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LEADERSHIP AND EFFICIENCY IN PROFESSIONAL CYCLING: INDIVIDUAL ABILITIES OR TEAMWORK

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Abstract

The aim of this paper is to assess the determinants of cyclists' performance over the season, particularly the effect of being a team leader. The efficiency indicator used is the number of Cycling Quotient (CQ) points accumulated by riders divided by the number of kilometers (or, alternatively, days) of competition. The results show that efficiency depends mainly on individual features (such as age and the body mass index), and the calendar of competition chosen by riders. However, the most decisive feature in enhancing rider efficiency is team status. Specifically, the estimates show that being team leader increases efficiency significantly.

Keywords: Cyclists' performance, leadership, teamwork

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INTRODUCTION

For most team sports, such as football, soccer or basketball, team victory in a match or a league is considered a victory for each and all of its members. By contrast, in the case of cycling, although the winner is always part of a team the success is credited to him individually. The media turn the winners into popular prominent figures that monopolize public recognition. In addition, the winner of a cycling event is usually one of the team leaders, i.e. a person previously designated by the coach for whom the rest of teammates work. It is unusual, except for example in the case of a breakaway allowed by the peloton for strategic reasons, for the winner of an important race not to be one of the team leaders. There are two basic reasons for this. First, the abilities and skills of team leaders are greater than those of other team members (in fact, they were chosen as leaders in the past due to their greater capabilities). Second, other team members exhaust their energies working for their leaders in order to enable them to strive for victory in the best conditions.[1] In this sense, cycling is a good example for studying the phenomenon of leadership. The key question to be asked here is as follows: is the better performance of the leader derived mainly from his greater capabilities or is it due to the support and help of their teammates? In the field of business this issue has been hotly debated. From the concept of "transforming leadership" developed by Burns (1978), Bass (1985) proposed the concept of "transformational leadership" as a process whereby leaders and followers cooperate to reach higher levels of motivation and performance. Applying this concept to sports leadership, it is clear that the leader always benefits from team work but also that he improves the performance of his teammates. In practice, some empirical papers, such as Bourner & Weese (1995),[2] have not found a significant relationship between executive leadership and organizational effectiveness in team sports, perhaps because in most cases team effectiveness involves many factors other than leadership.

In this context, the current paper tries to understand the factors - both personal and collective - that determine the performance of a professional cyclist. Moreover, it seeks to assess the impact of leadership and team quality on cyclist performance.

A key issue in this research is the quantification of the rider's performance over a season. The method usually adopted in cycling is to create numerical indicators based on riders' standings in all the contested races. The number of points accumulated by each rider over the season can be considered a good indicator of his performance. The two most commonly used scoring systems are the International Cycling Union (UCI) point scheme and the so called Cycling Quotient (CQ) ranking.[3]

However, not all cyclists participate in the same events nor do they have the same competition days over the year. Therefore, it would be appropriate for an indicator of performance to adjust the points accumulated by riders using the number of kilometers or days of competition. In this sense, the CQ Ranking constructs a rider "efficiency ratio", defined as the ratio between the number of points scored in a season and the number of kilometers ridden in competition (alternatively, the number of days of competition). This will be the performance indicator used in this research.

The rest of the paper is organized as follows. For the benefit of the reader who is not overly familiar with this sport, the next section describes the main features of professional road cycling. Although cycling is one of the most popular and traditional sports in some European countries, such as Italy, France, Belgium and Spain, it is a minority sport in the rest of the world. However, in recent years cycling has undergone a significant development in several English-speaking countries, such as the United States, Britain and Australia, which currently have some of the best teams and riders. Then, the few papers devoted to the analysis of the determinants of success or performance in professional cycling are summarized. The following section presents a model in which rider efficiency indicators are explained by a set of variables trying to capture both individual and team features. This model is estimated using information from an original dataset corresponding to the 2011 season. Finally, the last section summarizes the main conclusions of the paper.

MAIN FEATURES OF PROFESSIONAL CYCLING

As already pointed out, cycling is a team sport in which the overall standings are individual.[4] There are two types of cycling events: stage races and one-day races. The former events have between two and twenty-one stages. In these races, cyclists are ranked in the overall standings depending on the time they used to finish all the stages. The latter are held in a single day of competition, and although it seems that they have a lower degree of difficulty, the best one-day races (known as Top Classics) enjoy greater prestige that many stage races. Usually, teams have one or more leaders in each race, depending on the characteristics of the event. These leaders can compete for different targets. The main aim is to win the overall standings by time, but there are also other classifications, such as the point classification (the important thing here is not the time used to finish the stage but the order of arrival, as in the case of the motorcycling World Championship), or the best climber classification (based on the order of arrival at different mountain passes).[5] In order to win these races, leaders are always helped by their teammates, who act as assistants and perform multiple functions to help them. Among these functions are leading the big group when necessary, canceling breakaways, protecting the leader from the wind to reduce their level of effort in competition,[6] offering him food or water or even, in case of breakdown, giving him the bicycle. As teammates are hired mainly to help leaders to win, they are usually not very concerned about their final positions in the overall standings. In fact, some of the helpers who have worked hard during the race often tend to relax in the final kilometers once their targets have been fulfilled, sacrificing a few minutes in order to save energy for the next day.

While this behavior may not seem very competitive, cycling is a quite demanding sport. For example, the most prestigious stage race - the Tour de France - has 21 stages (with two rest days) covering more than 3,000 kilometers. The race is contested by 22 teams of nine riders. Most stages have more than 200 kilometers and there are four types of stages: mountain, flat, individual time-trial, and team time-trial. Mountain and flat stages are raced in a group, with all riders starting at the same time. By contrast, individual time-trial stages are raced in isolation: each cyclist sets off on his own with a time delay with respect to the previous rider, and attempts to finish the stage as fast as possible without being helped by any teammate. Meanwhile, team time-trial stages are contested jointly by all team members, who cooperate trying to achieve the best final time. The time allocated to all team members is that of the rider who finished in fifth place, so the team will try to reach the finish line in a bunch. Depending on the type of race, each rider is specialized in a certain task. Thus, helpers (also called watercarriers, “gregari” or “domestiques” in cycling slang) try to help the leader in flat and team time-trial stages. “Puncheurs” (classics specialists) also help the leader, but occasionally try to break away and reach the finish line before the bunch. The fastest riders (sprinters) try to win in the final meters of the stage. Climbers strive to win some mountain stages, but basically help their leaders in mountain passes. Finally, team leaders always try to finish races in the first positions of the bunch, and in the hardest stages they try to avail of their greater abilities to gain as many seconds as possible on their rivals.

The pattern is similar for one-day races, but in this case surprises are more likely. The winner might not be a leader or top rider (something that is almost impossible in stage races) because one-day races have a very strong random component. Accidents, bad weather, surprises, uncontrolled breakaways, etc, may lead to an unexpected winner in a single day.

Given the wide variety of events and standings, the targets of every rider and team may be different. However, a few cyclists - the leaders - are forced to compete every day in order to improve their time overall standings, which is the most prestigious classification. Usually, the remaining cyclists do not compete as hard as they could in some parts of the race to fulfill their goal of helping their leaders to win, i.e., they reduce their efforts at various points to save energy for when it is needed to help the leader.

