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Does the Red Flag Rule Induce Risk Taking in Sprint Finishes? Moral Hazard Crashes in Cycling's Grand Tours

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Abstract

Sprint finishes in professional cycling are fast, furious, and dangerous. A "red flag rule" (RFR) seeks to moderate the chaos of these finishes, but may induce moral hazard by removing the time penalty associated with crashing. To test for moral hazard, the authors use a 2005 rule change that moved the red flag from 1 km to 3 km from the finish. Data from Europe's Grand Tours indicate that, after the rule change, both the incidence and the size of crashes nearly doubled in the 1–3 km from the finish zone. There was no such increase in crashing rates in the 3–5 km zone.

Keywords

moral hazard, cycling, risk, Tour de France

Introduction

Sprint finishes in professional cycling are fast, often reaching speeds over 40 miles per hr. When a peloton of over 100 riders arrives intact for these finishes, the

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intricacies of team tactics, the quickly escalating pace, and the sheer mass of riders make cycling sprints among the most intense in the sports world. From a historical perspective—or from any other for that matter—no display of human powered speed and action can match these sprints. Of course, for these same reasons, these intense sprint finishes can also be frenetic, chaotic, and dangerous.

The *Union Cycliste Internationale* (UCI), the governing body for the sport of professional cycling, has instituted various rules to moderate the chaos of sprint finishes. One such rule—the "red flag rule" (RFR)—eliminates the risk of losing time to competitors due to crashing near the finish of a stage race in which cumulative time over multiple stages matters. We argue that this rule may unintentionally increase the risk of crashing by inducing moral hazard among sprinting cyclists. To test for the impact of the RFR, we take advantage of a 2005 rule change that changed the coverage of the RFR from 1 km to the finish to 3 km to the finish. We use crash data from the final 5 km of Europe's 'Grand Tours' (Tour de France, Giro d'Italia, and Vuelta a España) for several years before and after this change to test whether this rule induces moral hazard and increases the risk of crashing. The sport of cycling has sparked analyses into the economics of doping (Berentsen, 2002; Maennig, 2002), sprint strategy (Dilger & Geyer, 2009), and success determinants in the Grand Tours (Torgler, 2007), but our focus on induced moral hazard is novel.

The economics of moral hazard has been well developed in the realm of insurance markets in which people take greater risks once they insured against potential losses (e.g., Pauly, 1968; Shavell, 1979), but has relevance and provides insights to a wide array of other contexts (e.g., Atkeson, 1991; Bergemann & Hege, 1998; Hellmann, Murdock, & Stiglitz, 2000; Peltzman, 1975). In sports, rules often change the costs and benefits of risky strategies in ways that introduce the possibility of moral hazard. In Major League Baseball, recent analysis suggests that designated batter and relief pitcher rules induce moral hazard by reducing a pitcher's exposure to retaliation if he hits a batter with a pitch (Baldini, Gillis, & Ryan, 2010; Bradbury & Drinen, 2006).

Similarly, recent rule changes in various international soccer leagues and in the National Hockey League altered the costs and benefits of taking risks to try to score goals with moral hazard and other unintended effects. In the 1990s, soccer tournaments such as the European Cup and World Cup increased from 2 to 3 the number of points in the league standings earned by the winner of a match. Losers continue to earn 0 points, and each team earns 1 point if the match ends in a draw. By raising the marginal value of a win, the rule aims to encourage goal-scoring strategies thereby improving the appeal of the game to fans (Brocas & Carrillo, 2004). However, Haugen (2008) shows that, although the rule encourages offensive play, it also reduces competitive balance by increasing the differences between teams in the league standings. In the National Hockey League, a 2004 change gives teams that lose or tie during overtime of a regular season game one point in the standings. Abrevaya (2004) argues that this rule change would cause teams to play more conservatively during regulation time so as to get to overtime when losses are less costly (see also

Longley & Sankaran, 2007). Even though overtime may be more exciting for fans, regulation time may be more mundane.

In this article, we describe the details of the RFR and the apparent motivation behind the 2005 expansion in the coverage of this rule. We then discuss risk taking in the sprint finishes in order to set the context for our empirical analysis. This is particularly important, given the complexity and heterogeneity in sprint strategies across individual cyclists and teams. We describe our data and analysis in the subsequent section. Not only do we find no evidence that the change reduced crashes inside 3 km, we also find that the change may have *increased* crashes—a result that is consistent with a moral hazard response of riders taking greater risks when protected by the red flag. We conclude with thoughts about how alternatives to the RFR would potentially alter sprint strategies and eliminate the RFR moral hazard.

