ESSAYS ON EXPERIMENTAL GROUP DYNAMICS AND COMPETITION

by

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To my parents, Deb and Jeff

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ABSTRACT

This thesis consists of three chapters. In the first chapter, I investigate the effects of complexity in various voting systems on individual behavior in small group electoral competitions. Using a laboratory experiment, I observe individual behavior within one of three voting systems – plurality, instant runoff voting (IRV), and score then automatic runoff (STAR). I then estimate subjects' behavior in three different models of bounded rationality. The estimated models are a model of Level-K thinking (Nagel, 1995)[1], the Cognitive Hierarchy (CH) model (Camerer, et al. 2004)[2], and a Quantal Response Equilibrium (QRE) (McKelvey and Palfrey 1995)[3]. I consistently find that more complex voting systems induce lower levels of strategic thinking. This implies that policy makers desiring more sincere voting behavior could potentially achieve this through voting systems with more complex strategy sets. Of the tested behavioral models, Level-K consistently fits observed data the best, implying subjects make decisions that combine of steps of thinking with random, utility maximizing, errors.

In the second chapter, I investigate the relationship between the mechanisms used to select leaders and both measures of group performance and leaders' ethical behavior. Using a laboratory experiment, we measure group performance in a group minimum effort task with a leader selected using one of three mechanisms: random, a competition task, and voting. After the group task, leaders must complete a task that asks them to behave honestly or dishonestly in questions related to the groups performance. We find that leaders have a large impact on group performance when compared to those groups without leaders. Evidence for which selection mechanism performs best in terms of group performance seems mixed. On measures of honesty, the strongest evidence seems to indicate that honesty is most positively impacted through a voting selection mechanism, which differences in ethical behavior between the random and competition selection treatments are negligible.

In the third chapter, I provide an investigation into the factors and conditions that drive "free riding" behavior in dynamic innovation contests. Starting from a dynamic innovation contest model from Halac, et al. (2017)[4], I construct a two period dynamic innovation contest game. From there, I provide a theoretical background and derivation of mixed strategies

that can be interpreted as an agent's degree to which they engage in free riding behavior, namely through allowing their opponent to exert effort in order to uncover information about an uncertain state of the world. I show certain conditions must be fulfilled in order to induce free riding in equilibrium, and also analytically show the impact of changing contest prize structures on the degree of free riding. I end this paper with an experimental design to test these various theoretical conclusions in a laboratory setting while also considering the behavioral observations recorded in studies investigating similar contest models and provide a plan to analyze the data collected by this laboratory experiment.

1. INTRODUCTION

This thesis studies the dynamics of group decision-making. While the specific context of the studies contained within varies, the focus of the chapters of these thesis study individual behavior in an electoral process, the impact of how leaders are picked on both group performance and leader behavior, and a group innovation and experimentation process. Throughout this thesis I focus on behavioral aspects that cause individual behavior to differ from behavior predicted from standard economic models and assumptions. I apply an experimental laboratory setting as a means by which to provide a controlled environment to isolate behavior of interest while reducing the impact of outside confounding factors.

In the first chapter, I study how individual behavior differs in various electoral environments using a laboratory experiment. In particular, I analyze voter behavior in small groups using three different electoral mechanisms: a plurality voting system, an instant runoff voting (IRV) system, and a score then automatic runoff (STAR) system. The main differentiating factor of these three systems is the levels of *complexity* inherent across the three different systems. Complexity here is defined as the breadth of available relevant actions available to individual group members. This complexity differs substantially between these systems, potentially complicating the decision-making process. I test the hypothesis that this complexity causes individuals to rely on less sophisticated, heuristic based decision making which leads to a number of secondary effects in these small group elections; specifically, less strategic manipulation and improvements on aggregate group metrics in terms of outcomes.

To form a deeper understanding of how these individuals are making decisions across these different settings, I estimate several structural behavioral models using the collected laboratory data and compare these estimations to find evidence supporting which of these models best reflect the kinds of decision-making being employed by these subjects. In total, I estimate three different behavioral models: the Level-k model, the Cognitive Hierarchy (CH) model (Camerer, et al. 2004)[2], and the Quantal Response Equilibrium (QRE) model (McKelvey and Palfrey 1995)[3]. The first two of these models use "steps" of thinking, where individuals of higher order steps are responding to beliefs about behavior of lower order steps. The QRE model assumes individual behavior under degrees of noisy decision-making. I find strong evidence to indicate that individuals in the settings studied choose actions most closely reflected by the Level-k model, which uses the simplest belief structure combined with noisy, near best response errors in decision-making.

In the second chapter, I investigate the impact of how leaders are picked in groups on two primary factors: their group's performance on a group coordination task and subsequent ethical decisions made by that leader related to the group's performance. I again utilize an experimental setting to study both individual and group dynamics. In this study we employ different methods of choosing a leader: either by random chance, a voting system, or by a competition mechanism. Leaders facilitate coordination and communicate with group members during a group task over multiple rounds. Following the group task, leaders are asked to make decisions related to their groups performance framed as reporting this performance to an external regulatory body or set of shareholders. Over-reporting group performance leads to payoff gains for the leader at no cost to themselves or any other group members. Given this context, we are primarily interested in addressing two main questions: first, does the method by which leaders are chosen affect their willingness to be dishonest in the reporting task? And second, does the method by which leaders are picked impact group performance metrics?

Our results of this experiment indicate that how leaders are picked has little to no impact on group performance metrics, measured through either group effort, average group payoff, or by metrics such as the coordination rate of individual group members. However, we do find evidence that indicates how leaders are picked does impact their ethical decisions in the reporting task. More specifically, we find some evidence to indicate that a voting mechanism to choose leaders induces higher levels of honesty when compared to both the random and competition voting tasks. We also find considerable heterogeneity in how these leadership mechanisms interact with these honesty choices; while the random treatment and voting treatment both show fairly consistent marginal impacts on the leader's willingness to over-report group metrics, this behavior varies greatly depending on the magnitude of the incentives offered when leaders are selected by the competition mechanism.

In the third chapter, I provide an analysis of a two person, two period innovation contest game. The main questions addressed in this topic are three-fold. First, how does changing the contest structure affect “free-riding” behavior, or a reduction of effort by individuals in order to benefit from information generated by other’s actions? Second, how do the individual model parameters affect predicted behavior? And lastly, does empirically observed behavior match both the theoretical predictions and respond as predicted to changes in the contest environment? Starting with a model of innovation contests developed by Halac, et al. (2017)[4], I extend the two period model in their setting to include strategies wherein a mixed strategy is played in the first period followed by a pure strategy played in the second period. In this chapter I focus on two types of contests introduced in the original paper: a winner-take-all (WTA) competition in which the first person to obtain an innovation is rewarded, and an equal-sharing (ES) competition where the reward is non-rivalrous. I demonstrate the conditions that lead to a mixed strategy Nash equilibrium for risk-neutral agents in this setting. I provide support for how this equilibrium changes based on changes to model parameters. Furthermore, I demonstrate that not only does an ES competition create more incentive for free-riding behavior and reduces equilibrium effort in this game, but that model parameters in this model have heterogeneous effects on equilibrium behavior across games.

I continue this chapter by outlining an experimental procedure that serves an extension to a similar experimental study conducted in Deck and Kimrough (2017)[5] using a similar two-period innovation game environment. By allowing subjects to choose a mixed strategy in the first stage of this game rather than explicitly asking for pure strategies, it both expand the kinds of strategic choices individuals can engage in during this experiment as well as provide a direct avenue to be able to measure free-riding behavior. This procedure also provides an analogous environment to the theoretically motivated setting discussed previously. Ending this chapter I provide a brief overview with the variables of interest and planned data processes used to test the various hypotheses and address the key questions approached by this research topic.

2. THE EFFECT OF COMPLEXITY IN AN ELECTORATE: EXPERIMENTAL EVIDENCE

This chapter will be submitted to a journal for publication.

This paper investigates the effects of complexity in various voting systems on individual behavior in small group electoral competitions. Using a laboratory experiment, I observe individual behavior within one of three voting systems – plurality, instant runoff voting (IRV), and score then automatic runoff (STAR). I then estimate subjects' behavior in three different models of bounded rationality. The estimated models are a model of Level-K thinking (Nagel, 1995) [1], the Cognitive Hierarchy (CH) model (Camerer, et al. 2004) [2], and a Quantal Response Equilibrium (QRE) (McKelvey and Palfrey 1995) [3]. I consistently find that more complex voting systems induce lower levels of strategic thinking. This implies that policy makers desiring more sincere voting behavior could potentially achieve this through voting systems with more complex strategy sets. Of the tested models, Level-K consistently fits observed data the best, implying subjects make decisions that combine of steps of thinking with random, utility maximizing, errors.

2.1 Introduction

Democratic institutions around the world use voting systems that vary in complexity. For example, the most widely used voting system in the United States is the plurality voting system, which is relatively simple. Australia, on the other hand, uses an instant-runoff voting system, which is relatively complicated. Determining optimal behavior even in simple voting systems like plurality voting, however, depends on sets of complex beliefs. Notions of Nash Equilibrium can be applied to these voting settings but require mathematically rigorous calculations and complicated belief structures to solve for predicted equilibrium behaviors.[1] As these calculations become more difficult and cognitive load increases as the complexity of

[1]↑Examples of standard theory that reconcile familiar game theoretic concepts such as Nash equilibrium with a voting framework include Meyerson and Weber, 1993. [6]

the environment increases, Nash equilibrium predictions may not accurately reflect observed behavior.

In this paper, I demonstrate that the complicated nature of voting systems will result in a significant portion of the population exhibiting non-strategic behavior. Strategic behavior here is defined as payoff-maximizing decisions inconsistent with strict preferences for certain candidates. I make this prediction as even a simple voting system with relatively few relevant strategies, such as plurality voting, relies on complicated beliefs. The complicated nature of this mechanism, then, may drive individuals towards more heuristic decision making. Furthermore, as more and more complicated voting rules are introduced, this type of heuristic decision making may be relied upon to an even greater extent. As such, I predict that the level of non-strategic behavior increases as voting mechanisms become more complex, that is, as the set of undominated strategies increase. I expect that the more complex an environment is, the more likely it is to result in non-strategic behavior.

I aim to test these two predictions in this paper. I do this by analyzing individual behavior under several different voting rules that differ by complexity. Using data from a laboratory experiment, I estimate three established models of bounded rationality to determine the levels of strategic behavior: (i) Level-K (Nagel, 1995) [1], (ii) Cognitive Hierarchy (Camerer, et al. 2004) [2], and (iii) Quantal Response Equilibrium (McKelvey and Palfrey, 1995) [3]. I utilize both the laboratory experiment and the models to address several key questions regarding how complexity impacts both individual decision making and aggregate group outcomes.

This study creates an important addition to the existing body of literature for both the analysis of voting systems and the study of individual choices using a non-Nash equilibrium framework. By analyzing differences between voting systems and applying several different behavioral frameworks, this study meaningfully adds to the existing body of literature by providing a deeper understanding of individual behavior across relatively complicated mechanisms. The complex nature of these mechanisms is the main reason why the use of a behavioral framework is very useful when studying individual behavior. Two significant questions which this paper answers are otherwise unanswered in the rest of the existing literature. First, if we use behavioral models to analyze voter behavior, which of these models seems to reflect observed behavior best? Second, when comparing across different voting systems using these models of behavior, which voting system produces the most socially optimal results?

Three additional questions are also addressed by this study. First, is there non-strategic behavior in each environment? Second, is non-strategic behavior increasing in each voting rules' complexity and how does complexity affect behavior generally? Finally, which model best fits subject behavior? The first two questions provide important information regarding the implementation of an appropriate voting system by policy makers. The last question helps us to understand both how to interpret results from the first question and provide greater insight into individuals' decision making process. Observed laboratory data supports the notion that complexity does play an important role in shaping individual decision making. When individual behavior is estimated using the previously mentioned models, increased complexity is associated with decreased strategic voting behavior across all three models.

In order to better understand this decision making process, I use a laboratory experiment with three different voting systems – plurality, instant runoff voting (IRV), and score then automatic runoff (STAR) voting – designed to induce stratified, "Level-K style" thinking and decision making. Laboratory experiments are well suited for studying behavioral models of voting. Subject decision making is highly dependent on how likely the individual is to be a pivotal voter in a group. Because laboratory experiments provide an environment that allows for a high degree of control over preferences, how pivotal an individual can expect to be can be controlled for as well. It is this "pivotality" that is key to estimating an individual's level of strategic sophistication.

The main driver of behavior in this environment comes from a subject's choice to vote sincerely or strategically. In the former, decisions are consistent with an individual's private ordered preference for candidates. In the latter, their voting choices are inconsistent with this candidate preference order for some expected gain. If a group of voters votes sincerely, the aggregate group payoff is maximized. However, one individual may have the opportunity to submit an strategic voting profile which provides individual payoff gains at the expense of the total group payoff. Finding strategies which lead to unilateral payoff increasing deviations becomes more difficult as the set of available strategies increases. Therefore, both more sincere and more noisy behavior may occur in these more complicated institutions.

The experiment consists of six total treatments. In addition to the three previously mentioned voting systems, each subject is assigned to one of two preference sets within each voting system. The first of these preference sets, referred to as "non-strategic", contains a Nash equilibrium in which all subjects submit sincere voting profiles. The second of these, referred to as "strategic", has a set of preferences such that sincere voting is not a Nash equilibrium for that voting rule. Instead, there is one group member who can submit a payoff increasing strategic voting profile if all other subjects vote sincerely. Treatments are designed such that a voting rules are between subject, while preference types have within subject variation. "Non-strategic" preference profiles allow for a baseline measurement of behavior in which both strategic and sincere incentives are aligned, while the "strategic" preference profiles test subjects' ability to behave in a manner consistent with predicted strategic voting behavior. By analyzing an individual's choices in the roles of both non-pivotal and pivotal voters, I am able to measure an individual's level of strategic sophistication in the various bounded rationality models.

These treatments allow the testing of the following predictions. First, I test to see how complexity impacts voter behavior. Specifically, I test the hypothesis that increasing complexity decreases strategic behavior while increasing behavior behavior that does not appear to be strategic. Additionally, because of this reduced strategic voting, I predict that in the most complex voting environments group efficiency outcomes are maximized. Finally, I test the goodness of fit of the three bounded rationality models. It is my hypothesis that the cognitive hierarchy model provides the best fit for the observed data as these types of decision making problems lend themselves better to "step-type" thinking rather than decisions that are the consequences of noisy decision making, and the Cognitive Hierarchy model leaves room for more complex beliefs.

Results from the observed experimental data suggest that complexity has a large impact on individual behavior across voting systems. The Level-K estimates imply higher levels of sincere voting behavior, decreased levels of strategic voting behavior, and little change in noisy behavior as complexity across voting systems increases. The cognitive hierarchy estimation further supports the conclusion of decreased strategic behavior and increased sincere behavior between voting systems of increasing complexity. Furthermore, while the quantal response equilibrium estimates provide a good fit to the data for the most simple voting environment, sincere voting behavior is over-represented in the more complicated environments when compared to the QRE predictions. Of the tested models, the Level-K model used in this paper seems to fit the data best based on various goodness-of-fit tests including the Akaike's information criterion, the Bayesian information criterion, Vuong's non-nested likelihood ratio test (Vuong 1989) [7], and Clarke's non-parametric test for non-nested models (Clarke 2007) [8]. This seems to imply that individuals engage in "stepped thinking" when choosing strategies but may be prone to random, utility maximizing, errors.

