREE13	0.00	1.00	0.06	0.00	0.25
REFEREE14	0.00	1.00	0.08	0.00	0.27
BEFORE_EC	0.00	1.00	0.13	0.00	0.34
AFTER_EC	0.00	1.00	0.13	0.00	0.34
RECOVERY	-13.00	13.00	-0.15	0.00	2.63
RANKING	-16.00	10.00	-3.61	-4.00	4.97
STAKE	-1.00	1.00	0.01	0.00	0.21
SEASON11-12	0.00	1.00	0.17	0.00	0.38
SEASON12-13	0.00	1.00	0.20	0.00	0.40
SEASON13-14	0.00	1.00	0.20	0.00	0.40
SEASON14-15	0.00	1.00	0.21	0.00	0.41
PLAYOFF	0.00	1.00	0.06	0.00	0.23
STRENGTH1	-7.00	8.00	-0.21	0.00	3.13
STRENGTH2	-7.00	9.00	-0.28	0.00	2.69
INTER1	0.00	9.00	0.88	0.00	1.52
NONINTER1	-9.00	5.00	-1.09	-1.00	3.11
INTER2	0.00	9.00	0.88	0.00	1.52
NONINTER2	-9.00	5.00	-1.16	-1.00	2.52

Table A2. Descriptive statistics (part 2)

Variable	Minimum	Maximum	Moyenne	Médiane	Ecartype
GAP	-30,00	51,00	5,73	3,00	15,93
ST	*0,00*	*67,00*	*23,55*	*21,00*	*12,04*
OPP	*0,00*	*39,00*	*17,82*	*17,50*	*8,98*
METRES	-349,00	561,00	106,47	112,50	177,58
ST	*195,00*	*799,00*	*433,88*	*417,50*	*138,82*
OPP	*133,00*	*645,00*	*327,41*	*315,00*	*107,37*
RUNS	-67,00	111,00	22,84	29,00	35,55
ST	*58,00*	*179,00*	*107,83*	*105,00*	*23,71*
OPP	*45,00*	*158,00*	*84,98*	*81,00*	*21,85*
PASSES	-85,00	140,00	28,69	29,50	48,78
ST	*63,00*	*216,00*	*128,17*	*126,00*	*32,46*
OPP	*45,00*	*185,00*	*99,48*	*96,50*	*29,76*
KICKS	-16,00	13,00	-0,21	0,00	5,87
ST	*7,00*	*36,00*	*20,02*	*19,50*	*5,78*
OPP	*4,00*	*40,00*	*20,23*	*21,00*	*6,83*
LINEBREAKS	-7,00	23,00	3,13	3,00	5,02
ST	*0,00*	*26,00*	*7,05*	*6,00*	*4,81*
OPP	*0,00*	*15,00*	*3,92*	*3,50*	*2,83*
DEFENDERSBEATEN	-15,00	32,00	7,87	7,50	9,14
ST	*2,00*	*44,00*	*19,37*	*18,00*	*8,55*
OPP	*0,00*	*30,00*	*11,50*	*11,00*	*5,35*
OFFLOADS	-14,00	31,00	7,51	7,50	7,79
ST	*4,00*	*44,00*	*16,48*	*16,50*	*6,99*
OPP	*1,00*	*24,00*	*8,97*	*8,00*	*4,52*
TURNOVERS	-13,00	14,00	0,50	0,00	4,96
ST	*6,00*	*25,00*	*14,42*	*14,00*	*3,54*
OPP	*4,00*	*25,00*	*13,92*	*14,00*	*3,83*
RUCKS	-19,02	6,76	-2,04	-1,60	4,62
ST	*0,00*	*15,00*	*4,95*	*4,87*	*3,02*
OPP	*0,00*	*21,43*	*6,99*	*6,67*	*3,57*
ST Won	*38,00*	*126,00*	*70,25*	*66,50*	*16,56*
OPP Won	*26,00*	*112,00*	*57,50*	*54,00*	*17,07*
ST Lost	*0,00*	*9,00*	*3,58*	*3,50*	*2,16*
OPP Lost	*0,00*	*9,00*	*4,11*	*4,00*	*1,95*
TACKLES	-25,59	18,27	-4,97	-5,20	8,86
ST	*0,00*	*36,71*	*13,74*	*12,68*	*6,20*
OPP	*2,06*	*40,40*	*18,71*	*18,02*	*7,19*
Total ST	*40,00*	*158,00*	*85,82*	*79,00*	*26,58*
Total OPP	*42,00*	*179,00*	*104,30*	*103,00*	*25,25*
Missed ST	*0,00*	*30,00*	*11,52*	*11,00*	*5,35*
Missed OPP	*2,00*	*43,00*	*19,39*	*18,50*	*8,50*