The Red Flag Rule

Race organizers like to set the stage for exciting, fan-friendly sprint finishes by mapping out interesting stretches leading up to the finish and by offering time bonuses based on finishing placement. As a counterweight, the UCI, the governing body for the sport of professional cycling, has instituted various rules to moderate the chaos of sprint finishes during stage races, which are conducted over a series of days. In a stage race, riders begin together each day and ride a stage of about 100 miles. The first rider to finish a particular stage receives some accolades, but the overall winner of the race is the rider with the lowest cumulative time across all days. On many days, most or all of the riders in the race arrive at the end of a stage in a single pack or *peloton*. On such days, some riders may vie for the stage win, whereas others merely try to preserve their cumulative time. The riders in the former group are the sprinters; the riders in the latter group are known collectively as the general classification (GC) riders.

Two specific UCI rules leverage the importance of cumulative time in these stage races in an attempt to reduce the chaos and crashing in the final kilometers. The first rule dictates that riders finishing as a pack on a particular day earn the same time as the first rider in the pack to cross the line—as long as no more than a bike length separates any of the riders. This rule eliminates any time incentive for riders to vie for position within the pack. The rule does not, however, reduce the average speed of the finishing sprint since all riders have a time incentive to stay within roughly one bike length of the rider in front of them. Sprinters set the most intense pace in the final 100 m or so, but all the other riders are obliged by this rule to stay close behind.

The UCI's second rule that attempts to bring some order to sprint finishes involves the treatment of accidents and mishaps in the final kilometers. After riders pass beyond a marker, historically a red flag placed to indicate the final kilometer of a stage, crashes do not affect their cumulative time. Thus, if a major crash occurs between the red flag and the finish, all riders involved in the crash receive the same time as the group they were in when the crash occurred. While this RFR) applies equally to all riders, it particularly protects GC riders—for whom cumulative time matters most—from chaotic sprint finishes. In this article, we argue that this rule may have unintended consequences. Specifically, the RFR reduces the impact of crashes by removing time penalties associated with crashing. In this sense, the RFR functions as an insurance policy against crashing: once inside the red flag, a rider's stage time is insured against any crashes. Obviously, this is an incomplete policy that fails to insure against pain and injury, but on the margin it is nonetheless a form of insurance. And like most forms of insurance, it introduces a clear moral hazard. Riders may respond by taking greater risks once the red flag protects them against time losses due to crashing. This argument is consistent with evidence that automobile safety regulations (seat belts, energy absorbing steering columns, head restraints, padded dashboards, etc.) induce offsetting increases in driving intensity that reduce their net effect on driving safety (Crandall & Graham, 1984; Peltzman, 1975).

In 2005, the UCI extended the distance from the finish in which the RFR applies from 1 km to 3 km.[1] The red flag remains the marker for the final kilometer and a 3-km banner marks the point where the rule begins to apply, but for simplicity we refer to the rule uniformly as the "red flag rule." The UCI did not issue a press release to justify moving the RFR to the 3 km mark, but the general consensus is that the rule change was prompted by specific concerns from GC riders. In the years prior to 2005, several crashes near the 1 km mark stoked these concerns. For example, one major crash occurred 10 m inside the 1 km red flag in the 2004 Tour de France prompted a top placed rider, Tyler Hamilton, to have a serious discussion with the director of the Tour about future sprint finishes. Hamilton reported that they discussed the option of taking stage time at the 3 km to go mark so the sprint teams and sprinters could then vie for the stage win and placement without GC riders and teams in the mix. The director reportedly indicated that the UCI was considering a rule change that would affect the final 3 km,[2] presumably the RFR change that ultimately occurred January 2005. Although on paper this change seems quite similar to Hamilton's suggestion, we argue that the seemingly subtle difference lead to dramatically different rational responses on the part of riders.

Risk Taking in Sprint Finishes

Several features of stage race finishes shape team and individual tactics in ways that affect how aggressively riders choose to ride during the final kilometers of each stage. In this section, we discuss these considerations in detail. We present a simple contagion model to show how small changes in risk taking can dramatically affect crashes. We then discuss how differences in individual and team objectives shape the dynamics of risk taking in the final kilometers of a stage finish.

