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Cary Deck

Erik O. Kimbrough

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Experimenting with Contests for Experimentation*

Cary Deck† **Erik O. Kimbrough**‡

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Abstract

We report an experimental test of alternative rules in innovation contests when success may not be feasible and contestants may learn from each other. Following Halac *et al.* (forthcoming), the contest designer can vary the prize allocation rule from Winner-Take-All in which the first successful innovator receives the entire prize to Shared in which all successful innovators during the contest duration share in the prize. The designer can also vary the information disclosure policy from Public in which at each period, all information about contestants' past successes and failures is publicly available, to Private, in which contestants only know their own histories. In our setting, the optimal contest design in terms of maximizing the probability that at least one innovator is successful depends on the probability of successful innovation, given that innovation is feasible. Under some parameters the designer will prefer a WTA-Public contest; while, under others he will prefer Shared-Private. Our experiments provide evidence that Private disclosure contests behaviorally dominate Public disclosure, regardless of the prize allocation rule, and moreover that Shared-Private contests dominate WTA-Private contests.

JEL classifications: *C7, C9, D4, D7*
Keywords: *research and development, contests, experiments*

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†Department of Economics, University of Arkansas, Fayetteville, Arkansas, Economic Science Institute, Chapman University, Orange, California, and University of Alaska-Anchorage, Anchorage, Alaska, e-mail: cdeck@walton.uark.edu

‡Corresponding Author: Department of Economics, Simon Fraser University, 8888 University Drive, Burnaby, BC V5A 1S6, Canada, e-mail: ekimbrou@sfu.ca

1 Introduction

The use of contests to spur innovation is not new. In 1714 the British government instituted prizes for the creation of methods to accurately measure longitude (Moldovanu and Sela, 2001). Recently, contests have seen increasing popularity as a mechanism for encouraging innovation in diverse arenas. In fact, the 2011 America COMPETES Reauthorization Act allows US government agencies to conduct contests to encourage innovation. Perhaps the best known example of an innovation contest is the Ansari XPrize, which offered \$10 million to the first private entity to build a craft with a demonstrated capability to carry three people 100 kilometers above the Earth twice in a two week span. The prize was claimed by Mojave Aerospace Ventures in 2004 and helped invigorate interest in private space exploration to the point that Virgin Galactic now accepts reservations for future space flights. Other examples that might be of interest to readers of this paper are the Millennium Prizes which offer \$1 million to the first person to solve any of several classic math problems. While there have been many innovation contests, there has been little heterogeneity in their structure, with the first successful innovator claiming the full prize.

An important consideration for re-designing innovation contests is a recognition that not all innovations are possible and thus the contest may not have a winner (Loury, 1979; Chowdhury, 2009). Taylor (1995) distinguishes between research tournaments and innovation contests. The former has a fixed deadline and success is relative; while, the latter has a fixed threshold for success but no deadline. Innovation contests are closely connected to patent races (e.g. Dasgupta and Stiglitz 1980, Grossman and Shapiro 1987, Harris and Vickers 1987, Erkal and Minehart, and experimental work by Sbriglia and Hey 1994, Zizzo 2002, Deck and Erkal 2013). One issue that has been examined in detail in the race literature is the degree to which one party's intermediate success can be observed and copied by rivals (e.g. Scotchmer and Green, 1990; d'Aspremont *et al.*, 2000; Bessen and Maskin, 2009; Fershtman and Markovich, 2010). If early progress can easily be copied, then players may have an incentive to delay their own costly efforts. However, the ability of others to incorporate a rival's discovery could reduce the time until an ultimate success is reached or increase the probability that someone is ultimately successful.

Recently, Halac *et al.* (forthcoming) developed a model specifically focused on innovation contests, building on previous work on contests with learning by Choi (1991), Malueg and Tsutsui (1997), Mason and Välimäki (2015), and Moscarini and Squintani (2010). Halac *et al.* (forthcoming) consider the problem faced by the contest designer who wants to maximize the chance that an innovation is made.[1] The innovator is assumed to receive no private benefit from the innovation beyond the prize money, and the contest designer does not value a second or alternative solution.[2] In Halac *et al.* (forthcoming) there is a single step stochastic innovation process which a player can attempt to complete in each time period. The tools at the contest designer's disposal are how the prize is distributed among those who succeed in innovation (with a continuum of policies including winner-take-all and equal sharing among successful innovators) and to what degree the results from previous innovation attempts become public or remain private (ranging from all results made public to all kept private).[3]

The intuition for the tradeoffs created by these mechanisms for a contest designer is as follows. A winner-take-all policy provides a strong incentive to attempt innovation; however, prize sharing alleviates the concern that a successful innovator's efforts

[1]Notice that this objective is different from that of a planner who seeks to maximize welfare.

[2]Thus, the innovation itself is not patentable so the innovator cannot retain intellectual property rights. An alternative interpretation is that contest entry requires innovators to turn over all resulting intellectual property to the contest designer.