Table A2. Descriptive statistics (part 3)

Variable	Minimum	Maximum	Moyenne	Médiane	Ecartype
SCORERSSUCCESS	-100,00	75,00	-0,81	0,00	28,40
ST	*0,00*	*100,00*	*71,45*	*73,86*	*20,92*
OPP	*25,00*	*100,00*	*72,25*	*72,08*	*20,40*
CONV total ST	*0,00*	*9,00*	*2,23*	*2,00*	*1,99*
CONV total OPP	*0,00*	*5,00*	*1,26*	*1,00*	*1,18*
CONV suc ST	*0,00*	*8,00*	*1,71*	*1,00*	*1,76*
CONV suc OPP	*0,00*	*3,00*	*0,92*	*1,00*	*0,92*
PEN total ST	*0,00*	*12,00*	*4,07*	*4,00*	*2,18*
PEN total OPP	*0,00*	*9,00*	*4,35*	*4,00*	*2,16*
PEN suc ST	*0,00*	*8,00*	*2,86*	*3,00*	*1,84*
PEN suc OPP	*0,00*	*8,00*	*3,07*	*3,00*	*1,86*
SCRUMS	-71,43	88,89	-0,26	0,00	24,03
ST	*0,00*	*100,00*	*19,97*	*14,84*	*20,31*
OPP	*0,00*	*71,43*	*20,22*	*20,00*	*15,86*
ST Won	*0,00*	*13,00*	*6,11*	*6,00*	*2,73*
OPP Won	*1,00*	*15,00*	*6,14*	*5,50*	*2,71*
ST Lost	*0,00*	*5,00*	*1,45*	*1,00*	*1,25*
OPP Lost	*0,00*	*8,00*	*1,58*	*1,00*	*1,34*
LINEOUTS	-44,44	39,47	1,32	0,00	17,31
ST	*0,00*	*54,55*	*20,23*	*18,75*	*13,37*
OPP	*0,00*	*45,45*	*18,92*	*18,18*	*10,86*
ST Won	*4,00*	*17,00*	*10,14*	*10,00*	*2,84*
OPP Won	*2,00*	*20,00*	*9,86*	*10,00*	*3,15*
ST Lost	*0,00*	*17,00*	*2,64*	*2,00*	*2,15*
OPP Lost	*0,00*	*8,00*	*2,31*	*2,00*	*1,50*
PENALTIES	-12,00	8,00	-0,78	-1,00	4,41
ST	*4,00*	*18,00*	*10,92*	*11,00*	*2,85*
OPP	*4,00*	*22,00*	*11,70*	*12,00*	*3,09*
OUTNUMBER	-37,00	68,00	0,22	0,00	11,37
ST	*0,00*	*68,00*	*5,07*	*0,00*	*9,00*
OPP	*0,00*	*37,00*	*4,85*	*0,00*	*6,05*
OUTNUMBER13	-10,00	6,00	-0,19	0,00	1,44
ST	*0,00*	*6,00*	*0,12*	*0,00*	*0,81*
OPP	*0,00*	*10,00*	*0,31*	*0,00*	*1,48*

Notes: ST is for "Stade Toulousain", OPP is for "Opponent", CONV is for "Conversions", PEN is for "Penalty attempts", suc is for "Success". For each variable, we separate the value for Stade Toulousain and the value for the opponent before the difference between them is computed. Descriptive statistics of these primary variables appear in italic. Raw data that are used to compute them are also displayed when relevant.