The rest of this paper is organized into the following sections. Section 2 provides a brief discussion of the existing literature and how this study contributes to the body of research concerned with decision making in voting systems. Section 3 gives a theoretical overview of the voting systems involved and the models of bounded rationality that are used. Section 4 provides a background of the overall design and procedures of the experiment. Section 5 discusses the results of this experiment. Section 6 is a brief discussion and conclusion of these results.

2.2 Related Literature

The analysis of voting systems can broadly be broken up into two categories: those studies that examine behavior *within* a voting system and those studies that examine behavior *between* voting systems. This study itself finds itself firmly within the second of these categories, though elements from papers in both types of studies have been incorporated and built upon. Therefore a brief understanding of both types of studies is necessary.

A wide range of literature exists for examining individual behavior within a single voting system. Early examples Fiorina and Plott (1978) [9] and Plott (1982) [10], both of which examine committee decision making using plurality vote rules. One key aspect of many of these papers is measuring the "sophistication" of voting behaviors within groups. Both Herzberg and Wilson (1988) [11] and Felsenthal, et al. (1988) [12] present early evidence that more sophisticated behavior by voters is often present, though the highest degrees of sophistication may be lacking. For example, the former study found the highest degree of strategic sophistication was only present in their sample roughly 30% of the time. Similar conclusions are reached in Forsythe, et al. (1993) [13], where voters cast votes for their second favorite and strategic options 36% of the time.

Another large body of literature compares behavior between different electoral systems. Studies that investigate sincere and strategic behavior in different voting rules include Forsythe, et al. (1996) [14], Gerber, Morton, and Rietz (1998) [15], Morton and Rietz (2007) [16], Abramson, et al. (2010) [17], and Bassi (2014) [18]. Results of these studies consistently find that strategic behavior is observed significantly more often in simple plurality voting rules but less so in more complicated systems such is Borda count and approval voting. Abramson, et al. (2010) [17] in particular points to the use of heuristic decision making in more complicated voting system as a reason for fewer observations of strategic behavior in those systems. Kube and Puppe (2008) [19] also investigates these differences in a limited information environment, finding that more information leads generally to more strategic behavior as well. Interesting investigations of other types of behavior include Baron, et al. (2005) [20], which investigates voter behavior aimed at damaging other types of voters at individual cost. The authors find there that plurality voting produces less socially optimal results.

Of additional relevance to this study includes the application of behavioral models to compare individual behavior across different types of games. Camerer, et al. (2004) [2] applies their Cognitive Heirachy models across many different games with a mostly consistent number of average steps of thinking. Georganas, et al. (2015) [21] applies a Level-K model to estimate steps of thinking across several different games, though finds little cross-game correlation. Both of these papers provide theoretical founding to the estimation methods found within our paper. Other papers that take a similar approach include Rubinstein (2016) [22], Allred, et al. (2016) [23], Costa-Gomes and Crawford (2006) [24], and Chong, et al. (2005) [25]. A comprehensive review of the use of Level-K models specifically can be found in Crawford, et al. (2013) [26].

Combining then all the previously mentioned fields of study includes the area of papers that use behavioral models with voting systems themselves (Bassi and Williams (2014) [18] and Bassi (2015) [27].) The second of these papers specifically applies both a Level-K and Quantal Response Equilibrium model to plurality, approval voting, and borda count voting systems. The authors find, contrary to earlier studies, plurality voting produces more optimal results when compared to alternative voting schemes in terms of pure sincere voting behavior and measures of efficiency. They also find that QRE fits the experimental data better than comparable Level-K predictions. Bastek and Mantovani (2018) [28] also develops predictions in several voting models using a cognitive hierarchy model. Results of that study show compromise candidates are more likely to be selected under approval voting or instant runoff voting compared to a plurality voting scheme.

2.3 Theoretical Background

Here I focus on three different electoral systems and three models of boundedly rational behavior. The electoral systems used in this study are the plurality, instant runoff (IR), and score then automatic runoff (STAR) voting systems. The models of bounded rationality used for forming hypotheses and analyzing results include the Level-K model, the Cognitive Heirarchy (CH) model, and a model of Quantal Response Equilibrium (QRE).

2.3.1 Three voting systems

While the voting systems used in this study appear on the surface to be very different, all three can be described among a set of similar dimensions. Taking from Myerson and Weber (1993) [6], these electoral systems can in an abstract sense be defined by *ballots* and *candidates*. The *complexity* of a voting system, defined here as the set of undominated strategies a voter has, is dependent on both of these dimensions. Here we define complexity this way for several reasons. First, it is a concrete and quantifiable way to compare the voting systems outlined below. Second, the notion of complexity is important in its relationship for a decision-maker's ability to make decisions optimally. In this way, the breadth of available relevant decisions is one natural way to define complexity. While the strategy space might be difficult to search over in terms of choosing an optimal strategy, we assume an agent has at least the ability to eliminate strategies that are completely sub-optimal in that they are dominated by other, better strategies.

Let the number of candidates be defined by the variable k where the number of candidates form the set $K = \{1,2,...,k\}$. Each voter submits a ballot, which is a vector of the form $v = (v_1,...,v_k)$, where v_k is the number of votes given to candidate k. The winner of the election is the candidate who receives the largest total number of votes on all submitted ballots. We place a restriction on voters preferences such that each voter has a strict preference ordering between candidates such that no voter is indifferent between candidates and preferences are transitive.

Furthermore we can denote V as the set of all possible ballots that a voter could submit under the rules of the election. Note that in the context of this paper, this definition is synonymous with a given players strategy set. Furthermore, when only considering plurality rule, IRV, and STAR, this set V is finite. At this point we have established the generic terminology that will be applied to each individual voting system. We now will proceed with formulating each voting rules' systems in choosing a winner, its strategy set, and its set of weakly dominated strategies. Of final note, the set of undominated strategies created by the elimination of weakly dominated strategies as done in this study creates a generalized *upper bound* for the total number of undominated strategies for a given voting setting. Given an idiosyncratic set of number of voters and preference types, the specific set of undominated strategies for a specific setting may be fewer than the amount produced by the following methods. Given the large disparity between these upper bounds for the settings used in the experimental design, however, this still provides an intuitive benchmark for comparing these systems in terms of some notion of complexity.

Plurality Vote

A plurality voting rule is a voting system defined by each voter only having one vote to cast. This vote can only be applied to a single candidate and the candidate that has the most total votes wins. Ties are broken uniformly at random. In an example election using plurality rule with three candidates (without abstention), the voters set of ballots V would take the form of,

$$V = \{(1,0,0),(0,1,0),(0,0,1)\}$$

Given the simple nature of this voting system with only one vote that must go to a single candidate, it is easy to see that the number of items in the ballot set V for a given voter in a plurality system is equal to $|K|$ (the cardinality of K). Furthermore, if we define $v_m = 1$ as the decision for the voter to vote for candidate m, any voting vector v that the voter submits maximizes the probability that candidate m is selected.

Observation 1.1. In a plurality voting system with k candidates, the number of items in the ballot set V is equal to $|K|$

If a voter holds some set of preferences over the set K then, it follows that submitting a ballot of $v_m = 1$ is weakly dominated if candidate m is the least preferred candidate for the voter. Since a voter can at least weakly improve their payoffs by voting for a different candidate other than their least preferred candidate (as doing so increases the probability that another candidate is selected while decreasing the probability that the least preferred one is selected), it follows then that voting for the least preferred choice is always a weakly dominated strategy.

Observation 1.2. In a plurality voting system with k candidates, submitting a ballot where $v_m = 1$ and m is the least preferred candidate is always a weakly dominated strategy.

Therefore, if we define the complexity of this system by the set of strategies that are weakly undominated, that set would have a total of $|K| - 1$ items in it.

Instant runoff voting (IRV)

Instant runoff voting is defined by each voter submitting a ranking of candidates followed by a series of automatic runoffs in which candidates are sequentially eliminated until a single candidate receives a majority of votes. Generally speaking the process proceeds as follows: first, each voter submits a ballot that contains an ordered ranking of all candidates. Each candidate then receives one vote from each voter who ranked them first with a "1". If a single candidate receives a majority of all votes available, that candidate wins immediately. If not, the candidate with the lowest number of votes is eliminated and all voters who had submitted ballots with that eliminated candidate ranked first now give their votes to whatever candidate they ranked next highest. This process continues until one candidate receives a majority of all total votes and they are picked to be the winner of the election. All ties are broken uniformly at random.

In a sample election of 3 candidates, each voter would have a set of ballots V which would take the form of,

$$V = \{(1,2,3),(1,3,2),(2,1,3),(2,3,1),(3,1,2),(3,2,1)\}$$

In the case of IRV, the number of possible ballots in the set V is always equal to $|K|!$, or the factorial of the number of items in the set K.

Observation 2.1. In instant runoff voting, the number of possible ballots in the set V is always equal to $|K|!$.

Defining the set of weakly dominated strategies for IRV is a bit more complicated than the plurality voting case as the set of strategies is much larger and the process in general is more complex. However, some properties of IRV allow us to intuitively solve for this set.

One of the convenient features of IRV is that it satisfies the later-no-harm criterion. This means that in any election, if a voter gives an additional ranking or positive ranking to a less-preferred candidate, it does not cause a more preferred candidate to lose. Because of this property, any ballot in which the least preferred candidate is ranked first is weakly dominated by all other ballots.

Suppose in the limiting case we have 3 candidates, a, b, and c that constitute $V = \{(a,b,c),(a,c,b),(b,a,c),(b,c,a),(c,a,b),(c,b,a)\}$ (where for example (a,b,c) represents a ballot where a is ranked higher than b, which is subsequently higher ranked than c). Furthermore, suppose candidate c is the voter's least preferred candidate. We can show that both ballots (c,a,b) and (c,b,a) are weakly dominated by all other strategies. First consider (c,a,b). This strategy must be weakly dominated by (a,c,b) as it has the same probability of selecting candidate b but has at least a weakly higher probability of selecting a, which has a strictly better payoff than c. Furthermore, (c,a,b) is weakly dominated by (b,a,c) as both ballots have the same probability of selecting a but at least a weakly higher probability of selecting b, which leads to a strictly higher payoff. Similarly, we can apply this same logic to ballots (b, c, a) and (a, b, c) weakly dominating ballot (c, b, a). Thus it must be that any ballot where the least preferred candidate is ranked highest must be weakly dominated by at least one other strategy.

Observation 2.2. In an IRV system with k candidates, submitting a ballot where candidate m is ranked highest and m is the least preferred candidate is always a weakly dominated strategy.

Because the scope of these dominated strategies extends generally only to ranking the least preferred candidate highest, the number of weakly dominated strategies for a voter in an IRV system is equal to $|K|!/|K|$.

Score Then Automatic Runoff (STAR) voting

A STAR voting system can be defined as a two stage voting system that, as the name suggests, uses a scoring stage followed by an automatic runoff stage to select its candidates. In the first stage, each voter assigns a score to each candidate on a numerical scale, usually from 1 to 5 or 1 to 10. After all ballots are submitted, the score of each candidate is calculated by summing all individual scores submitted by all voters. The candidates with the two highest scores are then selected to participate in a second stage runoff, with ties being broken uniformly at random.

After the two runoff candidates are selected, each voter automatically assigns their one vote to whichever candidate they had scored higher when they submitted their initial ballot. If a voter scored both candidates the same, they assign their vote for neither candidate. The candidate selected by this system is the one which receives the most votes in this second stage runoff. Ties again are broken uniformly at random.

The number of different ballots a voter can submit in this system is quite large even in an election with a modest number of candidates. For example, a truncated version of the ballot sets available to a voter in a 3 candidate election that allows a score of 1 to 5 would be:

$$V = \{(1, 1, 1), (1, 1, 2), (1, 1, 3), ..., (5, 5, 4), (5, 5, 5)\}$$

Thus the cardinality of the set of ballots is a function of both the range of scores a voter can give to each candidates and the number of candidates. Ultimately, if we define S as the range of scores each voter can assign to a candidate, this means that the cardinality of V, $|V|$, can be given by $S^{|K|}$.

Observation 3.1. In STAR voting, the number of possible ballots in the set V is always equal to $S^{|K|}$.

Showing what strategies are weakly dominated in a STAR system is very similar to that in the IRV system. One key difference in the qualities between these two systems is that STAR, and score systems in general, do not have the later-no-harm criterion. This means that, for example, increasing the scores of an individual candidate increases the probability that that candidate is chosen but also decreases the probability any other candidate is chosen, including those that are scored higher than it. Conversely, reducing the score of a candidate increases the probability that all other candidates are elected. Furthermore, in the case of a strategy's effect in the runoff stage, giving a higher score to the least preferred candidate than any other candidate is harmful since this means that voters vote will be applied to a less preferred candidate. Therefore we can intuit that any strategy in which the least preferred candidate is given a score greater than or equal to any other candidate must be weakly dominated.

Observation 2.2. In a STAR system with k candidates, submitting a ballot where candidate m is assigned a score greater than or equal to the score of any other candidate and m is the least preferred candidate is always a weakly dominated strategy.

Furthermore, if we want to determine how many weakly dominated ballots exist for a given voter, we can apply the following rule. If S is the range of scores available to a voter and there exist K candidates in an election, the number of weakly dominated strategies for a voter in an STAR system is equal to:

$$\sum_{\mathrm{i}=1}^{S} \mathrm{i}^{K-1}$$

2.3.2 Three models of bounded rationality

Now that we have established a basic framework for the voting systems used in this study, we can describe the models of bounded rationality we will be using and how they relate to the voting selection systems. Traditional models of Nash equilibrium behavior in voting systems (such as that found in Meyerson and Weber, 1993 [6]) are useful at defining equilibria in voting systems. However, the set of calculations and beliefs by individuals in even a modestly sized electorate in a simple voting mechanism can be complex. Therefore, it is reasonable to assume individuals rely on other, boundedly rational models of decision making in such complex systems. All three of the boundedly rational models of behavior used here (Level-K, CH, and QRE) can provide avenues to predict non-standard equilibrium behavior which may be viewed in an experimental setting. After describing each model, we will then describe how that model relates to our voting framework.

Level-K

For this paper we use a definition of Level-K reasoning adapted from Nagel (1995) [1] along with a method of estimating individual's levels from Georganas, Healy, and Weber (2015) [21]. In this section we first describe the basic framework of Level-K along with some predictions of Level-K and how it applies to our different voting models. Following that is a brief overview of the model used to estimate this behavior.

The Level-K model specifies that each individual decision maker is of some type (or level) k which determines their beliefs about the population of all other opponents and subsequently informs their decisions. Assume that some player has some Level-K and some set of beliefs $v(k)$. In the standard Level-K model, a players beliefs about other players $v(k)$ $\forall\ k > 0$ is usually assumed to be that a player believes all other players are of type $k-1$. Using this assumption, behavior is then solved for inductively.

First, Level-0 players exogenously play a strategy σ_{i}^{0} that is naive. Here we assume that this naive strategy takes the form of randomizing uniformly over all strategies, which is the standard assumption for this model in the existing literature. One natural replacement for the random uniform strategy in a voting environment could be a sincere voting strategy. While this is an acceptable substitution in concept, the resulting effect only causes a 1-

level shift in the estimation of the Level-K model. Furthermore, estimating behavior in these models computationally in this setting becomes somewhat more complicated as not all strategies are predicted to be observed with positive probability without some sort of notion of "sufficiently noisy" behavior. A major advantage of the random uniform strategy assumption is it places a positive probability of any given strategy being observed and doesn't risk maximum likelihood estimations of parameters from facing a zero likelihood problem.