[3]Thus, they (and we) implicitly assume that the designer can monitor the performance of all contestants.

will not be rewarded. Non-disclosure of rivals' past failures reduces discouragement; while, public disclosure provides information about the remaining prize money. The interaction of these mechanisms is complex. However, in a two-player, two-period version of the model due to Halac *et al.* (forthcoming), the result is that the optimal innovation contest is either one with private information and prize-sharing or with public information and winner-take-all rules, depending on the likelihood that innovation is possible.[4]

This paper employs a within-subject experimental design to test the predictions of Halac *et al.* (forthcoming). We focus on this paper for a number of reasons. First, this prominent model is based on the "workhorse exponential-bandit framework [of] Keller *et al.* (2005)" which has been widely used to study innovation in theory (Halac *et al.*, forthcoming, p. 1). Second, the levers of policy available to the contest designer in the model are straightforward and potentially available to contest designers in practice. Third, the theory makes counterintuitive predictions that yield surprising policy prescriptions. As Smith (1994) points out, one valuable use of laboratory experiments is in institutional testbedding, since the lab allows researchers to try out a novel institution in a low stakes setting prior to field implementation.

As a preview of the experimental findings, a prize sharing rule without the ability to monitor a rival's success in period one does the most to encourage innovation. Further, when initial outcomes are private, a winner-take-all prize can discourage investment after an initial failure. That observed behavior doesn't completely match the theoretical predictions highlights the importance of laboratory test-bedding. Our experiments suggest that the domain over which a private disclosure, equal-sharing contest is preferred by the designer is even larger than anticipated.

[4]In the more general setting in continuous time with N potential innovators, they find that prize-sharing with public disclosure only after some number of successes have occurred is often the optimal policy; though in many cases, the private disclosure, equal-sharing policy is optimal.

2 Theoretical Considerations

The theory motivating the experiments is drawn directly from Halac *et al.* (forthcoming) and hence this section closely follows Section 2 of that paper. Sufficient details are provided for the reader to understand the setting and the predicted behavior, but the reader seeking greater detail or proofs should consult Halac *et al.* (forthcoming).

Consider a contest designer whose objective is to encourage R&D directed towards a certain goal, while also avoiding costly duplication. Specifically, the designer is assumed to have lexicographic preferences where the primary focus is on the chance that an innovation is made and the second dimension is the investment cost.[5] This goal may (the good state) or may not (the bad state) be obtainable. Formally, let the probability of the good state in which the goal is achievable be $p_{good} \in (0, 1)$. Further, suppose there are two risk-neutral, non-discounting prospective innovators (players), each of whom has an identical prior $p_0 = p_{good}$ regarding the probability that the goal is achievable. Also, let there be 2 periods in which each player can privately choose whether or not to attempt innovation at a cost $c > 0$. Conditional on being in the good state, R&D success is stochastic. That is, if a player invests, and the state of the world is good, he will discover the innovation with probability $\lambda \in (0, 1)$. All innovators' draws are *iid* given the state of the world. If the player does not invest or the state of the world is bad, he will discover the innovation with probability 0.

The designer has a prize budget v to offer incentives for the players to innovate, and he wants at least one success (a second success has no marginal benefit). Following Halac *et al.* (forthcoming), the designer can vary two dimensions of the innovation contest: the *prize allocation rule*, which determines how the prize is allocated between successful innovators, and the *information disclosure policy*, which determines what

[5] There is no benefit to the designer of having multiple successful innovations, and it is normatively appealing that the designer also seeks to discourage costly duplication effort.

information the designer discloses about the period 1 choices and outcomes of other players prior to period 2.

Prize allocation rule. There are two prize allocation rules: *Winner-Take-All (WTA)*, in which the first successful innovator collects the entire prize (unless both succeed in the same period, in which case the prize is shared); and *Shared*, in which any innovator who succeeds in any period earns an equal share of the prize.

Information disclosure policy. There are two information disclosure policies: *Public*, in which the designer makes public all information about decisions and outcomes in period 1; and *Private*, in which the designer shares no information about what transpired in period 1.

The result is four types of innovation contests, each of which creates very different incentives for innovation. To see why, each contest type is discussed in turn, but first one should note that a player would never choose to innovate in period 2 after his own success in period 1.

WTA-Public. The *WTA-Public* format combines a winner-take all allocation rule with full disclosure of period 1 outcomes prior to period 2. First consider the problem faced by a player deciding whether to enter in period 1 of a *WTA-Public*. A player's expected prize conditional on being successful equals $\tilde{v} = \lambda v/2 + (1 - \lambda)v$ assuming the other player is attempting innovation. As long as $p_0 \lambda \tilde{v} > c$, a player prefers to enter the contest in period 1. If a player is unsuccessful in period 1, the decision to try again in period 2 is contingent upon what happened to the other player in period 1. If the other player was already successful there is no reason to engage in R&D in period 2 since the player cannot claim any portion of the prize. If the other player was also not successful in period 1 then the (Bayesian) belief about the probability that the state of the world is good is $p_1 = \frac{p_0(1-\lambda)^2}{p_0(1-\lambda)^2+1-p_0}$ and the player will enter the contest again in period 2 if and only if:

$$p_1 \lambda \tilde{v} \geq c \tag{1}$$

Shared-Public. In a *Shared-Public* contest, information is publicly disclosed after period 1 as in *WTA-Public*, but the prize allocation rule divides the prize equally among any players who succeed, regardless of whether they succeed in period 1 or 2. Since period 1 successes are publicly disclosed, any player whose counterpart was successful in period 1 will know with certainty that the state of the world is good and will know that the reward for success in period 2 is $v/2$, since the prize is shared by all who succeed. If $\lambda v/2 \geq c$, the lagging player will attempt to duplicate his counterpart's success in period 2. Thus at period 1, the incentive to enter is lower than in in *WTA-Public* as the expected prize is reduced. [6] On the other hand, if $\lambda v/2 < c$ then the lagging player will not enter in period 2, so that this contest is equivalent to *WTA-Public*. Moreover, if neither player succeeds in period 1, then the decision to enter in period 2 is still governed by the inequality in (1). Thus, from the designer's point of view, the *WTA-Public* contest weakly dominates the *Shared-Public* contest.