The probability that a crash occurs in the final stretch of a stage depends on many factors. Although many of these crash factors relate to weather conditions, road surface, and course routing, how cyclists respond to these conditions by adjusting speed and negotiating turns largely determines the crash probability. We express this probability using the function:

$$p = \Pr\,(\text{crash}) = f(\mathbf{x}, \theta), \tag{1}$$

where $\mathbf{x}$ is a vector of crash factors and θ captures the rider's risk taking. While random factors—such as puncturing a tire at full sprint speed or hitting a painted line on a wet road surface in the middle of a fast turn—also play a role, the impact of these factors is clearly shaped by θ.

Cyclists have little control over $\mathbf{x}$, but choose how much risk (θ) to take in the final kilometers based on the expected benefits and costs of risk taking. As in many sports, intense competition forces top cyclists to carefully weigh these costs and benefits at the same time they respond to race and road conditions. Often, it is precisely this calculus of risk taking and envelope pushing by elite athletes that intrigues us as spectators today just as it did the Roman crowds packed around the Circus Maximus to watch chariot races. To illustrate how this plays out in sprint finishes, consider the commentary of two elite riders after stage 11 of the 2003 Giro d'Italia, which ended in a crash after a tight turn on wet roads. Robbie McEwen, who won the stage, smugly said, "That kind of turn in the rain is kind of my specialty. I made my move before final turn … then I just went full gas." Those caught in the crash were less pleased, as Alessandro Petacchi complained, "[organizers] want to have spectacular finishes, but they can't put a corner 150m from the end … otherwise we'll crash all the time!"

The expected benefits of risk taking in the final kilometers include competitive rewards such as winning the stage, gaining time over competitors, and earning time bonuses for high placement.[3] Allowing for different individual objectives and team dynamics adds greater nuance to these expected benefits. The expected costs of risk taking include some equally obvious penalties. First, crashing hurts. It can also result in injuries that can end a rider's race or even, in extreme cases, his career. Despite the drama and potential trauma of bike crashes, however, most cyclists who crash continue the race.

In a stage race, where cumulative time over multiple days determines a rider's overall placement, crashing imposes an additional penalty in the form of time lost to competitors. The RFR removes this penalty and thereby reduces the expected cost of risk taking. If this time loss really does impose an additional cost on crashing, the cyclist should choose to take greater risks after passing under the red flag. In the case of an individual cyclist, this increase in θ may be so small that the impact on the probability of crashing (p) is trivial, but when we surround this cyclist with other cyclists small increases in θ can have a substantial aggregate effect on crashing in the peloton.

In a frantic peloton that is gearing up for a sprint finish, crashes are contagious in much the same way that diseases or nuclear fission involve chain reactions. If a rider goes down, he will likely bring nearby riders down with him—and those riders may bring others down with them. To demonstrate, suppose that a crashing rider causes two other riders to crash with probability q and no additional riders to crash with probability $1 - q$. We specify this contagion probability also as a function of rider risk taking (θ) and exogenous factors ($\mathbf{z}$), that is,

$$q = g(\mathbf{z}, \theta). \tag{2}$$

If the peloton were of infinite size then, conditional on a crash occurring, the expected number of riders crashing would be

$$E[\#\text{riders crashing}|\text{ crash occurs}] = 1 + q(2 + q(4 + q(8 + \ldots))) = \frac{1}{1 - 2q}, \tag{3}$$

which implies that the expected number of riders crashing in a sprint finish would be

$$E[\#\text{riders crashing}] = p[1 + q(2 + q(4 + q(8 + \ldots)))] = \frac{p}{1 - 2q}. \tag{4}$$

These expressions show how changes in p or q can inflate the number of riders crashing. Specifically, nonlinearity of Equation 4 with respect to q implies that small changes in p or q can dramatically affect the number of riders crashing when q is large.

