THE TRADEOFF BETWEEN PERFORMANCE AND QUITTING IN HIGH POWER TOURNAMENTS

Chaim Fershtman
Tel Aviv Univeristy

Uri Gneezy
University of California, San Diego

Abstract
Tournaments may be characterized by the performance they induce as well as by the rate of quitting and dropouts of participants. Although most of the attention in the literature is on the performance induced by high power incentives, there are many daily situations in which dropouts and quitting are a major concern. Using a field experiment in schools and a model of dynamic tournament we examine the effect of different levels of rewards on the rate of quitting. Our experiment indicates that there is a possible tradeoff between performance and quitting. Strong incentives tournaments induced participants to exert more effort and exhibit a better performance but, at the same time, it induces a higher rate of quitting. We present a multi-stage tournament model that gives rise to a similar characterization. (JEL: C93, C73, D8, J30)

1. Introduction

Tournaments are games in which players' payoffs depend on the ranking of their performance. Extensive literature on tournaments has emerged since the seminal paper of Lazear and Rosen (1981). The main focus of the literature has been on static tournaments in which players choose effort levels that, together with their abilities, stochastically determine their relative performance.[1] However, many real-life tournaments display a dynamic structure in which the tournament is played over time and with effort decisions made at each period after players have observed (at least partially) their relative position in the race. In such dynamic tournaments, players also have the option to quit in the middle of the tournaments if, after observing their relative performance, they become discouraged and choose not to exert any further effort.

A useful and interesting example is the growing debate about the introduction of high-power incentives in schools. The main motivation is to improve performance and elicit more effort from students and teachers. Some of these high-power incentive schemes are based on the introduction of tournaments among students. Students wish

This paper was edited by Patrick Bolton.

We thank Sagit Bar-Gill, Efrat Barkai, Itay Feinmesser, Hanoch Frankovitz, and Tali Ziv for helpful research assistance and two anonymous referees and the Editor of this journal for useful comments and suggestions. Fershtman is a member of the CEPR.

E-mail: fersht@post.tau.ac.il (Fershtman); ugneezy@ucsd.edu (Gneezy)

1. See for example Green and Stokey 1983; Nalebuff and Stiglitz 1983; O'Keeffe, Viscusi, and Zeckhauser 1984; Rosen 1986; Bull, Schotter, and Weigelt 1987; Moldovanu and Sela 2001; Che and Gale 2003.

Journal of the European Economic Association April 2011 9(2):318–336
 DOI: 10.1111/j.1542-4774.2010.01012.x

to acquire education and knowledge, but they also compete with one another on relative success and grades. The question we raise in this paper is whether any performance improvement resulting from the introduction of high-power incentives would come at the cost of increased quitting. Quitting can take the form of dropping out of school or a sharp decline in effort.

In some tournaments, such as an R&D race, one is interested mainly in the upper tail of the distribution—those who win the tournament and complete the innovation. However, in other tournaments, such as manufacturing or education, the planner may be interested also in the lower tail of the distribution and, in particular, in possible quitting behavior. Although some incentive programs take this dropout risk into account (see for example Angrist and Lavy 2009) and implement special programs for the weak students, other programs ignore it and hence, as we shall claim, may have undesirable results (see the discussion in Cornwell, Hee Lee, and Mustard 2003).

Quitting is a strategic decision, and as such it may be affected by incentive schemes provided to participants. Intuition suggests that higher rewards may reduce the likelihood of quitting. Yet our analysis indicates that the relationship between incentives and quitting is more complex. The question we focus on is whether incentives that elicit greater effort may also induce more quitting.

We distinguish between two types of quitting, *nonparticipating* and *quitting in the middle*. At the outset of a tournament, players consider the task to be performed, their incentives, and their opponents' abilities. At that point, players can decide not to participate in the tournament at all. But even when they choose to participate, they may later decide to quit in the middle of the tournament in response to new information or to self-assessments of their relative success.

Quitting can be a rational decision, particularly when players face unfavorable conditions that imply the odds of winning are small (see Lippman and McCardle 1987). But quitting often leads to being socially stigmatized. We admire people who do not quit "against all odds". One of the all-time best-selling children's books is *The Little Engine That Could,* which champions the virtue of persistence and not quitting. Another example is the popular saying: "A quitter never wins and a winner never quits." Thus, in many real-life scenarios, quitting will typically incur social or psychological costs that players prefer to avoid.[2]

The social cost of quitting affects players' behavior in tournaments. Even if a player realizes, in the middle of a tournament, that his chance of winning is negligible, he may continue the race simply to avoid the cost of quitting. The quitting decision balances the effort cost of continuing the race with the social cost of quitting. If the cost of completing the race is sufficiently high, then a player will prefer to quit even at the cost of being labeled a "quitter".

In this paper we use a field experiment and a formal tournament model to examine the relationship between incentives and quitting. In both settings we manipulated the

2. The social stigma may vary from one society or culture and another. Even within a particular society, individuals may assign varying levels of importance to such stigmatization.

incentives and then examined the effect of different incentives on players' choice to quit the tournament.

The participants in our study were 10th-grade high school students who were asked to run a 60-meter race during their physical education class. Participants ran twice, with the teacher measuring their speed. The first run was individual and involved no competition or rewards. In the second run, participants were matched in pairs and ran side by side. We varied three parameters of the second race. The first was the matching scheme: participants were matched either at random or according to ability (based on their times in the first run). The second parameter was the level of incentives: none, low, or high. Finally, in some treatments we let the participants run side by side (hereinafter the *direct tournament*) while in others each pair ran on the same track but separately, with the results of their performance announced only at the end (hereinafter the *indirect tournament*). In the latter procedure there was no direct strategic interaction between the players throughout the race, because neither runner could establish his relative position and so could not condition his effort on that position.

Our experiment shows a clear pattern of quitting. There was almost no quitting in the middle of no- or low-incentive tournaments. Even though it was sometimes clear by the middle of the race which runner was going to win, the losing participant continued the race. In contrast, there was substantial quitting in high-incentive tournaments (even though they induced higher levels of performance. Finally, nonparticipating behavior was observed only in tournaments with small or no rewards. Not surprisingly, quitting in the middle occurred only when players ran side by side. In the indirect tournament, where players ran separately, no quitting was observed.