Table A3. Correlations

	GAP	HOME1	HOME2	DELOC	HOME3	RAIN	REFEREE7	REFEREE11	BEFORE_EC	AFTER_EC	RECOVERY	RANKING	STAKE	SEASON11-12	SEASON12-13	SEASON13-14	SEASON14-15	PLAYOFF	STRENGTH1	STRENGTH2	INTER1	NONINTER1	INTER2	NONINTER2	METRES	RUNS	PASSES	KICKS	LINEBREAKS	DEFENDERSBEATEN	OFFLOADS	TURNOVERS	RUCKS	TACKLES	SCORERSSUCCESS	SCRUMS	LINEOUTS	PENALTIES	OUTNUMBER	OUTNUMBER13
GAP	1,0	0,6	0,5	0,2	-0,5	-0,1	0,0	-0,1	0,1	0,0	0,0	-0,2	0,3	0,0	0,0	-0,1	-0,1	-0,1	-0,4	-0,3	0,0	-0,4	0,0	-0,3	0,4	0,2	0,1	0,5	0,6	0,4	0,2	-0,2	-0,1	-0,4	0,3	-0,3	-0,3	-0,4	-0,4	-0,1
HOME1		1,0	0,9	0,5	-0,9	-0,1	0,0	-0,2	0,1	-0,1	0,0	0,1	0,0	0,1	0,0	0,0	0,0	0,1	-0,4	-0,4	0,1	-0,5	0,1	-0,4	0,3	0,2	0,2	0,3	0,4	0,3	0,2	-0,1	-0,2	-0,2	0,1	-0,2	-0,2	-0,4	-0,3	-0,1
HOME2			1,0	0,0	-0,8	-0,1	0,0	-0,1	0,1	-0,1	0,0	0,0	0,0	0,0	0,0	0,1	0,0	0,0	-0,3	-0,3	0,1	-0,4	0,1	-0,4	0,3	0,3	0,2	0,2	0,3	0,3	0,2	-0,1	-0,1	-0,2	0,1	-0,2	-0,1	-0,4	-0,3	-0,1
DELOC				1,0	-0,4	0,0	0,1	-0,2	0,0	-0,1	0,1	0,1	-0,1	0,2	0,0	-0,2	-0,1	0,2	-0,3	-0,2	0,0	-0,3	0,0	-0,2	0,0	0,0	0,0	0,2	0,1	0,1	0,0	-0,1	-0,2	-0,1	0,0	-0,1	-0,1	-0,1	-0,1	0,0
HOME3					1,0	0,1	0,0	0,1	-0,1	0,1	0,0	-0,1	0,0	-0,1	0,0	0,0	0,0	-0,1	0,4	0,3	-0,1	0,4	-0,1	0,4	-0,3	-0,2	-0,2	-0,3	-0,3	-0,3	-0,1	0,1	0,2	0,2	-0,1	0,2	0,1	0,4	0,3	0,1
RAIN						1,0	-0,1	0,0	0,1	-0,1	0,0	-0,2	0,0	0,0	0,0	0,1	0,0	-0,1	0,1	0,0	0,0	0,1	0,0	0,0	0,0	0,0	0,0	0,1	-0,2	-0,1	0,0	0,1	0,2	0,0	0,0	0,1	0,0	0,0	0,0	-0,1	0,0
REFEREE7							1,0	-0,1	0,0	0,0	0,2	0,1	0,0	0,0	0,1	0,0	0,0	0,4	-0,1	-0,1	-0,1	-0,1	-0,1	0,0	-0,1	0,0	-0,1	0,2	-0,1	0,0	-0,1	-0,1	0,0	-0,1	0,1	-0,1	-0,1	0,0	0,0	0,2
REFEREE11								1,0	0,1	0,0	0,0	0,1	0,0	0,1	0,0	0,1	0,0	0,0	0,1	0,2	0,0	0,1	0,0	0,2	0,0	0,0	0,0	-0,1	0,0	0,0	0,0	-0,1	0,2	0,0	0,0	0,1	0,0	0,1	0,1	0,0
BEFORE_EC									1,0	-0,2	0,0	0,0	0,0	0,1	0,0	0,0	0,0	-0,1	-0,1	-0,1	-0,2	-0,1	-0,2	0,0	0,1	0,0	0,0	0,0	0,1	0,1	0,1	0,0	0,1	-0,1	0,1	-0,2	-0,2	-0,1	0,0	0,0
AFTER_EC										1,0	-0,1	-0,1	0,0	0,1	0,0	0,0	0,0	-0,1	0,0	0,0	-0,1	0,1	-0,1	0,1	-0,1	-0,1	-0,1	0,0	0,0	0,0	-0,1	-0,1	0,1	-0,1	-0,1	0,2	0,1	0,1	0,0	0,1
RECOVERY											1,0	0,1	-0,1	0,0	0,1	0,0	0,0	0,2	-0,1	-0,1	0,0	-0,1	0,0	0,0	0,1	0,1	0,1	0,1	0,0	0,0	0,1	-0,1	0,0	0,0	0,2	0,1	0,2	0,1	0,0	0,2
RANKING												1,0	-0,1	-0,1	-0,1	0,1	0,3	0,1	-0,1	-0,1	-0,2	0,0	-0,2	0,0	-0,1	-0,1	-0,2	0,0	0,0	-0,1	-0,1	-0,1	0,1	0,0	-0,1	0,0	0,2	0,1	0,1	0,0
STAKE													1,0	-0,2	-0,2	-0,2	0,1	0,0	0,0	-0,1	0,0	0,0	0,0	-0,1	0,1	0,1	0,0	0,2	0,2	0,1	0,1	0,0	0,1	-0,1	-0,1	-0,2	-0,2	0,0	0,3