REVIEW OF THE LITERATURE ON PERFORMANCE IN PROFESSIONAL CYCLING

To date, professional cycling has been the subject of very little research in the field of sport economics. Most papers deal with the analysis of the factors determining individual performances in the Tour de France (Torgler, 2007; Coupé & Gergaud, 2012) and with the study of television audiences for this sport (Van Reeth, 2013; Rodríguez et al. 2013).[7] In addition, Dilger & Geyer (2009) examine the causes of winning the final sprint of a race, analyzing the effect of slipstreaming.[8] There are also some papers devoted to describing how this sport is organized and how its labor market works (Calvet, 1980; Desbordes, 2006; Rebeggiani & Tondani, 2008; Di Domizio & Palombini, 2011) and to analyzing the effects of doping (Rabenstein, 1997; Brewer, 2002; Soulé & Lestrelin, 2011). Finally, Cherchye & Vermeulen (2006) and Rogge et al. (2013) develop multidimensional indicators to measure athletic performance of riders and teams in the specific case of cycling.

Regarding cyclists' performance, the main references are the papers by Torgler and Coupé & Gergaud. The paper by Torgler (2007) is pioneering in the sense that it analyzes for the first time the determinants of athletic performance in a cycling event (the 2004 Tour de France). Torgler identifies riders' performance by their position in the overall standings and tries to determine whether the rider's performance is due to individual or team features, concluding that both are very important for the final standings. One of the most significant explanatory variables in Torgler's paper is being a team leader. The leader is usually the most qualified team rider, but he is also the individual for whom teammates work. The issue of the influence of co-workers' attributes on individuals' pay in team sports has been previously analyzed by Kahane (2001) and Idson & Kahane (2004). Torgler's paper adds some evidence to the effects of teammates on cyclists' performance.

Coupé and Gergaud (2012) extend the analysis of Torgler by incorporating a new issue: the effect of doping on performance. In the year 2011, the French sports daily L'Equipe leaked a secret report from the International Cycling Union (UCI) which contained information about a doping suspicion index for each of the cyclists participating in the 2010 Tour de France. This document was designed to direct the investigations of UCI inspectors towards the most suspect riders. The suspicion index, which ranged from 0 (low suspicion) to 10 (high suspicion) was constructed from the blood and urine parameters recorded in the rider's Biological Passport.[9] Using this information, Coupé & Gergaud analyze the effect of the suspicion index on the overall standings of the 2010 Tour de France. They conclude that the doping suspicion index has a very small effect in the cyclists' final standings. They also observed that being a team leader is one of the most relevant factors in improving the individual performance in the Tour de France.

DETERMINANTS OF THE PROFESSIONAL CYCLIST PERFORMANCE

The efficiency index

Professional cyclists have a wide variety of sporting goals, and therefore it is very difficult to come up with an accurate measure of rider performance over the season. For example, Cherchye & Vermeulen (2006) and Rogge et al. (2013) build multidimensional indicators of performance using Data Envelopment Analysis (DEA) for a specific race, the Tour de France. In the first paper, these indicators permit the ranking of all the riders participating in the Tour de France between 1953 and 2004, using information about their standings in several classifications (time, points, mountain…). In the second paper, the authors use this methodology to analyze the performance of all the teams participating in the Tour de France for the period 2007-2011. However, when we use information from a whole season (not only from a specific race), during which riders must compete in many different races (stage races, one-day races, flat or mountainous…), it is better to proxy athletic performance by a single indicator, namely the number of points accumulated by riders as a result of their standings in all the season's events. This indicator is called the Cycling Quotient (CQ). As its creators point out, "the CQ-ranking is a world ranking of professional road cyclists, based on their performances during the last 12 months. It can be seen as the non-official successor of the UCI-ranking which disappeared when the Pro Tour was introduced in 2005".[10]

In stage races, riders receive points according to the position reached in the final overall standings and in each stage. They also accumulate points according to their standings in one-day races and in the World and National championships (both road and time-trial). Moreover, the scoring received depends on the category of the event, which is based on its prestige and historical significance. The most-valued stage race is the Tour de France (600 points to the winner, decreasing to 20 from position 50 onwards), followed by the *Vuelta* of Spain and the *Giro* of Italy (500 points to the winner, decreasing to 15 from position 50 onwards). In the case of one-day races, the most valued are the so called Top Classics or "cycling monuments" that grant 275 points to the winner, decreasing to 5 from position 50 onwards. The World Championship is another one-day race even more highly-valued than the five Top Classics.[11]

Obviously, the number of points accumulated by each cyclist over the season will depend on the kind of races he contests, and also on the number of kilometers (or days) of competition. Sometimes, injuries and illnesses reduce the number of days of competition for some riders, and so they obtain fewer points than rivals that are able to complete the competition schedule. For this reason, the creators of the CQ Ranking propose an index of rider efficiency defined as the ratio of the number of CQ points accumulated over the season to the number of kilometers of competition (this ratio will be called *Efficiency per km*). Alternatively, a second index is defined as the ratio of the number of CQ points to the number of days of competition (*Efficiency per day*). Both indicators provide almost the same information and will be used in this paper as a measure of rider performance over the season.[12]

Although these ratios are computed for all professional cyclists, the sample used here refers only to those riders belonging to the 18 teams in the highest category of professional cycling. The selected year is 2011. There are three categories of professional cycling teams. In the first division there are 18 teams called UCI ProTeams. The second division includes the so called Professional Continental teams and, finally, the third division is composed of the Continental teams. UCI ProTeams are obliged to participate in all the races belonging to the UCI WorldTour.[13] The other teams can only participate in the lower category races, although Professional Continental teams may be invited by organizers to participate in some of the top races depending on a variety of factors (nationality, number of points accumulated…). There is an important reason for selecting a sample of riders belonging to UCI ProTeams: these are the only teams that share a common competition schedule, obliged, in this case, by the UCI. This assures the homogeneity of the efficiency indexes computed for all riders and avoids possible biases derived from significant differences in competition calendars. However, since teams usually consist of about 30 cyclists and only nine compete in each race, many of them also participate in lower quality races over the season, sometimes as a way of training. Thus, members of the same team rarely have a similar competition schedule. For this reason, to estimate the determinants of rider efficiency it is necessary to control for the competition schedule chosen by each rider in order to reduce the heterogeneity in scoring.

A second advantage of only sampling riders from UCI ProTeams has to do with the effectiveness of anti-doping controls for those riders. In an experimental way in 2008 and in an effective manner (applying penalties) since 2009, all cyclists belonging to UCI ProTeams must follow the Biological Passport program (nowadays it is also compulsory for Professional Continental teams). These riders are subject to continuous blood and urine analyses to test the evolution of several parameters over the season. Many prohibited products and doping techniques (such as blood transfusions) trace a clear path in blood parameters that can be followed by the UCI inspectors. In some cases a prohibited product is found, but often only small changes in the normal parameters are observed. A reasonable suspicion is enough to punish a rider: in these cases the UCI prohibits the rider from competing.[14] If the data set included riders who were not subject to the Biological Passport program, it would be impossible to know whether the better performance of a non-controlled rider was due to greater effort or ability or, on the contrary, to taking prohibited substances. However, since the Biological Passport is currently the most advanced program for fighting against doping in any sport, it can be assumed that the sample used in this paper is not affected by this kind of bias. It can therefore be assumed that the observed differences in rider performance are generated only by differences in levels of effort and the quality of riders and teams.