In order to model this trade-off between performance and quitting, we present a two-player, three-stage stochastic tournament model. The first player that completes the three stages of the tournament wins a prize. At the start of the tournament, players choose a (costly) flow of probability of success that remains constant throughout the tournament—provided they both players continue to race.[3] Quitting is costly, and it is not allowed unless the player is lagging two stages behind the leader.

In the model, the possibility of quitting affects the players' strategic choice of success probabilities. Players take into account that their choice affects not only the speed with which they advance in the race but also their own and their rival's quitting decision. The model distinguishes between quitting and no-quitting equilibria. Focusing on the relationship between the size of the final prize and the equilibrium quitting choice, the model shows that, for a tournament with a small prize, there is only a no-quitting equilibrium. Moreover, for a range of medium-level prizes there exist both no-quitting and quitting equilibria, and for a tournament with a large prize there is only a quitting equilibrium. In this respect, the predictions of the model are similar to the outcome of our experiment.

Our model provides a possible explanation for the effect of incentives on quitting. High-powered incentives induce high effort, which implies a higher cost of finishing the tournament. Whenever the higher costs are greater than the social costs of quitting,

3. See Lee and Wilde (1980) and Grossman and Shapiro (1987) for further details about such models.

lagging players are inclined to quit. Our experiment does not identify any actual reasons for quitting.[4] Yet we do believe that the relationship between incentives and quitting depends in part on the social context in which the tournaments are carried out.

Thus, our main result is the existence of a possible trade-off between performance and quitting in high-incentive tournaments. Such tournaments induce participants to exert more effort and to perform better, but they also induce more quitting. Note that this result is not another instance of the familiar *crowding out* argument (see for example Gneezy and Rustichini 2000; Frey and Jegen 2001). Quitting did not occur in our experiment when monetary incentives replaced intrinsic motivation (no difference in quitting rates for no-pay versus low-pay tournaments). The problem we raise in this paper occurs only with substantial payments. Finally, although the social cost of quitting is part of our model, we assume that this cost is fixed and is independent of the size of the final prize.

Quitting in tournaments is also discussed in Muller and Schotter (2003), who use a laboratory experiment to study static tournaments in which players were required to choose an effort level. Their main result is that, with sufficient asymmetry in the paired players' abilities, the low-ability player might give up and drop out of the race (*no participation*). In a field study, Falk and Ichino (2006) measure the output of subjects in two treatments: one in which participants work at the same time in the same room and another in which participants work alone and thus peer effects are ruled out. The authors find evidence of peer effects and observe that these effects raise productivity. They also find that low-productivity workers are significantly more sensitive than are other workers to the behavior of peers.

This paper is also related to the literature on workers' interim performance evaluations. When workers are engaged in a dynamic tournament (for example, a promotion tournament), firms may adopt a "no feedback" policy whereby workers are not informed about their relative positions in the tournament. Alternatively, firms can choose a feedback policy in which the workers' relative positions are revealed at prespecified stages of the tournament; workers may respond to this information by adjusting their effort. The literature's focus is on the desirability of an interim evaluation feedback policy (for example, Lizzeri, Meyer, and Persico 1999; Aoyagi 2007; Ederer 2008). In our experiment, the players that ran side by side (in the direct tournament) could constantly observe their position in the race. But in the indirect tournament there is no interim evaluation, and not until the tournament is over do players learn about their relative performance. Interim evaluation may affect workers' effort, because it affects their incentives and may provide a signal regarding their relative ability (see Ederer, 2008). In this paper we examine the effect of interim evaluations on players' decisions to quit the tournament and on the relationship between the tournament reward levels and the decision to quit.

4. Our sample size is too small for such an investigation. Future research, which could vary the social context in which tournaments are carried out, may provide a better understanding of this important phenomenon.

2. Quitting and Incentives: a Field Experiment

2.1. Experimental Design

The study was conducted at four different schools in the Tel Aviv area.[5] Participants were 10th-grade boys[6] who ran 60-meter races. The races were conducted during physical education classes and closely followed standard class practice: the boys ran twice along a track 60 meters long. The first race was an individual run with no rewards and no competition; the second race was manipulated in several ways, as discussed in what follows.

The class gym teachers were present during the experiment. Their role was to introduce the experimenters and to measure the speed. The participants knew that the experiment had two stages, but they were not told at the outset what the second stage would be. The introduction was given by the experimenters.[7] There were no written instructions for the runners, and the experimenters read out the same text in all the treatments. The first run was an individual run, after which participants were told their score privately. We separated participants who had finished the first run from those who had yet to complete it. After all the participants had finished the first run, we explained the second part. The second run was identical within each treatment.

The possibility of quitting was not discussed or even mentioned by the experimenters. The participants were told only about the prize (if any) to be awarded the winner; nothing was mentioned about the losers in the race.

The procedure was manipulated in several ways.[8] In the control treatment, the participants ran alone the second time as well. (This setup was used to control for unobservable factors that might cause differences between the two outcomes.) In all other experimental treatments, the teacher matched the boys in pairs. The participants were not informed about the matching method, for which there were two possible procedures as follows.

- *Random matching.* The participants were matched randomly, ignoring their speed in the first round.
- *Matching by time*. The teacher began by matching the two fastest runners, then the next two fastest runners, and so on.[9]

In a normal footrace, where runners are running side by side, participants can observe their relative position at each moment in the race; they can observe who is ahead and how much distance remains in the race. A runner's efforts may be affected

5. The schools were Aliance, Ironi D, Shmuel Hanagid, and Ze'ev.

6. We used only boys because competition may affect boys and girls differently in this task; see Gneezy and Rustichini (2004).

7. Part of the introduction concerned the technicalities of the race (where the runners should start, where they should run, what is the finishing line, and so forth).

8. For each *class* that participated in the experiment there was only one manipulation. Participants in each class knew only about one of the possible tournament procedures.

9. When more than two boys had achieved the same time in the first round, the match was random.

TABLE 1. Number of participants in each tournament.