Of course, in practice, the number of riders crashing cannot exceed the size of the peloton. Equations 3 and 4 become more complicated in a finite peloton, but it remains true that contagion affects crash size nonlinearly. To elucidate these effects, we simulate crashes from this model for a peloton of 150 riders using $p = \theta$ and $q = 4\theta$. Figure 1 shows the simulated average number of riders crashing as a function of risk taking (θ).The graph shows a sharp rise in average crash size once θ increases beyond 0.12, which corresponds to $q > 0.5$. Thus, for low values of q, marginal increases in risk taking will not affect crash size much. However, for moderately large values of q, small increases in risk taking dramatically affect crash size. For example, increasing θ from 0.15 to 0.16 raises the average crash size from 53 to 69 riders, whereas an increase from 0.05 to 0.06 raises the average crash size from 1.7 to 1.9 riders. To show the role of contagion, we plot this expectation separately for a case that fixes $p = 0.1$ and a case that fixes $q = 0.4$. These curves show that the nonlinearity emanates from the contagion component of the model (q); without an effect of risk taking on contagion, crash size remains relatively constant.

This crash contagion is an ex post phenomenon: conditional on one rider crashing, it dictates the likely domino effect on other riders. There are also potentially important *ex ante* effects of induced risk taking by a few riders. Specifically, a handful of riders choosing to take greater risks can prompt other riders to take greater risks. Crashes can be contagious, but so can risk taking. Positional externalities offer one simple explanation for this risk taking contagion (Frank, 1991, 1997, 2005; Schelling, 1978). Competition implies that relative position matters, which

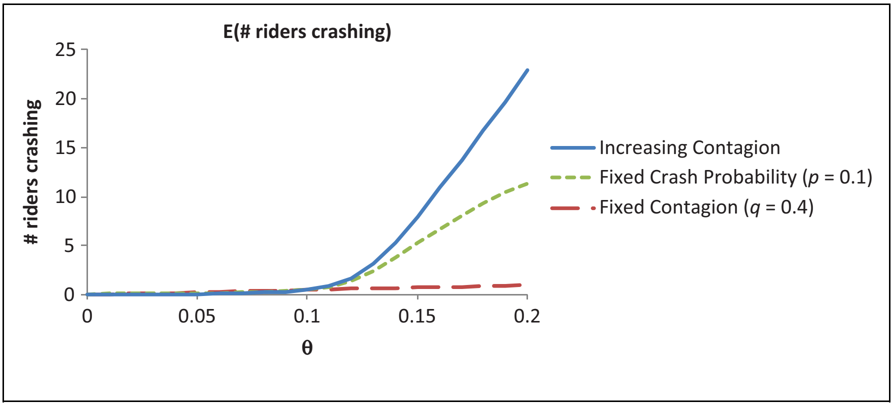

Figure 1. Expected number of riders crashing (y-axis) as a function of risk taking (θ; x-axis) as simulated from the contagion model in the text and assuming a peloton of 150 riders. We set $p = \theta$ and $q = 4\theta$ to generate the "increasing contagion" curves. For the "fixed contagion" curve, we set $q = 0.4$ and $p = \theta$, and for the fixed crash probability curve, we set $p = .1$ and $q = 4\theta$.

often forces other riders to respond to greater risk taking by taking more risks themselves. When gearing up for a sprint, relative position matters for most members of a peloton *not* because they are looking to win the sprint but rather because they are hoping to stay near the front in order to avoid the crash contagion, as crashes propagate laterally and backward through a peloton. Thus, increased risk taking by a few riders may actually spark a wave of greater risk taking, sometimes motivated (ironically) by a form of risk *aversion*—attempting to stay near the front of the peloton to stay in contention and out of trouble, a dynamic explored below.

The dynamics of sprint finishes are in reality more nuanced than this abstraction suggests. Individual cyclists can have very different objectives in a stage race. Some cyclists have incredible sprint speed, but cannot compete with GC riders in time trials and on mountain climbs. These sprinters aim to win stages on days without major climbs. On such days, the dynamics of drafting mean that the peloton often arrives intact at the end of the stage. Sprinters try to position themselves near the front of a race in the final kilometers, typically just behind a teammate or two who can set them up for the sprint finish. In a standard stage race, there may be several specialized sprinters, each surrounded by a team of several riders, jostling aggressively for position in the closing kilometers as the pace steadily quickens. Although the objectives of GC contenders and their teams are different, they are certainly not left out of this frenzy. These GC teams may not lead out the sprint in the final kilometer, but they have compelling incentives to ride near the front of the peloton to reduce the risk of contagious crashes and the possibility of their competitors opening up time gaps at the finish. With sprinters, GC contenders and their respective teams all vying for position near the front of the pack, even marginally greater risk taking by one rider can impose significant externalities on the rest of the peloton because of high speeds and contagious risk taking and crashing.