Each player of Level-K $\forall\ k > 0$ plays the strategy that maximizes their expected utility for the beliefs described above (or randomizes between strategies that are indifferent on if several maximize expected utility). For example, a Level-1 player plays the strategy that maximizes their expected utility under the belief that they are playing against only Level-0 players. A Level-2 player plays a strategy which maximizes their expected utility under the belief they are playing against exclusively Level-1 players, and so on. Using this recursive process, we can make predictions about individual behavior for each possible level.

This model extends itself to the use of voting mechanisms quite effectively. Again, assume a level-0 player is randomizing uniformly across their entire strategy space. First we will consider then how we can predict behavior in the plurality voting system. Then we will extend these predictions to the IRV system, followed by the STAR system.

Consider a voter i in a plurality voting system of level-1. Furthermore, consider an example of a 3 candidate election with candidates a, b, and c. Finally, assume voter i has some preference over these candidates such that $a > b > c$. Given their beliefs about the behavior of a level-0 player, $v_{\mathrm{i}} = (1, 0, 0)$ and $v_{\mathrm{i}} = (0, 1, 0)$ have the same probability of c being elected. However, $v_{\mathrm{i}} = (1, 0, 0)$ has a higher probability of a being elected than $v_{\mathrm{i}} = (0, 1, 0)$. This logic analogously extends to $v_{\mathrm{i}} = (1, 0, 0)$ and $v_{\mathrm{i}} = (0, 0, 1)$; both have the same probability of b being elected but $v_{\mathrm{i}} = (1, 0, 0)$ has a higher probability of a being elected than $v_{\mathrm{i}} = (0, 0, 1)$. From this we can conclude that given these beliefs, a level-1 player's optimal strategy is to vote sincerely for their most preferred candidate.

For levels 2 and above, behavior depends on the preferences of all other voters. It is possible that given their beliefs about the other voters, level-2 and above voters may be pivotal in a manner where voting sincerely is no longer a payoff maximizing decision.

It can also be shown that in an IRV system, sincere voting is an optimal strategy for level-1 players as well. Again consider the previous example of a 3 candidate election but this time using an IRV voting system. The following proof is adapted from Basteck and Mantovani (2018). First it can be shown that ranking c first is a dominated strategy. $v_{\text{i}} = (c, b, a)$ is dominated by $v_{\text{i}} = (a, b, c)$. Since other voters are believed to be behaving uniformly random, both give the same probability of b being elected but $v_{\text{i}} = (a, b, c)$ has a higher probability of a being elected. Furthermore $v_{\text{i}} = (c, a, b)$ is dominated by $v_{\text{i}} = (b, a, c)$ for similar reasons; both give the same probability of a being elected but $v_{\text{i}} = (b, a, c)$ has a higher probability of b being elected.

We can continue this argument further: $v_{\text{i}} = (b, c, a)$ is dominated by $v_{\text{i}} = (a, c, b)$ and $v_{\text{i}} = (a, c, b)$ is dominated by $v_{\text{i}} = (a, b, c)$. This leaves us with two remaining strategies, namely $v_{\text{i}} = (a, b, c)$ and $v_{\text{i}} = (b, a, c)$. Again, $v_{\text{i}} = (a, b, c)$ dominates $v_{\text{i}} = (b, a, c)$ since both have the same probability of c being elected but $v_{\text{i}} = (a, b, c)$ has a higher probability of a being elected. Thus sincere voting is the optimal level-1 strategy in an IRV system. Like plurality voting, sincere strategies may not be the the optimal strategy for a voter of level-2 or higher; this largely depends on the preferences of the other voters and how pivotal any individual voter is given their beliefs about other voters and their levels.

For a STAR voting system we rely on a bit of intuition for what the optimal strategy is for a level-1 player. As discussed in the previous section of this paper, STAR as a system does not have the “later-no-harm” criterion, meaning that assigning more points to a single candidate increases the probability of that candidate being elected but also decreases the probability that all other candidates are elected. However, consider the following example that uses a 4 candidate election using a STAR-5 system.

Assume that voter i has preferences over candidates a, b, c, and d such that $a > b > c > d$. Due to the beliefs about level-0 players, any strategy that maximizes the probability that a is elected involves some ballot where $v_{\text{i}a} = 5$. This is because increasing the amount of points a candidate receives from that player increases the probability that the given candidate is elected and decreases the probability all other candidates are elected. Furthermore, this optimal strategy must also involve some ballot where $v_{\text{i}d} = 1$ as this minimizes the probability that their least preferred candidate is elected. The relative amount of points the other two candidates receive is not exactly clear. Again, increasing the points either of these two candidates receive decreases the probability that a is elected. However, intuitively, it is clear that it does not make sense for a voter to assign more points to c than to b due to the fact they prefer b to c. Thus it must be the case that whatever ballot they submit must involve a strategy such that the point assigned to each candidate follows a strategy where $v_{\mathrm{i}a} > v_{\mathrm{i}b} \geq v_{\mathrm{ic}} \geq v_{\mathrm{i}d}$. This provides a notion that the optimal strategy for a level-1 voter is at least *weakly* sincere. In other words, a level-1 voter's optimal strategy always involves a ballot in which no candidate which is less preferred receives more points than a candidate is more preferred. The specific optimal strategy will be idiosyncratic to the preferences and size of the existing electorate.

As with the other two systems, optimal strategy for a level-2 and above voter depends on how pivotal an individual voter is and the preferences of the electorate. Level-2 and above optimal strategies in no way are inherently sincere and may fall under the category of strategic voting strategies if a voter is sufficiently pivotal.

The estimation method used for determining an individual subject's level in this experiment is borrowed from Georganas, Healy, and Weber (2015). Their approach uses maximum-likelihood estimation. For each player i and Level-K, they define a likelihood function $L(s_{\mathrm{i}}|k, \lambda_{\mathrm{i}}, \epsilon_{\mathrm{i}})$ for each Level-K based on the assumption that player i players the Level-K strategy s_{i}^k with probability ϵ_{i}, and otherwise maximizes a random expected utility with beliefs $v(k)$, extreme-value-distributed noise, and sensitivity parameter $lambda_{\mathrm{i}}$. Both parameters ϵ_{i} and λ_1 differ across players. Note that this estimation relies on being able to identify level $k > 1$ strategies, which we are able to do from the design of the experiment used in this study for our specific set of induced preferences.

Let $I_{\mathrm{i}}(s_{\mathrm{i}}, k)$ be an indicator function that equals one if it is observed that a player of Level-K plays their Level-K strategy in that game, and 0 otherwise. The Likelihood function can be defined as:

$$\begin{aligned} L(s_{\mathrm{i}}|k, \lambda_{\mathrm{i}}, \epsilon_{\mathrm{i}}) = \epsilon_{\mathrm{i}} I_{\mathrm{i}}(s_{\mathrm{i}}, k) + (1-\epsilon)(1 - I_{\mathrm{i}}(s_{\mathrm{i}}, k)) \\ \times \left(\frac{exp(\lambda_{\mathrm{i}} \sum_{\kappa} u_{\mathrm{i}}(s_{\mathrm{i}}, \sigma_{\mathrm{j}}^k v(k)(\kappa)}{\int_{S_{\mathrm{i}}} exp(\lambda_{\mathrm{i}} \sum_{\kappa} u_{\mathrm{i}}(z_{\mathrm{i}}, \sigma_{\mathrm{j}}^k v(k)(\kappa) dz_{\mathrm{i}}} \right) \end{aligned}$$

For all $k = 0$, $L(s_{\mathrm{i}}|0, \lambda_{\mathrm{i}}, \epsilon_1)$ is equal to σ_{i}^0 which is the random uniform distribution over the voter's strategy space. Furthermore, the maximum likelihood of observing the set of strategies of a single voter is given by:

$$L^*(s_{\mathrm{i}G}|k) = \underset{\lambda_{\mathrm{i}}>0, \epsilon_{\mathrm{i}}\in[0,1]}{max} \prod_{\gamma\in G} L(s_{\mathrm{i}\gamma}|k, \lambda_{\mathrm{i}}, \epsilon_{\mathrm{i}})$$

Finally, the maximum-likelihood level for player i is then given by:

$$k_{\mathrm{i}}(G) = arg \underset{k\in\mathbb{N}_0\cup\{N\}}{max} L^*(s_{\mathrm{i}G}|k)$$

In practice this means that we calculate the likelihood of a player being of each discrete level based on their choice of strategies and then subsequently choose the level with the highest calculated likelihood.

Cognitive Hierarchy

This is the cognitive hierarchy model formulated by Camerer et al. (2004) [2]. First these authors assume players are differentiated inherently in the number of 'steps' of reasoning, each at various levels of reasoning. At the first level, level-0, players are assumed to choose a strategy uniformly at random. Level-1 players best respond to a population of level-0 players, while level-2 and above players best respond based on a belief of the population of all other players being a mix of all levels lower than their own level. In other words, players of a given Level-K are best responding to a given belief about their opponents' levels are drawn from a distribution that places probability only on levels $0 \leq l < k$.

In Camerer et al. (2004) [2] it is assumed that individuals' levels are drawn i.i.d. according to a probability distribution f, where $f(k)$ gives the probability that an individual player is of that a Level-K. A Level-K player forms beliefs about the frequency of their opponents levels given by the following equation:

$$g_k(l) = \frac{f(l)}{\sum_0^{k-1} f(l)}$$

They hold this belief for all levels up to but not including or above their own level. It is assume in the original study, which will also be assumed here, that f takes a Poisson distribution and then maximum likelihood estimation is used to estimate the parameter τ. Generally speaking, most values of τ are found to be between 1 and 2 in the original study.

For this study, as we did with the Level-K model, we do adapt the use of a 0-step thinker using a strategy which randomizes uniformly over the entire strategy space. Like in the Level-K model, this may be a somewhat contentious assumption. Here again it can be assumed that this is used as a placeholder to represent sufficiently noisy behavior. It could be assumed that the proper naive strategy is instead a sincere voting strategy, though this in reality changes little about the predictions these models make in the context of this study specifically and again only causes a shift of estimated steps of thinking down by one. Furthermore, like the estimation of the Level-K model, the assumption of random uniform 0-step behavior has convenient computational advantages in avoiding a zero likelihood problem when estimating the CH model.

When applying this to our voting systems, the cognitive hierarchy model conforms well to our environment to make meaningful predictions. In fact, much of the analysis and predictions made by the cognitive hierarchy model follow similar predictions made by the previously discussed in the previous Level-K model analysis. Level-0 and Level-1 players behave identically do how we would expect to as described in the Level-K environment. A 2-step thinker in the cognitive hierarchy model behaves either like a level-1 or level-2 type player in the Level-K model depending on their beliefs about τ[2]. More general predictions about behavior above 2 steps of thinking can be made though they are beyond the scope of this paper. For a further analysis and proof of properties of certain voting systems in the cognitive hierarchy model for steps of thinking beyond our simple two step framework, see Basteck and Mantovani (2018).

Quantal Response Equilibrium

One common observation about behavior in laboratory setting is that it is often shown to be very noisy. While we can use the random uniform decision making as a basis for "sufficiently noisy" behavior in the other two models just described, it is also useful to model

[2]↑Note that this is not true for the Cognitive Hierarchy model in general. In principle it is possible that some convex combination of Level-1 and Level-2 behavior could be optimal depending on beliefs about τ, but the statement here holds true using the voting system framework found in this paper.

behavior in a way that accounts for variable amount of noise in decision making. One of the ways one can do this is by modeling utility and decision making with probabilistic choice models. One of the most popular models that incorporates that probabilistic decision making is the Quantal Response Equilibrium (QRE) from McKelvey and Palfrey (1995) [3].

The QRE uses a parameter μ which accounts for noise in best response functions and is used in the expected payoff of each strategy. The choice function used in this study is sometimes referred to as the logistic quantal response function. Suppose we have some set of players $N = \{1, .., n\}$. Denotes player is jth strategy as s_{ij}. Furthermore we can define $(s_{\mathrm{ij}}, \boldsymbol{\pi}_{-\mathrm{i}})$ as the mixed strategy profile where player i plays pure strategy s_{ij} and all other players play mixed strategy $\boldsymbol{\pi}$. We can define the player's expected payoff of this mixed strategy profile to be $\bar{u}_{\mathrm{ij}}(\boldsymbol{\pi})$. In the quantal response equilibrium, players observer a noisy evanulation of stategy values given by the following equation:

$$\hat{u}_{\mathrm{ij}}(\boldsymbol{\pi}) = \bar{u}_{\mathrm{ij}}(\boldsymbol{\pi}) + \epsilon_{\mathrm{ij}}$$

If we make the standard assumption on ϵ_{i}j as found in McKelvey and Palfrey (1995) that it takes the form of an extreme value distribution, the logit equilibrium is given by:

$$\boldsymbol{\pi}_{\mathrm{ij}} = \frac{\mathrm{e}^{(1/\mu)\bar{u}_{\mathrm{ij}}(\boldsymbol{\pi})}}{\sum_{k=1}^{J_{\mathrm{i}}} \mathrm{e}^{(1/\mu)\bar{u}_{\mathrm{i}k}(\boldsymbol{\pi})}}$$

In practice we calculate this QRE starting at $\frac{1}{\mu} = 0$ (where players are simply playing strategies that take the form of a mixed strategy where strategies are chosen using a random uniform choice probability). We trace a branch of equilibria which begins at $\frac{1}{\mu} = 0$ to some value of $\frac{1}{\mu}$, for example 10. At each value of $\frac{1}{\mu}$, a new equibrium is calculated where all players chose a mixture of strategies based on the given value of $\frac{1}{\mu}$ and their (correct) beliefs of other players' strategies. These equilibrium strategies are updated as the value of $\frac{1}{\mu}$ changes. One of the important features of QRE is that as $\frac{1}{\mu}$ grows large enough, QRE converges to a Nash equilibrium.

In its application to voting games, predictions of voters' behavior in various voting systems isn't exactly clear. As stated previously, play will converge to a Nash equilibrium but it isn't necessarily true that this equilibrium will resemble the same kinds of strategies predicted by either cognitive hierarchy or in Level-K. It is possible this play that is motivated more by noisy behavior instead of steps of thinking may more accurately reflect behavior in the lab. An observation pointed out in Bassi (2014) [27] is that if a voter is not pivotal, that is none of their strategies affects the outcome of the election, QRE does not converge to a pure strategy but instead converges to a mixed strategy since the utility of all strategies in this situation is the same. Previous findings in that study also indicate that QRE fits experimental data better than Level-K equilibrium predictions, and that players were not able to reach equilibrium levels of strategic reasoning but reach intermediate levels instead. One of the challenges of using QRE in this study is the adaptation of QRE to a very large strategy space. The specifics of how this challenge has been approached are covered more in the appropriate passages in the results section.

2.4 Experimental Design

The experiment is designed to study the relationship between complexity and voter behavior in three voting systems. The experiment employed a total of 210 subjects recruited from the student population at Purdue University who participated in 12 experimental sessions. Computerized experimental sessions were run using oTree (Chen, et al. 2016) [29] at the Vernon Smith Experimental Economics Laboratory. A total of 17 experimental sessions were held. Instructions were read aloud to subjects at the beginning of the experiment. Each session lasted approximately 90 minutes.