	Indirect, time matched	Direct, time matched	Direct, randomly matched
No reward	28	72	42
Small reward	40	58	64
Large reward	68	34	24

by these observations. However, we can design a race where players compete against one another but not directly—that is, each competitor runs separately on the same track and for the same distance but without observing the other competitor. After the two runners complete their runs, their performance is compared and the player who achieves the best time wins. We thus have two treatments based on how the tournament is conducted.

- *Direct race*. Each pair runs on the same track, side by side.
- *Indirect race*. Each pair runs on the same track but separately, without observing each other.

  Finally, one of the following three incentive schemes was applied in the second period.
- *No monetary incentive*. In this treatment, no extrinsic monetary incentive was awarded but everyone could observe the tournament's winner.
- *Small monetary incentive*. The winner was announced and received a small prize of three colored pens worth NIS 10 (about $2 at the time).
- *Large monetary incentive*. In this treatment, the prize was NIS 50 (more than $10 at the time).

The number of participants in each tournament is summarized in Table 1.

2.2. Nonparticipating versus Quitting in the Middle

Two forms of quitting interested us:

(i) runners who choose not to participate in the second run (nonparticipating); and
(ii) runners who start running, but quit before finishing the race (quitting in the middle).

There was no penalty for quitting other than such behavior becoming common knowledge. As emphasized previously, the possibility of quitting was neither mentioned to, nor discussed with, participants. The number of participants who chose to quit in the different treatments is given in Table 2. Note, however, that only participants who were behind in the race quit in the middle. Therefore, when the table lists the average number of quitters it means the percentage of races that ended up with "quitting in the middle" (and *not* the percentage of quitters from the entire population of participants). On the other hand, nonparticipating is given in terms of the

TABLE 2. Number of participants who quit, by treatment.

			Nonparticipating	Quitting in the middle
Time matched	Direct	No reward	3 (.041)	1 (.027)
		Small reward	2 (.034)	1 (.034)
		Large reward	0	6 (.350)
	Indirect	No reward	0	0
		Small reward	2 (.050)	0
		Large reward	0	0
Randomly matched	Direct	No reward	1 (.024)	0
		Small reward	3 (.047)	0
		Large reward	0	5 (.420)

Note: Figures in parentheses are the fraction of players in the treatment among the total number of players.

percentage of participants who chose not to participate, since they made their choice at the tournament's outset (that is, before potential losers were identified).

Table 2 summarizes the main result of our experiment: Most quitting in the middle occurred in tournaments with high rewards. Looking specifically at direct tournaments, we see that (a) the losing runner quit in 11 of the 29 tournaments with large rewards, but (b) the losing runner quit in only 2 of the 118 tournaments with small or no rewards. On the other hand, there was no nonparticipating in high-reward tournaments, whereas one of the players chose not to participate in 9 (of the 118) tournaments with small or no rewards.

Aggregating the observations by incentives, we see that the difference in the quitting rate between the no-reward and small-reward tournaments is not statistically significant at the 0.1 level.[10] However, the difference between no reward and a large reward is significant ($Z = -5.713$, $p < 0.01$), as is the difference between the small reward and the large reward ($Z = -5.91$, $p < 0.01$).

Out of 29 losers in the *direct* high-reward tournament, 11 runners (38%) quit in the middle, but there were no quitters among the 68 participants in the *indirect* high-reward tournament. This difference is statistically significant ($Z = -4.625$, $p < 0.01$). We can therefore make the following observations.

Observation 1 (quitting in the middle):

(i) In direct tournaments with no or small rewards, quitting in the middle of a race was a relatively rare event (occurring in about 2% of the races). In direct tournaments with large rewards, there was significantly more quitting in the middle (in about 38% of the races).

(ii) In tournaments with high rewards, there was significantly more quitting in the middle when players ran together (direct tournaments) than when players ran separately (indirect tournaments).

10. The statistics is based on a binomial test of proportions. "Significant" difference means that the fraction of participants who quit is statistically different at the p level.

Observation 2 (nonparticipating): In our experiment, nonparticipating occurred *only* in tournaments with no rewards (4 out of 142, or 2.8% of participants) or small rewards (7 out of 162, or 4.3% of participants). Large rewards always induced participation by all the runners.[11]

It is somewhat puzzling that quitting in the middle was a relatively rare event in the no- or low-reward tournaments. In most cases, the race was not neck and neck. The general impression was that the winner was often evident by the middle of the race. Although the losing runners had the option to quit, almost all chose to continue running. Thus it is clear that the monetary prize is not the only relevant motivation. Quitting may well be associated with a stigma or with negative feelings that prevent players from quitting—even when it's obvious they have (almost) no chance of winning and even when there's little or no money at stake.

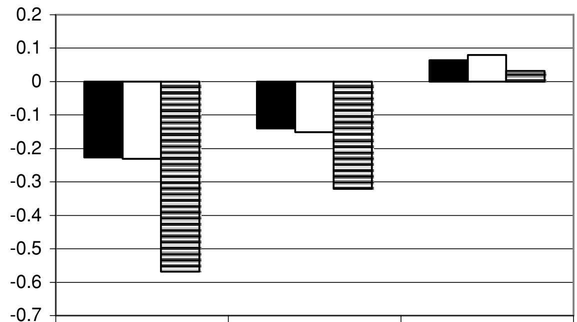
The small number of quitters in the indirect race is not surprising; it confirms that quitting results from a runner's capacity to observe his relative position during the race. In the indirect race, runners are unaware of their relative performance in the course of the race. Hence they cannot be *disappointed* until the race is over.

Next we examine the first run of the quitters to see if they exhibit any particular characteristics. In the high-reward direct tournaments, we observe six quitters when the runners were matched by time. Looking at their performance in the first round, when they ran separately, we find that three of the six quitters had a better result than the average (or median) result of losers in the same type of tournament.[12] Looking at each pair of runners, we find that three of the quitters had a better result than their competitors in the first run and that three other quitters had a worse result than their competitors. In the high-reward tournament with random matching of participants, there were five quitters. Two of the quitters had a better result in the first run than the average (and median) result of the losers. Comparing the first-run results of each pair of runners, we find that four quitters had a worse result than their running mate and that one had a better result than his competitor.

