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Suspicious Blood and Performance in Professional Cycling

Tom Coupé[1] and Olivier Gergaud[2]

Abstract
In this note, the authors analyze whether the International Cycling Union's "index of suspicion," which reflects the extent to which a rider is suspected of using doping, correlates with performance during the 2010 Tour de France and the 1-year period before and after the 2010 Tour de France. Though our point estimates suggest a medium-sized performance improving effect of being suspected of doping, the index of suspicion can only explain a very small part of the variation in performance. This could be because the current doping practice in cycling has little effect on diverse rankings in these races.

Keywords
doping, cycling, Tour de France

Introduction

The use of past blood tests, the so-called biological passports, to detect suspicious changes in blood values is becoming a more and more widespread weapon in the fight against doping in sports. For example, the 2012 London Olympics will be the first Olympics where such tests will be used for certain competitions (McGrath, 2011[1]). Despite this increasing popularity, the usefulness of such tests to detect doping is still controversial, from an ethical and legal point of view but also from the point of view of its capacity to detect actual doping.

One of the reasons that it is hard to check the usefulness of these tests is that it is very hard to get the biological passport data for a large sample of athletes. In this

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article, we use, what is as far as we know, the first such large data set with publicly available information on the biological passports of almost 200 top-level cyclists.

On May 13, 2011, the French Sport Newspaper *L'Equipe* published an "Index of Suspicion," a list containing the names of about 200 professional cyclists and the degree to which their blood values were "suspicious," that is, showed signs of the possible use of doping, at the eve of the 2010 Tour de France, arguably the most important international cycling race. This list, made by a doping (detection) specialist, on demand of the International Cycling Union, is based on an evaluation of blood tests of the cyclists, tests submitted between 2008 and the eve of the Tour 2010. On the basis of this evaluation, the riders were categorized into 11 categories, ranging from 0 (*not suspect*) to 10 (*very suspect*).

In this note, we first analyze whether this index of suspicion can help predict the performance during the 2010 Tour de France and the year before and after the start of the 2010 Tour de France. If suspicious blood values are a good indicator of the use of performance enhancing drugs, and if, in addition, performance enhancing drugs actually do enhance performance significantly, there should be a positive correlation between the index of suspicion and performance. The absence of such correlation would suggest either that doping is not effective or alternatively that the index of suspicion is not a good indicator of doping.

We then try to distinguish between these two explanations by running an instrumental variables (IV) regression, where we instrument the index of suspicion by other doping-related variables such as belonging to a team where managers have been suspected of doping or such as having been suspected of doping based on other indicators than the biological passport. The reason to use instruments is the idea that if the index of suspicion is an imperfect indicator of the use of effective performance enhancing drugs, then the coefficient of the index of suspicion in a performance regression will be biased toward zero due to the so-called errors-in-variables problem. To get an unbiased coefficient of the effectiveness of doping, we can instrument one (imperfect) indicator of doping by other (equally imperfect) indicators of doping (see Wooldridge, 2008, pp. 526–527).

This article is not the first article that investigates doping in sports (see, e.g., Berentsen, 2002; Haugen, 2004; Eber, 2008, for a theoretical analysis of doping behavior or Dilger, Frick, & Tolsdorf, 2007, for a selective survey of doping cases in cycling and other sports) or the determinants of success in cycling (e.g., Torgler, 2007). This is the first article however that studies, using a large sample of athletes, the effectiveness of biological passports as a weapon in the fight against doping.[2]

Analysis

Does the Index of Suspicion Predict Performance?