Data and Analysis

In this section, we use the change in the placement of the red flag in 2005 to test whether the red flag induces greater risk taking. In this exercise, we face one primary empirical challenge: risk taking (θ) is not directly observable. We can observe crashes, how many riders are involved, and where the crash occurs. We use these observable outcomes as an indication of changes in risk taking associated with the placement of the red flag.

We collected data from live stage reports archived at www.cyclingnews.com for the three grand tours, Tour de France, Giro d'Italia, and Vuelta a Espana. Each year these tours include 20–21 stages, of which 15 or so are subject to the RFR (the rule is not in effect for prologues, individual and team trial stages, and summit finishes). We compiled data for the final 5 km of these tours for 12 years (1999-2010). Crashes create great fanfare, especially in the final kilometers, so these are always included in live stage reports. When a crash occurs, the report generally indicates both the approximate location of the crash relative to the finish and the size of the crash, sometimes with the names of the riders who went down.

Although the occurrence of a crash is always noted and the location is generally fairly precise, the size of the crash is reported precisely for small crashes but less so for large crashes—which are sometimes described simply as "huge" or "massive." In recognition of this measurement error, our analysis also uses a typology of crashes that matches the level of accuracy in the stage reports by categorizing crashes by the number of riders implicated: 0, 1, 2 to 5, 6, or more. In addition to these crash data, we use stage results to construct measures of finishing group size, where a finishing group is considered distinct if there is more than a 10 s interval between consecutively placed riders. Finishing group size is helpful in understanding the potential for contagion effects of crashes and the potential for crashes to occur.

Figure 2 graphically depicts the location and sizes of crashes in the three tours combined for each year in our data. The location of the red flag is indicated by the dark horizontal line that shifts to 3 km in 2005. The left panel depicts each crash with a dot and reveals the increased frequency of crashes after the change in the RFR. The right panel adds crash size using larger bubbles for crashes with a greater number of riders. Not only has there been a greater frequency of crashes since the change in the RFR, but the size of those crashes may have also increased.

To test statistically whether the RFR actually increases crashes by inducing a moral hazard response by cyclists, we first turn to simple unconditional tests of mean crash rates. Later, we estimate models that allow us to control for other crash factors. Table 1 shows that 4% of red flag stages ended in a crash in the years before the rule change. This nearly doubled to 7% after the red flag moved. When we look only at

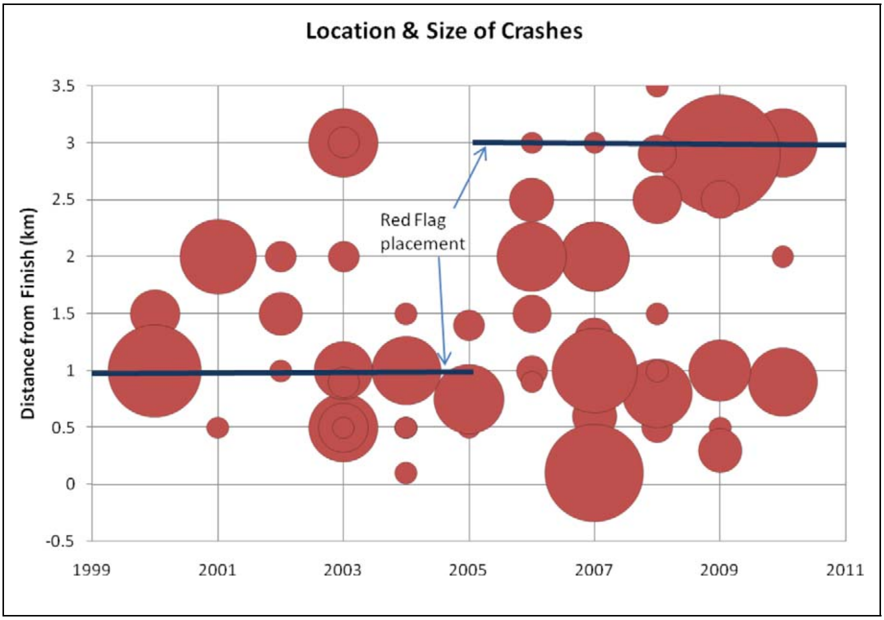

Figure 2. Location and size of crashes in the final 3.5 km by year. The size of crashes (approximate number of riders) is indicated by bubble size.

red flag stages that ended with a sprint that was contested by the peloton (i.e., when we exclude red flag stages in which a small breakaway group of riders finished before the chasing peloton), the probability of a crash is greater but this same pattern is evident. As a test that the RFR induced greater risk taking through moral hazard, these two increases in crash probabilities have one-sided *p* values of .11 and .08, respectively. The average number of riders crashing per stage more than doubled after the RFR change, increasing from 0.19 to 0.45, or an average of one rider crashing every five stages to one rider crashing every two stages. When we isolate contested finishes, we see an increase from 0.25 to 0.61. These increases have one-sided *p* values of .08 and .07, respectively.