Model specification

As has been noted, rider performance can be explained by a set of variables representing relevant features of individuals and teams. With regard to personal features, the sample used provides information on basic variables such as *age* (proxy of total experience), *seniority* (number of years of experience in the current team or, alternatively, a dummy variable that takes the value of one if 2011 is the first year the cyclist competes for the current team) and the *body mass index* (*BMI*). Human Capital theory considers that age and seniority represent specific training, which is positively correlated with productivity in a relevant period of the working life. To be precise, the relationship between age and productivity is usually inverted-U shaped over the total working life. The estimation results will show the sign of this relationship for the used sample of professional cycling. As for seniority, this variable shows whether a better adaptation of riders to teams improves individual performance, given their age. Usually, the first months inside a new team imply changes in training methods, in the competition schedule, and possibly even in the country of residence, giving rise to an abnormal rider performance. Once the rider is fully adapted to the team, his efficiency will be optimum. Thus, it is expected that the greater the seniority, the better the rider performance. Finally, the effect of the *body mass index* (*BMI*) on efficiency is ambiguous. Usually, a low *BMI* characterizes team leaders because cycling is an endurance sport in which the great efficiency in energy use in all terrains (flat, mountain, time-trial…) is achieved by those riders with a low *BMI*.[15] Also, the best climbers usually have the lowest *BMI*.[16] However, a low *BMI* is not a necessary condition for efficiency. For example, sprinters are the riders who win most races (and get more CQ points) but they have the highest *BMI*, along with time-trial specialists.

In a different vein, cycling is a team sport in which the quality of the set of teammates could lead to an improvement in the individual performance of each of team members. This is the case in team time-trial races, in which all team members cooperate in order to arrive at the finish line in the quickest time. Undoubtedly, in this case the quality of the group leads to an improvement in the overall standings of each member. In the other races, however, the most important goal is to ensure the best classification for the team leader. In other words, the higher quality of teammates does not positively affect the individual standings of those riders dedicated to working for their leaders (and not for their own gain). It may even happen that the higher the quality of the teammates, the greater the effort that riders must make in order to help others to win, leading to a decrease in their own efficiency. In order to measure team quality, three variables will be used. The first is the *total number of CQ points accumulated by the team over the 2011 season minus the CQ points accumulated by each rider*. It must be pointed out that if team quality were measured by the total number of CQ points accumulated in 2011 by all team members, this variable would be endogenous because greater individual efficiency would allow teams to obtain more points. The second variable used to proxy team quality is the *total number of CQ points accumulated by the team over the 2010 season*. This variable is not affected by the performance of riders in 2011. Finally, the third variable used is the team budget. The sign for these variables is not clear. Riders' performances should improve when their teammates are more qualified (both in terms of CQ points or earned wages). However, this is strictly true only in the case of team leaders. For other riders, to be part of a stronger team may imply a greater effort in favor of the leader, at the cost of more personal targets and receiving a lower score.

It must be highlighted that the CQ scoring system gives points to riders depending upon the category of the event (some races have more prestige than others). With the aim of controlling for the competition schedule, the following variables were included in the estimation: *percentage of days of competition in the 2011 season devoted to the Tour de France* (a three-week long race which is the most important in the world) and *percentage of days devoted to first and second category one-day races* (called "Classics") *including World and National Championships*[17] (the reference category is the *percentage devoted to the remaining races*, which are less relevant). It is expected that rider efficiency increases as the percentage of competition days devoted to the highest level events rises, since these events provide more CQ points than the rest. However, these races are more difficult to win (there is more competition than in other events) and thus it could be possible that some of the riders who choose them as a target obtain fewer points, and therefore a lower efficiency index.

The model includes controls for rider *nationality*. Since professional cyclists come from many countries (there are riders from 44 countries in the sample), a set of dummy variables has been included to identify countries that provide the most riders (the remaining countries are grouped in the reference category). The nationality variable will capture to what extent tradition and history, the training and selection methods, the existence of cycling schools and the management of national cycling federations in each country may influence rider's performances. Obviously, there are large differences among countries in the level of professional cycling. In some countries, there are structures and organizations that greatly assist young riders, by providing them with scientific training methods and medical assistance that ensures a better development of their professional careers. On the contrary, other countries lack such structures and riders appear spontaneously rather than by planning. Traditional countries in cycling are Italy, France, Spain, Belgium and The Netherlands. However, in recent times the center of gravity of cycling has been moving towards the Anglo-Saxon world, from which some of the best teams are coming (mainly British, American and Australian). Additionally, three other variables are included in the estimation in an attempt to proxy some features related to riders' nationality. These are the *percentage of days of competition in the 2011 season covered in the riders' country*, the *percentage of days of competition in the 2011 season covered in the main sponsor's country*, and a *dummy variable that takes a value of 1 if the rider has the same nationality as the main sponsor of the team*. The first variable tries to capture the externality produced by the opportunity of training every day on the roads where competitions take place. The second allows taking into account the fact that the sponsor usually puts pressure on team members in order to maximize performance in those races held in the sponsor's country (where he obtains the greatest advertising revenues). Finally, the third variable permits us to determine whether the fact that the leader belongs to a team of his same nationality encourages his sporting commitment and performance.

Finally, it is expected that the main determinant of rider performance is being a team leader or not. *Team leader* is a dummy variable that takes the value of 1 if the rider is one of the team leaders and 0 if he is a helper.[18] Teams usually have more than one leader to face the different events. As has been noted, team leaders are the best riders, having achieved this status because of their effort and special abilities. At the same time, they have the advantage that teammates work for them throughout the race. Therefore, the efficiency index can be expected to significantly increase if the rider is a team leader.

In the context of this model, the team leader variable suffers clearly from the problem of endogeneity. If the most qualified cyclists (i.e. the most efficient) become team leaders, then the team leader variable will be correlated with unobservables relegated to the error term. Given this, if the efficiency equation is estimated without correcting for the endogeneity of the leadership variable, inconsistent estimators will be obtained. Therefore, to determine the true effect of leadership on efficiency (once the effect of the superior ability of leaders has been eliminated) it will be necessary to instrument this variable: only in this way will the estimated coefficients be free of endogeneity bias.

The model to assess the determinants of rider efficiency, and in particular the effect of leadership, is presented below. The equation to be estimated is as follows:

$$E_i = X_i^{'}\beta + \eta_1 L_i + \varepsilon_i \qquad (1)$$

where the efficiency indicator, E_i, can be explained by a vector of variables, X_i, which includes personal features (*age*, *squared age, experience in current team* and the *body mass index*), team features (*CQ points accumulated by the team, team budget*), competition schedule (*types of races*) and a set of control variables for *rider* *nationality*. Equation (1) also includes the key variable of this analysis, *team leader*, L_i. Finally, this equation incorporates a random disturbance, ε_i.

All the variables included in vector X_i are assumed to be exogenous. On the other hand, the team leader variable, L_i, will present a problem of endogeneity if more qualified and efficient riders are more likely to be leaders. In order to correct this bias, this variable must be instrumented by carrying out a two-step estimation. In the first stage, a leadership equation will be estimated (equation 2):

$$L_i = X_i^{'}\lambda + F_i^{'}\theta + \mu_i \qquad (2)$$

where X_i includes all the exogenous variables representing personal and team attributes that enter the efficiency equation and F_i is a vector of variables that have no effect on efficiency after leadership has been controlled. This vector includes two variables representing pure leader attributes. These variables, used as instruments in the leadership equation and not included in the efficiency equation, are the fact of *having been declared positive prior to 2011*[19] and the *number of CQ points obtained by the rider in the previous season (year 2010).* These variables may affect leadership directly but not efficiency. Regarding doping, taking prohibited products any year different to 2011 should not raise efficiency in 2011, but it could be important for becoming a team leader in the past.[20] Finally, having won a lot of CQ points in the previous season can help the rider to be a leader in the current year, but it is not necessarily related to the value of his efficiency index in 2011.