Regressing performance on the index of suspicion. We use two performance measures based on the performance during the Tour de France: the logarithm of the total time needed to finish the Tour de France and the logarithm of the final ranking in the yellow jersey competition.[3] As additional measures of performance, we use the log of the number of points a rider collected in the widely used Cycling Quotient (CQ) ranking. The CQ ranking measures the riders' performance throughout the year,[4] and we use both the points collected in the year leading up to the 2010 Tour de France (CQ2010) and year following the start of the 2010 Tour de France (CQ2011). These different performance measures are used to capture different time periods: the results of the Tour de France have the advantage that they capture the performance immediately after the index was composed but have the disadvantage that they measure the performance in only one specific race. The CQ2011 gives the performance over a longer stretch of time and is based on the riders' performance in many different races but has the disadvantage that, if athletes' doping status changes over time, the index of suspicion measured at the eve of the 2010 Tour might become less and less relevant as the year progresses. Finally, CQ2010 has the advantage that it measures performance during the period the blood measurements were taken but has the disadvantage that this is before the actual index was composed. Hence, one cannot exclude that the (interpretation of the) blood samples were (was) affected by the riders' performance.

Our main explanatory variable of interest is the categorical variable which reflects the score on the index of suspicion. Categorical variables are typically included as explanatory variables in regression analysis by creating a dummy variable for each specific category. However, given that there are a lot of categories (11 categories, ranging from 0 to 10) and some of these categories have only few observations in them, one might want to consider this index as almost continuous and hence, include the index as just one variable. Below we also present a specification where, instead of the index, we included two dummies each grouping a number of categories—an omitted first dummy for categories 0 and 1 reflecting little or no suspicion of doping, a second dummy for categories 2–4 reflecting a medium level of suspicion, the third dummy being for categories 5 and up reflecting high levels of suspicion. In this way, we allow for a nonlinear effect of the doping categories on performance. The first two dummies represent each about 40% of the riders in the sample, while the last category represents about 20%. A third specification compares the performance of those with little or no suspicion of doping (categories 0 and 1) to the other cyclists.

In addition to the main explanatory variable/variables of interest, we include a number of reasonably exogenous variables that could influence performance. Following Torgler (2007), we include the body mass index (BMI; weight divided by the square of length in meters) and a dummy for French riders, the latter reflecting the higher incentives the home riders have in the Tour de France. We also include the age at the start of the 2010 Tour.[5]

Table 1 gives the results of regressions where we run a specific dimension of performance on a constant, our doping-related variable/variables and our other explanatory variables. We find a sizable and significant effect on the time needed to finish the race: depending on the specification, compared to an unsuspected rider

Table 1. Using the Index of Suspicion and Exogenous Controls as Explanatory Variables

	TDF Time	TDF Time	TDF Time	TDF Rank	TDF Rank	TDF Rank	CQ2011	CQ2011	CQ2011	CQ2010	CQ2010	CQ2010
Index of suspicion	−0.001			−0.042			0.036			0.029		
	(−1.43)			(−1.38)			(1.20)			(1.05)		
Index of suspicion (2–4)		−0.004**			−0.242			0.149			0.272*	
		(−1.97)			(−1.62)			(0.92)			(1.85)	
Index of suspicion (5–10)		−0.003			−0.244			0.305			0.326*	
		(−1.26)			(−1.18)			(1.51)			(1.87)	
Index of suspicion (2–10)			−0.004**			−0.242*			0.199			0.289**
			(−1.98)			(−1.75)			(1.34)			(2.19)
Body mass index	0.004***	0.004***	0.004***	0.249***	0.250***	0.250***	−0.013	−0.011	−0.012	0.031	0.041	0.041
	(4.66)	(4.64)	(4.65)	(4.40)	(4.36)	(4.34)	(−0.20)	(−0.17)	(−0.18)	(0.52)	(0.69)	(0.68)
Age	−0.001*	−0.001*	−0.001*	−0.030*	−0.030*	−0.030*	−0.019	−0.02	−0.019	−0.007	−0.008	−0.008
	(−1.94)	(−1.94)	(−1.93)	(−1.70)	(−1.71)	(−1.71)	(−1.03)	(−1.06)	(−1.01)	(−0.43)	(−0.51)	(−0.49)
French	−0.003	−0.003	−0.003	−0.049	−0.047	−0.047	−0.031	−0.016	−0.028	−0.011	0.036	0.032
	(−1.29)	(−1.30)	(−1.36)	(−0.37)	(−0.35)	(−0.35)	(−0.19)	(−0.10)	(−0.17)	(−0.08)	(0.28)	(0.25)
Constant	8.584***	8.585***	8.585***	−0.089	−0.06	−0.06	6.209***	6.149***	6.135***	5.121***	4.838***	4.839***
	(468.38)	(467.17)	(468.52)	(−0.06)	(−0.04)	(−0.04)	(4.45)	(4.40)	(4.40)	(4.03)	(3.78)	(3.80)
Adjusted R^2	0.099	0.104	0.109	.089	0.086	0.092	−0.007	−0.007	−0.005	−0.013	−0.001	0.004
N	170	170	170	170	170	170	196	196	196	195	195	195