In Table 2, we present results from three different models, each of which shows a significant positive effect of the RFR change on crashes. We predict three outcome variables: (a) a $\{0,1\}$ crash indicator variable, (b) a tobit model for the number of riders crashing, and (c) and an ordered probit model for four categories of crashes (defined by 0, 1, 2–5, and 6+ riders crashing). We estimate this final ordered probit on crash type to address measurement error, which is particularly relevant for massive crashes. We estimate each of these models using two samples. First, we use all stages for which the red flag was in effect. Second, we use only those stages for which there was a contended bunch sprint. Restricting the sample in this way reduces the sample size from 454 to 342, but increases the precision of the results because

Table 1. Mean Crash Probability and Number of Riders Crashing Between 1 and 3 km to the Finish Before and After the RFR Change

	All Red Flag Stages			'Contended' Red Flag Stages		
	Before	After	*p* Value[a]	Before	After	*p* Value[a]
Crash {0,1}	0.04	0.07	.11	0.06	0.10	.08
Riders Crashing	0.19	0.45	.08	0.25	0.61	.07
Number of stages	227	227		176	166	

[a] *p* value is for one-tailed *t* test (assuming equal variances) that crashing increased after the red flag rule covered this zone.

Table 2. Estimation Results for Crashes Occurring Between 1 and 3 km to the Finish With Two-Tailed *p* Values in Parentheses

	Probit on Crash {0,1}[a]		Tobit on # Riders Crashing		Ordered Probit on Crash Type[b]	
Stages Included:	Red Flag	Contended RF	Red Flag	Contended RF	Red Flag	Contended RF
Red flag at 3 km {0,1}	0.25* (0.22)	0.29* (0.16)	3.38* (0.19)	3.84* (0.15)	0.26* (0.19)	0.31* (0.13)
Finishing group size	0.0030 (0.066)	0.0010 (0.56)	0.038 (0.054)	0.014 (0.46)	0.0030 (0.044)	0.0011 (0.51)
Stage Day	−0.037 (0.057)	−0.037 (0.053)	−0.51 (0.067)	−0.51 (0.054)	−0.042 (0.033)	−0.043 (0.022)
Tour de France {0,1}	0.016 (0.95)	0.043 (0.86)	0.36 (0.89)	0.77 (0.78)	0.034 (0.88)	0.067 (0.77)
Vuelta d'Espana {0,1}	0.037 (0.88)	0.052 (0.84)	1.82 (0.57)	2.13 (0.51)	0.10 (0.68)	0.13 (0.62)
Constant	−1.65	−1.39	−20.7	−17.4		
Cut 1					1.64	1.40
Cut 2					1.76	1.51
Cut 3					2.28	2.05
Pseudo R^2	0.07	0.04	0.04	0.05	0.07	0.04
N	454	342	454	342	454	342

Note. [a] Marginal effects for the red flag coefficient are 2% and 4%, respectively. [b] Marginal effects for the red flag coefficient are {−3% for no crash, 0.4% for 1 rider, 2% for 2–5 riders, and 1% for 6+ riders} and {−4% for no crash, 0.7% for 1 rider, 2% for 2–5 riders, and 1% for 6+ riders}, respectively. * Indicates statistical significance at the 10% level on the one-tailed test that the red flag rule increased crashes.

crashes rarely occur in finishes without a bunch sprint. Based on these results, we reject the null hypothesis of no RFR effect in favor of the one-tailed alternative that the RFR increases crashes at the 10% level. Moreover, this effect seems important: the tobit results suggest that the RFR is associated with three or four more riders crashing per stage in the 1–3 km interval. Aside from this primary result, these results also suggest that crashes are more likely in the high energy, early days of stage races.