SEASON11-12														1,0	-0,2	-0,2	-0,2	0,1	0,1	0,2	0,1	0,1	0,1	0,1	-0,1	-0,1	0,0	0,1	-0,1	-0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,1	-0,1	-0,1	0,0
SEASON12-13															1,0	-0,3	-0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,1	0,0	0,0	-0,1	0,0	0,0	0,1	0,1	0,0	0,1	-0,2	-0,1	0,0	0,0	0,0
SEASON13-14																1,0	-0,3	-0,1	-0,1	-0,1	0,0	-0,1	0,0	-0,2	0,0	0,0	0,0	-0,1	-0,1	0,0	0,0	-0,1	0,1	0,0	0,0	0,3	0,0	0,1	0,1	-0,1
SEASON14-15																	1,0	0,0	0,1	0,0	-0,1	0,1	-0,1	0,1	0,0	-0,2	-0,2	-0,1	0,1	0,0	0,0	0,1	0,0	-0,1	0,0	0,1	0,1	0,1	0,1	0,0
PLAYOFF																		1,0	-0,1	-0,2	-0,1	-0,1	-0,1	-0,1	-0,1	0,0	0,0	-0,1	-0,1	-0,1	0,0	-0,1	0,0	0,1	0,0	0,1	0,1	0,0	0,0	0,2
STRENGTH1																			1,0	0,8	0,3	0,9	0,3	0,7	-0,1	-0,1	0,0	-0,2	-0,1	-0,1	-0,1	0,2	0,1	0,1	0,0	0,0	0,2	0,2	0,1	0,1
STRENGTH2																				1,0	0,4	0,6	0,4	0,8	-0,1	-0,1	-0,1	-0,2	-0,1	-0,1	-0,1	0,1	0,1	0,1	0,0	0,0	0,2	0,1	0,2	0,1
INTER1																					1,0	-0,2	1,0	-0,2	0,2	0,2	0,2	0,0	0,1	0,1	0,1	0,1	0,1	0,0	0,0	0,1	-0,1	0,1	0,0	0,0
NONINTER1																						1,0	-0,2	0,8	-0,2	-0,2	-0,2	-0,2	-0,2	-0,1	-0,2	0,1	0,1	0,1	0,0	0,0	0,3	0,2	0,1	0,1
INTER2																							1,0	-0,2	0,2	0,2	0,2	0,0	0,1	0,1	0,1	0,1	0,1	0,0	0,0	0,1	-0,1	0,1	0,0	0,0
NONINTER2																								1,0	-0,2	-0,2	-0,2	-0,2	-0,2	-0,1	-0,2	0,1	0,1	0,1	0,0	0,0	0,2	0,1	0,2	0,1
METRES																									1,0	0,7	0,7	-0,2	0,6	0,7	0,6	0,3	0,0	-0,3	0,1	0,0	-0,1	-0,3	-0,4	-0,1
RUNS																										1,0	0,9	-0,2	0,3	0,6	0,6	0,3	-0,2	0,1	0,1	0,0	-0,1	-0,3	-0,2	0,0
PASSES																											1,0	-0,2	0,3	0,5	0,6	0,3	-0,2	0,1	0,1	0,0	-0,1	-0,3	-0,3	-0,1
KICKS																												1,0	0,1	0,0	-0,1	-0,5	-0,2	-0,1	0,1	-0,2	-0,3	0,0	0,0	0,0
LINEBREAKS																													1,0	0,6	0,5	0,0	-0,1	-0,6	0,0	-0,1	-0,1	-0,2	-0,4	-0,1
DEFENDERSBEATEN																														1,0	0,6	0,1	-0,2	-0,7	0,1	0,0	0,0	-0,2	-0,2	0,0
OFFLOADS																															1,0	0,3	-0,1	-0,3	0,1	0,0	-0,1	-0,1	-0,2	0,0
TURNOVERS																																1,0	0,1	0,0	-0,1	0,0	-0,1	-0,2	0,0	0,1
RUCKS																																	1,0	0,1	-0,1	0,1	-0,1	0,2	-0,1	-0,1
TACKLES																																		1,0	-0,1	0,0	-0,1	0,0	0,2	0,1
SCORERSSUCCESS																																			1,0	0,0	0,0	0,1	0,1	0,1
SCRUMS																																				1,0	0,2	0,4	0,2	0,0
LINEOUTS																																					1,0	0,1	0,2	0,2
PENALTIES																																						1,0	0,3	0,1
OUTNUMBER																																							1,0	0,2
OUTNUMBER13																																								1,0