Note. TDF = Tour de France. CQ = cycling quotient. The omitted category is the no suspicion category, which consists of Categories 0 and 1. We use robust standard errors. t statistics in parentheses.

(category 0), a rider in the highest category of doping (category 10) needs about 0.4–1% less time to finish the 2010 Tour de France. Given it took the riders somewhere between 5,500 and 6,000 min to finish The Tour de France, this means an estimated time gain of roughly between half an hour and 1 hour. Similarly, in terms of ranking a highly suspected rider would be ranked 30–50 percentage points better. That is, if competing with unsuspected riders, he would rank first rather than second or fifth to seventh rather than tenth.[6]

We also find that having a higher BMI or being younger is bad for a rider's performance in the Tour de France (both in terms of time and ranking) while there does not seem to be a home advantage for French riders.[7] Comparing the size of the effects, one can see, for example, that being somewhat or highly suspect will about offset the effect on the general standing of the Tour de France of having a BMI that is one point higher or is about equivalent to the effect of being 4–8 years older. Together the explanatory variables explain about 10% of the variation in time and ranking at the end of the Tour de France.[8]

If we look at the CQ ranking points, we see there is a positive though insignificant effect of the index on the CQ2011 ranking but a positive and significant effect on the CQ2010 ranking. Suspected riders have about 30 percentage points more CQ points in 2010 than unsuspected riders.[9] Noteworthy is further that none of the other variables are significant for the CQ ranking.

In addition to the regressions reported in Table 1, we checked whether the results of specific stages (there were 21 stages in the Tour de France 2010) are correlated with the index of suspicion. We found a clear negative correlation between the level of significance of the doping variable/variables and the level of difficulty of the stage as measured by the sum of the kilometers where riders have to climb, weighted by the steepness of the various climbs (the average slope coefficient times length in kilometers of each hill or mountain[10]). For example, the regression for stage 17, which has the highest degree of difficulty, shows that riders in the lowest category needed about 1.7 percentage points more time than riders who were in the highest category of suspicion. The correlation between the *t* statistic (which is negative) of the doping variables and the level of difficulty of the race is about -0.3, hence the higher the difficulty the more negative the *t* statistic is.[11] Also in these stage regressions, the adjusted R^2 is consistently low.

We further checked the predictive power of the index of suspicion on the points for sprints (green jersey) and for the climbers trophy (dotted jersey) but found no significant effects for these competitions.[12]

So far we did not include any indicators of past performance as explanatory variables in our regressions. In this way, we avoided that past performance would hide part of the effect of doping as past performance itself could have been affected by doping. From the other side, however, excluding past performance which could proxy for ability or talent means our estimates could be biased because of omitted variables. We therefore also present the results of regressions that include several indicators of past performance.

Table 2. Rider's Type and Average Index of Suspicion Score

Type	Obs	*M*	*SD*	Min	Max
Stage points specialist	44	2.23	2.24	0	10
Helper	49	2.29	2.33	0	8
Sprinter	21	2.33	2.39	0	8
Time trial specialist	18	2.61	2.43	0	8
Climber	33	2.70	2.48	0	8
Leader/top rider	32	4.22	2.68	0	10

As a first indicator which is related to past performance, we include dummies for the type of the rider.[13] Column 2 of Table 2 gives the frequency of the six types in the sample.