A counter to our results is that crash frequency and crash size would have increased even without the RFR change. One alternative explanation for an increasing trend in crashes is that finishing routes are more dangerous, though there is no quantitative way to explore this. There seems to be little evidence from rider responses to stages that this is the case, with the notable exception of the 2009 Giro d'Italia where riders protested a dangerous finishing circuit in Milan. Alternatively, it is possible that sprints have become more congested leading to more crashes. Increased congestion could occur if stages are getting shorter so that more riders arrive at the finish line with more energy and are therefore able to go faster into the finish. However, the historic data on the Tour de France indicate that stages have remained rather consistent in length over the past 15 years, which would cast doubt on this suggestion. Other reasons for more congestion at the finish may be that, with better training and better technology, it less likely that small groups will break away before the sprint finish. While the average finishing group size was in fact slightly higher after the rule change, this increase is not statistically significant.[4] Furthermore, we control for finishing group size in the regressions in Table 2. In short, the red flag result is almost certainly not an artifact of more congested sprint finishes.

To test for changes in crash frequency and crash size outside the 1–3 km zone, we reestimated the models in Table 2 looking only at crashes within 1 and 3 and between 5 and 3 km from the finish. Estimating the model with these subsamples of our data enables us to test whether the apparent impact of the RFR change on crashes in the 1–3 km zone is due to a general increase in crashes in the final kilometers of stage finishes. To frame these results, keep in mind that the RFR was in effect throughout the sample in the 0–1 km interval, but was never in effect in the 3–5 km interval. We note that estimates for the 0–1 km interval provide a test of either a general increase in crash rates that is unrelated to the RFR or a spillover effect of the RFR change putting the 1–3 km zone under red flag protection (e.g., if the change has indeed encouraged riders to increase risk taking and speed further from the finish, this implies that they carry greater speeds into the last kilometer, which may increase the risk of a crash in this zone) or both. Table 3 shows that the crash rate did not change after the rule change in either the 0–1 or 3–5 km to the finish zones. Crashes did increase across all three models in the 0–3 km zone, although the point estimates for this zone are lower than for the 1–3 km zone shown in Table 2. This result adds credence to our moral hazard theory. If crashes had been increasing for reasons unrelated to the RFR, then we would have expected to see more crashes at all intervals.

Conclusion

In many settings, the concept of moral hazard provides useful insights into how individuals make decisions under risk—particularly in the face of interventions to

Table 3. Estimation Results for Crashes Occurring in 0–1, 0–3, and 3–5 km to Finish Intervals for Contended Red Flag Stages With Two-Tailed p Values in Parentheses

	Probit on Crash {0,1}			Tobit on # Riders Crashing			Ordered Probit on Crash Type		
Interval:	0–1 km	0–3 km	3–5 km	0–1 km	0–3 km	3–5 km	0–1 km	0–3 km	3–5 km
Red flag at 3km {0,1}	0.16	0.22*	0.064	1.67	2.37*	−0.10	0.16	0.23*	0.0067
	(0.44)	(0.15)	(0.84)	(0.43)	(0.13)	(0.96)	(0.43)	(0.13)	(0.98)
Finishing group size	0.0065	0.0079	−0.0029	0.072	0.081	−0.027	0.0066	0.0078	−0.0036
	(0.0015)	(<0.001)	(0.27)	(<0.001)	(<0.001)	(0.26)	(<0.001)	(<0.001)	(0.15)
Stage Day	−0.0094	−0.018	−0.071	−0.11	−0.21	−0.54	−0.013	−0.022	−0.072
	(0.60)	(0.18)	(0.046)	(0.51)	(0.11)	(0.058)	(0.41)	(0.085)	(0.018)
Tour de France {0,1}	−0.55	−0.30	−0.32	−5.11	−2.71	−1.91	−0.43	−0.22	−0.26
	(0.029)	(0.10)	(0.40)	(0.063)	(0.13)	(0.49)	(0.079)	(0.18)	(0.49)
Vuelta d’Espana {0,1}	−0.42	−0.27	−0.23	−4.16	−1.78	−1.89	−0.36	−0.19	−0.23
	(0.087)	(0.14)	(0.56)	(0.12)	(0.34)	(0.50)	(0.13)	(0.30)	(0.52)
Constant	−1.76	−1.76	−1.04	−19.5	−18.4	−7.46			
Cut 1							1.79	1.77	0.96
Cut 2							2.10	2.01	1.17
Cut 3							2.35	2.45	1.80
Pseudo R^2	0.10	0.04	0.09	0.06	0.03	0.06	0.08	0.04	0.08
N	347	738	324	347	738	324	347	738	324