Notes: in order to lighten the table, we have only included the REFEREE variables that turned to be significant and the level of significance of the correlations is not indicated (for our sample, correlations of about 0.2 in absolute value are significant at 5 %).

Table 1. Matches played by Stade Toulousain (2011-2016)

Season	Friendly matches	French championship		European cup		Total
		Regular phase	Play-offs	Regular phase	Play-offs	
2011-2012	3	26	2	6	1	38
2012-2013	3	26	2	6	1	38
2013-2014	3	26	1	6	1	37
2014-2015	2	26	2	6	0	36
2015-2016	4	26	1	6	0	37
Total	15	130	8	30	3	186

Table 2. Outcomes of Stade Toulousain matches (French championship, 2011–2016)

Season	Victories	Draws	Defeats	Points scored	Points conceded	Gap
2011–2012	21	1	6	24	17	+7
2012–2013	18	0	10	27	19	+8
2013–2014	13	2	12	21	17	+4
2014–2015	17	0	11	22	19	+3
2015–2016	16	2	9	26	15	+10
Total / mean	85	5	48	24	17	+6

Table 3. Expected sign for explanatory variables

Variable	Expected sign
HOME1/2	+
DELOC	?
HOME3	-
RAIN	-
REFEREE1-14	?
BEFORE_EC	?
AFTER_EC	-
RECOVERY	+
RANKING	-
STAKE	+
SEASON11-12	?
SEASON12-13	?
SEASON13-14	?
SEASON14-15	?
PLAYOFF	-
STRENGTH1/2	-
INTER1/2	-
NONINTER1/2	-
METRES	+
RUNS	+
PASSES	+
OFFLOADS	+
KICKS	+
SCORERSSUCCESS	+
TACKLES	-
RUCKS	-
LINEOUTS	-
SCRUMS	-
DEFENDERSBEATEN	+
LINEBREAKS	+
TURNOVERS	-
PENALTIES	-
OUTNUMBER	?
OUTNUMBER13	?