Table 2 further gives the mean suspicion index scores for the different types of riders. There is little variation over types with one exception: the mean suspicion score is substantially higher for the leader/top rider category as compared to all other categories.

Further, we created an indicator of whether the Tour de France 2010 was the first Tour de France in which a rider participated and an indicator of how many times, in the last 3 years before the 2010 Tour de France, a rider made it to the top 20 in the Tour de France. Finally, to capture possible team effects, we created a variable that reflects the past performance of the team, as measured by the median CQ2010 score of a rider's teammates.

Table 3 shows that these additional variables typically have expected signs—the leader/top rider category (the omitted category in our regression) does better than other categories in terms of time and ranking in the 2010 Tour de France. Also in terms of the 2010 and 2011 CQ ranking points, they do better than all other types, except for the stage points specialists. The BMI remains positive and significant for the Tour de France, while nationality again does not seem to matter. In contrast to previous specifications, age is no longer a significant factor for the Tour de France. A surprising finding is that the median 2010 CQ ranking of a rider's teammates has a positive and significant effect on the time needed to finish the 2010 Tour de France (but not on the ranking). This suggests that having many good riders in a team can be detrimental for each individual rider's performance in the Tour de France. At the same time, having good teammates also has a positive effect on the 2011 CQ ranking points (but not the 2010 CQ ranking points). Adding these variables has two overall effects. First, it adds substantially to the R^2 of the regression, which increases to 15–20% for the CQ rankings and 35–40% for the Tour de France results. Second, including these variables makes the doping variables insignificant. Both effects are mainly due to the inclusion of the rider-type dummies—these dummies explain quite well performance differences in the Tour and in terms of the CQ ranking, but they also render the suspicion variables insignificant as they are correlated with the index of suspicion as can be seen from Table 2.