WTA-Private. A *WTA-Private* contest combines the winner-take-all allocation rule with a disclosure policy that withholds information about the decisions and

[6] This may also encourage free-riding as players may benefit from waiting to learn more about the state of the world. Our parameter choices are such that this situation does not arise.

outcomes in period 1 until the end of period 2. The period 1 decision is essentially the same as the period 1 decision for a *WTA-Public* contest. Where the two differ is in the second period. In the *WTA-Private* contest, period 2 R&D may be futile as the other person may have already been successful and thus claimed the entire prize. The period 2 entry decision of player i thus depends on the following inequality:

$$\Pr(j \text{ failed}|i \text{ failed})p_1\lambda\tilde{v} \geq c \tag{2}$$

Since $\Pr(j \text{ failed}|i \text{ failed})p_1 < p_1$, there are situations in which players will want to enter in period 2 under *WTA-Public* rules, but not under *WTA-Private* rules. Thus, from the designer's perspective *WTA-Public* dominates *WTA-Private*.

Shared-Private. A *Shared-Private* contest combines the prize sharing allocation rule with the non-disclosure rule. Since information about success (and failure) remains private, the intentional duplication problem that arises under *Shared-Public* is alleviated here, although duplication could still occur. Since a player can learn nothing about the counterpart after period 1, there is no loss in assuming that a player will enter in period 1 if they enter the contest at all. For parameters such that both players enter the contest in period 1, a player who is unsuccessful in period 1 must take into account two alternative possibilities when deciding whether to try again in period 2. First, his counterpart may have succeeded already, in which case the player's posterior belief that he is in the good state of the world is 1, and he will earn $v/2$ if he enters and succeeds in period 2. Second, his counterpart may have also failed in period 1, in which case his posterior is p_1, and he will earn $\tilde{v}$ if he enters and succeeds in period 2. The decision to enter in period 2 thus depends on the following inequality:

$$\Pr(j \text{ succeeded}|i \text{ failed})\lambda\frac{v}{2} + \Pr(j \text{ failed}|i \text{ failed})p_1\lambda\tilde{v} \geq c \tag{3}$$

Crucially, there are combinations of parameters under which (3) is less stringent than (1), so that the designer may sometimes prefer a *Shared-Private* contest to *WTA-Public*, despite *WTA-Public* (weakly) dominating both *WTA-Private* and *Shared-Public* in the sense of maximizing the probability of at least one success. Intuitively, this is because concealing information in *Shared-Private* eliminates the discouragement spillover that arises from observing two unsuccessful attempts at innovation in period 1 that can arise in *WTA-Public* and because sharing the prize allows the player to condition his value of entry in period 2 partly on the possibility that his counterpart was successful (and not only on the possibility that he failed). Various combinations of parameters can generate the same results, but the conditions are non-monotonic, making simple comparisons difficult. Our experimental design uses parameter values that alter this comparative static to provide a test of the model. The specific parameters and associated theoretical predictions are in the next section.

3 Experimental Design

The experiments are designed to evaluate the relative success of each innovation contest structure for encouraging innovation. In particular, the goal is to determine whether *WTA-Public* dominates both *WTA-Private* and *Shared-Public* as predicted but that the relative success of *WTA-Public* and *Shared-Private* depends on the likelihood of innovation success. Specifically, we hold constant the values of v, c, and p_{good} at \$40, \$6, and 0.8, respectively and vary the value of λ within each contest format. While in principle, we could have varied other parameters to get similar comparative static predictions, we chose to vary λ because we thought that this was the simplest for subjects to understand and still offer policy guidance to contest designers facing challenges of varying difficulty.[7]

The experiments were conducted in the Experimental Economics Laboratory at the University of Alaska - Anchorage. Subjects were recruited from the lab's standing pool of volunteers, the vast majority of who are undergraduates at the school. Subjects were given \$5 for arriving on time for the one hour study. Subjects also received salient earnings which averaged \$26.11. A total of 56 subjects completed the study. Six additional subjects, one per session, served as monitors, a role that is explained below.

The decision environment is complex and several iterations of the experimental procedures were tested in pilot sessions. The final design delivered instructions via an automated PowerPoint presentation, physical props, and a written response form in order to facilitate subject understanding.[8] To further facilitate understanding of the within-subject design, the various treatments, which correspond to the different innovation contest formats, were introduced in a fixed sequence, although subjects could revisit past decisions at any point in an effort to mitigate possible order effects. Here the experimental procedures are described in the corresponding manner to facilitate reader understanding.