Data and estimation

Table A1 of the Appendix displays the definitions of all the variables used in the estimation and Table A2 shows the descriptive statistics. The sample used in this paper consists of 468 riders belonging to the 18 first category teams of professional cycling in the 2011 season.[21] On average, cyclists have accumulated 2.5 CQ points per each 100 kilometers of competition (or 3.9 per day). The average age was 28.9 years, the number of years in the current team was 2.6, and the *BMI* was 21.2. Only 9.2% of cyclists were team leaders. At the same time, 5.6% of riders were punished for doping before 2011. Regarding the competition schedule, only 15% of the calendar is devoted to the main races (the Tour de France and the main one-day races). The average budget of sampled teams was about 10.3 million euro in 2011. Finally, regarding countries of origin, Italy and Spain have the highest number of riders (14.3% and 11.5% of the total number, respectively) followed by Belgium, The Netherlands and France.

The estimation results using instrumental variables (two-stage least squares-2SLS/IV) are shown in Tables 1A-1B and 2A-2B for alternative specifications of the determinants of *efficiency per 100 km* and *efficiency per day* respectively. Tables A3A and A3B of the Appendix display the estimates of the leadership equation (first-stage). Tables 1A-1B and 2A-2B also provide tests of overidentification (*Hansen J statistic*), underidentification (*Kleinbergen-Paap rk LM statistic*), weak identification (*Kleinbergen-Paap rk Wald F statistic*) and an endogeneity test for the *team leader* variable.[22] The values of these tests show that the instrumentation process is valid. First, the *Hansen* test is a test of overidentifying restrictions. The value of this test (for example, 1.90 for equation A from Table 1A; p-value=0.17) shows that the null hypothesis (instruments are valid, i.e., uncorrelated with the error term) cannot be rejected, and that the excluded instruments are correctly excluded from the estimated equation. Second, the *Kleinbergen-Paap rk LM statistic* is a test of whether the equation is identified (the excluded instruments are correlated with the endogenous regressor). The null hypothesis is that the equation is underidentified, so a rejection of the null indicates that the model is identified. The value of this test (for example, 27.88 for equation A from Table 1A; p-value=0.0000) shows that the null hypothesis is rejected. The *Kleinbergen-Paap rk Wald F statistic* is a test of weak identification (it arises when the excluded instruments are weakly correlated with the endogenous regressor). Compared with the Stock-Yogo critical values, the results suggest that weak identification is not a concern. Finally, for the endogeneity test the null hypothesis is that the specified endogenous regressor (the team leader variable) can actually be treated as exogenous. The value of this test statistic (34.48 for equation A from Table 1A; p-value=0.0000) shows that the null hypothesis must be rejected (i.e., team leader is an endogenous variable and needs to be instrumented).

Table 1A: Determinants of efficiency per kilometer in professional cycling (2SLS/IV estimates). Team leader variable is instrumented

	Dependent variable: (Efficiency per Km)*100					
	(A)		(B)		(C)	
	Coefficient	*Robust z*	*Coefficient*	*Robust z*	*Coefficient*	*Robust z*
Constant	12.669	1.91*	12.734	1.95*	12.032	1.91*
Team status						
Team leader	13.368	7.39**	13.204	7.47**	13.326	7.35**
Personal features						
Body mass index (BMI)	0.210	1.62	0.208	1.60	0.212	1.65*
Age	-0.974	-2.37**	-0.951	-2.38**	-0.983	-2.40**
Age^2	0.014	2.14**	0.014	2.12**	0.014	2.18**
Experience in current team						
Experience in current team	0.012	0.14	-		0.009	0.12
First year in current team	-	-	-0.597	-1.83*	-	-
Team quality						
2011 team CQ points excluding rider	-0.00003	-0.26	-0.00003	-0.31	-	-
2010 team CQ points	-	-	-	-	0.0001	0.78
Team budget	-	-	-	-	-	-
Competition schedule						
% Tour de France	-0.013	-0.86	-0.015	-0.99	-0.013	-0.82
% Main one-day races	0.077	1.71*	0.079	1.77*	0.078	1.74*
Rider nationality						
Spain	-0.597	-0.86	-0.522	-0.76	-0.522	-0.74
Italy	0.023	0.04	0.079	0.14	0.030	0.05
France	-1.168	-1.12	-1.058	-1.02	-1.050	-0.98
Belgium	-0.946	-1.25	-0.844	-1.15	-0.874	-1.13
Netherland	0.673	1.24	0.666	1.23	0.630	1.20
Great Britain	1.040	1.15	1.080	1.23	1.033	1.19
United States	-0.426	-0.57	-0.384	-0.52	-0.459	-0.62
Australia	0.872	1.10	0.898	1.17	0.840	1.05
Germany	-0.900	-0.89	-0.813	-0.83	-0.969	-0.94
Russia	-0.492	-0.60	-0.436	-0.54	-0.556	-0.69
Other nationality–related factors						
% Competition in rider's country	0.018	1.38	0.019	1.40	0.018	1.32
% Competition in sponsor's country	-0.007	-0.58	-0.007	-0.57	-0.005	-0.48
Rider-sponsor share same nationality	-0.108	-0.23	-0.239	-0.52	-0.083	-0.18
F(21,446)	4.15		4.35		4.11	
Hansen J statistic χ^2 (1) (overidentification test)	1.90		1.73		1.85	
Kleinbergen-Paap rk LM statistic χ^2 (2) (underidentification test)	27.88		28.13		28.04	
Kleinbergen-Paap rk Wald F statistic (weak identification test)	43.69		44.24		43.66	
Endogeneity test for team leader χ^2(1)	34.48		35.43		34.16	
Number of observations	468		468		468	

** and * denote significance at the 5% and 10% levels

Table 1B: Determinants of efficiency per kilometer in professional cycling (2SLS/IV estimates). Team leader variable is instrumented

	Dependent variable: (Efficiency per Km)*100					
	(D)		(E)		(F)	
	Coefficient	*Robust z*	*Coefficient*	*Robust z*	*Coefficient*	*Robust z*
Constant	11.998	1.93*	11.807	1.84*	11.851	1.87*
Team status						
Team leader	13.145	7.42**	13.269	7.30**	13.114	7.38**
Personal features						
Body mass index (BMI)	0.211	1.63	0.202	1.56	0.200	1.54
Age	-0.961	-2.41**	-0.966	-2.38**	-0.942	-2.38**
Age^2	0.014	2.16**	0.014	2.16**	0.014	2.13**
Experience in current team						
Experience in current team	-	-	0.012	0.15	-	-
First year in current team	-0.613	-1.88*	-	-	-0.585	-1.80*
Team quality						
2011 team CQ points excluding rider	-	-	-	-	-	-
2010 team CQ points	0.0001	0.92	-	-	-	-
Team budget	-	-	0.063	1.16	0.060	1.12
Competition schedule						
% Tour de France	-0.014	-0.94	-0.012	-0.82	-0.014	-0.94
% Main one-day races	0.079	1.80*	0.078	1.76*	0.080	1.81*
Rider nationality						
Spain	-0.435	-0.62	-0.475	-0.68	-0.403	-0.59
Italy	0.091	0.16	0.082	0.14	0.133	0.23
France	-0.915	-0.86	-1.061	-1.05	-0.957	-0.95
Belgium	-0.757	-1.00	-0.909	-1.22	-0.814	-1.12
Netherland	0.616	1.19	0.522	0.99	0.513	0.99
Great Britain	1.076	1.28	0.988	1.17	1.013	1.24
United States	-0.417	-0.57	-0.530	-0.70	-0.494	-0.67
Australia	0.863	1.11	0.901	1.13	0.924	1.18
Germany	-0.891	-0.90	-1.000	-0.98	-0.915	-0.92
Russia	-0.505	-0.64	-0.746	-0.90	-0.685	-0.84
Other nationality–related factors						
% Competition in rider's country	0.018	1.34	0.016	1.21	0.016	1.24
% Competition in sponsor's country	-0.006	-0.46	-0.003	-0.20	-0.003	-0.21
Rider-sponsor share same nationality	-0.217	-0.47	-0.076	-0.17	-0.200	-0.44
F(21,446)	4.30		4.21		4.41	
Hansen J statistic χ^2 (1) (overidentification test)	1.67		1.80		1.64	
Kleinbergen-Paap rk LM statistic χ^2 (2) (underidentification test)	28.37		28.58		28.80	
Kleinbergen-Paap rk Wald F statistic (weak identification test)	44.28		42.18		42.75	
Endogeneity test for team leader χ^2(1)	35.07		33.83		34.70	
Number of observations	468		468		468	