Throughout the duration of the session, subjects were asked to complete a series of tasks used to measure both their strategic thinking and several related variable such as cognitive ability and generosity. In total, subjects completed five total tasks, The first of these tasks was the voting game task using one of three voting systems: plurality, IRV, and STAR. Additional tasks included the undercutting game found in Georganas, et al., 2015, the social value orientation slider task from Murphy, et al. 2011, and a set of standard and non-standard Cognitive Reflection Test questions (Thomson and Oppenheimer, 2016 & Toplak, et al., 2014) [30]. Finally, subjects were asked to complete a set of demographics survey questions, which can be found in Appendix B. Subjects were paid in USD for all decisions across all tasks in addition to a $5 participation payment for an average of $18.10

2.4.1 Voting game task

	Plurality Vote	Instant Runoff Vote	STAR Vote
Strategic preferences	Treatment 1	Treatment 2	Treatment 3
Non-Strategic Preferences	Treatment 4	Treatment 5	Treatment 6

Figure 2.1. Treatment structure

The voting game task used in this experiment asked subjects to participate in a series of simulated elections using the three previously described voting systems and difference sets of individual preferences. This part of the experiment leveraged a 3 by 2 experimental design, which can be seen in Figure 2.1. Subjects were asked to participate as voters in an election using one of the different voting systems (between subject) and using two different types of preference sets (within subject). This part of the experiment lasted a total of 40 rounds. Subjects were paid during this part of the experiment at a rate of 1 USD to 80 points.

In each round, subjects matched into groups of three and were presented with information including a list of alternatives that the group would pick from. Additionally, the payoff that each group member would receive for each alternative being picked was provided, with each group member being able to view all group members' potential payoffs. Subjects were also presented with the total number of "votes" they and the other members of their groups had received this round. Finally, they were asked to submit a voting decision in accordance with the voting system being used in their treatment. Voting decisions were made simultaneously. An example of this decision screen is shown in Figure 2.2.

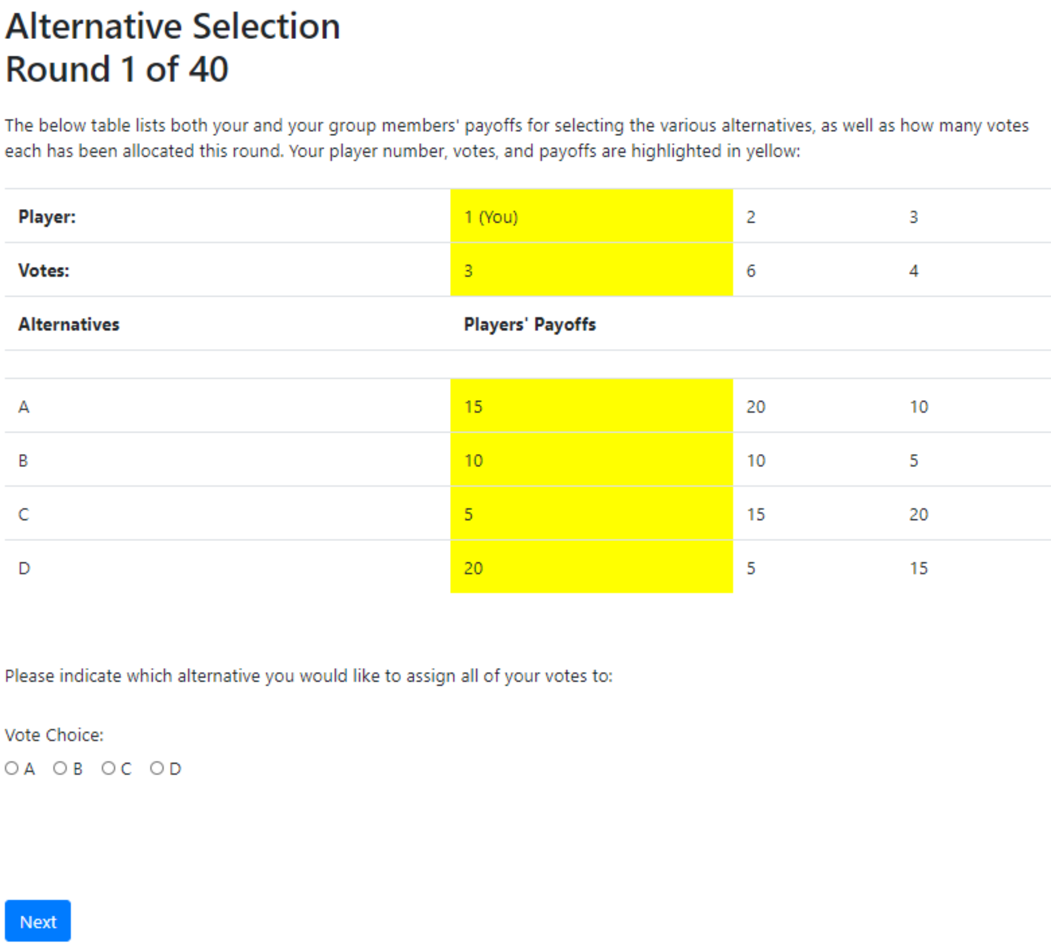

Figure 2.2. Voting decision screen

When making a voting decision, each subject was presented with their potential payoffs for each alternative being chosen as well as the potential payoffs for the other group members for each alternative. This constituted a "preference set". There are two different preference sets that were presented for subjects when making decisions. These can be grouped into "strategic" and "non-stratgeic" preference sets. The key difference between these sets of preference is that in the "non-strategic" preference set, there exists a Nash equilibrium when all group members play sincere voting strategies. In a "strategic" preference set, playing sincere strategies is not a Nash equilibrium. Instead, at least one group member has one or more best responses to other group members playing sincere strategies.

These two types of preference sets also tie in closely with the Level-K model of decision making. When viewed in the context of a Level-K decision making model, the level 1 strategy for all group members is to make sincere voting decisions. In the "non-strategic" preference set, all player level $K \geq 1$ strategies are identical. However, in the "strategic" preference sets, for some group members there exists some strategy such the level 2 strategy is not identical to the level 1 strategy[3]. It is also the case in these preference sets that all player level $K \geq 2$ strategies are identical. The order in which subjects interacted with these types of preference sets was determined randomly before the session began.

When all subjects submitted their voting decisions, the chosen alternative was selected by the computer following the appropriate voting rule. The amount of "votes" a subject had this round created a weight to their voting decision. Mechanically, this weight acted as if N individuals had submitted an identical voting profile, where N is the number of votes a subject received. For instance, if a subject had 5 "votes" in a round and voted for an alternative "A", in a plurality voting system "A" would receive 5 votes from that subject. Votes were not allowed to be split into different voting decisions in a single round.

Once the selected alternative was calculated, a results screen was displayed for subjects. This results screen showed again the subjects payoffs for each alternative, their votes, and all other group members votes and payoffs. Additionally, the alternative that was selected was displayed as well as how many points the subject received that round. However, other information that was provided varied slightly between treatments due to the different nature of the different selection mechanisms. For instance, in the plurality voting treatment, it was displayed which alternative each group member assigned their votes to. However, in the IRV treatment, it was displayed which ranking each group member gave each alternative and in the STAR treatment it was displayed how many points each group member assigned to each alternative.

[3]↑strategies in this design are consistent with a maximum two steps of thinking for two reasons. First, existing literature using the CH and Level-K show that mean steps of thinking in subjects generally lie only between 1 to 2 steps of thinking with very few subject exhibiting strategies beyond 2 steps. Given the complex nature of the environment studied here, its reasonable to expect very few 3-step types within the subject population. The second reason is the other design features chosen by this study do not allow for higher than 2 steps of thinking without also creating circular preference, where individual strategies associated with higher-order steps of thinking are indistinguishable from those strategies chosen by lower steps of thinking, making estimation of individual subject types infeasible.

In addition to these individual voting decisions, a chart was also provided that summarized how the voting decisions were aggregated. Again, the form of this chart varied slightly between treatments. A visual example of this results screen for the plurality treatment can be seen in Figure 2.3. Examples of this results screen for the other two treatments can be seen in Appendix B.

Figure 2.3. Voting results screen

After each round, subjects were re-matched into new groups using random re-matching. While the task lasted for 40 rounds in total, these 40 rounds were broken up into sets of 8 round blocks, with each block having a new set of "strategic" or "non-strategic" payoffs (though these preference sets were never labeled for subjects as such). Sets of payoffs did not change for the duration of a block. A subject's individual preference within the group, however, was randomly determined among the set of available payoffs that round. Between blocks, a brief message was displayed to all subjects informing them that a new block had started with potentially new sets of values. After the completion of round 40, the experiment then proceeded to the second part of the experiment, which consisted of several additional tasks.

2.4.2 Additional tasks

In addition to the voting game task, subjects were also asked to complete four additional tasks. These tasks included an undercutting game, a social value orientation task, a cognitive reflection test, and finally a set of demographics survey questions. The use of these tasks was to measure both the type of reasoning found in the main voting game task as well as related decision making processes.

The first of these tasks was a modified version of the undercutting game found in Georganas, et al., 2015. As the Level-K estimation method used in this study also borrows from this paper, this task was implemented to establish a possible correlation between decisions made in the voting game task and the untercutting game. Both games are designed to induce similar types of step-level strategic thinking.

In the undercutting game, subjects were placed in pairs and were asked to choose between one of seven strategies. The best response to a player playing strategy s_{j} is almost always to play $s_{\mathrm{i}} = s_{\mathrm{j}} - 1$ thus "undercutting" them. More specific details of this game can be found in the original paper and instructions to this game can be found in Appendix B. The only modification made here in this study to the original game is an adjustment to the points earned for each strategy such that it isn't possible to earn negative points in a round. An example of a round of this game is found in Figure 2.4.

Decision Page (Round 1 of 8)

	Other's actions	1	2	3	4	5	6	7
Your actions								
1		(12,12)	(21,1)	(11,11)	(11,11)	(11,11)	(11,11)	(0,11)
2		(1,21)	(11,11)	(21,1)	(11,11)	(11,11)	(11,11)	(11,11)
3		(11,11)	(1,21)	(11,11)	(21,1)	(11,11)	(11,11)	(11,11)
4		(11,11)	(11,11)	(1,21)	(11,11)	(21,1)	(21,1)	(21,1)
5		(11,11)	(11,11)	(11,11)	(1,21)	(11,11)	(11,11)	(11,11)
6		(11,11)	(11,11)	(11,11)	(1,21)	(11,11)	(11,11)	(11,11)
7		(11,0)	(11,11)	(11,11)	(1,21)	(11,11)	(11,11)	(0,0)

Please choose which action you would like to take. As a reminder, your possible actions are listed along the left hand side of the table, while the other participant's actions are listed along the top of the table.

Please select which action you would like to take:

Next

Figure 2.4. Undercutting game

In each round subjects were asked to choose a strategy. Both subjects chose their strategies simultaneously, after which it was displayed which strategy the subject and their partner chose and the payoff that subject earned that round. 8 total rounds of the undercutting game were played and between each round subjects were re-matched with new partners using random re-matching.

The second of these tasks was a social value orientation task, implemented very similarly to Murphy, et al., 2011 [31]. This was done to measure individuals' motivations for making decisions that are potentially pro-social. Because sincere voting profiles resulted in the highest aggregate group payoff in the voting game task, it is possible that the pro-social nature of individual subjects could drive more sincere voting behavior instead of a lack of strategic sophistication. The implementation of this task aimed to help control for this in later analysis.

Subjects were placed in pairs with a partner and asked to choose an allocation dividing 150 points between the pair in a slider task identical to Murphy, et al., 2011 [31]. Once both partners selected an allocation, both subjects were informed how many points they earned for this task. The total points earned was the sum of the allocation each partner chose for themselves and the share their partner chose for them. Subjects were then randomly re-matched with new partners and asked to complete a new SVO task. A total of 6 SVO tasks were done which were made up of the six primary SVO slider items from Murphy, et al, 2011.

Next, subjects were asked to complete a series of standard and non-standard Cognitive Reflection Test questions. These questions help to measure slower, more deliberate problem solving which may also be correlated with the sort of strategic thinking found in Level-K or Cognitive Hierarchy decision making. Subjects were asked a total of 8 questions which included the three "standard" CRT questions and 5 questions taken from Thomson and Oppenheimer, 2016 [32] as well as Toplak, et al., 2014 [30]. Subjects were paid \$0.25 per question answered correctly.

The last of these tasks was a basic demographics survey which asked subjects to answer questions including their education, experience with previous experiments, age, gender, among other questions. These questions were non-incentives. A full list of questions along with the formatting of these questions is included along with the rest of the subject interface in Appendix B.

2.5 Results

When looking at the overall effects of different voting systems, it is natural to first consider the overall effect that these different institutions have on individual behavior. Additionally, understanding how aggregate group measures of efficiency change is also key for a policy maker to implement the appropriate voting mechanism for a group. For the first of these considerations, then, it is important to analyze elements such as strategic, sincere, and "noisy" actions is key to our understanding of how individuals respond to more noisy environments. For the second of these considerations, analysis is focused on aggregate group payoffs and social welfare efficiency.

2.5.1 Effects on individual decisions

As voting systems become more complicated, we predicted that strategies that individuals use to become less complicated as a result. In other words, as individuals become more overwhelmed with the breadth of considerations that come with added complexity, we should expect to observe more heuristic and even noisy decision making. Here we focus our analysis using the previously described models of bounded rationality as covered in section 3.2. The first focus in this section will be on the Level-K model, followed by the Cognitive Hierarchy model, and lastly Quantal Response Equilibrium. While individual conclusions of these models differ between each other, all three support the conclusion that as voting systems become more complex in their strategy spaces, individuals behave in a less sophisticated manner.

The first and most simple way that that individual behavior can be analyzed at an aggregate level is simply placing each of these decisions into four different categories. Those categories include sincere/non-strategic choices, strategic choices, dominated choices, and all other choices. Here we define a sincere decision as one in which an individual makes a decision in accordance to their individual preferences. In a plurality voting system that means voting for the most preferred candidate. In IRV this means providing a ranking that strictly aligns with their preference ranking. In STAR this behavior is broadly expanded to weakly sincere behavior; any decisions in which no candidate receives more points than a more preferred candidate. Furthermore, strategic choices correspond to choices that are not sincere by definition but instead are payoff increasing deviations from sincere behavior when all other group members are assumed to be sincere in their decision making. Finally, a dominated decision is one in which the strategy chosen by an individual is one which is dominated by other available strategies, the set of which was outlined in Section 3.1.

As seen in Figure 2.5, this experiment indicates that STAR voting produces the most sincere and least strategic behavior of the three different systems. Plurality produces the second most sincere decisions but also the most strategic decisions. Those in the IRV system produced the least number of sincere decisions but also a very high number of decisions not falling into any of the other three categories. If individuals were acting perfectly in a strategic sense, 75% of all decisions would be sincere and 25% strategic across all three systems. As observed from the experimental data, subjects chose to select strategic actions far more often in the plurality voting treatment when given the opportunity to compared to the other two voting treatments. When given a set of preferences consistent with a strategic type, subjects in the plurality voting treatment selected strategic actions 74.22% of the time, compared to 45.66 % in the IRV treatment and 18.58% in the STAR treatment. These differences between treatments are highly statistically significant with t-statistics of 10.635, 23.316, and 10.276 for comparisons of strategic voting rates for strategic types when comparing plurality vs. IRV, plurality vs. STAR, and IRV vs. STAR respectively.