Thus, we were unable to find any significant characterization of the quitters. As discussed in what follows, the decision to quit is a combination of different considerations. One consideration is the stigma attached to quitting, which may vary within the population. Also, runners adjust their effort to the incentives they are offered. Running times are often slower in a tournament with no or low rewards, and we did not see much quitting in these races. When there was a large ability gap between runners, it is possible that the low-ability runner had already given up at the race's start but participated anyway, without investing much effort, in order to avoid any social stigma from quitting.

11. The difference between no rewards and high rewards is significant at the 0.05 level (p-statistic $= -1.905$, $p = 0.0284$). The difference between small and high rewards is statistically significant at the 0.01 level (p-statistic $= -2.385$, $p = 0.0085 < 0.01$).

12. Two quitters actually had a result better than the average (and median) result of all participants (winners and losers) in the race.



	Indirect Time-Matched	Direct Time-Matched	Direct Random-Matched
■ No reward	-0.2264	-0.14067	0.06356
□ Small reward	-0.230476	-0.1515	0.07932
⊟ Large reward	-0.568	-0.32	0.03167

FIGURE 1. Average changes in times of winners (in races with no quitting) in all treatments.

2.3. Incentives and Performance

We now turn to discuss the effect of incentives on performance. Toward this end, we examine the difference in players' performance between the first and second round of running. The basic statistics of all the runs is provided in Table A1 of the Appendix.

The presence of quitters raises some difficulties in evaluating the effect of incentives on runner performance. We cannot measure the performance of quitters, but ignoring them creates a selection problem because they may have lower ability or lower drive to compete. One way to overcome this problem is by comparing only the performance of winners in the different treatment types of races. The problem with this approach is that the performance of winners may be affected by the behavior of losers. In other words, if the losing player quits in the middle of the race then the winning runner no longer has competition and so may reduce his effort.

In order to see this effect, we look at the high-reward races. Overall we had 29 races with large rewards, of which 11 included a quitter. As expected, when the second race was against a quitter, winners' average improvement over their first race was much less (-0.0540 seconds) when compared with the average improvement (-0.2156 seconds) of winners whose competitors did not quit. Testing the difference between the two averages yields a t-statistic of 1.43 and a p-value of 0.081. Because quitting significantly affects the performance of winners, we consider the effect of incentives on winners' performance only in races with no quitting.

As Figure 1 indicates, large rewards have a strong effect on the performance of winners in the second-round races. For the direct time-matched treatments, the average improvement of winners (in the races with no quitting) in the high-reward setup was -0.360 seconds, compared with –0.140 seconds and –0.135 seconds in the low-reward and no-reward treatments, respectively. Testing the difference between average winners' improvement under high versus *low* rewards yields $t\text{-stat} = 1.585$ and

p-value $= 0.061$; testing the difference between average improvement of winners under high versus *no* rewards yields t-stat $= 1.824$, p-value $= 0.0374$. Large rewards had a similar effect in the indirect tournament. The average improvement of the winners in races with large rewards was -0.568 seconds, but with small or no rewards the average improvement in performance was only -0.230 and -0.220 seconds, respectively. Our statistical analysis indicates that winners in the high-reward tournaments perform better (that is, show more improvement between their first- and second-round races) than winners in the low- or no-reward tournaments.[13] We can therefore conclude that participants respond to large incentives, which induce better performance by the winners.

Observe that there was little difference in the performance of players in the low-reward and no-reward tournaments—a result that relates to the literature on the counterproductivity of small incentives.[14]

3. A Model of Quitting in Tournaments

We consider a two-player, three-stage tournament. The first player to complete the three stages wins the prize W while the loser gets nothing. Players are risk neutral and are labeled A and B. The race at each stage is modeled in continuous time.[15] At the outset of the tournament, players choose p_A and p_B, which can take values in a finite set Ω and provide a flow of probabilities of success (hazard rates) for each player at any given stage in the race. The cost of having these probabilities is given by $c(p_j) = \alpha p_j^2$, where $j = A, B$.

The state of the race is given by (a, b); $a, b \in \{0, 1, 2, 3\}$, where a (resp. b) describes the stage at which player A (resp. B) is. The tournament starts at the state $(0, 0)$. Success by player A, for example, would change the state of the race to $(1, 0)$. The race ends whenever $\text{Max}\{a, b\} = 3$. The intermediate stages provide no intrinsic value, but they lead the players to the final prize, which is not awarded until the race is completed.

13. Testing the difference between the average improvement under large versus *low* rewards yields a *t-stat* $= 1.68$, *p-val* $= 0.05$; testing the difference between the average improvement under large versus *no* rewards yields a *t-stat* $= 1.44$ and a *p-val* $= 0.078$. Recall that there was no quitting in the indirect tournaments, so we do not have a selection problem and therefore can look at the performance of all the participants. The average improvement with large rewards was -0.302 seconds, whereas the average improvement with small and no rewards was –0.081 and -0.077 seconds, respectively.

14. It is interesting that, in two of the treatments (indirect tournament with time-matched participants and direct tournament with randomly matched participants), the second-round improvement in the no-incentive and low-incentive treatments is not statistically significant. Moreover, in the direct, time-matched case, the low-incentive treatment actually yielded worse performance than the no-incentive treatment. This result relates to the literature on the counterproductivity of small incentives that claims that paying small amounts of money is sometimes worse than paying no money at all (see for example Frey and Jegen 2001; Gneezy and Rustichini 2000). This literature emphasizes the difference between intrinsic motivation and monetary incentives, and it claims that small monetary incentives may have a negative effect on performance. See Benabou and Tirole (2003) for a theoretical discussion of this issue.

15. The continuous-time structure implies that with probability 1 there is exactly one winner of the race.

The players choose (p_A, p_B) at the outset of the race, and these probabilities remain in effect as long as the two players continue racing. Only when one of the players quits the race may the other player reoptimize and change her "speed". So as long as both players remain in the race, each is committed to the hazard rates she chose at the start of the tournament.

In order to simplify the analysis, we allow quitting only at states of the race in which one of the players has a substantial advantage. Specifically, a player may quit only when she is two stages behind—that is, at either (2, 0) or (0, 2). Quitting is costly. The cost of quitting, denoted by S, could be monetary but also can be interpreted as a social cost: the stigma of being a quitter.