** and * denote significance at the 5% and 10% levels

Table 2A: Determinants of efficiency per day of competition in professional cycling (2SLS/IV estimates). Team leader variable is instrumented

	Dependent variable: Efficiency per day					
	(A)		(B)		(C)	
	Coefficient	*Robust z*	*Coefficient*	*Robust z*	*Coefficient*	*Robust z*
Constant	18.384	1.74*	18.483	1.77*	17.394	1.73*
Team status						
Team leader	21.101	7.22**	20.843	7.31**	21.043	7.19**
Personal features						
Body mass index (BMI)	0.335	1.63	0.332	1.61	0.339	1.66*
Age	-1.449	-2.20**	-1.410	-2.20**	-1.460	-2.23**
Age^2	0.021	1.97**	0.020	1.94*	0.021	1.99**
Experience in current team						
Experience in current team	0.021	0.17	-		0.018	0.14
First year in current team	-	-	-0.955	-1.86*	-	-
Team quality						
2011 team CQ points excluding rider	-0.00005	-0.29	-0.00005	-0.34	-	-
2010 team CQ points	-	-	-	-	0.0001	0.71
Team budget	-	-	-	-	-	-
Competition schedule						
% Tour de France	-0.021	-0.88	-0.023	-1.00	-0.020	-0.84
% Main one-day races	0.143	1.96**	0.146	2.01**	0.144	1.99**
Rider nationality						
Spain	-0.932	-0.84	-0.810	-0.74	-0.822	-0.73
Italy	0.085	0.09	0.173	0.19	0.092	0.10
France	-1.753	-1.07	-1.579	-0.97	-1.584	-0.94
Belgium	-1.334	-1.11	-1.174	-1.00	-1.236	-1.00
Netherland	1.102	1.29	1.091	1.28	1.028	1.24
Great Britain	1.530	1.07	1.591	1.15	1.497	1.10
United States	-0.766	-0.65	-0.701	-0.61	-0.827	-0.70
Australia	1.192	0.98	1.234	1.04	1.143	1.10
Germany	-1.439	-0.89	-1.300	-0.82	-1.546	-0.94
Russia	-0.644	-0.51	-0.558	-0.44	-0.741	-0.59
Other nationality–related factors						
% Competition in rider's country	-0.031	1.46	0.031	1.48	0.030	1.41
% Competition in sponsor's country	-0.011	-0.52	-0.010	-0.51	-0.009	-0.44
Rider-sponsor share same nationality	-0.250	-0.34	-0.455	-0.62	-0.206	-0.28
F(21,446)	3.86		4.03		3.81	
Hansen J statistic χ^2 (1) (overidentification test)	2.00		1.83		1.95	
Kleinbergen-Paap rk LM statistic χ^2 (2) (underidentification test)	27.88		28.14		28.04	
Kleinbergen-Paap rk Wald F statistic (weak identification test)	43.69		44.24		43.66	
Endogeneity test for team leader χ^2(1)	33.41		34.33		33.15	
Number of observations	468		468		468	

** and * denote significance at the 5% and 10% levels

Table 2B: Determinants of efficiency per day of competition in professional cycling (2SLS/IV estimates). Team leader variable is instrumented

	Dependent variable: Efficiency per day					
	(D)		(E)		(F)	
	Coefficient	*Robust z*	*Coefficient*	*Robust z*	*Coefficient*	*Robust z*
Constant	17.333	1.74*	17.057	1.66*	17.124	1.69*
Team status						
Team leader	20.761	7.27**	20.958	7.14**	20.715	7.23**
Personal features						
Body mass index (BMI)	0.336	1.64*	0.323	1.58	0.320	1.56
Age	-1.424	-2.23**	-1.435	-2.21**	-1.397	-2.20**
Age^2	0.020	1.97**	0.021	1.98**	0.020	1.95*
Experience in current team						
Experience in current team	-	-	0.022	0.18	-	-
First year in current team	-0.979	-1.90*	-	-	-0.938	-1.83*
Team quality						
2011 team CQ points excluding rider	-	-	-	-	-	-
2010 team CQ points	0.0001	0.85	-	-	-	-
Team budget	-	-	0.091	1.08	0.087	1.04
Competition schedule						
% Tour de France	-0.023	-0.96	-0.020	-0.84	-0.022	-0.95
% Main one-day races	0.147	2.05**	0.145	2.00*	0.147	2.06**
Rider nationality						
Spain	-0.681	-0.61	-0.752	-0.68	-0.635	-0.58
Italy	0.187	0.21	0.168	0.19	0.248	0.28
France	-1.371	-0.82	-1.597	-1.00	-1.432	-0.90
Belgium	-1.050	-0.87	-1.284	-1.08	-1.134	-0.98
Netherland	1.005	1.23	0.871	1.05	0.856	1.04
Great Britain	1.562	1.18	1.434	1.07	1.471	1.14
United States	-0.764	-0.67	-0.930	-0.78	-0.875	-0.75
Australia	1.178	0.98	1.231	1.00	1.267	1.05
Germany	-1.422	-0.89	-1.591	-0.97	-1.455	-0.91
Russia	-0.665	-0.53	-1.018	-0.78	-0.924	-0.72
Other nationality–related factors						
% Competition in rider’s country	0.030	1.42	0.027	1.31	0.027	1.34
% Competition in sponsor’s country	-0.008	-0.41	-0.004	-0.18	-0.004	-0.18
Rider-sponsor share same nationality	-0.415	-0.58	-0.196	-0.27	-0.390	-0.54
F(21,446)	3.97		3.90		4.08	
Hansen J statistic χ^2 (1) (overidentification test)	1.77		1.90		1.74	
Kleinbergen-Paap rk LM statistic χ^2 (2) (underidentification test)	28.37		28.58		28.80	
Kleinbergen-Paap rk Wald F statistic (weak identification test)	44.28		42.18		42.76	
Endogeneity test for team leader χ^2(1)	34.04		32.77		33.63	
Number of observations	468		468		468	

** and * denote significance at the 5% and 10% levels

Equations A to F from Tables 1A-1B and 2A-2B differ in the way of measuring riders' experience and team quality. The outcomes are consistent in general with the hypotheses put forward in the previous section. First, being a team leader raises cyclist efficiency, independently of the way this ratio is measured (i.e., CQ points per 100 km or per day of competition).[23] It should be noted that the estimated coefficient of the leadership variable is free of the bias induced by the fact that team leaders are more qualified than other riders.