[7]The other obvious candidate to vary is p_{good}, which could be used to generate similar predictions. Ultimately, this design decision is arbitrary *ex ante*, although it could have behavioral implications *ex post*.

[8]The PowerPoint is available for download here:
`https://www.dropbox.com/s/3gqqvpkarwnn6ui/FinalInstructions.pptx?dl=0`.

3.1 Start of a Session

Subjects entered the lab and were seated at private cubicles. An automated presentation was shown on a screen at the front of the lab. As explained in the presentation, one subject was randomly selected to be the monitor based on the role of a die. The role of the monitor was to ensure that all of the procedures described in the presentation were implemented exactly.

3.2 Individual Choices

The presentation first described how an *Individual* choice task would work. These tasks involve a single period in which a single player could choose to attempt to make an innovation. To the subjects, opportunity to engage in R&D was presented as the opportunity to draw a poker chip from a bag containing 20 chips. Drawing a green chip corresponded to innovation success (worth $40) and drawing a black chip corresponded to innovation failure (worth $0). The cost of innovation was implemented as an opportunity cost as subject would receive $6 for not drawing a chip. Since the $p_{good} = 0.8$, subjects were informed that a 10 sided die would be rolled and if the die landed on a 1 or a 2 then a bag with 20 black chips would be used and if the die landed on a 3 - 10 a bag containing a mix of green and black chips would be used. The die, chips, and bags were shown to the subjects. The presentation explained that the response form would contain 5 individual choice tasks that differed by the number of green chips that might be in the bag (i.e. the value of λ). The presentation also explained that subjects would complete a total of 25 tasks, the five *Individual* tasks plus 20 additional tasks that would be explained as the experiment progressed, and that exactly one of these 25 tasks would be randomly selected to determine the subject's payment. No outcomes were realized until all 25 tasks were completed. After going through some example scenarios, the subjects completed a set of comprehension questions, correct answers to which were worth \$0.50 apiece. Once every subject's responses to the comprehension questions were checked by the researcher, the response forms for *Individual* choices were distributed and subjects indicated their choices.[9]

The specific values of λ were 0.00, 0.15, 0.25, 0.40, and 0.70, which correspond to 0, 3, 5, 8, and 14 green chips accordingly. Because of the individual nature of these tasks, in addition to familiarizing subjects with the experiment, responses can be used to classify the risk attitude of a subject. The specific values of λ were selected as they closely correspond to the constant relative risk aversion (CRRA) parameter thresholds from Holt and Laury (2002).

3.3 Shared - Private Choices

After everyone had completed the *Individual* tasks, *Shared-Private* contests were introduced. Referred to only as Private choices, the task introduced the concept of a two period problem in which the outcomes depended on the choices and success of two players. The presentation went through several examples after which the subjects answered more paid comprehension questions. Finally, the response forms were distributed and the subjects could make their decisions. At this point in the experiment, subjects were required to attempt innovation in period 1. This design feature was intended to reduce confusion by focusing subjects' attention on second period decisions.[10] The response form only asked the subject if she wanted to make a second draw from the bag conditioned on having drawn a black chip initially. The

[9]Copies of the comprehension questions, response forms, and survey are available in an online appendix: https://www.dropbox.com/s/zfg30pyxrudepj1/ResponseForm.pdf?dl=0.

[10]Choices were elicited via the strategy method, as subjects were subsequently allowed make decisions for period 1; see below.

values of λ were 0.05, 0.25, 0.50, 0.75, and 1.00. We discuss the predicted behavior for different values of λ below after introducing the other contest formats.

3.4 Subsequent Choices

In turn the *WTA-Private*, referred to as Private Choice - First Green, the *WTA-Public*, referred to as Public Choice - First Green, and the *Shared-Public*, referred to as Public Choice - Any Green were introduced. In each case the directions explained the difference between the current rules and the rules that were in place previously. The presentation went through relevant examples to highlight the changes and each section involved paid comprehension questions. The values of λ were the same in each of these contest formats as in *Shared-Private*.

3.5 End of the Experiment

After completing all 5 response forms, subjects were then given the option to opt out of any of the two period innovation contests they wished by placing an X over the specific scenario on the appropriate response form. This implementation of the strategy method was designed to reduce confusion by facilitating backward induction. This also means that subjects could not opt to not attempt innovation in period 1, but then attempt innovation in period 2.[11] That is, the decision to opt out meant that the subject would not draw a chip at either opportunity and as a result would earn $12 ($6 for each opportunity to draw a chip that was not taken). As explained to the subjects, random pairs were formed among those subjects that did not opt out, and thus one's period 2 decisions were always contingent on both players attempting innovation in period 1.

[11] Given the parameters, this is never an optimal strategy.

Once all of the subjects were satisfied with their responses, all of the forms were collected. The monitor then rolled a die to decide which task would be used for determining payment. The monitor then rolled another die to determine the number of green chips that the monitor would place in the bag. The researcher then held the bag while the monitor drew on behalf of each subject (with replacement). This process was done in front of the subjects. Each subject had been assigned an ID number to maintain anonymity while allowing the subject to know when the monitor was drawing on her behalf. With the exception of the monitor, the subjects then completed a brief survey that included demographic questions and the cognitive reflection task (CRT) of Frederick (2005), received their payment in private, and were dismissed from the experiment.