Comparing sincere behavior among sincere types also provides important insight into subject behavior. When subjects were of non-strategic types, subjects submitted sincere voting profiles at a rate of 80.97% in the plurality treatment, 50.76% in the IRV treatment, and 77.08% in the STAR voting treatment. Again, using a two tailed comparison of means, these differences bear out as statistically significant with t-statistics of 19.521, 2.760, and -16.036 for comparing plurality vs IRV, plurality vs STAR, and IRV vs STAR. What is perhaps the most surprising here is the significantly higher rate of sincere voting for non-strategic types in the STAR voting treatment compared to the IRV voting treatment, but the lower rate of strategic voting of strategic types in STAR in comparison to IRV. This indicates that subjects are heuristically relying on on intuitive sincere voting profiles while being unable to find proper non-sincere strategic actions relatively more often in the STAR treatment in comparison to the IRV treatment.

There are a few conclusions that can be drawn from these base-level observations. First is that the ability to find and use strategic strategies in the STAR system seems to be quite difficult for subjects. This combined with the probably intuitive use of sincere strategies likely explains the high prevalence of sincere strategies and relatively few observations of strategic decisions. Second, many of the strategies falling into the "other" category for IRV can likely be explained by the strictness of defining sincerity in the IRV elections. Only one of the available 24 strategies can be defined as sincere and six total strategies can be defined as strategic for a given decision maker. This suggests that individuals are likely making decisions that may attempt to be strategic though in many of these cases are not more beneficial (or are even detrimental) compared to a sincere strategy. Lastly, Plurality voting is the closest that approaches the theoretical prediction of 75% of all decisions being sincere and 25% being strategic. The relative simplicity of the plurality voting system lends itself well to driving individuals towards sincere decision making when it is optimal but also lends itself easy opportunities to strategically manipulating results when the opportunity presents itself.

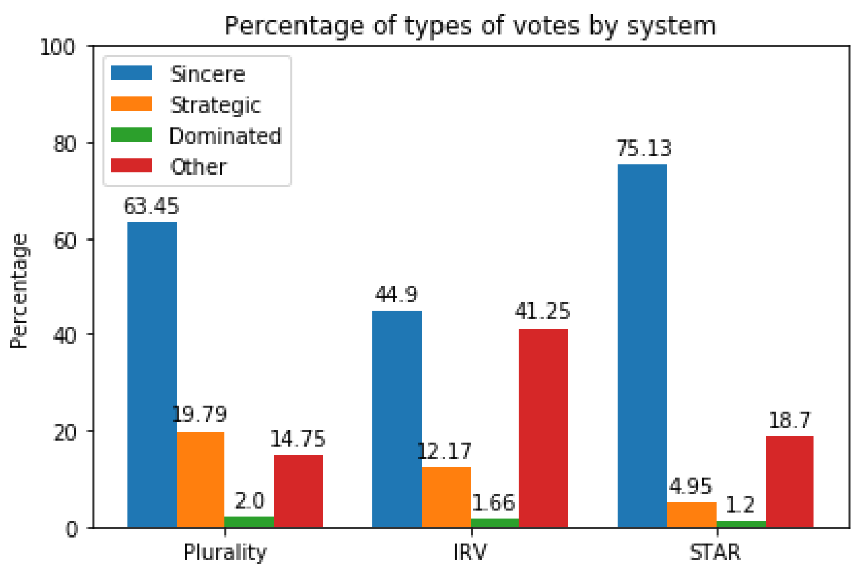

Figure 2.5. Types of voting by system

Figure 2.6 and Table 2.1 present the results of the Level-K estimation of this behavior. Findings here also closely align with the conclusions that were made in the previous paragraphs. As seen in Figure 2.6, individuals in the plurality voting system are overwhelmingly estimated to most likely be Level-2 types based on their observed decision making. On the other hand, in the STAR system, individuals are by a vast majority represented as being Level-1 types with relatively few Level-2 types. IRV lies in the middle of these two with a roughly even split between Level-1 and 2 types. As complexity in these voting systems increases, more individuals emerge as Level-1 types due to their associated sincere (or closely payoff equivalent) behavior and while strategic behavior decreases by a large amount. Of note as well is the relatively small change in the representation of Level-0 types in the data. This indicates that while the level of sophistication is decreasing at the upper end of decision making, more complicated environments are also not inducing significantly more noisy behavior.

A regression analysis (Table 2.1) continues to hold up these results. Here we add controls for a player's estimated level in the undercutting game, their individual cognitive reflective test score, and if the individual was classified as "prosocial" on the social value orientation task. Estimations are done using a random effects estimation across sessions. This helps to control for other correlated factors such as general strategic reasoning and ability (using the UG level and CRT score). Since sincere behavior produces the highest aggregate group payoffs, individuals who are especially prosocial are controlled for as well. Results here from all estimated models continue to support the conclusion that IRV reduces the amount of Level-2 types observed in the data with STAR increasing this difference even more so. Of additional interest perhaps is that CRT score is both positive and significantly associated with an individuals estimated level.

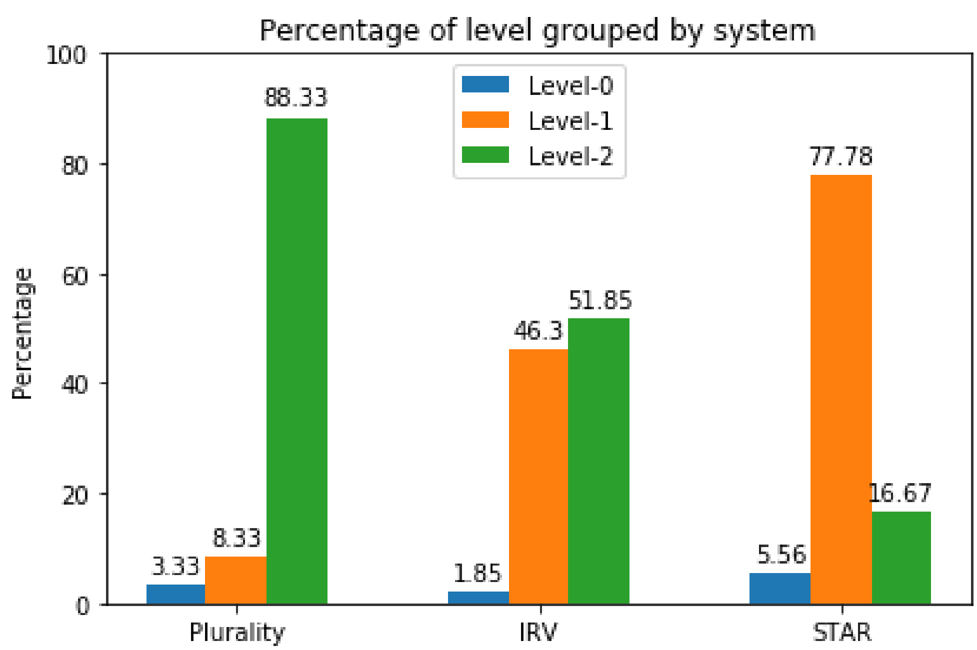

Figure 2.6. Distribution of levels

Table 2.1. Level-K Estimates

	(1)	(2)	(3)	(4)
VARIABLES	Mean Level	Mean Level	Mean Level	Mean Level
IRV	-0.350***	-0.339***	-0.347***	-0.340***
	(0.0905)	(0.0903)	(0.0896)	(0.0916)
STAR	-0.739***	-0.731***	-0.745***	-0.747***
	(0.0905)	(0.0902)	(0.0896)	(0.0903)
UG Level		0.0405*	0.0360	0.0364
		(0.0226)	(0.0244)	(0.0245)
CRT Score			0.0359**	0.0360**
			(0.0180)	(0.0181)
"Prosocial"				-0.0263
				(0.0780)
Constant	1.850***	1.730***	1.576***	1.589***
	(0.0623)	(0.0953)	(0.122)	(0.128)
Observations	168	168	168	168
R-squared	0.287	0.299	0.316	0.316

Random effects estimated standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Results estimated from the data using the cognitive hierarchy model show similar trends. Figure 2.7 shows the estimated value of τ for each of the three voting systems with bootstrapped standard errors represented by the black vertical bar. Again, as complexity increases, mean steps of thinking decreases implying the use of fewer and fewer strategies that can be defined as "strategic". This difference in τ found between voting systems is large and pairwise significant between the different voting mechanisms. Very clearly the degree of complexity in these voting systems has a large impact on an individuals ability to successfully find and exploit manipulative strategies for their own benefit. It is worth pointing out that if "sincerity" in voting behavior is a desirable outcome, IRV might actually be the best performing system here as estimated with by the CH model. As 1 step of thinking corresponds with sincerity voting, IRV has a value of τ that matches this metric the closest compared to plurality (comparatively more strategic) and STAR (comparatively more noisy).

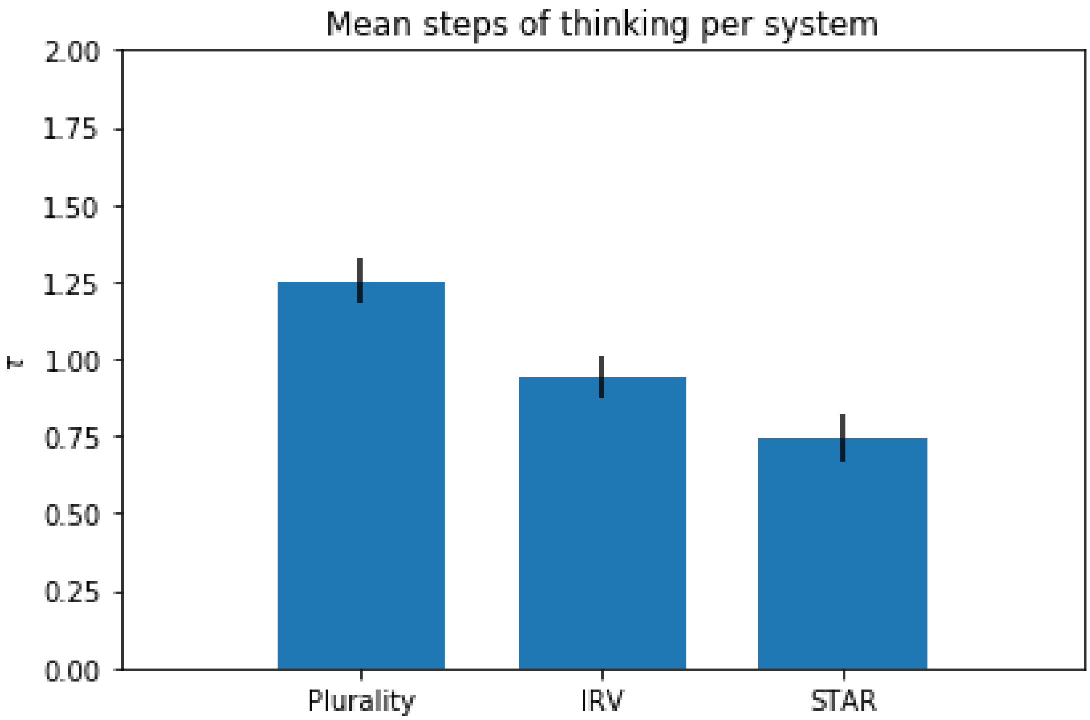

Figure 2.7. Cognitive Hierarchy estimates. Error bars represent a 95% boostrapped confidence interval of τ

The last of the analysis in this section concerns itself with comparing the observed experimental data to quantal response equilibrium predictions. There are two ways in which QRE is approached here. The first is defining a "path" of QRE solutions using a fixed point method and comparing that path to observed results from the data. This method was described previously in section 3.2 where individual QRE's are calculated from a path starting ant $\frac{1}{\mu} = 0$ and extending along as $\frac{1}{\mu}$ becomes arbitrarily large. Figures 8, 9, and 10 provide several examples of this practice. The remainder of these visualized QRE calculations are provided in Appendix D.

Figure 2.8 provides the traced QRE predictions for strategies in the plurality voting system for player 1 in both a non-strategic preference set (preference set 1) and a strategic preference set for which player 1 is a pivotal voter (i.e. a voter with a non-sincere level-2 strategy). Each line on Figure 2.8 (as well as Figures 9 and 10) represent a path for QRE which shows the relative frequency of the corresponding strategies for a fixed level of $\frac{1}{\mu}$, as specified by the figure key. The colored points on the figure are the observed frequencies of these strategies in data and correspond to the path of the same color (i.e. in Figure 2.8 the blue point corresponds with the observed frequency of sincere strategy A in the data as compared to the theoretical QRE frequency as given by the blue line). The labels p_n correspond to strategy $n \in \{A, B, C, D\}$, with special note given to the proper sincere and strategic strategies. The points representing the observed strategies have been placed along a value of $\frac{1}{\mu}$ which most closely approximates the theoretically predicted frequencies of the respective strategies.

Here we can see that for this setting which lacks a significant amount of strategic complexity, the QRE paths fit the observed frequencies in the data relatively well for values of $0 \leq \frac{1}{\mu} \leq 1$. This is consistent with similar findings found in Bassi (2014) [18] where observations fit predicted QRE outcomes fairly well, as seen by the relative closeness that the observed frequency of these strategies lie in comparison to their theoretically predicted frequencies. While some noisy play may exist, subjects seem to be responding to this noise appropriately as predicted by this model. One significant observation of note is that sincere voting is observed with far more frequency in the non-strategic preference set than predicted, a trend that persists throughout all 3 different voting mechanisms.

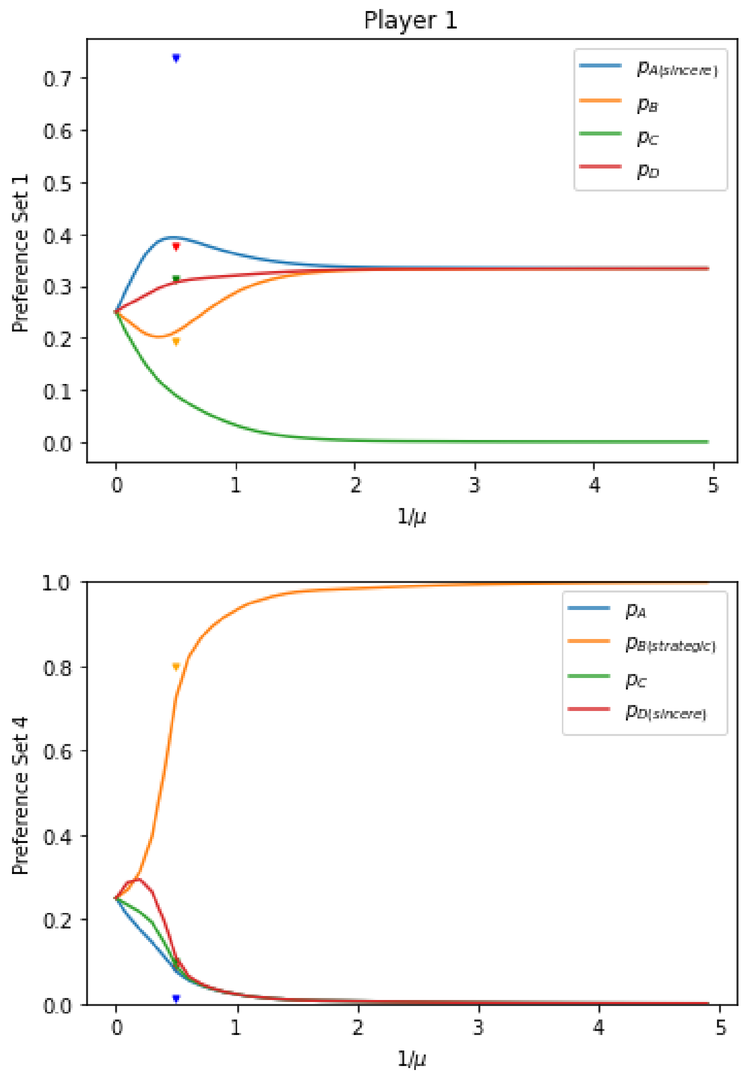

Figure 2.8. Plurality QRE Estimates

One of the challenges in presenting these QRE estimations and the conclusions that can be drawn with them is presenting QRE estimations and strategy frequencies similarly to those in the simple plurality model quickly becomes messy when a large number of strategies in introduced. Therefore for IRV, we have estimated these QRE paths for all strategies and grouped them into sets of similar strategies. These are strict sincere strategies (s, using the earlier definition of sincerity under QRE), weakly sincere strategies (ws, strategies that rank the most preferred candidate with a "1" but otherwise do not meet the definition of strict sincerity), strategic ($strat$) strategies, and all other o strategies. Figure 2.9 again presents the traced QRE predictions for strategies in the IRV voting system for player 1 in both a non-strategic preference set and a strategic preference set for which player 1 is a pivotal voter. It can be observed in this visualization that, estimates based on these categories seem to differ more significantly from observed data than plurality does in a similar context. Specifically, sincere and weak sincere strategies appear more often than predicted in both types of preference sets and strategic incentives. Furthermore, best fit values of $\frac{1}{\mu}$ take on lower values compared to the plurality system across a large number of fitted values for $\frac{1}{\mu}$ for the various player types across different preference sets. This means that not only do individuals rely on sincere or similar strategies than QRE would predict and further reinforces the idea that sophisticated behavior is limited to a larger extent in more complicated voting systems, as evidenced by more noisy (lower $\frac{1}{\mu}$) decision making. An empirical test of this trend is discussed later in this section and is shown in Table 2.2.