Second, it is observed that the *body mass index* (*BMI*) variable is only significant for equation C from Table 1A and equations C and D from Tables 2A and 2B respectively. The positive sign of this coefficient shows that the greater the *BMI*, the higher the efficiency. It is true that riders with higher *BMI* are favored in one-day races, sprints and time-trials, but in many stage-races or mountain stages, the most favored riders are those with lower *BMI*. Thus, for the Tour de France, a quite difficult three-week race, Torgler (2007) and Coupé & Gergaud (2012) observe that riders' overall standings improve as *BMI* diminishes. However, for the season as a whole, there is no reason to expect the same outcome because riders compete in a mix of stage and one-day races with differing degrees of difficulty, and stronger riders could hence be favored.

Third, the *age* and *squared age* variables are also highly significant in the estimations. The signs of their coefficients show that the relation between efficiency and age is U-shaped. For example, in the case of equation A from Table 1A, efficiency decreases as age increases up to the age of 34.3 and beyond this point efficiency increases. Therefore, during the greater part of their professional careers riders tend to be less efficient the older they are. Only at the end of their careers (very few riders continue beyond 35 years of age) does being older imply more efficiency. Usually, labor experience adds new knowledge that raises productivity, but in this case it seems that having more experience reduces efficiency over the greater part of working life. As an alternative way of measuring specific training, the years of experience as a professional rider was used instead of age, but the outcomes did not change (both variable are closely related, since they measure the same feature).[24]

Regarding *experience in current team*, this variable is not significant in the estimations but the dummy variable *first year in current team* is always significant and has the expected negative sign. This shows clearly that in order to be perfectly integrated in a new team a period of adaptation is needed.

With regard to team quality variables (the *number of CQ points accumulated by the team excluding the rider in 2011*, the *number of CQ points accumulated by the team over the previous year (2010)* and *team budget*), none of them is significant. We would expect a higher team quality (and therefore a higher wage bill for the set of teammates) to lead to an improvement in the athletic performance of each individual. However, the number of CQ points for a rider would not be increased when the quality of their teammates rises if it implies that there are more leaders for whom cyclists must work. In this case, cyclists have even more reasons to renounce their personal targets and the lack of significance of these variables may be logical.[25] It is only when the rider is a team leader (and the effect of this variable was already taken into account in the model) that his performance might be improved because his teammates are better athletes, as they work for him.[26]

As far as *competition schedule* is concerned, the estimations show that cyclists who concentrate their calendar of competition on the most relevant one-day events (first and second category classic races and World and National Championships) are the most efficient. This is an expected outcome since these races provide many CQ points. However, cyclists who participate in the Tour de France do not increase efficiency, even though this is the most prestigious race. Therefore, choosing a good competition schedule at the beginning of the season seems to be decisive in order to achieve the highest levels of efficiency.

Finally, the estimation results indicate that riders' nationality and the three variables included to proxy other features related to riders' nationality (the *percentage of days of competition in the 2011 season covered in the riders' country*, the *percentage of days of competition in the 2011 season covered in the main sponsor's country* and a *dummy variable that takes a value of 1 if the rider has the same* *nationality as the main sponsor of the team*) are not significant. It can be stated that cycling is now a sport in which professionals move easily in a broad labor market, not being affected by the places where races are contested or by the nationality of the sponsors that hire them.

Regarding the leadership equation (see, Tables A3A and A3B of the Appendix) some very interesting results are obtained. With respect to the *body mass index* (*BMI*), it is observed that the lower the *BMI*, the higher the likelihood of being a team leader. Riders are usually penalized by high *BMI* when climbing but not in time-trials, flat stages and sprints. In any case, many leaders need to be good climbers, the reason being that time losses in mountain stages are greater than in other kinds of races since teammates cannot help them when the bunch is broken (something that is very frequent in mountain stages). This might be the reason we observe a negative sign for the coefficient of this variable. Another significant variable is having been declared positive in an anti-doping control prior to 2011. Cyclists who have taken prohibited substances in the past have a higher likelihood of being team leaders at present.[27] At first sight, this result could adversely affect the credibility of cycling. It is possible that some riders took prohibited products in the past to become leaders of a team (to achieve a "name" in this sport), and that once this goal was fulfilled they continued to use the assistance and cooperation of teammates to enhance their performances. However, it should be noted that times have changed in cycling since the implementation of the Biological Passport procedure in 2009. This method of control makes it easier to uncover cheaters and ensures fairness and equal opportunities among riders. Finally, the number of CQ points obtained by the rider in the previous season (year 2010) is significant and has the expected sign: having obtained a lot of CQ points in the 2010 season can help the rider to be considered for leadership in the 2011 season.

CONCLUSIONS

The aim of this paper is to assess the determinants of cyclists' performance over the season, particularly the role played by being a team leader. To do so, a sample is constructed comprising 468 professional riders belonging to the 18 first category teams in the 2011 season. The efficiency indicator is the number of CQ points accumulated by riders divided by the number of kilometers (or, alternatively, days) of competition. The estimation results show that efficiency depends mainly on individual features (such as age, body mass index and the fact that 2011 is the first year the cyclist competes for the current team) and the calendar of competition chosen by riders. Thus, the relationship between efficiency and age is U-shaped, and efficiency grows as BMI increases and diminishes when riders are new to the team. On the other hand, efficiency is greater when riders concentrate their efforts on the most relevant one-day races (first and second category one-day races and the World and National Championships). Since these events receive more CQ points than the rest, choosing a suitable competition schedule seems to be one of the most relevant decisions a rider must take at the beginning of the season in order to raise efficiency.

However, the most decisive feature in enhancing rider efficiency is team status. Specifically, the estimates show that being a team leader significantly increases efficiency. Team leaders have two main features: they are the most qualified riders, and they benefit from the work done by all their teammates. Therefore, to assess the true impact of leadership on efficiency, this variable must be instrumented in order to avoid the endogeneity bias generated by the greater abilities - and therefore the higher efficiency - of leaders. On the other hand, none of the variables measuring team quality is significant in explaining riders' efficiency. The reason may be that, for most riders, being in a stronger team involves working harder in favor of their leaders, which in turn implies giving up their personal targets in order to ensure that leaders may obtain more CQ points.

APPENDIX

Variable definitions, descriptive statistics and leadership estimates (first stage)

Table A1: Variable definitions

Dependent variables	
(Efficiency per Km)*100	This index is defined as the number of CQ (Cycling Quotient) points accumulated by each rider in the 2011 season divided by the number of kilometers of competition and multiplied by 100. Only races of category .1 or above and finished races are counted. This index covers almost all races contested by the riders included in the sample. Very few riders from UCI ProTeams compete in races of category below .1. All the information over the efficiency index is available in http://www.cqranking.com
Efficiency per day	Number of CQ (Cycling Quotient) points accumulated by each rider in the 2011 season divided by the number of days of competition
Independent variables	
Team status	
Team leader	A dummy variable that takes a value of 1 if the rider is one of the team leaders and a value of 0 if he is a teammate
Personal features	
Body mass index (BMI)	This indicator is defined as weight (in kilograms) divided by squared height (in meters)
Age	Age
Age^2	Squared age
Experience in current team	
Experience in current team	Number of years of experience in current team
First year in the current team	A dummy variable that takes a value of 1 if 2011 is the first year the rider works for the current team
Team quality	
2011 team CQ points excluding rider	Number of CQ points accumulated by the team members at the end of the 2011 season minus the number of CQ points accumulated by the rider
2010 team CQ points	Number of CQ points accumulated by the team members at the end of the 2010 season
Team budget	Annual team budget in millions of euro (Source: www.sportune.fr)
Competition schedule	
% Tour de France	Percentage of days of competition in the 2011 season devoted to the Tour de France (the most relevant three-week long race)
% Main one-day races	Percentage of days of competition in the 2011 season devoted to first and second category one-day races (Milano-San Remo, Ronde van Vlaanderen,