Table 3. Adding Possibly Endogenous Controls

	TDF Time	TDF Time	TDF Time	TDF Rank	TDF Rank	TDF Rank	CQ2011	CQ2011	CQ2011	CQ2010	CQ2010	CQ2010
Index of suspicion	0			0.006			−0.003			−0.009		
	(−0.00)			(0.21)			(−0.12)			(−0.34)		
Index of suspicion (2–4)		−0.003			−0.117			0.02			0.154	
		(−1.49)			(−0.92)			(0.13)			(1.12)	
Index of suspicion (5–10)		0			0.012			0.046			0.068	
		(−0.17)			(0.07)			(0.24)			(0.41)	
Index of suspicion (2–10)			−0.002			−0.079			0.027			0.129
			(−1.16)			(−0.65)			(0.19)			(1.02)
Body mass index	0.002**	0.002**	0.002**	0.132***	0.129***	0.126***	−0.043	−0.04	−0.04	0.018	0.028	0.03
	(2.51)	(2.41)	(2.38)	(2.90)	(2.79)	(2.77)	(−0.65)	(−0.60)	(−0.61)	(0.32)	(0.51)	(0.54)
Age	0	0	0	0.001	0.001	0.001	−0.050**	−0.050**	−0.050**	−0.041**	−0.041**	−0.041**
	(−0.84)	(−0.82)	(−0.83)	(0.04)	(0.05)	(0.04)	(−2.43)	(−2.44)	(−2.44)	(−2.38)	(−2.42)	(−2.44)
French	−0.002	−0.002	−0.002	0.044	0.026	0.012	−0.024	−0.008	−0.01	−0.061	−0.014	−0.005
	(−0.66)	(−0.80)	(−0.94)	(0.30)	(0.18)	(0.09)	(−0.15)	(−0.05)	(−0.06)	(−0.46)	(−0.11)	(−0.04)
Climber	0.006	0.006	0.005	0.450*	0.453*	0.414	−0.607**	−0.587**	−0.594**	−0.651***	−0.623***	−0.598**
	(1.60)	(1.62)	(1.40)	(1.70)	(1.71)	(1.53)	(−2.25)	(−2.16)	(−2.20)	(−2.82)	(−2.68)	(−2.56)
Time trial specialist	0.015***	0.015***	0.014***	0.974***	0.971***	0.938***	−0.483*	−0.463	−0.469*	−0.603**	−0.575**	−0.553**
	(3.88)	(3.78)	(3.78)	(3.80)	(3.71)	(3.65)	(−1.72)	(−1.65)	(−1.66)	(−2.55)	(−2.39)	(−2.28)
Helper	0.013***	0.012***	0.012***	0.898***	0.894***	0.859***	−0.869***	−0.847***	−0.854***	−0.964***	−0.927***	−0.905***
	(4.19)	(4.30)	(3.94)	(4.27)	(4.23)	(3.96)	(−3.63)	(−3.50)	(−3.55)	(−4.79)	(−4.55)	(−4.42)
Sprinter	0.012***	0.012***	0.012***	0.907***	0.897***	0.870***	−0.603**	−0.583**	−0.588**	−0.619***	−0.582***	−0.565***
	(4.32)	(4.38)	(4.09)	(4.44)	(4.39)	(4.16)	(−2.50)	(−2.39)	(−2.42)	(−2.97)	(−2.77)	(−2.68)
Stage points specialist	0.018***	0.017***	0.017***	1.078***	1.071***	1.054***	−0.033	−0.014	−0.02	−0.274	−0.246	−0.228
	(4.91)	(4.87)	(4.74)	(4.63)	(4.55)	(4.41)	(−0.11)	(−0.05)	(−0.06)	(−1.09)	(−0.99)	(−0.91)
Top20 in previous three TDF	−0.006***	−0.006***	−0.006***	−0.631***	−0.628***	−0.641***	0.360***	0.364***	0.362***	0.304**	0.307**	0.314**
	(−3.24)	(−3.06)	(−3.26)	(−2.87)	(−2.77)	(−2.88)	(2.84)	(2.84)	(2.88)	(2.37)	(2.38)	(2.45)
First-time participant	−0.001	−0.001	−0.001	−0.152	−0.15	−0.143	0.175	0.171	0.172	0.215	0.206	0.205
	(−0.55)	(−0.53)	(−0.49)	(−0.94)	(−0.91)	(−0.88)	(1.01)	(0.98)	(0.98)	(1.43)	(1.37)	(1.36)
Teammates	0.000**	0.000**	0.000**	0	0	0.001	0.001*	0.001*	0.001*	0	0	0
	(2.15)	(2.30)	(2.29)	(1.19)	(1.26)	(1.27)	(1.94)	(1.88)	(1.89)	(0.72)	(0.63)	(0.62)
Constant	8.597***	8.599***	8.601***	0.689	0.79	0.895	7.836***	7.735***	7.748***	6.768***	6.440***	6.386***
	(544.85)	(533.08)	(545.75)	(0.67)	(0.74)	(0.86)	(5.81)	(5.69)	(5.71)	(5.74)	(5.36)	(5.34)
Adjusted R^2	.369	.376	.375	.427	.428	.429	.159	.155	.159	.186	.187	.19
N	170	170	170	170	170	170	196	196	196	195	195	195

Note. Significance level 1% (***), 5% (**), 10% (*). CQ = cycling quotient. The omitted category is the no suspicion category, which consists of Categories 0 and 1. We use robust standard errors. *t* statistics in parentheses.

Including rider-type dummies in our specification allows different types of riders to have different levels of expected performance, but it still forces the effect of the suspicion index (and other variables) to be the same for all categories. We therefore also experimented with separate regressions for each category, thus allowing maximum flexibility. Most of the estimates in these regressions were insignificant however and in general no clear patterns could be observed, which is not surprising, given that for each category only a relatively small number of observations is available.

The Effect of Doping on Performance

So far we showed that the index of suspicion does "affect" performance as long as we do not control for past performance of the riders. We also showed that even in these specifications where we did not control for past performance, variations in doping can only explain a small part of the variation in performance.