3.6 Predicted Behavior

In the *Individual* choices, a risk-neutral player will enter whenever $\lambda > 0.1875$. Table 1 reports the predicted entry decision for the four main contest structures of interest for each value of λ, under the assumption of risk neutrality.

In general, WTA-Public is expected to induce more innovation than WTA-Private and at least as much innovation as Shared-Public. The main other prediction of interest is that when λ is low (0.25), the WTA-Public contest is predicted to induce the most innovation, but when λ is high (0.75), the Shared-Private contest is predicted to induce the most innovation. Thus, the theory makes predictions about which contest the designer will prefer under various regimes, and the experiment will allow us to determine whether the same contests that are theoretically optimal are also behaviorally optimal.

WTA-Private		
λ	Period 1	Period 2 | f_i
0.05	Exit	Exit
0.25	Enter	Exit
0.50	Enter	Exit
0.75	Enter	Exit
1.00	Enter	Exit

WTA-Public			
λ	Period 1	Period 2 | f_i & f_j	Period 2 | f_i & s_j
0.05	Exit	Exit	Exit
0.25	Enter	Enter	Exit
0.50	Enter	Enter	Exit
0.75	Enter	Exit	Exit
1.00	Enter	Exit	Exit

Shared-Private		
λ	Period 1	Period 2 | f_i
0.05	Exit	Exit
0.25	Enter	Exit
0.50	Enter	Enter
0.75	Enter	Enter
1.00	Enter	Exit

Shared-Public			
λ	Period 1	Period 2 | f_i & f_j	Period 2 | f_i & s_j
0.05	Exit	Exit	Exit
0.25	Enter	Enter	Exit
0.50	Enter	Enter	Enter
0.75	Enter	Exit	Enter
1.00	Enter	Exit	NA

Table 1: **Summary of Predicted Behavior for Two-Period Contests.** Let f be an indicator variable for failure in period 1, and let s be an indicator variable for success in period 1.

4 Experimental Results

In the *Individual* tasks, the participants had to decide if they wished to attempt an innovation or not. Table 2 classifies participants based upon their decisions in the *Individual* task. 89% of the participants behaved in a manner consistent with having CRRA utility.[12] Borrowing the classifications from Holt and Laury (2002), Table 2 suggests that the vast majority of the participants can be classified as risk neutral or slightly risk averse. A few participants are risk averse, but only a very small number are very risk averse or risk loving.

The results now shift to the two-period two-player innovation contests. While the focus of the experiments is on behavior in period 2, it is worth noting that all four contest structures should generate identical period 1 decisions given the selected parameters. This is largely the case. Table 3 shows the average period 1 entry rate by λ. With the exception of the case in which innovation is highly unlikely ($\lambda = 0.05$),

[12]The comparable rate in the baseline condition of Holt and Laury (2002) was 87%.

participants should engage in R&D in period 1, and they typically do. However, participants also frequently engage in R&D in period 1 even when they should not.

Share of Subjects	CRRA Parameter Interval
0.05	$(-\infty, -0.12]$
0.30	$[-0.12, 0.15]$
0.36	$[0.15, 0.40]$
0.14	$[0.40, 0.69]$
0.04	$[0.69, \infty]$
0.11	NA

Table 2: Behavior in Individual Contests.

Table 4 shows the results of a linear probability regression model with standard errors clustered at the subject level, as subjects do not interact. The specification includes indicator variables for each contest structure interacted with each value of λ as well as various control variables for age, sex, risk (the number of entry decisions in the *Individual* tasks), and CRT score. The constant term captures entry rates conditional on the covariates in the *Shared-Private* contest with $\lambda = 0.05$, and the coefficients on the other contest$\times\lambda$ variables can be interpreted as marginal effects of the specified treatment and parameter combination.[13]

The theory predicts identical behavior across treatments for each value of λ in period 1. Table 3 reports the treatment entry rates, the average entry rate across treatments and the p-value associated with the F-test that the relevant coefficients in column (1) of Table 4 are identical. Only when $\lambda = 0.05$ do we find a significant treatment difference, driven by slightly higher entry rates in the *Public* contests.

Turning to the main focus of the paper, Figure 1 plots the percentage of potential innovators who attempt R&D again in period 2 after a period 1 failure. Several

[13]The results are qualitatively unchanged if we instead use logistic regression (see Appendix A), but we prefer OLS for ease of interpretation.

λ	*Shared Private*	*WTA Private*	*Shared Public*	*WTA Public*	Average Entry Rate	Test of Equal Entry F-Stat	p-value
0.05	0.62	0.59	0.73	0.71	0.66	3.06	0.04
0.25	0.84	0.82	0.86	0.89	0.85	1.02	0.39
0.50	0.93	0.88	0.93	0.98	0.93	2.37	0.08
0.75	0.96	0.91	0.89	0.95	0.93	1.33	0.27
1.00	0.66	0.71	0.75	0.73	0.71	1.25	0.30

Table 3: Behavior in Period 1 of Innovation Contests.

patterns become immediately apparent in this figure. First, in a *Shared-Public* contest, there is considerable copy-catting after a rival's success, particularly when λ is high.[14] Column (2) of Table 4 provides regression analysis of period 2 behavior with standard errors clustered at the subject level. The copycat behavior is evidenced by the positive and significant coefficients for the SharedPublic $\times$ Other Success_1 $\times$ $\lambda = 0.50$ and SharedPublic $\times$ Other Success_1 $\times$ $\lambda = 0.75$ variables in column (2) of the table.[15] This leads to Finding 1.