*Indicates statistical significance at the 10% level on the one-tailed test that the red flag rule increased crashes.

reduce their exposure to risk. Although insurance provides the classic setting for understanding and exploring moral hazard, its influence as a ubiquitous feature of human behavior is apparent in a much wider range of contexts. This influence is often more nuanced when risk exposure is not mediated by explicit insurance contracts, but it is no less important. To have their intended effect (typically, improved safety), interventions that implicitly reduce risk exposure should be informed by potential moral hazard implications. We argue that such an unintended moral hazard effect is evident in sprint finishes in cycling's major stage races.

After a particularly nasty crash 400 m from the finish of stage one of the 2003 Tour de France, Levi Leipheimer, a top American cyclist, stated that "[b]icycle racing is getting faster and faster, and the Tour is becoming bigger and bigger, and riders are taking more risks."[5] Our results suggest that riders have continued to take greater risks in sprint finishes since then—partly as an unintended consequence of a rule that aims to reduce the chaos of these finishes. This RFR has historically applied to the final 1 km of stages. In 2005, the UCI modified the rule to apply to the final 3 km. We use this rule change to test whether removing time penalties associated with crashing induces a moral hazard response among riders that increases crashes in sprint finishes. The complex dynamics of a sprinting peloton imply that only a few riders need to ride more aggressively when protected by the RFR in order to catalyze greater risk taking across much of the peloton.

Data from 1999 to 2010 from Europe's Grand Tours indicate that both the incidence and the size of crashes have nearly doubled in the 1–3 km interval since that zone came under RFR protection in 2005. While some of this increase may be attributable to larger finishing pelotons, our econometric analysis attributes much of it to the RFR. As a comparison, there was no such increase after 2005 in crashing rates in the 3–5 km interval. These results are consistent with induced moral hazard and suggest that the RFR may protect GC riders (for whom cumulative time matters most) at the expense of more crashing among the peloton more broadly. Any equally compelling explanation for this result, which we find unlikely, would have to involve a change in 2005 that affected the interval of 1–3 km to the finish without changing crash rates in the 3–5 km interval. While Leipheimer may indeed be right that the grand tours were getting faster and bigger and that riders were taking greater risks even before the RFR change, our analysis suggests that the change has since induced greater risk taking inside 3 km compared to outside 3 km to the finish.

Can we extrapolate from our analysis and speculate that removing the RFR altogether might reduce crashes in sprint finishes? This is a complicated question because other offsetting responses might moderate any such effect. In particular, removing the rule would make it all the more important for GC riders and their teams to avoid crashing in the final kilometers. This may lead these teams to ride even more aggressively in an escalating positional "arms race" at the front of the peloton. It is also possible, however, that removing the rule might open new strategies. For example, without red flag protection, perhaps, GC teams would choose to stay a safe distance off the back of the peloton for the final kilometers. They could then close the gap to a bike length or less just before the finish line in order to receive the same time as the main pack. With such a strategy, GC riders might risk losing a few seconds on competitors—but requiring these teams to navigate these risks and returns might actually make dramatic sprint finishes even more intriguing.

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Notes

1. Specifically, UCI rule 2.6.027 currently states: "In the case of a duly noted fall, puncture or mechanical incident in the last 3 km of a road race stage, the rider or riders involved shall be credited with the time of the rider or riders in whose company they were riding at the moment of the accident. His or their placing shall be determined by the order in which he or they actually cross the finishing line. If, as the result of a duly noted fall in the last 3 km, a rider cannot cross the finishing line, he shall be placed last in the stage and credited with the time of the rider or riders in whose company he was riding at the time of the accident."
2. For the Hamilton's brief description of this exchange, see http://www.legendinc.com/Pages/MarbleheadNet/MM/Articles/TylersTourdeFrance04.html.
3. In contrast to the UCI rules that pertain to all professional races, whether and how to allocate time bonuses for stage placement is at the discretion of the organizers for each race. In 2008 and 2009, the Tour de France no longer granted time bonuses. The Giro and Vuelta both continued to offer time bonuses.
4. For all red flag stages, the average finishing group size before and after the rule change was 70 and 75, respectively (p value .47). For contested finishes, the average group size was 87 and 96, respectively (p value .22).
5. *San Francisco Chronicle*, July 9, 2003.

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