Our model is designed to focus on the quitting aspect of the race and, in particular, on the relationship between the prize W and the decision to quit. We choose a three-stage structure in order to enable larger gaps between the players. Larger gaps encourage quitting because they allow for a larger advantage in favor of one of the players, which is associated with a lower probability of winning for the player who is behind in the race.[16]

Our model assumes that the hazard rates are fixed throughout the race provided the two players continue to compete. An alternative setup would allow players to condition their effort or hazard rate on the state of the race. Such a setup would be simpler to analyze—except for the resulting imprecision of what "quitting" means. When speed can be self-adjusted, players may avoid costly quitting simply by staying in the race and choosing to lower their speed (or hazard rate). Of course, reducing speed may also be viewed as quitting, though formally the player is still in the race. In order to avoid such vagueness in the definition of quitting, we adopt a model in which (a) the choice of p_i is made at the outset of the race and hence (b) the only remaining decision is whether to continue in the race or to quit.

Let $V_A^{(a,b)}(p_A, p_B)$ be the value of the race for player A whenever the state of the race is (a, b) and the players' choices of hazard rates are (p_A, p_B). The rules of the game imply that $V_A^{(3,b)} = W$ for every $b < 3$ and that $V_A^{(a,3)} = 0$ for every $a < 3$. We can use these values to construct all the other relevant values.

We start with the case of (2, 2). As in Lee and Wilde (1980) and Grossman and Shapiro (1987), the value of the players is given implicitly by

$$rV_A^{(2,2)} = p_A\big(W - V_A^{(2,2)}\big) + p_B\big(-V_A^{(2,2)}\big) - c(p_A), \tag{1}$$

where r is the discount rate. Rearranging equation (1) yields

$$V_A^{(2,2)}(p_A, p_B) = \frac{p_A W - c(p_A)}{r + p_A + p_B}. \tag{2}$$

16. In a two-stage race, one of the players may achieve an advantage of one stage which may be insufficient to discourage the other player from continuing. In a longer race with more intermediate stages, it is possible for the leader to gain an advantage decisive enough that sufficiently reduces the probability of a comeback for the runner that is lagging behind and thus encourages him to quit.

We can follow the same procedure and find the values for player A whenever the state of the race is (2, 1):

$$V_A^{(2,1)}(p_A, p_B) = \frac{p_A W + p_B V_A^{(2,2)} - c(p_A)}{r + p_A + p_B}. \tag{3}$$

The value $V_A^{(1,2)}(p_A, p_B)$ is defined similarly.

Assume now that the race reaches the state (2, 0). Player A is thus two stages ahead in the race, and player B must choose whether to quit (and suffer the penalty of $-S$) or to continue in the race at the same speed. By comparing the values of the two options we can see that player B will continue the race if and only if

$$\frac{p_B V_B^{(2,1)} - c(p_B)}{r + p_A + p_B} \geq -S. \tag{4}$$

Thus, given W, S, and r, the set of possible pairs (p_A, p_B) can be divided into two (possibly empty) subsets Ω_q^B and Ω_c^B. Whenever $(p_A, p_B) \in \Omega_c^B$, condition (4) holds and player B does not quit; whenever $(p_A, p_B) \in \Omega_q^B$, condition (4) does not hold and player B quits when the race reaches the state (2, 0). Because the race is symmetric, Ω_q^A and Ω_c^A are defined analogously. Therefore,

$$V_A^{(0,2)}(p_A, p_B) = -S \quad \text{if } (p_A, p_B) \in \Omega_q^A$$

and

$$V_A^{(0,2)}(p_A, p_B) = \frac{p_A V_A^{(1,2)} - c(p_A)}{r + p_A + p_B} \quad \text{if } (p_A, p_B) \in \Omega_c^A.$$

When player B quits the race at state (2, 0), player A remains the sole participant in the tournament and may adjust her speed or effort accordingly. Since there is only one stage remaining in the tournament, player A will choose $p_A^{(2,-)}$ such that

$$p_A^{(2,-)} = \text{Arg}\max_p \left\{ \frac{pW - c(p)}{r + p} \right\}. \tag{5}$$

The value of the race at this point is

$$V_A^{(2,-)} = \frac{p_A^{(2,-)} W - c\left(p_A^{(2,-)}\right)}{r + p_A^{(2,-)}}. \tag{6}$$

We can now construct the value of the race for player A at state (2, 0):

$$V_A^{(2,0)}(p_A, p_B) = V_A^{(2,-)} \quad \text{whenever } (p_A, p_B) \in \Omega_q^B$$

and

$$V_A^{(2,0)}(p_A, p_B) = \frac{p_A W + p_B V_A^{(2,1)} - c(p_A)}{r + p_A + p_B} \quad \text{whenever } (p_A, p_B) \in \Omega_c^B.$$

Given these values, we can repeat the same procedure and define $V_A^{(1,1)}(p_A, p_B)$, $V_A^{(1,0)}(p_A, p_B)$, and $V_A^{(0,1)}(p_A, p_B)$.[17] Finally, we can use the values constructed so far to establish that

$$V_A^{(0,0)}(p_A, p_B) = \frac{p_A V_A^{(1,0)} + p_B V_A^{(0,1)} - c(p_A)}{r + p_A + p_B}; \tag{7}$$

the value $V_B^{(0,0)}(p_A, p_B)$ is defined similarly.

The race can be described now as a normal-form game in which each player chooses a probability p_A or p_B and receives the payoffs given by (7).

A *no-quitting equilibrium* is a pair (p_A^*, p_B^*) that satisfies the Nash condition such that $V_A^{(0,0)}(p_A^*, p_B^*) \geq V_A^{(0,0)}(p_A, p_B^*)$ for every possible p_A (and satisfies a similar condition for B) such that $(p_A^*, p_B^*) \in \Omega_c^B$ and $(p_A^*, p_B^*) \in \Omega_c^A$.

A *quitting equilibrium* is a pair of strategies (p_A^*, p_B^*) that satisfy the above Nash condition and for which either $(p_A^*, p_B^*) \in \Omega_q^B$ or $(p_A^*, p_B^*) \in \Omega_q^A$.

In the no-quitting equilibrium, both players continue in the race even when one of them is two stages behind, since the value of continuing the race is greater than the negative value (that is, stigma) of quitting. There are several possible quitting equilibria. It is possible to have an asymmetric equilibrium in which one of the players quits when facing a two-stage disadvantage in the race; also, a symmetric equilibrium may exist in which the two runners would quit if they are two stages behind their opponent.