Our findings could be interpreted as meaning that the index of suspicion is not a very good indicator of doping. However, such interpretation would rely on the assumption that performance enhancing drugs are indeed effective in enhancing performance. Of course, this underlying assumption might be wrong, and maybe, performance enhancing drugs do not enhance performance much.[14]

To be able to find the performance enhancing effects of doping (in contrast to effect of the index of suspicion), we treat the index of suspicion as a variable that measures doping use with error. To find the effect of doping, we thus need to solve an error-in-variable problem, which can be done by instrumenting our index of suspicion by other (possibly imperfect) measures of the use of doping (see Wooldridge, 2008, pp. 526–527).

There are several possible instruments. First from the "cyclisme-dopage" website,[15] a website that collects information about doping in cycling, we create a dummy that indicates whether a 2010 Tour de France participant has ever been caught using doping.[16] Second, we use the same source to create two team-level variables: one variable that indicates the percentage of team managers[17] of a given team who were ever been caught using doping (as a former rider) and another variable that indicates the percentage of teammates that have been caught using doping. The idea behind these two variables is that an individual is more likely to be using doping in an environment where doping is more common (either because there is a less negative attitude to doping use or because there is an easier access to doping products). Note that recently the Union Cycliste Internationale (UCI) introduced a new rule that bans passed doping convicts of ever managing a team.[18]

Table 4 gives the first-stage result of our IV regressions. Table 5 gives the second-stage results.[19] We present both the results of specifications including and excluding the indicators of past performance as explanatory variables.

From Table 4, one can see that our instruments are only weakly correlated with our doping indicator which means we have to interpret our IV regression results with

Table 4. First-Stage Instrumental Variable (IV) Regression—The Determinants of the Index of Suspicion

	Index of Suspicion (TDF results)	Index of Suspicion (CQ2011)	Index of Suspicion (TDF results)	Index of Suspicion (CQ2011)
Body mass index	−0.226	−0.240*	−0.27	−0.25
	(−1.47)	(−1.69)	(−1.54)	(−1.56)
Age	0.038	0.052	−0.016	0.0018
	(0.73)	(1.14)	(−0.31)	(0.04)
French	−1.731***	−1.607***	−1.65***	−1.59***
	(−4.02)	(−4.14)	(−3.44)	(−3.67)
Climber			−1.75**	−1.82***
			(−2.15)	(−2.66)
Time trial specialist			−1.76**	−1.81***
			(−2.02)	(−2.24)
Helper			−2.08***	−2.08***
			(−2.97)	(−3.31)
Sprinter			−1.83***	−1.85***
			(−2.62)	(−2.89)
Stage points specialist			−1.31	−1.85***
			(−1.56)	(−2.62)
Top 20 in previous			−0.45	−0.43
three TDF			(−1.27)	(−1.49)
First-time participant			−0.55	−0.38
			(−1.22)	(−0.94)
Teammates			0.0013	0.0007
			(0.85)	(0.52)
Percentage of teammates	−0.722	−0.344	−0.51	−0.088
with doping past	(−0.47)	(−0.24)	(−0.31)	(−0.06)
Percentage of managers	−0.065	−0.325	−0.1565	−0.359
with doping past	(−0.06)	(−0.31)	(−0.14)	(−0.35)
Doping past dummy	1.174*	0.956*	0.944	0.84
	(1.9)	(1.78)	(1.55)	(1.57)
Constant	6.746**	6.514**	10.59***	9.75***
	(2.14)	(2.22)	(2.77)	(2.77)
Adjusted R^2	.087	.085	.12	.12
N	170	196	170	196

Note. This is the first-stage regression of an IV regression of doping on a set of explanatory variables including three instruments. Columns 2–3 differ from columns 4–5 in the extent of explanatory variables that are included. Columns 2 and 4 are IV for the Tour de France results, while columns 3 and 5 are for the 2011 cycling quotient (CQ) ranking. The first stage for the 2010 CQ ranking is almost identical as for the 2011 CQ ranking as the observations used for these regressions differ only by one rider. *t* statistics in parentheses. Significance level 1% (***), (5% (**), 10% (*).