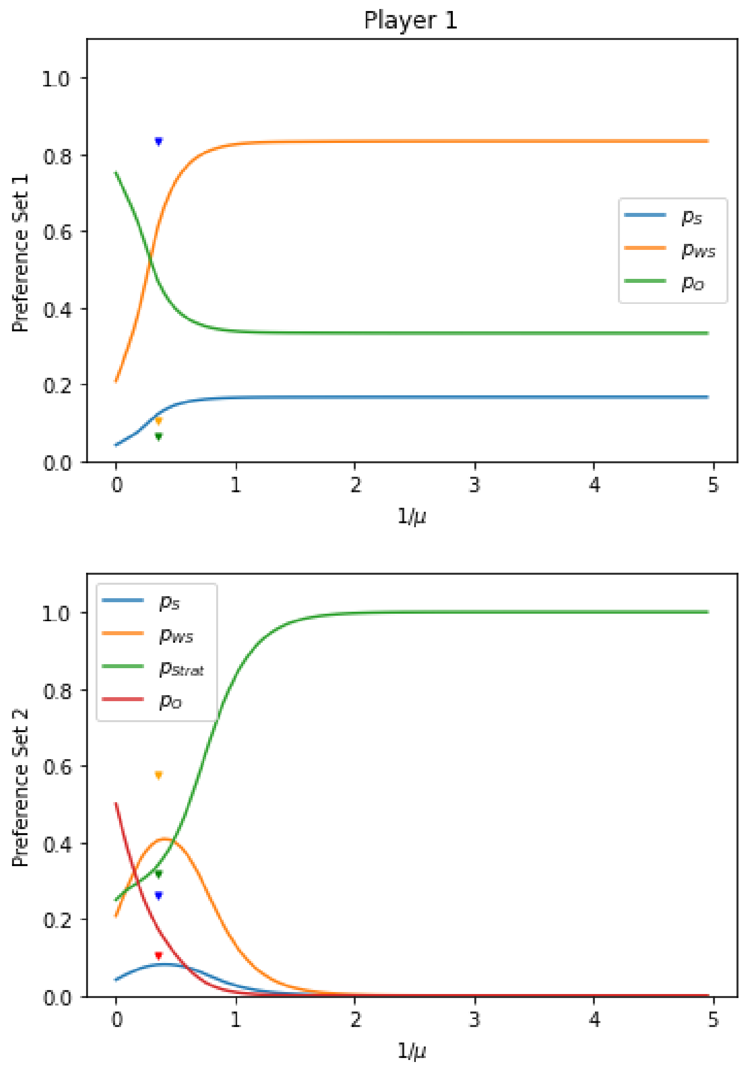

Figure 2.9. IRV QRE Estimates

Next we estimate the QRE outcomes and predictions for STAR in a similar manner. Again, a major challenge arises in presenting and analyzing this setting in a way that makes sense with a relatively large number (256) of strategies. Figure 2.10 presents the analysis of the STAR setting using a subset of strategies, again for player 1 in the same types of preference sets outlined for the previous two voting systems. While it is true that the strategy space for the STAR setting is quite large, the reality from the observed data is that subjects tend to choose from a relatively small subset of these strategies. In fact, the top 5 most used strategies for any given set of preferences and any given player consistently make up the super-majority ($> 60\%$) of all observed strategies.

To better represent the decision-making found in the data, we have taken the top 5 strategies of each type of player in each set of preferences and the QRE path has been traced for an environment where only those strategies are being played. Some new strategies here include the Nash equilibrium best response strategy to random play (BR, only when this is not identical to strict sincerity), and Bullet-N strategies, where a player plays a strategy where the N most preferred candidates are assigned the most points possible and all other candidates are assigned the least points possible. Again, the observed frequency of these strategies are given by the points in Figure 2.10 and correspond to the theoretically predicted frequencies of the same colored "path" or label (for example, point p_2, BR corresponds to the blue line, which represents the theoretical QRE frequencies of strategies 1,2,3, and 4). An interesting result of approaching the QRE estimation in this way is the relatively more sophisticated estimation of behavior compared to both IRV and Plurality voting with higher values of $\frac{1}{\mu}$. Despite this, sincere or "sincere-like" strategies are over-represented by experimental data compared to the theoretically predicted QRE results in both types of preferences sets, much like what was observed under the IRV voting rule.

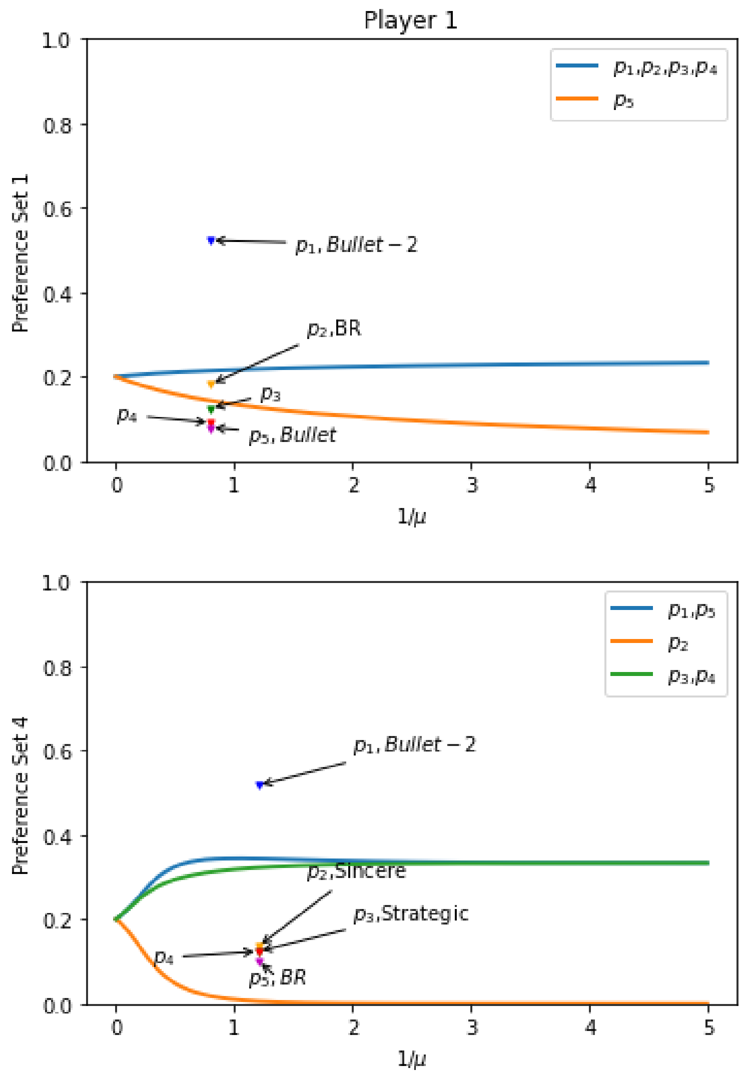

Figure 2.10. STAR QRE Estimates

The second way that $\frac{1}{\mu}$ has been calculated for each of the three systems is by using an "empirical payoff" approach taken from Palfrey, Holt and Goeree (2016) [33]. This approach relies on using the observed data to instead estimate a value of $\frac{1}{\mu}$ using maximum likelihood estimation rather than relying on a fixed point path for given values of $\frac{1}{\mu}$ starting at $\frac{1}{\mu} = 0$ and subsequently fitting observational data long this path. This specifically allows us to view QRE's relationship with the STAR voting system and its relatively large strategy space in a different context using all possibile strategies rather than limiting analysis to only a few frequently observed strategies. Results of this estimation can be viewed in Table 2.2. This table presents the pooled estimates of the mean and 95% confidence interval of $\frac{1}{\mu}$ for each of the voting treatments. Results found here are consistent with those results found in Figures 8 through 10, with values of $\frac{1}{\mu}$ between approximate one and zero. It is worth noting that there is not a large statistical difference between the mean estimates of $\frac{1}{\mu}$ in the pluraliry and instant runoff voting treatments in this pooled data (due to the very high pooled standard error estimated in the plurality voting treatment). However, these estimates are significantly higher than those estimated for the STAR treatment. Furthermore, estimated values of $\frac{1}{\mu}$ decline going from plurality to IRV and finally STAR voting systems, with the estimate of $\frac{1}{\mu}$ being statistically significantly larger for plurality compared IRV and subsequently IRV being larger than STAR. The STAR estimates is very close to 0, indicating substantially low levels of sophistication in decision making, substantially more so than the QRE estimates presented inf Figure 2.10 would imply. An additional conclusion that can be drawn from this is that QRE may not be an appropriate behavioral framework from which to analyze the sorts of decisions in these voting settings with relatively large strategy sets. Additionally, while the pooled data seems to point to a lack of significant difference between the plurality and IR treatments, when $\frac{1}{\mu}$ is estimated for each individual player type in each preference set, the majority of these individual estimates are significantly greater in the plurality voting treatment in comparison to the instant runoff voting treatment. For a full set of these estimates broken down by preference set and individual player role, see Appendix E.

Table 2.2. Empirical QRE Estimates

$\frac{1}{\mu}$ Estimates	Mean	Lower 95% CI	Upper 95% CI
Plurality	1.135	0.401	5.878
IRV	0.646	0.427	0.865
STAR	$2.539 * 10^{-8}$	$1.062 * 10^{-10}$	$1.269 * 10^{-7}$

In order to test which model is the best fitting among these 3 competing models, I apply 4 statistical tests of fit. The tests I use are the Akaike's information criterion, the Bayesian information criterion, Vuong's non-nested likelihood ratio test (Vuong 1989) [7], and Clarke's non-parametric test for non-nested models (Clarke 2007) [8].

All of these models compare the likelihood estimation across models in order to make statements about the "goodness of fit" for a model. The first step for comparing these models was to reconstruct a set of likelihood estimates that could me adequately used to compare each model. To do this, I take the various estimates from Figure 2.6, Figure 2.7, and Tables 2.3 through 2.5. Then, using the estimated parameters and observed data, I construct the likelihood value for each subject given their choice of actions in the data. From there, we can use each of the aforementioned measures of model comparison to draw conclusions on which models may fit the data best.

The Akaike's information criterion (AIC) draws comparisons across models using the total likelihood fit of each model and makes corrections based on the number of estimated parameters. If $\hat{L}$ is the value of the log-likelihood function and K is the total parameters estimated in a model, the equation for the AIC is given by:

$$AIC = -2(\hat{L}) + 2K$$

For the purposes of this estimation, $\hat{L}$ in my estimation is the sum of the individual likelihood values for each subject in the data.

Similarly, the Bayesian information criterion, using the same set of variables, is given by a similar equation:

$$BIC = -2(\hat{L}) + klog(n)$$

Where n is the number of datapoints used in the estimation of the likelihood function. For both BIC and AIC, lower values are preferable to higher values and show a better fit to the data.

Table 2.3 displays both the AIC and BIC estimates from the data. Separated out are the AIC and BIC for the entire set of treatments, and then calculated for the data from each treatment individually. Generally speaking, the conclusions that can be drawn from this estimate are that the model of Level-K behavior greatly outperforms both the CH and QRE models in goodness of fit. While QRE out performs the CH model in terms of the full sample and the plurality voting data, the CH model does perform better in both the IRV and STAR data.

Table 2.3. AIC and BIC Estiamtes

AIC Estimates	Full Sample	Plurality	IRV	STAR
Level-K	30032.1	3428.9	8931.2	17680.0
Cognitive Hierarchy	40831.8	5909.2	11055.6	23871.0
QRE	38797.1	3774.4	11069.5	23957.2
BIC Estimates	Full Sample	Plurality	IRV	STAR
Level-K	30038.4	3433.1	8935.2	17684.0
Cognitive Hierarchy	40834.9	5911.3	11057.6	23873.0
QRE	38800.2	3776.5	11071.5	23959.2

The other two estimators, those being the Clarke test and the Vuong test, instead take into account the differences between individual observations for each subject-level estimated likelihood value. The first of these, Clarke's non-parametric test for non-nested models, is the easier of the two to calculate. Here we state the null hypothesis as follows:

$$H_0 : Pr_0 \left[ln \frac{f(Y_{\mathrm{i}}|X\mathrm{i};\beta_*)}{g(Y_{\mathrm{i}}|Z\mathrm{i};\gamma_*)} > 0 \right] = 0.5$$

Where $f(Y_{\mathrm{i}}|X\mathrm{i};\beta_*)$ and $g(Y_{\mathrm{i}}|Z\mathrm{i};\gamma_*)$ are the maximized likelihood values of our two models. Letting $d_{\mathrm{i}} = lnf(Y_{\mathrm{i}}|X\mathrm{i};\hat{\beta_n}) - lng(Y_{\mathrm{i}}|Z\mathrm{i};\hat{\gamma_n})$ the test statistic is given by:

$$B = \Sigma_{\mathrm{i}=1}^{n} I_{(0,+\infty)}(d_{\mathrm{i}})$$

Where I is the indicator function. This equation is the number of positive differences between the likelihood function and is distributed Binomial with parameters n and $\theta = 0.5$.

In practice, this test is conducted by taking the difference of each likelihood value and counting the differences. If model F_β is a "better" model than G_γ, B will be significantly larger than its expected value under the null hypothesis ($n/2$). For an upper tail test, the null hypothesis is rejected when $B \geq c_\alpha$, where c_α is chosen to be the smallest integer such that

$$\Sigma_{c=c_\alpha}^{n} \binom{n}{c} 0.5^n \leq \alpha$$

For a lower tail test, the inequality is reversed and the sum goes from $c = 0$ to $c = c_\alpha$

Table 2.4 shows the results from the Clarke test below with the relevant upper and lower critical value counts. Again, I separate these estimates between the full sample and then again for the data collected in each treatment. I find that the Level-K model performs significantly better than either the CH or QRE models in both the full data set and in each subset of data, with the exception of the plurality voting treatment where both QRE and the Level-K model perform similarly. In both the IRV and STAR voting data, there doesn't seem to be a significant different in the level of fit between the CH and QRE models.