Finding 1. A *Shared-Public* innovation contest encourages costly duplication following successful innovation.

While a rival's success leads to costly duplication in *Shared-Public*, if neither participant is successful in period 1, then a *Shared-Public* contest and a *WTA-Public* contest are strategically equivalent. This is the pattern revealed in Figure 1. Statistical support for this pattern can be found in Table 4. Wald tests cannot reject that the coefficient on Shared-Public $\times$ $\lambda = X$ equals the coefficient on WTA-Public x $\lambda = X$ for X = 0.05, 0.25, 0.50, 0.75, or 1.00, all p-values > 0.15. This provides the support Finding 2.

[14] When $\lambda = 1$, either both innovators are successful in period 1 or both fail and hence costly duplication cannot arise.

[15] Note that when $\lambda = 0.05$ or 0.25, even when the other person has already succeeded, a risk-neutral player will choose not to copycat because the expected value of entry for a shared prize is low. When $\lambda = 1$, it is not possible for one player to succeed in period 1 and the other player to fail.

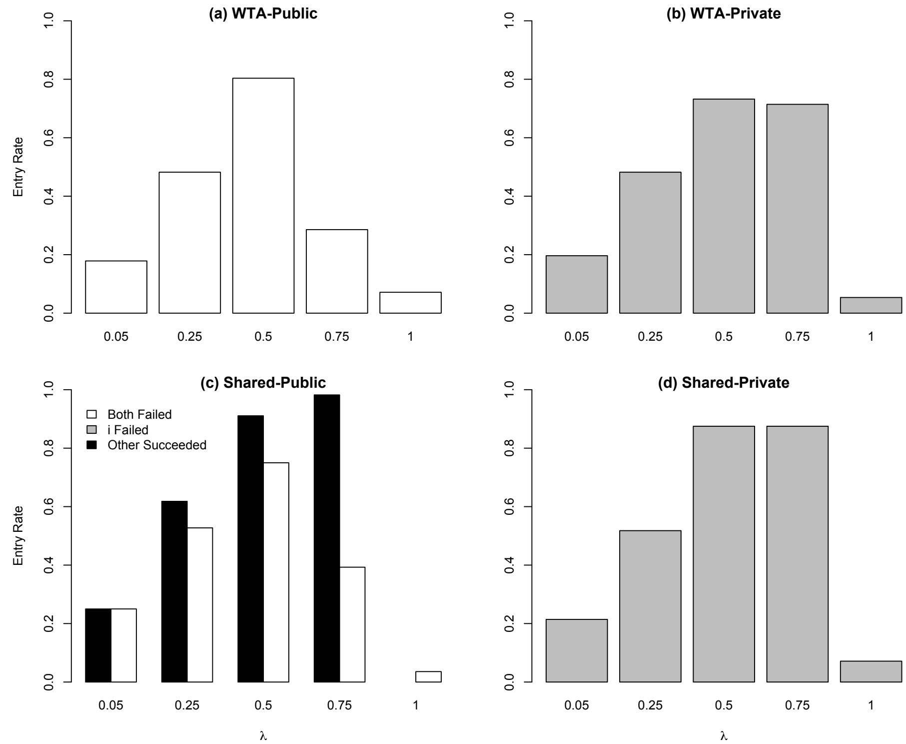

Figure 1: **Probability of Entry in Period 2.**

Finding 2. A *Shared-Public* contest and a *WTA-Public* contest are behaviorally indistinguishable in period 2 if neither potential innovator had success in period 1.

Findings 1 and 2 together confirm that a *WTA-Public* contest dominates a *Shared-Public*.

Another pattern that is apparent from Figure 1 is that *WTA-Private* and *Shared-Private* lead to qualitatively similar behavior. In both types of contests, when innovation success is likely, many participants engage in R&D even after an initial failure. [16] However, the rate at which a second attempt at innovation is made is statistically higher in *Shared-Private* than in *WTA-Private*. Formally, Wald tests that the coefficients on WTA-Private $\times$ $\lambda = X$ and Shared-Private $\times$ $\lambda = X$ for X = 0.05, 0.25,

[16]When $\lambda = 1$, failure in period 1 reveals that the bad state has occurred with certainty, and there is no point in attempting to innovate. Very few participants do.