	Paris-Roubaix, Liege-Bastogne-Liege, Giro di Lombardia, Gent-Wevelgem, Amstel Gold Race, Fleche Wallonne, Clasica San Sebastian, Vattenfall Cyclassics, GP Plouay, GP de Quebec and GP de Montreal), and the World and National Championships
% Other races	Percentage of days of competition in the 2011 season devoted to the rest of races
Rider nationality	
Spain	A dummy variable that takes a value of 1 if the rider is Spanish and a value of 0 otherwise
Italy	A dummy variable that takes a value of 1 if the rider is Italian and a value of 0 otherwise
France	A dummy variable that takes a value of 1 if the rider is French and a value of 0 otherwise
Belgium	A dummy variable that takes a value of 1 if the rider is Belgian and a value of 0 otherwise
Netherland	A dummy variable that takes a value of 1 if the rider is Dutch and a value of 0 otherwise
Great Britain	A dummy variable that takes a value of 1 if the rider is British and a value of 0 otherwise
United States	A dummy variable that takes a value of 1 if the rider is American and a value of 0 otherwise
Australia	A dummy variable that takes a value of 1 if the rider is Australian and a value of 0 otherwise
Germany	A dummy variable that takes a value of 1 if the rider is German and a value of 0 otherwise
Russia	A dummy variable that takes a value of 1 if the rider is Russian and a value of 0 otherwise
Other countries	A dummy variable that takes a value of 1 if the rider belongs to another country and a value of 0 otherwise
Other nationality–related factors	
% Competition in rider's country	Percentage of days of competition in the 2011 season covered in the rider's country
% Competition in sponsor's country	Percentage of days of competition in the 2011 season covered in the country of the main sponsor
Rider-sponsor share same nationality	A dummy variable that takes a value of 1 if the rider has the same nationality as the main sponsor of the team

Doping variable	
Declared positive prior to 2011	A dummy variable that takes a value of 1 if the rider was declared positive in an anti-doping control prior to 2011 (or he was declared positive later on due to events occurred prior 2011)
Rider CQ points in 2010	
Rider CQ points in 2010	Number of CQ points accumulated by each rider in the previous season (2010)

Table A2: Descriptive statistics

	Mean	*St. dev.*	*Min.*	*Max.*
Dependent variables				
Efficiency per 100 Km	2.542	2.905	0.068	24.610
Efficiency per day	3.928	4.568	0.102	41.946
Independent variables				
Team status				
Team leader	0.092	0.289	0	1
Personal features				
Body mass index (BMI)	21.246	1.233	17.915	25.848
Age	28.951	4.221	20.890	40.315
Age^2	855.967	252.557	436.409	1,625.305
Experience in current team				
Experience in current team	2.611	2.172	0.420	17
First year in current team	0.346	0.476	0	1
Team quality				
2011 team CQ points excluding rider	7,404.462	1,745.458	3,413	10,566
2010 team CQ points	7,434.502	1951.733	4,494	11,133
Team budget (in millions of euro)	10.298	2.999	6.500	15.000
Competition schedule				
% Tour de France	8.749	12.386	0	39.623
% Main one-day races	6.463	3.785	0	21.818
% Other races	84.788	13.331	43.860	100.000
Rider nationality				
Spain	0.115	0.320	0	1
Italy	0.143	0.351	0	1
France	0.064	0.245	0	1
Belgium	0.096	0.295	0	1
Netherland	0.073	0.260	0	1
Great Britain	0.032	0.176	0	1
United States	0.053	0.225	0	1
Australia	0.060	0.237	0	1
Germany	0.047	0.212	0	1
Russia	0.043	0.202	0	1
Other countries	0.271	0.445	0	1
Other nationality–related factors				
% Competition in rider's country	18.572	17.963	0	86.000
% Competition in sponsor's country	14.151	17.201	0	75.949
Rider-sponsor share same nationality	0.468	0.500	0	1
Doping variable				
Declared positive prior to 2011	0.056	0.229	0	1
Rider CQ points in 2010				
Rider CQ points in 2010	276.344	332.349	4	2,204
Number of observations	468			

Table A3A: Determinants of leadership (first-stage)

	Dependent variable: Team leader					
	(A)		(B)		(C)	
	Coefficient	*Robust t*	*Coefficient*	*Robust t*	*Coefficient*	*Robust t*
Constant	-0.188	-0.38	-0.185	-0.38	-0.175	-0.36
Personal features						
Body mass index (BMI)	-0.024	-2.64**	-0.025	-2.63**	-0.025	-2.66**
Age	0.042	1.36	0.041	1.33	0.043	1.40
Age^2	-0.0007	-1.25	-0.0007	-1.21	-0.0007	-1.29
Experience in current team						
Experience in current team	-0.0007	-0.11	-		-0.0005	-0.08
First year in current team	-	-	0.026	1.12	-	-
Team quality						
2011 team CQ points excluding rider	-0.000001	-0.22	-0.000001	-0.20	-	-
2010 team CQ points	-	-	-	-	-0.000004	-0.87
Team budget	-	-	-	-	-	-
Competition schedule						
% Tour de France	0.002	2.14**	0.002	2.23**	0.002	2.13**
% Main one-day races	-0.001	-0.35	-0.001	-0.37	-0.001	-0.34
Rider nationality						
Spain	0.044	0.94	0.040	0.84	0.040	0.85
Italy	0.021	0.51	0.019	0.45	0.019	0.47
France	0.107	1.40	0.103	1.34	0.100	1.28
Belgium	0.096	1.91*	0.092	1.85*	0.090	1.73*
Netherland	-0.020	-0.59	-0.020	-0.59	-0.022	-0.70
Great Britain	0.053	0.66	0.052	0.65	0.045	0.56
United States	0.034	0.49	0.033	0.47	0.031	0.44
Australia	0.036	0.93	0.034	0.91	0.036	0.97
Germany	0.090	1.12	0.087	1.09	0.092	1.14
Russia	-0.022	-0.39	-0.024	-0.43	-0.020	-0.36
Other nationality–related factors						
% Competition in rider's country	-0.002	-2.05**	-0.002	-2.08**	-0.002	-1.98**
% Competition in sponsor's country	0.0002	0.29	0.0002	0.28	0.0002	0.18
Rider-sponsor share same nationality	0.028	0.89	0.034	1.08	0.030	0.95
Other instruments						
Declared positive prior to 2011	0.147	1.71*	0.144	1.68*	0.147	1.71*
Rider CQ points in 2010	0.0005	8.57**	0.0005	8.64**	0.0005	8.57**
F(22,445)	6.47		6.51		6.44	
Number of observations	468		468		468	

** and * denote significance at the 5% and 10% levels

Table A3B: Determinants of leadership (first-stage)