Table 2.4. Clarke estimates. Critical values represent the upper and lower tail counts required for a 95% confidence estimate

Clarke Estimates	Full Sample	Plurality	IRV	STAR
Level-K vs CH	167	60	53	54
Level-K vs QRE	136	33	50	53
CH vs QRE	51	4	26	21
Critical values	$96 \geq$ or ≤ 72	$45 \geq$ or ≤ 19	$36 \geq$ or ≤ 18	$36 \geq$ or ≤ 18

Lastly I perform Vuong's non-nested likelihood ratio test, which is conducted similarly to the Clark test though with some key differences. This test again uses the differences between the individual subject-level likelihood values. However, the null hypothesis is somewhat different. Specifically, using similar notation as before,

$$H_0 : E_0 \left[ln \frac{f(Y_{\mathrm{i}}|X\mathrm{i};\beta_*)}{g(Y_{\mathrm{i}}|Z\mathrm{i};\gamma_*)} \right] = 0$$

Under general conditions it can be shown that the expected value given in the null hypothesis can be consistently estimated by $(1/n)$ times the ratio statistic, or in other words:

$$\frac{1}{n} LR_n(\hat{\beta}_n, \hat{\gamma}_n \xrightarrow{a.s} E_0 \left[ln \frac{f(Y_{\mathrm{i}}|X\mathrm{i};\beta_*)}{g(Y_{\mathrm{i}}|Z\mathrm{i};\gamma_*)} \right]$$

where $\hat{\beta}_n$ and $\hat{\gamma}_n$ are the maximum likelihood estimators of β_* and γ_*. This likelihood ratio statistic is asymptotically normally distributed, and the actual test statistic is therefore

$$under H_0 : \frac{LR_n(\hat{\beta}_n, \hat{\gamma}_n}{(\sqrt{n}\hat{\omega}_n)} \xrightarrow{D} N(0,1)$$

where the numerator is the difference in the summed log-likelihoods for the two models, $LR_n(\hat{\beta}_n, \hat{\gamma}_n) \equiv L_n^f(\hat{\beta}_n - L_n^g(\hat{\gamma}_n)$ and $\hat{\omega}_n$ is the estimated standard deviation of the individual likelihood ratios.

Table 2.5 reports the results of these estimated test statistics in the form of appropriate Z-scores, with p-values for a one sided test reported in parentheses.

Table 2.5. Vuong Estimates. P-values are reported in parentheses.

Vuong Estimates	Full Sample	Plurality	IRV	STAR
Level-K vs CH	18.81	15.29	12.20	23.20
	(0.00)	(0.00)	(0.00)	(0.00)
Level-K vs QRE	11.47	2.15	8.67	16.87
	(0.00)	(0.016)	(0.00)	(0.00)
CH vs QRE	-3.98	-12.24	0.05	0.28
	(0.00)	(0.00)	(0.48)	(0.39)

As with the Clark test, Level-K clearly out performs both CH and QRE across all samples. In terms of fit, QRE out performs the CH model in the full sample and in the plurality voting treatment but there is no large statistical difference between those two models in the IRV and STAR treatments.

The difference in performance between these models can be speculated upon. One of the most likely reasons for the Level-K model performing better generally likely has to do with the flexibility of the estimation method of the different types from the subject data. In particular, the method taken from Georganas, et al (2015)[21] selects types based on 1) if an individual plays their Level-K strategy or 2) if they play a strategy close to optimal given an assumed Level-K and their beliefs about the strategies played by other player types in the population. This allows for estimation of levels on "near" optimal behavior consistent with a given subject type. In contrast, both the CH and QRE methods estimate parameters given a much stricter set of consistency requirements in beliefs and predicted behavior. Observations which are not consistent with model predictions are weighted much more heavily than those in the Level-K estimation. This is likely a major cause in the differences produced by the various maximum likelihood estimation procedures.

2.5.2 Effects on aggregate outcomes

When considering the performance of different voting systems, it is important to consider the efficiency of these systems in terms of aggregate group outcomes. Here we focus on three key measures of aggregate group efficiency: average social welfare efficiency and the Condorcet winner propensity. Social welfare efficiency is calculated as the sum of all individual group members' payoffs for the chosen alternative divided by the maximum total payoff the group could have earned in aggregate for a single chosen alternative. The second is defined on the frequency that a Condorcet winner is chosen by a group. A Condorcet winner is further defined as a candidate who would win in a pairwise election between that candidate and every other possible candidate.

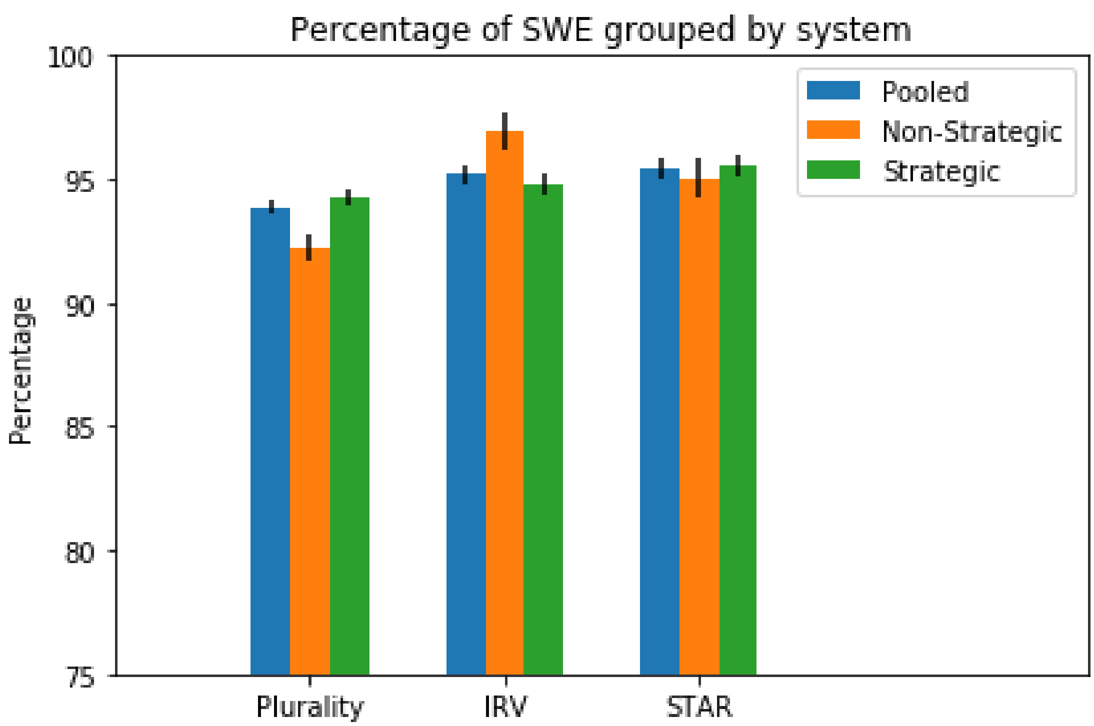

Figure 2.11. Social Welfare Efficiency. Black bars represent 95% confidence intervals.

We can see in Figure 2.11 that social welfare efficiency is quite high at above 90% for all three voting systems. The figure displays the calculated social welfare efficiency in each of the three voting systems for three types of preference sets: pooled (all preference sets), non-strategic preference sets, and strategic preference sets. Robust standard errors are displayed by the vertical black line. While not much variation is found between these different types of sets within each voting system, SWE is found to be greater in both IRV and STAR at at statistically significant level (p-value = 0.000 for STAR vs plurality, p-value = 0.003 for IRV vs plurality, two tailed t-test for equal means), though in economic terms this difference is practically very small. The average SWE between IRV and STAR is not a statistically significant difference (p-value 0.596, two tailed t-test for equal means). For references, as a "baseline" of behavior to compare these outcomes to, if subjects chose strategies using a random uniform strategy, SWE is predicted to be between 75% and 83% depending on preference set and voting treatment.

Figure 2.12 displays both the Condorcet winner and loser propensity across all three systems. For those preference sets that contained a Condorcet winner, the calculated levels of these statistics appear to have very little variance between plurality, IRV, and STAR. While there is some evidence that suggests that Condorcet winner propensity may be lower in IRV and STAR compared to plurality voting, this difference is nonetheless not statistically significant at any relevant significance level.

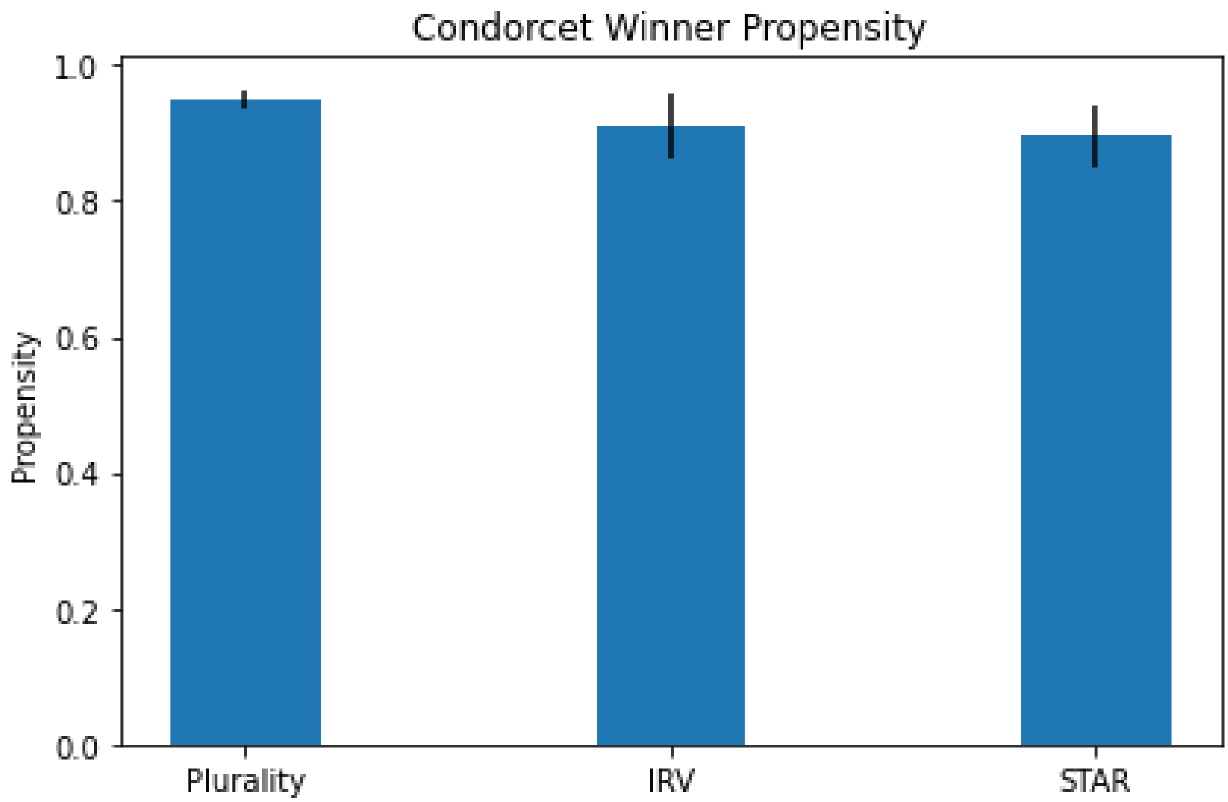

Figure 2.12. Condorcet Winner propensity

2.6 Discussion

Complexity in these systems clearly has a rather large effect on individual decision making as well as certain aggregate measures of group efficiency. This is not an accident; as social choice functions, voting systems aggregate individual choices into group decisions and factors that effect individual choices will then affect aggregate group outcomes. What may not be clear from the data, however, is if there exists one single "best" voting system in an objective sense. While added complexity may improve group outcomes and drive individuals to simpler strategies when compared to very simple systems, it appears at least certain benefits gained from sufficiently complex systems decrease as complexity continues to increase. For instance, the appearance of greater frequencies of noisy strategies that do not fit into categories of either strategic nor sincere strategies increase as the complexity of the system increases. Additionally, some evidence here suggests that aggregate outcomes in terms of Social Welfare

Efficiency are best under IRV compared to both plurality vote and STAR, though this difference in a practical sense is somewhat small. Furthermore, estimates under the Level-K model seem to suggest that Level-1 sincere types are maximized under a STAR voting system, while the CH model shows evidence that sincere decision making may be found most in an IRV system rather than the STAR or plurality voting mechanisms.

When assessing the goodness of fit of each of our models, that being the Level-K, QRE, and Cognitive Hierarchy models, what is clear by every measure of goodness-of-fit is that the Level-K model fits observed subject behavior more accurately in almost every case and often by clear margins. Between Cognitive Hierarchy and QRE, QRE outperforms CH in terms of goodness-of-fit in the simpler voting mechanisms but both behave comparably in more complicated voting systems. One possible explanation for these results is the specificity of strategies required to identify 1- and 2-step thinkers in the CH model and the flexibility of QRE from estimating behavior that is "good enough". In the more complicated voting systems, some strategies' payoffs deviate very little from the optimal strategy for each step of thinking. Such errors are punished substantially in terms of identifying types in the CH model but not as severely in the QRE model. The Level-K model used in this study, however, takes advantage of both of these elements. If a player makes a choice of action that is close to the optimal Level-K strategy in terms of payoff, this is still captured in the estimation of that player's likelihood function. This combination of estimating levels from a strict strategy prediction while still having the flexibility to estimate a player's level accurately if small mistakes are made from optimal behavior is likely the cause to explain why the Level-K model outperforms the other two models frequently, especially in large strategy spaces. Further investigation is warranted but it appears that for estimation in games with large discreet strategy sets and relatively shallow payoff hills, the method found in Georganas, et al. (2015) [21] is highly appropriate compared to other models of boundedly rational behavior.

What is apparent from the evidence provided by the various measures covered in this study is the benefits of implementing a STAR or IRV system largely outweigh any sort of costs associated with more complicated systems. Very noisy behavior does not substantially increase as complexity increases but social welfare increases in both systems when compared to a plurality vote mechanism. Sincere behavior is maximized in the most complicated voting mechanism, which is advantageous for both social scientists and policy makers studying preference-revealing behavior. Sincerity may also carry secondary benefits as well among voters themselves who feel they may not be forced into making less desirable, value compromising strategic voting decisions. Such utility can have potentially large beneficial downstream effects such as positively impacting voter turnout and general approval of an electoral system.

Additionally, it is important to consider other potential costs associated with complexity not empirically measured in this study. One very important one is what effects it may have when voting is voluntary. If cognitive load is viewed as a computation cost in decision making when voting, increasing complexity potentially makes the act of voting itself more costly for individuals to participate in. Converse to the benefit of increased sincere voting, this increase in cognitive load could potentially could depress voter turnout, a highly important consideration from a policymaker prospective. However, real world implementation and proper incentives might avoid this. For instance, New Zealand's elections in 2020 say voter turnout of 82.5% of eligible voters compared the the United States where 66.7% of eligible voters participated in the US general election. This is despite New Zealand using a much more complicated IRV voting system compared to the US's plurality voting system and both countries having voluntary voting systems. Without other mechanisms to encourage voter participation, however, it would not be surprising to see voter turnout decrease if IRV or other complicated alternative systems were implemented exogenously in the United States. Future investigations and experiments where voter participation itself can be made endogenously may want to investigate the effect that different voting systems may have on this decision.