Table 4. Estimation results (block 1, part 1)

Independent variables	Dependent variable: GAP					
	(1)	(2)	(3)	(4)	(5)	(6)
Intercept	10.26**	10.26**	12.65***	10.88**	10.86**	11.34**
	(2.44)	(2.43)	(3.00)	(2.51)	(2.49)	(2.51)
HOME1	7.50***	-	-	7.79***	7.75***	8.04***
	(4.77)	-	-	(5.08)	(4.76)	(4.96)
HOME2	-	7.50***	-	-	-	-
	-	(4.25)	-	-	-	-
DELOC	-	7.48***	-	-	-	-
	-	(3.05)	-	-	-	-
HOME3	-	-	-0.03***	-	-	-
	-	-	(4.64)	-	-	-
RAIN	-4.54	-4.54	-4.69	-4.73*	-4.53	-4.71
	(1.59)	(1.57)	(1.61)	(1.67)	(1.58)	(1.66)
REFEREE1	0.32	0.32	-2.88	-0.07	0.34	-0.13
	(0.04)	(0.04)	(0.38)	(0.01)	(0.04)	(0.02)
REFEREE2	-1.93	-1.94	-3.88	-2.62	-1.95	-2.54
	(0.33)	(0.32)	(0.65)	(0.44)	(0.33)	(0.43)
REFEREE3	-3.33	-3.33	-6.18	-3.35	-3.31	-3.29
	(0.65)	(0.64)	(1.22)	(0.68)	(0.66)	(0.68)
REFEREE4	-8.64	-8.64	-10.22	-9.28*	-8.62	-9.29
	(1.54)	(1.53)	(1.62)	(1.66)	(1.49)	(1.62)
REFEREE5	-2.28	-2.28	-6.26	-2.52	-2.12	-2.32
	(0.43)	(0.42)	(1.07)	(0.48)	(0.40)	(0.45)
REFEREE6	-0.12	-0.12	-2.48	0.00	-0.05	0.07
	(0.01)	(0.01)	(0.23)	(0.00)	(0.01)	(0.01)
REFEREE7	-4.71	-4.71	-7.71	-4.65	-4.74	-4.65
	(0.83)	(0.83)	(1.31)	(0.85)	(0.85)	(0.85)
REFEREE8	-2.96	-2.96	-6.88	-2.97	-2.88	-2.86
	(0.59)	(0.59)	(1.36)	(0.60)	(0.58)	(0.58)
REFEREE9	-6.31	-6.31	-10.20*	-6.74	-5.35	-5.93
	(1.14)	(1.14)	(1.90)	(1.22)	(0.94)	(1.04)
REFEREE10	-5.90	-5.91	-11.05*	-7.46	-6.18	-7.55
	(0.96)	(0.97)	(1.74)	(1.27)	(1.01)	(1.28)
REFEREE11	-4.64	-4.64	-8.20*	-4.32	-4.61	-4.35
	(0.97)	(0.98)	(1.78)	(0.91)	(0.96)	(0.91)
REFEREE12	-0.21	-0.22	-1.07	-1.15	-1.45	-1.85
	(0.03)	(0.03)	(0.12)	(0.14)	(0.16)	(0.22)
REFEREE13	-8.12	-8.12	-11.90*	-8.30	-8.43	-8.43
	(1.15)	(1.13)	(1.68)	(1.15)	(1.20)	(1.17)
REFEREE14	-6.67	-6.67	-9.96**	-7.60	-6.93	-7.69
	(1.37)	(1.37)	(2.11)	(1.58)	(1.41)	(1.58)

***, **, *: significant at 1, 5, and 10 %, respectively. Student t in brackets.

Table 4. Estimation results (block 1, part 2)