	Dependent variable: Team leader					
	(D)		(E)		(F)	
	Coefficient	*Robust t*	*Coefficient*	*Robust t*	*Coefficient*	*Robust t*
Constant	-0.168	-0.35	-0.192	-0.40	-0.189	-0.39
Personal features						
Body mass index (BMI)	-0.025	-2.66**	-0.025	-2.61**	-0.024	-2.60**
Age	0.042	1.37	0.042	1.37	0.041	1.34
Age^2	-0.0007	-1.25	-0.0007	-1.26	-0.0006	-1.22
Experience in current team						
Experience in current team	-	-	-0.0007	-0.11	-	-
First year in current team	0.027	1.18			0.026	1.12
Team quality						
2011 team CQ points excluding rider	-	-	-	-	-	-
2010 team CQ points	-0.000005	-0.96	-	-	-	-
Team budget	-	-	-0.001	-0.26	-0.001	-0.24
Competition schedule						
% Tour de France	0.002	2.22**	0.002	2.15**	0.002	2.23**
% Main one-day races	-0.001	-0.37	-0.001	-0.34	-0.001	-0.36
Rider nationality						
Spain	0.036	0.74	0.043	0.94	0.040	0.84
Italy	0.017	0.40	0.019	0.48	0.017	0.43
France	0.094	1.20	0.106	1.41	0.102	1.35
Belgium	0.086	1.65*	0.095	1.90*	0.091	1.84*
Netherland	-0.022	-0.70	-0.020	-0.61	-0.020	-0.62
Great Britain	0.043	0.55	0.049	0.63	0.048	0.62
United States	0.030	0.42	0.032	0.45	0.031	0.44
Australia	0.035	0.95	0.034	0.90	0.033	0.88
Germany	0.089	1.11	0.090	1.11	0.087	1.08
Russia	-0.022	-0.39	-0.019	-0.33	-0.022	-0.37
Other nationality–related factors						
% Competition in rider's country	-0.002	-2.00**	-0.002	-2.06**	-0.002	-2.09**
% Competition in sponsor's country	0.0001	0.17	0.0002	0.26	0.0002	0.19
Rider-sponsor share same nationality	0.036	1.16	0.029	0.95	0.035	1.14
Other instruments						
Declared positive prior to 2011	0.143	1.67*	0.147	1.71*	0.144	1.68*
Rider CQ points in 2010	0.0005	8.64**	0.0005	8.42**	0.0005	8.49**
F(22,445)	6.49		6.64		6.71	
Number of observations	468		468		468	

** and * denote significance at the 5% and 10% levels

NOTES

1. Leaders know that without the cooperation of their teammates it would be almost impossible to win. In fact, leaders usually share their winner's cash prize with all teammates. This internal recognition is very important in order to preserve a good climate inside the team and to pursue new goals.

2. They use data from the Canadian Hockey League.

3. The differences between both points systems will be fully described later on.

4. There are some exceptions. For instance, there is a team classification in stage races. This is computed on the basis of the time employed by the three top-ranked riders in each stage. At the end of the race all these times are added up and the winner is the team which accrues the least amount of time.

5. Moreover, some races usually reward the most combative rider, the best young rider, etc.

6. Kyle (1976) estimates that the effect of slipstreaming reduces the power needed to ride at the same speed as the cyclist riding ahead by around 33%.

7. The papers by Van Reeth (2013) and Rodríguez et al. (2013) find that television audiences depend basically on the type of race, the competitive balance and the nationality of the riders who are in the leading positions of the overall standings.

8. This consists of beginning the sprint just behind a rival or a teammate, minimizing effort in order to overtake him at the end.

9. The Biological Passport is a record of periodical and random analyses (blood and urine) made by UCI inspectors in order to know if cyclists show significant variations in several biological markers of doping which may indicate the use of blood transfusions or banned methods.

10. See http://www.cqranking.com/men/asp/info/whats.asp. The CQ-ranking was developed by Andy Roose, Peter Samoy, Jasper Van Hoof and Mark Vanderwegen. The advantage of the CQ Ranking with respect to the UCI points system (WorldTour Ranking) is that the former includes many more events than the latter (almost all the races contested by the sampled riders are considered in CQ) and is therefore more comprehensive. The UCI points system considered only 27 events in 2011, the so called UCI WorldTour league (see http://www.uciworldtour.com).

11. The scoring rules of the CQ Ranking are available in http://www.cqranking.com/men/asp/gen/rules.asp.

12. To compute the efficiency index, only races of Category 1 or above and finished races are counted. This criterion allows including almost all the races contested by the sampled riders (who belong only to first category teams).

13. The UCI WorldTour is a cyclist league that includes the best stage races and one-day races.

14. Since 2009, the number of cyclists punished because of their abnormal Biological Passport (BP) markers or because they were officially declared positive (i.e., a prohibited product was detected) was 66 in 2009 (5 due to abnormal BP), 57 in 2010 (3 due to abnormal BP), 52 in 2011 and 35 in 2012 (3 due to abnormal BP). See CQ Ranking (http://www.cqranking.com).

15. Miguel Indurain (winner of five Tours de France) was an exception to this rule (his *BMI* was 24.7, higher than the average) but he could actually be considered a pure time-trial specialist who was able to defend his position in the mountain stages.

16. It would be quite useful to have information on other physical parameters (such as power in watts, maximum oxygen uptake-VO2max…) but these data are not available for all sampled riders.

17. See Table A1 of the Appendix for the names of the races belonging to each category.

18. The type of rider is identified from the information reported by teams and also from the information included in Coupé & Gergaud (2012), inspired by the paper by Unwin et al. (2006). See http://www.theusrus.de/Blog-files/TDF2010.txt.

19. Or in 2012-2013 for events that occurred before 2011 (as in the case of Lance Armstrong).

20. No sampled rider was declared positive in 2011. Cyclists who were declared positive prior to 2011 and who were punished during 2011 were not included in the sample. For instance, Alberto Contador was declared positive in 2012 from a blood test carried out in 2010, and in spite of the fact that he competed in 2011 the CQ points accumulated in 2011 were annulled (in this case it was impossible to compute the efficiency index).

21. In order to avoid the efficiency index being affected by illness or injuries that shorten the rider's season, all cyclists who did not complete at least 4,500 kilometers of competition were excluded from the sample (this figure is approximately one third of the average number of kilometers a cyclist accumulates over a season).

22. These tests are provided by the *ivreg2* command of STATA. The endogeneity test implemented by ivreg2 is defined as "the difference of two Sargan-Hansen statistics: one for the equation with the smaller set of instruments, where the suspect regressor

is treated as endogenous, and one for the equation with the larger set of instruments, where the suspect regressor is treated as exogenous… Under conditional homoskedasticity, this endogeneity test statistic is numerically equal to a Hausman test statistic" (see, *STATA help* for *ivreg2*, STATA, Statacorp, Texas, http:www.estata.com). The test statistic is distributed as chi-squared with degrees of freedom equal to the number of regressors tested.

23. Torgler (2007) and Coupé & Gergaud (2012) obtained the same outcome. In both cases, being a team leader was found to improve riders' standings in the Tour de France.

24. However, in the paper by Torgler (2007) professional experience was not significant. Meanwhile, Coupé & Gergaud (2012) observe in some model specifications that rider standings in the 2010 Tour de France improves with age, maybe because this event is extremely tough and demands a lot of professional experience.

25. Coupé & Gergaud (2012) and Torgler (2007) also highlight this issue. When working for leaders, teammates renounce competing for the top positions in races, making it easier for leaders to attain these positions and thereby obtain more CQ points. It should be noted that the scoring system in cycling does not consider the work done by teammates in favor of their leaders, only the final positions occupied by riders.

26. An attempt was made to measure the effect of the distribution of talent within the team by including the coefficient of variation of the efficiency index for all team members in the equations, but this variable was never significant. These estimates are not included in the text but are available for consultation.

27. Although this dummy variable takes the value 1 if the positive test took place prior to 2011, the sentence might not be issued until after 2011. This is the case of Lance Armstrong and the teammates who testified against him in 2012 and admitted having taken prohibited products prior 2006.

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