Entered Contest	Period 1 (1)	Period 2 (2)
WTA-Public ×λ=0.05	0.107*	-0.036
	(0.049)	(0.063)
WTA-Public ×λ=0.25	0.232**	0.268**
	(0.068)	(0.087)
WTA-Public ×λ=0.50	0.304***	0.589***
	(0.068)	(0.081)
WTA-Public ×λ=0.75	0.268***	0.071
	(0.066)	(0.067)
WTA-Public ×λ=1	0.125	-0.143*
	(0.068)	(0.060)
Shared-Public ×λ=0.05	0.089	0.036
	(0.047)	(0.057)
Shared-Public ×λ=0.25	0.268***	0.314***
	(0.066)	(0.079)
Shared-Public ×λ=0.50	0.357***	0.536***
	(0.065)	(0.081)
Shared-Public ×λ=0.75	0.321***	0.179**
	(0.064)	(0.064)
Shared-Public ×λ=1	0.107	-0.179**
	(0.067)	(0.058)
Shared-Public × Other Success$_1$ × λ=0.05		0.000
		(0.058)
Shared-Public × Other Success$_1$ × λ=0.25		0.091
		(0.080)
Shared-Public × Other Success$_1$ × λ=0.50		0.161**
		(0.056)
Shared-Public × Other Success$_1$ × λ=0.75		0.589***
		(0.072)
WTA-Private ×λ=0.05	-0.036	-0.018
	(0.051)	(0.060)
WTA-Private ×λ=0.25	0.196**	0.268**
	(0.065)	(0.079)
WTA-Private ×λ=0.50	0.250***	0.518***
	(0.069)	(0.093)
WTA-Private ×λ=0.75	0.286***	0.500***
	(0.067)	(0.077)
WTA-Private ×λ=1	0.089	-0.161*
	(0.069)	(0.062)
Shared-Private ×λ=0.25	0.214***	0.304***
	(0.056)	(0.081)
Shared-Private ×λ=0.50	0.304***	0.661***
	(0.063)	(0.069)
Shared-Private ×λ=0.75	0.339***	0.661***
	(0.065)	(0.065)
Shared-Private ×λ=1	0.036	-0.143*
	(0.063)	(0.065)
Age	-0.005	0.003
	(0.005)	(0.002)
Female[a]	-0.017	-0.087*
	(0.069)	(0.041)
Cognitive Reflection	-0.091**	0.016
	(0.029)	(0.021)
# of Entries in Individual Choices	-0.006	0.079**
	(0.025)	(0.026)
Constant	0.879***	-0.017
(Shared-Private ×λ=0.05)	(0.143)	(0.116)
Observations	1119	1342
R-Sq.	0.167	0.395

Clustered standard errors in parentheses.
* p < 0.05, ** p < 0.01, *** p < 0.001
[a] One subject chose not to identify as male or female, so the regression includes a dummy for that subject, which is suppressed in the table.

Table 4: Regression Analysis of Contest Entry, by Period.

0.50, 0.75, or 1.00 reject the null of equal entry rates, as predicted (see Table 1), only when $\lambda = 0.50$ and 0.75, p-values = 0.03 and 0.02, respectively. This provides the basis for Finding 3.

Finding 3. A Winner-Take-All payment rule discourages innovation in period 2 when period 1 outcomes remain private.

While Finding 3 is consistent with the theoretical predictions, it is important to recognize that behavior in these contests does not closely follow the theory. For *Shared-Private*, participants are not predicted to engage in R&D when $\lambda = 0.25$, but they do. For *WTA-Private* participants are never predicted to engage in R&D following failure in period 1, but commonly do anyway. Interestingly, both of these errors work in the favor of the designer.

A fourth pattern that emerges from Figure 1 is that Public disclosure of period 1 outcomes can discourage innovation when success is likely. In particular, when $\lambda = 0.75$ a second innovation attempt is more likely in *Shared-Private* than *Shared-Public* and more likely in *WTA-Private* than *WTA-Public*. These comparisons are statistically significant based on Wald tests comparing the relevant coefficients in Table 4, both p-values < 0.001. This provides the support for Finding 4.

Finding 4. Public disclosure of period 1 outcomes can discourage subsequent innovation attempts regardless of the payment rule.

Finding 4 contradicts the prediction that a *WTA-Public* contest dominates a *WTA-Private* contest. Findings 3 and 4 together suggest that a *Shared-Private* contest may be the best choice for the designer. The final finding addresses this issue directly. Theoretically, a *Shared-Private* contest should only be preferable to *WTA-Public* when $\lambda = 0.75$. When $\lambda = 0.25$ the reverse should be true. For the other values of λ used in the experiment, the two should generate the same pattern of behavior. Table 5 reports the p-values associated with testing that period 2 entry behavior is the same for each λ based on the regression results in Table 4. The results in Table 5 show that *Shared-Private* leads to more period 2 R&D when it should, but never leads to lower period 2 R&D. This yields the following.

Finding 5. A Shared-Private contest encourages the most innovation.

λ	Entry Rate Difference[a]	Test of Equal Entry F-Stat	Test of Equal Entry p-value
0.05	0.04	0.32	0.57
0.25	0.04	0.21	0.65
0.50	0.07	1.58	0.21
0.75	0.60	77.27	<0.001
1.00	0.00	0.00	1.00

[a]Difference in entry rates computed as *Shared-Private* − *WTA-Public*.

Table 5: Comparison of Shared-Private and WTA-Public.