Independent variables	Dependent variable: GAP					
	(1)	(2)	(3)	(4)	(5)	(6)
BEFORE_EC	1.60	1.59	0.26	1.79	1.05	1.37
	(0.60)	(0.60)	(0.09)	(0.64)	(0.37)	(0.47)
AFTER_EC	1.79	1.79	0.81	1.83	1.08	1.28
	(0.44)	(0.44)	(0.20)	(0.44)	(0.25)	(0.29)
RECOVERY	0.54	0.54	0.67*	0.59	0.52	0.57
	(1.37)	(1.35)	(1.82)	(1.45)	(1.26)	(1.36)
RANKING	-0.46*	-0.46*	-0.46*	-0.47*	-0.49*	-0.49*
	(1.89)	(1.87)	(1.79)	(1.91)	(1.95)	(1.95)
STAKE	17.86**	17.86**	19.46***	16.98**	17.91**	17.07**
	(2.43)	(2.41)	(2.77)	(2.27)	(2.43)	(2.29)
SEASON11-12	-0.51	-0.51	0.80	-1.06	-0.18	-0.88
	(0.11)	(0.11)	(0.19)	(0.23)	(0.04)	(0.19)
SEASON12-13	-2.65	-2.65	-1.70	-3.04	-2.51	-2.96
	(0.68)	(0.67)	(0.44)	(0.75)	(0.64)	(0.74)
SEASON13-14	-3.58	-3.58	-2.11	-4.08	-3.45	-3.91
	(0.98)	(0.95)	(0.60)	(1.13)	(0.95)	(1.09)
SEASON14-15	-2.53	-2.54	-1.28	-2.92	-2.77	-3.11
	(0.62)	(0.60)	(0.30)	(0.71)	(0.66)	(0.74)
PLAYOFF	-8.86**	-8.85**	-9.27**	-9.40**	-9.46**	-9.77**
	(2.26)	(2.26)	(2.23)	(2.34)	(2.40)	(2.42)
STRENGTH1	-0.75*	-0.75*	-0.94**	-	-	-
	(1.82)	(1.81)	(2.44)	-	-	-
STRENGTH2	-	-	-	-0.76	-	-
	-	-	-	(1.31)	-	-
INTER1	-	-	-	-	-1.30	-
	-	-	-	-	(1.51)	-
NONINTER1	-	-	-	-	-0.67	-
	-	-	-	-	(1.54)	-
INTER2	-	-	-	-	-	-1.16
	-	-	-	-	-	(1.28)
NONINTER2	-	-	-	-	-	-0.64
	-	-	-	-	-	(1.02)
Observations	132	132	132	132	132	132
R^2	0.49	0.49	0.48	0.49	0.50	0.49
Adj. R^2	0.36	0.36	0.35	0.36	0.36	0.35
Heteros. corr.	Yes	Yes	Yes	Yes	Yes	Yes
JB (p-value)	0.04	0.04	0.04	0.06	0.05	0.06

***, **, *: significant at 1, 5, and 10 %, respectively. Student t in brackets.

Table 5. Estimation results (block 2)