We now turn to solve the above tournament game and to investigate the relationship between the final prize W and the equilibrium quitting choice. We perform a numerical analysis assuming that $c(p_A) = 10p_A^2$, $S = 1$, and $r = 0.05$.[18] We then discretize the (p_A, p_B) space having a 100×100 matrix of possible values. For each possible pair of (p_A, p_B), we use the values described in equations (1)–(7) to construct the relevant values $V_A^{(0,0)}(p_A, p_B)$ and $V_B^{(0,0)}(p_A, p_B)$. Finally, we identify the equilibrium strategies (p_A^*, p_B^*) of the normal-form game that we constructed. We then use equation (4), and the specification of the value function that follows, to check whether the equilibrium is a quitting or a no-quitting equilibrium. This procedure is repeated for different values of W in order to study the relationship between the tournament prize rewarded and equilibrium quitting behavior.

Our analysis indicates that there are, indeed, two types of equilibria. For low levels of W—that is, $5 < W < 22$—there is only a no-quitting equilibrium. For

17.
$$V_A^{(1,1)}(p_A, p_B) = \frac{p_A V_A^{(2,1)} + p_B V_A^{(1,2)} - c(p_A)}{r + p_A + p_B};$$
$$V_A^{(1,0)}(p_A, p_B) = \frac{p_A V_A^{(2,0)} + p_B V_A^{(1,1)} - c(p_A)}{r + p_A + p_B};$$
$$V_A^{(0,1)}(p_A, p_B) = \frac{p_A V_A^{(1,1)} + p_B V_A^{(0,2)} - c(p_A)}{r + p_A + p_B}.$$

18. Note that fixing $\alpha = 10$ is just a choice of numéraire.

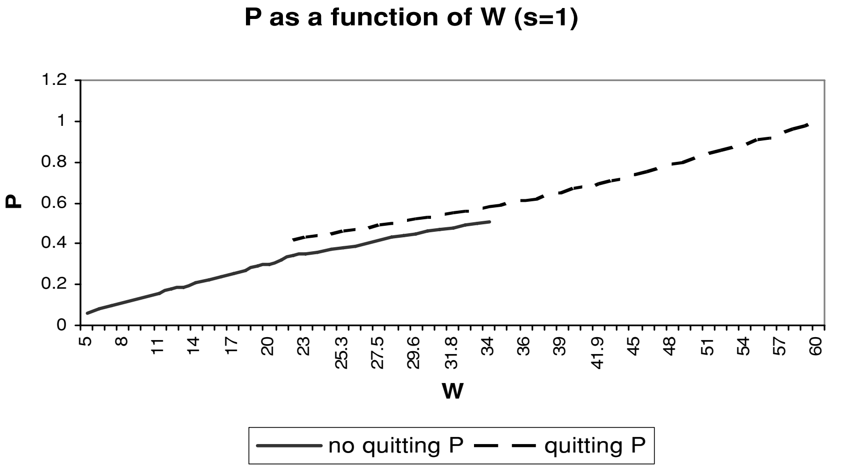


FIGURE 2. Quitting and no-quitting equilibria.

TABLE 3. No-quitting and quitting equilibria for different levels of *S*.

S	Range of no-quitting area (value of *W*)	Range of quitting area (value of *W*)	Range of no-quitting area (value of p^*)	Range of quitting area (value of p^*)
0.5	5.00–17.00	13.25–60.00	0.06–0.25	0.23–0.99
1.0	5.00–34.00	22.25–60.00	0.06–0.51	0.42–0.99
1.5	5.00–65.00	25.00–58.75	0.06–0.99	0.52–0.99

Note: W, value of the reward; p^*, equilibrium hazard rate.

$22.25 < W < 34$ there are two types of equilibria: quitting and no-quitting.[19] For higher values of W, $34 < W < 60$, there is only a quitting equilibrium. Figure 2 depicts the symmetric equilibrium choice of hazard rate (of the two players) and the two types of equilibria for different values of W. As expected, for the two types of equilibria, the equilibrium choice of hazard rate is an increasing function of W.

The predictions of our model coincide with the results of our experiment. In the tournament with no or small prizes, there was no quitting in the middle of a race. Quitting occurred only in races with large prizes—races that were, indeed, run much faster.

Changing S, the social cost of quitting, will affect players' temptation to quit in the middle. We therefore recalculate the equilibrium of the tournament for different levels of S (see Table 3). For $S = 0.5$ there are still three ranges of W that give rise to different types of equilibria, but the lower S means that the no-quitting equilibrium

19. There are only symmetric equilibria for this tournament. Either both players quit or neither player quits.

exists only for a lower range of W. Specifically, there is a no-quitting equilibrium for $5 < W < 17$ and a quitting equilibrium for $13.25 < W < 60$.

Increasing S does not necessarily have a monotonic effect on the existence of the two types of equilibria. For example, increasing S from 1.0 to 1.5 results in a no-quitting equilibrium for the whole relevant range of W and a quitting equilibrium only for $25 < W < 58.75$. Consequently, for very high levels of W there exist only no-quitting equilibria.

So far we have considered a simple tournament that rewards the winner with a fixed prize W. The role of this prize is to incentivize the players to invest more effort in the tournament. A tournament designer who cares about performance, but would like to discourage quitting, may adopt a different design. One possible design along these lines is to award two prizes (W, L) in the race. The winner gets W, as before, but the loser now receives prize L upon finishing the race without quitting. Making L sufficiently large will discourage quitting. Quitting occurs when the value of continuing the race is negative *and* less than the stigma of quitting—that is, when $V_A^{(0,2)}(p_A, p_B) < -S$. Yet if we provide the payment L, then the value of continuing the race increases and the incentives to quit are reduced.

However, providing L reduces the incentives of the players to invest effort. One way to describe the (W, L) incentive scheme is that L is an *appearance fee* paid to the player who participates without quitting and that the winner's prize is $W - L$. Clearly, the payment of L reduces the incentives of both players to invest effort in the race.