The analysis in table 4 also reveals that personal characteristics have some impact on innovation behavior. In particular, in period 1 the results indicate that subjects with higher CRT scores are less willing to enter, while age and gender do not play a role. With respect to period 2, women are less likely to try again, but age and CRT scores are not significant determinants. Risk is significant in period 2, but not period 1. This is driven by the fact that the expected gain from entering is closer to the expected cost in period 2, providing more scope for the levels of risk aversion observed in the Individual tasks to influence behavior.

5 Conclusion

As contests continue to be used as a mechanism to encourage innovation in a targeted area, it is important to understand how the specific structure of the contests impacts the incentives of potential innovators. In the laboratory, we vary two aspects of a contest's structure that a designer can manipulate: the payment rule and the disclosure rule, which Halac *et al.* (forthcoming) model theoretically. A winner-take-all contest with public disclosure of early successes and failures avoids the later copycat behavior that a contest with public disclosure in which all successful innovators share in the prize encourages. Further, public disclosure in a winner-take-all contest should encourage more innovation than a winner-take-all contest where this information remains private, as the fear of being locked out of the prize discourages subsequent attempts to innovate. However, a key insight of Halac *et al.* (forthcoming) is that in some situations a contest where early outcomes remain private and all successful innovators share in the prize can be optimal. This is because such a contest avoids the discouraging effect that learning of other's failures can provide while eliminating the concern about being shut out of contention for prize money.

In the laboratory, public disclosure did encourage wasteful copycat behavior when the prize was shared, indicating that a winner-take-all contest is preferable to a shared prize contest when performance is publicly disclosed.[17] However, public disclosure is found to discourage innovation attempts regardless of the payment scheme. Further, a winner-take-all rule discourages innovation when outcomes from early attempts at innovation remain private. Therefore, from a behavioral perspective a private information prize sharing contest is optimal in our setting. Of course, further research on this topic such as understanding why public revelation discourages innovation is warranted along with tests of alternative contest structures.

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[17] In the general model of Halac *et al.* (forthcoming), sharing can also weaken the overall incentive to innovate, but that does not arise theoretically or behaviorally in the discrete two period setting.

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A Additional Analysis

Entered Contest	Period 1 (1)	Period 2 (2)
WTA-Public $\times\lambda$=0.05	0.573*	-0.239
	(0.251)	(0.416)
WTA-Public $\times\lambda$=0.25	1.449***	1.316**
	(0.412)	(0.455)
WTA-Public $\times\lambda$=0.50	2.272***	2.904***
	(0.594)	(0.523)
WTA-Public $\times\lambda$=0.75	1.803***	0.407
	(0.437)	(0.383)
WTA-Public $\times\lambda$=1	0.679	-1.315*
	(0.363)	(0.582)
Shared-Public $\times\lambda$=0.05	0.471*	0.213
	(0.238)	(0.338)
Shared-Public $\times\lambda$=0.25	1.797***	1.519***
	(0.441)	(0.413)
Shared-Public $\times\lambda$=0.50	3.751***	2.575***
	(0.987)	(0.485)
Shared-Public $\times\lambda$=0.75	2.591***	0.923**
	(0.553)	(0.333)
Shared-Public $\times\lambda$=1	0.573	-2.059**
	(0.347)	(0.772)
Shared-Public $\times$ Other Success$_1$ $\times$ λ=0.05		0.000
		(0.323)
Shared-Public $\times$ Other Success$_1$ $\times$ λ=0.25		0.403
		(0.351)
Shared-Public $\times$ Other Success$_1$ $\times$ λ=0.50		1.280**
		(0.471)
Shared-Public $\times$ Other Success$_1$ $\times$ λ=0.75		4.644***
		(1.128)
WTA-Private $\times\lambda$=0.05	-0.176	-0.115
	(0.251)	(0.386)
WTA-Private $\times\lambda$=0.25	1.158**	1.316**
	(0.371)	(0.412)
WTA-Private $\times\lambda$=0.50	1.616***	2.476***
	(0.479)	(0.545)
WTA-Private $\times\lambda$=0.75	2.017***	2.381***
	(0.531)	(0.445)
WTA-Private $\times\lambda$=1	0.471	-1.628*
	(0.367)	(0.680)
Shared-Private $\times\lambda$=0.25	1.298***	1.470***
	(0.333)	(0.426)
Shared-Private $\times\lambda$=0.50	2.272***	3.466***
	(0.546)	(0.540)
Shared-Private $\times\lambda$=0.75	3.027***	3.466***
	(0.715)	(0.494)
Shared-Private $\times\lambda$=1	0.182	-1.315*
	(0.317)	(0.635)
Age	-0.037	0.019
	(0.031)	(0.012)
Female[a]	-0.237	-0.576*
	(0.586)	(0.271)
Cognitive Reflection	-0.755***	0.103
	(0.227)	(0.136)
# of Entries in Individual Choices	-0.093	0.526**
	(0.212)	(0.179)
Constant	2.788**	-2.941***
(Shared-Private $\times\lambda$=0.05)	(1.079)	(0.801)
Observations	1119	1342
R-Sq.	0.19	0.34

Clustered standard errors in parentheses.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
[a] One subject chose not to identify as male or female, so the regression includes a dummy for that subject, which is suppressed in the table.

Table A1: Logistic Regression Analysis of Contest Entry, by Period.

Table A1 shows that the analyses reported in the body of the paper are robust to using logistic regression in place of OLS.