care. A rider's own doping past is correlated with his suspicion index score (at the 10% level in the specifications without the past performance variables), but neither is the doping past of the managers or of other team members. The second-stage

Table 5. Instrumental Variables (IV) Results

	TDF Time	TDF Rank	CQ2011	CQ2010	TDF Time	TDF Rank	CQ2011	CQ2010
Index of suspicion	−0.004	−0.234	0.509	0.743*	−0.002	−0.132	0.357	0.715
	(−1.05)	(−0.87)	(1.57)	(1.75)	(−0.78)	(−0.61)	(1.18)	(1.49)
Body mass index	0.003**	0.197**	0.121	0.261	0.001	0.089	0.063	0.263
	(2.26)	(2.31)	(0.98)	(1.5)	(0.96)	(1.18)	(0.53)	(1.31)
Age	0	−0.017	−0.053	−0.059	0	0.001	−0.057**	−0.062
	(−0.87)	(−0.67)	(−1.55)	(−1.25)	(−0.69)	(0.07)	(−2.16)	(−1.53)
French	−0.008	−0.383	0.763	1.207	−0.006	−0.185	0.573	1.17
	(−1.29)	(−0.80)	(1.22)	(1.41)	(−1.02)	(−0.50)	(1.04)	(1.27)
Climber					0.001	0.193	0.063	0.74
					(0.17)	(0.37)	(0.09)	(0.69)
Time trial specialist					0.011	0.715	0.178	0.727
					(1.41)	(1.38)	(0.26)	(0.67)
Helper					0.007	0.599	−0.107	0.549
					(0.9)	(1.05)	(−0.15)	(0.49)
Sprinter					0.008	0.638	0.089	0.728
					(1.02)	(1.19)	(0.13)	(0.68)
Stage points specialist					0.014**	0.891**	0.627	1.025
					(2.19)	(1.98)	(0.87)	(0.94)
Top 20 in previous three TDF					−0.007***	−0.697***	0.501**	0.598**
					(−2.59)	(−2.75)	(2.57)	(2.04)
First-time participant					0	0.078	−0.048	−0.046
					(0.02)	(0.41)	(−0.19)	(−0.13)
Teammates					0.000*	0.001	0.001	0
					(1.84)	(1.14)	(0.83)	(−0.06)
Constant	8.605***	1.235	2.961	−0.341	8.622***	2.027	4.403	−0.88
	(−277.53)	(−0.56)	(−1.01)	(−0.08)	(240.7)	(0.84)	(1.24)	(−0.15)
N	170	170	196	195	170	170	196	195

Note. CQ = cycling quotient. *t* statistics in parentheses. Significance level 1% (***), 5% (**), 10% (*).

regression result shows sizable point estimates of the effect of doping which have the expected sign but also that this point estimate is insignificantly different from zero for all but the CQ2010 index (when no past performance is used). This low level of significance suggests that the low predictive power of the index of suspicion could be related to the fact that doping enhancing techniques are not very effective. Of course, the weakness of our instruments makes it hard to make strong conclusions about this. Still, the latter is consistent with Enserink (2008) who wrote: "By the tough standards of modern medicine, there's little hard evidence for the efficacy of dozens of compounds on the list of the World Anti-Doping Agency (WADA). They are rarely tested in placebo-controlled trials; for most, the evidence is what medical researchers would call 'anecdotal'."

Conclusion

In this article, we investigate to what extent the index of suspicion of doping, which was used by the International Cycling Union to monitor participants of the 2010 Tour de France, correlates with the performance of these participants. Our point estimates show, as long as we do not control for past performance, a medium-sized performance improving effect of not having a low suspicion index on the overall standing and time at the end of the Tour de France, and on the results of some difficult stages, but not on the competition for the sprinters' or the climbers' jersey. We also find a positive effect on the overall performance in year before and after the 2010 Tour de France (the latter insignificant, however). At the same time, even the significant effects we find often have large standard errors and in all cases, the suspicion index can only explain a very small part of the variation in performance, this despite the fact that there is a substantial variation in the degree to which riders are suspected of using doping. Moreover, when adding variables that capture riders' past performance, the doping-related variables lose their significance.