Our model can easily accommodate this case of two prizes (W, L); we need only change the value of the losing states from 0 to L. That is, we now have $V_A^{(3,b)} = W$ for every $b < 3$ but also $V_A^{(a,3)} = L$ (instead of $V_A^{(a,3)} = 0$) for every $a < 3$. For every prize W, we define $L(W)$ as the lowest possible second prize that is sufficient to discourage quitting. Observe that there is no reason for the designer to provide a second prize higher than $L(W)$, because any increase in L will only reduce the incentives to invest effort. Therefore, if the goals is to induce performance but without having quitting, then the tournament should have the two prizes $(W, L(W))$. Although using $L(W)$ reduces performance it does guarantee that there will be no quitting.

We can use our analysis to solve for $L(W)$ and for the equilibrium effort in a race whose prize structure is $(W, L(W))$. For example, in our numerical analysis for $S = 1$, a single prize of $W = 47$ yields a quitting equilibrium and the equilibrium effort is $p = 0.77$. Paying $L = 2.34$ yields an equilibrium with no quitting, but the equilibrium effort falls to $p = 0.68$. By calculating the equilibrium for different values of L, we can show that $L(47) = 2.34$. In other words, if $W = 47$ then the lowest possible L that will ensure no quitting is $L = 2.34$.

High rewards are clearly necessary to provide performance incentives. However, a tournament designer who seeks also to prevent quitting should implement a $(W, L(W))$ payoff structure, which awards a second prize that is of sufficient value to discourage quitting.

4. Discussion

Our analysis identifies a possible trade-off between performance and quitting in high-power tournaments. The experiment does not identify the reason for quitting. We believe that the relationship between incentives and quitting depends partly on the social context, and we leave this issue for further research. But any explanation of the relationship between incentives and quitting should account also for the fact that, in the no-reward tournament, runners typically finish the race without quitting. Therefore, any viable explanation should involve intrinsic motivation and not merely monetary gains. Intrinsic motivation can be the joy of winning, the social stigma from quitting,[20] the desire to impress spectators, and so on.

Some of these intrinsic motivations explain why runners exert effort in a race without any monetary rewards. A social cost of quitting is necessary to explain why we rarely observed quitting in the middle of the low- and no-reward races. In many of these races, the winner's identity was clear well before the end of the race,[21] yet almost all runners continued on to finish the race. Whenever the social cost of quitting was above the cost of effort, runners did not quit.

Quitting may be defined not only as ceasing to exert effort but also as a drastic reduction in effort. In our model, players are not allowed to change their effort level. The runners in our experiment were allowed to modify their effort, but quitting was characterized by stopping to run. This seems to be rational behavior: if a runner gives up the chance of winning and is ready to bear the stigma of quitting, then no benefit can be derived from exerting even a minimal level of effort.

So then why do we observe more quitting in the high-reward tournament? As our model suggests, a comprehensive explanation should incorporate not only the social cost of quitting but also the cost of continuing the race. Large rewards induce players to run much faster; hence the cost of continuing the race without quitting is larger because of the extra effort required by the fast pace and the resulting fatigue. In the model, quitting occurred whenever the social cost of quitting was not sufficient to compensate for the larger cost of continuing the race.[22]

It is possible, however, that the stigma from quitting the race depends on the incentives themselves. Quitting may be considered more legitimate when the emphasis is placed on monetary rewards. But in races with no rewards, the runners are presumably

20. The stigma of quitting is not necessarily a constant. It could be a function of the prize, the two players' relative abilities, and/or the outcomes of other races in the treatment. For example, if many players quit then such behavior would become more acceptable, implying reduced social stigma.

21. Obviously, we could not ask runners in the middle of a race if they were sure who would win. But in a 60-meter run, any significant gap between the runners (especially between those of equal ability) makes for an excellent predictor of the winner's identity. However, given the stochastic element in any such race, no outcome is known with certainty.

22. Note that the higher cost of finishing the race is not, in itself, sufficient to explain our findings, since participants in the indirect high-reward tournaments ran fast but never quit.

competing for *the sake of competition* and not for monetary gains; consequently, quitting is less acceptable (that is, quitting entails higher social costs). Large rewards may change a player's state of mind and reduce social motivation. This is akin to the *crowding out* argument (Gneezy and Rustichini 2000; Frey and Jegen 2001). However, our findings here differ in that we observe no quitting in the race with small rewards. The trade-off on which we focus in this paper exists only when there are large rewards. That is, quitting did not occur in our experiment when intrinsic motivations were augmented by monetary incentives: the same rate of quitting was observed in the no-pay and the low-pay tournaments. In contrast to the familiar prescription to "pay enough or don't pay at all", the problem we raise in this paper occurs precisely when there are substantial rewards. Our model also demonstrates that we need not resort to the crowding out argument in order to explain our main result.

An alternative explanation of the no-quitting phenomenon (especially as regards to the no-reward tournament) is the *sunk cost fallacy* or *escalation* effect discussed in the psychological literature (see for example Arkes and Blumer 1985; Staw 1997; Arkes and Ayton 1999; Thaler 1999). This is defined as "the irrational tendency to choose to continue to invest money, time, or effort following unsuccessful investments". The existence of social rewards and social stigma has been recognized in the psychological literature as one explanation for the escalation effect: "Social rewards may pressure individuals and groups into persisting in a course of action in the face of negative feedback" (Street and Anthony 1997, p. 275).

5. Concluding Remarks

Whenever players are in direct competition with one another, social preferences may be an important determinant of their behavior. Winning (or quitting) may have a value in itself, irrespective of any monetary rewards. It affects how people view themselves, their self-esteem, and often how others evaluate them. Social rewards depend on the information players have regarding their relative performance. Therefore, an important part of tournament design concerns the nature of information flow during the tournament. When players receive bad news regarding their relative performance, they may decide to quit. Such quitting may be an important concern when the designer cares about total performance (for example, in firms) or when there is a special emphasis on reducing the number of quitters (as in most education systems).

Designing incentives for students has been the focus of many recent studies. For example, Angrist and Lavy (2009) study the effect of cash awards for good performance on matriculation exam results in Israel. The authors find that students eligible for cash awards for good performance were 6 to 8 percentage points more likely to pass their matriculation exams than other students in the same school. Interaction in the classroom has a tournament aspect, since students also compete in terms of their relative position in the class. The concern raised in this paper is that implementing high-reward incentives for students may have the unintended and undesirable effect of increasing dropout rates.