Independent variables	Dependent variable						
	GAP	METRES	RUNS	PASSES	DEFEND.	TACKLES	GAP
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Intercept	1.61	-3.25	0.66	-0.67	0.25	-0.23	1.76
	(1.23)	(0.29)	(0.45)	(0.21)	(0.58)	(0.55)	(1.47)
METRES	0.03***	-	0.03**	0.06**	-0.00	-0.01*	-
	(2.82)	-	(2.50)	(2.41)	(0.55)	(1.86)	-
RUNS	0.04	1.92**	-	0.85***	0.18***	0.19***	-
	(0.53)	(2.41)	-	(5.62)	(9.61)	(9.76)	-
PASSES	-0.05	0.92**	0.23***	-	0.00	0.02	-
	(1.07)	(2.39)	(4.59)	-	(0.26)	(1.31)	-
KICKS	0.73***	-3.81**	0.11	-0.38	0.02	-0.03	0.69***
	(3.29)	(2.01)	(0.39)	(0.69)	(0.34)	(0.52)	(3.16)
LINEBREAKS	0.75**	12.17***	-0.43	0.40	0.01	-0.19**	1.37***
	(2.62)	(4.31)	(1.25)	(0.68)	(0.13)	(2.31)	(6.27)
DEFENDERSBEATEN	-0.49*	-1.72	2.58***	0.19	-	-0.90***	-
	(1.79)	(0.54)	(10.87)	(0.26)	-	(16.74)	-
OFFLOADS	0.02	-0.38	0.72***	0.22	-0.08	-0.13**	-0.01
	(0.17)	(0.19)	(3.25)	(0.52)	(1.22)	(2.04)	(0.07)
TURNOVERS	-0.46*	0.57	-0.18	0.99*	-0.01	-0.07	-0.41
	(1.67)	(0.27)	(0.56)	(1.78)	(0.19)	(1.01)	(1.64)
RUCKS	-0.09	5.00***	-0.08	-1.54***	0.02	0.07	0.11
	(0.44)	(2.81)	(0.32)	(3.19)	(0.24)	(0.90)	(0.46)
TACKLES	-0.54**	-4.85*	2.43***	0.76	-0.83***	-	-
	(2.13)	(1.70)	(9.60)	(1.31)	(15.91)	-	-
SCORERSSUCCESS	0.12***	0.51*	0.05	-0.06	-0.01	-0.01	0.15***
	(4.49)	(1.69)	(1.64)	(1.01)	(1.29)	(1.38)	(5.55)
SCRUMS	-0.07	0.41	0.03	-0.03	-0.01	-0.01	-0.05
	(1.32)	(1.12)	(0.54)	(0.33)	(0.53)	(0.58)	(1.07)
LINEOUTS	-0.14***	-0.33	-0.05	0.03	0.01	-0.01	-0.12**
	(2.88)	(0.68)	(0.83)	(0.25)	(0.50)	(0.41)	(2.33)
PENALTIES	-0.89***	-4.28*	-0.38	1.01*	-0.01	-0.04	-0.96***
	(4.00)	(1.74)	(1.36)	(1.81)	(0.10)	(0.41)	(4.44)
OUTNUMBER	-0.14*	-1.20	-0.02	-0.33*	0.04	0.03	-0.18***
	(1.87)	(1.42)	(0.22)	(1.73)	(1.07)	(1.10)	(2.70)
OUTNUMBER13	0.55	-2.50	1.22**	-2.58*	-0.08	-0.02	0.49
	(0.60)	(0.43)	(2.01)	(1.82)	(0.52)	(0.12)	(0.73)
Observations	132	132	132	132	132	132	132
R^2	0.71	0.77	0.91	0.82	0.90	0.89	0.66
Adj. R^2	0.67	0.74	0.90	0.79	0.89	0.87	0.63
Heteros. corr.	Yes	Yes	Yes	Yes	Yes	Yes	Yes
JB (p-value)	0.88	0.57	0.49	0.21	0.03	0.04	0.47

***, **, *: significant at 1, 5, and 10 %, respectively. Student t in brackets.

Table 6. Final estimation results

Independent variables	Dependent variable: GAP
	(1)
Intercept	1.48
	(1.05)
HOME1	1.70*
	(1.71)
RAIN	-4.56**
	(2.28)
REFEREE3	-4.45
	(1.63)
REFEREE6	-7.73
	(1.37)
REFEREE7	-7.13***
	(3.72)
REFEREE10	-6.29
	(1.32)
REFEREE11	-4.22*
	(1.82)
RECOVERY	0.30
	(1.24)
RANKING	-0.44***
	(2.72)
STAKE	11.58***
	(2.82)
STRENGTH1	-0.74**
	(2.47)
SEASON11-12	4.35**
	(2.13)
SEASON13-14	2.76
	(1.20)
KICKS	0.41**
	(2.04)
LINEBREAKS	1.29***
	(7.22)
TURNOVERS	-0.40**
	(2.09)
SCORERSSUCCESS	0.14***
	(5.57)
SCRUMS	-0.10**
	(2.15)
LINEOUTS	-0.12**
	(2.52)
PENALTIES	-0.49**
	(2.41)
OUTNUMBER	-0.17***
	(3.04)
Observations	132
R^2	0.76
Adj. R^2	0.71
Heteros. corr.	Yes
JB (p-value)	0.33

***, **, *: significant at 1, 5, and 10 %, respectively. Student t in brackets.