Using an IV approach, we then try to establish whether this lack of predictive power is due to the low effectiveness of performance enhancing drug or because the index of suspicion is not a good indicator of the use of performance enhancing drugs. Using instruments based on (alleged) past doping of the rider, his teammates and managers, we find little evidence that doping actually enhances performance, but the weakness of our instruments means we have to interpret this finding with care.

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Notes

1. Zorzoli (2011) presents a graph showing that after the introduction of the passports, the percentage of suspicious blood samples has decreased substantially.
2. Using the time and ranking rather than the logarithm of time and ranking does not affect our conclusions.
3. The CQ ranking gives points to riders based on their performance in a large number of cycling competitions. The amount of points a rider gets depends both on the difficulty of the specific cycling competition and the place a rider obtained in that competition. We use the ranking of June 27, 2010, and June 26, 2011, which capture the performance of the riders in the 12-month period up to these respective dates. More information about the CQ ranking can be found at http://www.cqranking.com/men/asp/info/whats.asp.
4. They are only "reasonably" exogenous as one could argue that doping could influence weight and the length of a riders' career, the latter being correlated highly with the age of the rider.
5. For the ranking regression, the coefficients of the index of suspicion variables are barely significant however.
6. We also experimented with a nonlinear effect of BMI and age but did not find any support in the data for such specification.
7. If we use only the suspicion index variable/variables as explanatory variable/variables, the adjusted R^2, is very low at 1–2%.
8. We have more observations for the CQ points ranking than for the Tour de France as not all riders finished the Tour de France. Restricting the sample to be the same for the CQ ranking as for the Tour de France time results does not change our conclusions.
9. As an example, Stage 9 has a series of five famous mountains as follows: Côte de Châtillon—2.1 km climb to 3.9%, Col de la Colombière—16.5 km climb to 6.7%, Col des Aravis—7.6 km climb to 5.9%, Col des Saisies—14.4 km climb to 5.1%, Col de la Madeleine—25.5 km climb to 6.2%. The average difficulty score for this stage is $2.1 \times 3.9 + 16.5 \times 6.7 + 7.6 \times 5.9 + 14.4 \times 5.1 + 25.5 \times 6.2 = 395.12$.
10. Given the different nature of the stages, the time between riders varies quite a lot from one race to another and hence coefficients are not really comparable across races. Hence, we focus on *t* statistics. Note also that some easy races ended in sprints of (almost) the whole group of riders and hence have little variation in the dependent variable. The results of these regressions are available upon request from the authors.
11. We also found no effect on the probability of finishing the 2010 Tour de France which is not surprising as most riders that left the race left because of injuries after crashes.
12. The type of the rider in 2010 is based on his revealed performance in previous years is taken from Unwin, Theus, and Hoffman (2006) and can be found at http://www.theusrus.de/Blog-files/TDF2010.txt. This classification comes from a German cycling magazine.

13. An alternative but not testable hypothesis would be that riders are all equally doped which also would lead to the conclusion that doping has no effect on the race outcome.
14. http://www.cyclisme-dopage.com/chiffres/tdf2010.htm.
15. It includes the cyclists who have had a positive doping control, have admitted they used doping or have been sanctioned (by Court, Federation, or Team) in the framework of a doping affair.
16. We get info about team managers of the 2010 Tour de France from the http://www.cyclisme-dopage.com website.
17. http://velonews.competitor.com/2011/06/news/uci-to-ban-doping-violators-from-team-staff-positions_179000.
18. We use both Two-Stage Least Squares - Instrumental Variables (2SLS - IV) and Conditional Mixed Process (CMP) procedure (Roodman, 2007), with both techniques leading to the same conclusions. Using specific dummies rather than the full index of suspicion also leads to similar conclusions.

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Bios

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