Appendix

TABLE A1. Basic statistics

			All Participants			Winners			Losers		
		N	Avg.	Median	S.D.	Avg.	Median	S.D.	Avg.	Median	S.D.
	No competition	41	−.056	−.02	.327	N. A.	N. A.	N. A.	N. A.	N. A.	N. A.
Randomly matched	No reward	42	.106	.13	.565	.105	.16	.438	.107	−.02	.680
	Small reward	64	.110	0	.594	.065	.03	.338	.154	−.03	.774
	Large reward	24	−.184	−.235	.553	−.098	.005	.536	−.270	−.275	.580
Time matched	No reward	72	−.065	−.03	.424	−.200	−.135	.333	.070	.06	.466
	Small reward	58	.004	0	.312	−.092	−.1	.320	.010	.1	.278
	Large reward	34	−.383	−.185	.657	−.497	−.42	.622	−.269	−.12	.690
Indirect	No reward	28	−.077	−.05	.399	−.226	−.135	.291	.073	.06	.445
	Small reward	40	−.081	−.1	.315	−.233	−.305	.284	.071	.05	.274
	Large reward	68	−.302	−.09	.753	−.568	−.28	.881	−.036	.05	.479

Note: Values shown are changes in times (time of round 2 minus time of round 1). A positive (negative) number implies running slower (faster) in the second round. For example, if we consider the randomly matched treatment and look at the intersection of the row for average of all participants and the column for large reward, then we see that participants ran (on average) 0.184 seconds faster in round 2 than in round 1. The data in this table do *not* include the participants who quit.

References

Angrist, Joshua and Victor Lavy (2009). "The Effects of High Stakes School Achievement Awards: Evidence from a Group-Randomized Trial." *American Economic Review*, 99, 1384–1414.

Aoyagi, Masaki (2007). "Information Feedback in a Dynamic Tournament." Discussion Paper No. 580, The Institute of Social and Economic Research, Osaka University.

Arkes, Hal R. and Peter Ayton (1999) "The Sunk Cost and Concorde Effects: Are Humans Less Rational than Lower Animals?" *Psychological Bulletin*, 125(5), 591–600.

Arkes, Hal R. and Catherine Blumer (1985). "The Psychology of Sunk Costs." *Organizational Behavior and Human Decision Process*, 35(1), 124–140.

Benabou, Roland and Jean Tirole (2003). "Intrinsic and Extrinsic Motivation." *Review of Economic Studies*, 70(3), 489–520.

Bull, Clive, Andrew Schotter and Keith Weigelt (1987). "Tournaments and Piece Rates: An Experimental Study." *Journal of Political Economy*, 95(1), 1–33.

Che, Yeon-Koo and Ian Gale (2003). "Optimal Design of Research Contests." *American Economic Review*, 93(3), 646–671.

Cornwell, Christopher M., Kyung Hee Lee. and David B. Mustard (2003). "The Effect of Merit-Based Financial Aid on Course Enrolment, Withdrawal and Completion in College." IZA DP #820.

Ederer, Florian P. (2008). "Feedback and Motivation in Dynamic Tournament." Working paper, MIT.

Falk, Armin and Andrea Ichino (2006). "Clean Evidence on Peer Effect." *Journal of Labor Economics*, 24(1), 39–57.

Frey, Bruno S. and Reto Jegen (2001). "Motivation Crowding Theory." *Journal of Economic Surveys*, 15(5), 589–611.

Gneezy, Uri and Aldo Rustichini (2000). "A Fine is a Price." *Journal of Legal Studies*, 29(1), 1–17.

Gneezy, Uri and Aldo Rustichini (2004). "Gender and Competition at a Young Age," *American Economic Review Papers and Proceedings*, 94(2), 377–381.

Green, Jerry R. and Nancy L. Stokey (1983). "A Comparison of Tournaments and Contracts." *Journal of Political Economy*, 91(3), 349–364.

Grossman, Gene M. and Carl Shapiro (1987). "Dynamic R&D Competition." *The Economic Journal*, 97(386), 372–387.

Lazear, Edward P. and Sherwin Rosen (1981). "Rank-Order Tournaments as Optimal Labor Contracts." *Journal of Political Economy*, 89, 842–864.

Lee, Tom and Louis L. Wilde (1980). "Market Structure and Innovation: a Reformulation." *Quarterly Journal of Economics*, 94(2), 429–436.

Lippman, Steve A. and Kevin F. McCardle (1987). "Dropout Behavior in R&D Races with Learning." *Rand Journal of Economics*, 18(2), 287–295.

Lizzeri, Alessandro, Margaret Meyer, and Nicola Persico (1999). "Interim Evaluations in Dynamic Tournaments: the Effect of Midterm Exam." Unpublished.

Moldovanu, Benny and Aner Sela (2001). "The Optimal Allocation of Prizes in Contests." *American Economic Review*, 91(3), 542–558.

Muller, Wieland and Andrew Schotter (2003). "Workaholics and Drop Outs in Optimal Organizations." Working paper, NYU.

Nalebuff, Barry J. and Joseph E. Stiglitz (1983). "Prizes and incentives: Towards a General Theory of Compensation and Competition." *Bell Journal of Economics*, 14(1), 21–43.

O'Keeffe, Mary W. Kip Viscusi and Richard J. Zeckhauser (1984). "Economic Contests: Comparative Reward Schemes." *Journal of Labor Economics*, 2(1), 27–56.

Rosen, Sherwin (1986). "Prizes and Incentives in Elimination Tournaments." *American Economic Review*, 76(4), 701–715.

Staw, Barry M. (1997). "The Escalation of Commitment: An Update and Appraisal." In *Organizational Decision Making*, edited by Zur Shapira. Cambridge University Press, pp. 191–215.

Street, Marc D. and William P. Anthony (1997). "A Conceptual Framework Establishing the Relationship Between Groupthink and Escalating Commitment Behavior." *Small Group Research*, 28(2), 267–293.

Thaler, Richard H. (1999). "Mental Accounting Matters." *Journal of Behavioral Decision Making*, 12(3), 183–206.