It may also be worth considering the incentives larger organizations may have when promoting different voting systems as well. High levels of strategic voting are commonly associated with the convergence of the number of political parties to only two. This is also known as Duverger's Law and has been a widely observed phenomena in the existing literature[4]. Therefore, democratic institutions with strong entrenched two-party systems like the United States likely will see substantial pressure to maintain a system like plurality voting from political parties to maintain a plurality voting system in order to continue to assert substantial electoral authority. It may be therefore difficult to impose even welfare improving voting systems in the face of potentially very powerful, and self interested, political organizations.

What is abundantly clear from this study is that the investigation of individual behavior using existing models of decision making is far from complete. What remains to be seen is how the outcomes outlined in this paper compare to other other widely used electoral systems, including systems with multiple stages of decision making. One critical avenue of investigation includes how the presence of imperfect and incomplete information may play in the role of individual decision making and how the quality of signals about other's decisions may play in the part of determining strategic behavior. As previously mentioned, how these different systems impact decisions to participate in electoral politics itself provides an open, but important, opportunity that has yet to be fully explored. While this study provides important implications of the impact of complexity alone on ballot decisions, such further investigations have an important role to play in the evaluation of our various democratic systems.

[4]↑For an example of an experimental study where this is a easily observable and studied phenomenon, see Forsythe, et al (1993) [13] and Hizen, Inukai, and Kurosaka (2010) [34]

3. THE EFFECT OF LEADER SELECTION ON HONESTY AND GROUP PERFORMANCE: EXPERIMENTAL EVIDENCE

This chapter will be submitted to a journal for publication.

With Raquel Asencio and Brian Roberson

This paper investigates the relationship between the mechanisms used to select leaders and both measures of group performance and leaders' ethical behavior. Using a laboratory experiment, we measure group performance in a group minimum effort task with a leader selected using one of three mechanisms: random, a competition task, and voting. After the group task, leaders must complete a task that asks them to behave honestly or dishonestly in questions related to the groups performance. We find that leaders have a large impact on group performance when compared to those groups without leaders. Evidence for which selection mechanism performs best in terms of group performance seems mixed. On measures of honesty, the strongest evidence seems to indicate that honesty is most positively impacted through a voting selection mechanism, which differences in ethical behavior between the random and competition selection treatments are negligible.

3.1 Introduction

Culture inside an organization can be shaped significantly by a number of important external and internal factors. One of the most important facets to this cultural development is leadership within the organization and the types of behaviors and practices this leadership does and does not promote. Some behaviors, such as the ethical behavior and honesty of a firm or public institution, are of great interest to the external share- and stakeholders of these types of organizations. Furthermore, inherent types of structures within an organization, such as how leadership is picked, may reinforce said ethical behavior through subtle but nonetheless important associations such as entitlement and accountability. Thus the broader investigation and research on ethical leadership is important to understanding how the ethical culture of some institutions form.

Research on ethical leadership is defined as, "the demonstration of normatively appropriate conduct through personal actions and interpersonal relationships, and the promotion of such conduct to followers through two-way communication, reinforcement, and decision-making" (Brown et al. 2005, p. 120). Scholars in this area have focused on the situational influences (e.g., ethical climate and culture; Treviño et al. 1998) and individual characteristics (e.g., agreeableness, conscientiousness; Brown and Treviño 2006) that lead to ethical leadership. The mechanism through which leaders are promoted may be an additional key aspect of how organizational culture develops. This includes the possible influence of a promotion mechanism on ethical decision making by leaders in an organization.

In this project we examine the behavioral ethics of how the nature of promotion into leadership roles in an organization affects the subsequent ethical behavior of leaders. We examine three principle mechanisms which are used frequently to promote leaders. Namely, we examine the effect of leaders being democratically chosen through voting, being selected by competition, and being selected randomly on subsequent group performance and ethical behavior. This project lies at the intersection of the emerging field of behavioral ethics — for an introduction see Bazerman and Tenbrunsel (2012)[35] — the literature in personnel economics on labor market tournaments, and the literature in organizational behavior on ethical leadership.

In order to examine the causal effect that these different types of leadership selection mechanisms might have on individual leaders, we use a laboratory experiment in which groups participate in a joint task both with and without a leader. Leaders are then subsequently asked to participate in a task that is related to the groups' performance in which they may choose to behave unethically in order to benefit themselves. In our experiment, this involves choose to report the truthful outcome of a group task or instead report an inflated value at different incentive levels. Laboratory experiments provide an ideal setting for studying both group and individual behavior due to the high amount of control researchers have on factors in this environment. For instance, an individual's decisions to behave ethically or not is influenced by large external social factors as well as individual internal factors. Using an experimental setting allows us to control these external factors to a large degree.

Despite the important impact different mechanisms of leader promotion may have on behavior and organizational culture, there is no direct examination of how the manner in which a leader is promoted to their position influences subsequent ethical behavior. By exploring how a discrete event — how a leader is selected — might influence subsequent ethical behavior on the part of the leader, this research examines an additional antecedent of ethical leadership that fills a gap at the intersection of the existing literature.

This study uses the previously mentioned laboratory setting to answer two key questions related to this gap in the literature. First, does the way in which leaders are selected have outsize impact on aggregate group performance? Second, do different leadership selection mechanisms impact the *honesty* of leaders in tasks related to that group's performance? These two questions are interrelated and existing experimental evidence suggests performance can have impact on decisions of honesty (see Section 2 of this paper for work related to this topic). One important factor which may be contributing to differences in outcomes may be the types of leaders selected by the different mechanisms rather than the causal impact of the selection mechanisms themselves. We attempt to control for this difference by controlling for different leader personality types during our estimation procedure. Regardless, it is still an important consideration by organizations if different selection mechanisms are producing disparate outcomes through acting as a "filtering" mechanism for personality type rather than a direct causal impact. In this case, the difference in conclusions matters functionally very little.

We approach the question of honesty using a task where acting dishonestly is always the weakly better option with respect to payoffs and do not come at the expense of other agents. This second topic has potentially strong implications on how organizations may wish to structure internal leader selection, especially when decisions leaders make may lack public verification and dishonest behavior is encouraged through a leader's personal gain.

We predict that, in terms of group efficiency, voting selection mechanisms will be weakly better than competition selection mechanisms, which in turn will weakly outperform a randomly selected leader. For measures of honesty we make a similar prediction: elected leaders will be weakly more honest than those selected by competition, which in turn will be weakly more honest than those selected at random. We make this prediction as those leaders not selected randomly will feel greater accountability for their group's performance and ownership of results, leading to both more efficient outcomes and higher levels of honesty. However, those leaders selected through a competition mechanism may feel a greater sense of entitlement to rewards, which may cause them to behave more dishonestly compared to an elected leader.

Results of this experiment consistently show that how leaders are picked does seem to have an impact on subsequent ethical behavior. Leaders selected at random and competition exhibit comparable levels of unethical behavior. Some strong evidence exists that seems to indicate that those leaders selected through a voting mechanism may behave more honestly than those selected either at random or through competition. Additionally, it is worth noting that, regardless of the method used to selected leaders, those groups with leaders vastly outperform those groups without leaders, which supports the existing evidence that performance of groups with leaders is primarily driven by leaders' communication acting as a coordination mechanism. However, how leaders are selected seems to create little, if any, difference in outcome in terms of group performance and efficiency. For example, there is little difference in levels of group performance when comparing those groups with leaders who were selected through voting versus those selected by a competition.

We reinforce these results related to leader honesty by providing and further analysis and discussion regarding the estimation of results from ordered data. As has been pointed out in related literature by Bond and Lang (2019)[36], there are certain assumptions that must be met to avoid potential problems inherent to ordinal data estimation. We provide evidence that the data estimated from our experiment meets the criteria of many of these assumptions brought up in that paper. Furthermore, we use an estimation procedure from Chen, et al. (2019)[37] which focuses on the treatment effects on the median rather than the mean, which both avoids the necessary assumptions required of ordinal data estimation and confirms our other results.

The rest of this paper is organized into the following sections. Section 2 provides a brief review of the related literature. Section 3 provides a theoretical background which motivates our primary identification and estimation methods. Section 4 provides a background of the overall design and procedures of the experiment. Section 5 discusses the results of this experiment. Section 6 is a brief discussion and conclusion of these results.

3.2 Literature Review

This project contributes to several important existing fields of research. Principally, as previously mentioned, this project contributes to the fields of behavioral ethics, the existing literature in personnel economics on labor market tournaments, and the literature on organizational behavior on ethical leadership. Additionally, this paper adds to the continued discourse surrounding the interpretation and use of discrete ordered scales and the interpretation thereof. Finally, this paper also building on the existing literature of experimental literature related to leadership, communication, legitimacy, and honesty.

The paper closest related study to our empirical investigation is Brandts, Cooper, and Weber (2015)[38]. That study focuses on the different efficiency outcomes between groups whose leaders are selected through either an electoral voting process or by pure random chance using a group coordination task in a laboratory setting. We expand on this analysis by adding an additional mechanism by which leaders are picked: a competition mechanism structured as a Tullock competition. On the efficiency side of things, our results differ in significant ways from Brandts, Cooper, and Weber (2015)[38]. Namely, we find that, while leaders are important in coordination tasks, *how* leaders are selected makes no apparent statistically significant difference in most metrics. Furthermore, those metrics where some difference is estimated show small, economically unimportant differences. Including a competition selection mechanism, however, does beg the question related to potential ethical behavior of individuals within an organization, as some existing evidence shows that outcomes from certain events (such as competitions) may affect individual behavior in important ways. Thus the introduction of a competition mechanism not only provides further investigation for leader selection on efficiency of group outcomes but concerns itself with broader behavioral ethics.

Behavioral ethics seeks to identify and understand what Bazerman and Tenbrunsel (2012)[35] describe as ethical "blind spots." For example, Schurr and Ritov (2016)[39] experimentally examine an environment in which subjects first compete in a contest, and then subjects participate in a task in which there is incentive to lie about a privately observed random event. In that setting, Schurr and Ritov (2016)[39] find that winning a contest generates, for winners, a sense of entitlement that increases subsequent unethical behavior. That is, the subsequent behavior of winners, in unrelated tasks, is found to be less ethical than that of losers. Related work by Kuhnen and Tymula (2012)[40] indicates that relative performance of individuals may create a feedback that influences self-perception of better future rankings within a group but subsequently reduces individual effort in future tasks. Further work done by d'Adda et al. (2017)[41] also applies the ethical framework to leadership roles in team competitions, with leaders being able to make unethical deicisons with negative externalities following a series of group competitions. Their work finds that leaders who behave dishonestly are more likely to inspire dishonest behavior among followers and incentivize dishonest behavior as well.

Several parts of our study contain important differentiations in method and results from earlier research, however. First, unlike Schurr and Ritov (2016)[39], we use a price menu task rather than a die rolling task contained in the original study, which allows for a more explicit rather than derived observation of levels of dishonest behavior. Furthermore, our study makes connections between honesty regarding a task related to the group's performance rather than in an unrelated task. Finally, in contrast with Shurr and Ritov (2016)[39], our results indicate that those leaders selected through a voting in exhibit significantly more subsequent truthful behavior compared to a random selection mechanism, while those selected by competition behave similarly to those in the random treatment. In addition, leader selection has little impact on overall group performance

Research on the benefits, and potential issues, of labor-market promotion tournaments, dates back to Lazear and Rosen (1981)[42].[1] In a recent survey on the topic, Sheremeta (2016)[44] notes that this literature has identified a number of concerns regarding promotion tournaments, including: (i) ex post payoff inequality, (ii) a discouragement effect for lower-ability workers, (iii) incentives to cheat and/or focus on self over the organization,

[1]↑For an introduction to the topic, see Chapter 11 of Lazear and Gibbs (2014)[43]

and (iv) gender issues with regards to competition.[2] The affect that competition has on subsequent ethical behavior is another potential drawback of promotion tournaments. For further review of tournament theory related to the management and management science literature, see Connelly, Tihanyi, Crook, and Gangloff (2014)[50]. For an empirical overview of corporate promotion tournaments, see Bognanno (2001)[51]. Finally, for an examination of social factors influencing behavior a various stages of a tournament(before, during, and after tournaments), see Garcia, Reese, and Avishalom (2018)[52].

Our project also contributes to the broad body of literature investigating the psychology and idiosyncratic nature of dishonesty. Specifically, we employ a model of path dependent costs to dishonesty, in which lying costs are both unique to each individual and depend on the relative performance of their associated group. Additionally, we add in the effect of how they are picked to be leaders within a group. We subsequently use this model to estimate the impact of different leadership selection systems on this lying costs. Significant support for these path dependent lying costs can be found in the existing literature. Kartik (2009) and Gneezy, et al. (2018)[53] both find that the magnitude of lying has significant impacts on the decision to lie. Abeler, et al. (2014)[54] finds that lying costs are substantial, even when the honesty of reported outcomes are not verifiable. Many other papers, such as Dufwenburg and Dufwenburg (2018)[55], Abeler, Nosenzo, and Raymond (2019)[56], and Khalmetski and Sliwka (2019)[57], find that both reputation and the degree of dishonesty are significant determinants to the degree of honesty in subjects. While this paper does not address the reputational or individual's perceptions of honesty, we do never-the-less find additional evidence that this conditional path dependence is important in decisions to be honest or dishonest.

Yaniv, Tobol, and Siniver (2020)[58] study the degree by which both self image and social image impacts dishonest behavior. Their study particularly finds that self image is a much less important than social image. Altay, Majima, and Mercier (2020)[59] study an

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[2] ↑For example, in the case of the gender difference concern, Bönte (2015)[45], utilizing a data set involving a survey of 25,000 participants from 36 countries, finds that women have a statistically significant and substantially lower self-reported preference to enter competitive situations than men. Additional work relating leadership and competition comparing genders can be found in Grossman, et al. (2019)[46]. For surveys of related work utilizing both field and laboratory data, see Niederle and Vesterlund (2011)[47], Dechenaux et al. (2015)[48], and Cassar and Katz (2016)[49]

environment where the public credit for ideas can be dishonestly represented and find that dishonesty is most often observed when the perception of competency was a driving factor and the odds of being found out were low. This further reinforces the idea that social image is perhaps the most important factor when predicting dishonest behavior.

Our study also contributes to the recent body of literature estimating and addressing the issues related to ordinal data. Bond and Lang (2019) provides a technical overview of various issues related to the estimation of treatment effects from ordinal data. In many cases, underlying necessary assumptions are not met by the estimated data. In this study we use an estimation procedure of median (rather than mean) treatment effects from Chen, et al. (2019)[37] to help address this issue. Several other papers including Kaiser and Vendrik (2020)[60], Kaplan and Zhuo (2020)[61], and Liu and Netzer (2020)[62] also address estimating effects from ordinal happiness scales. The application of checking required conditions in data such as first order and second order stochastic dominance is widely applied in the poverty literature, one example being Davidson and Duclos (2000)[63].

Finally, our work contributes to the general body of work using experiments related to the interaction between leadership, communication, and coordination. Antonakis, et al (2015)[64] examines both lab and field experiments which measure the impact of charisma from a leader on group performance, and find significant improvements of group outcomes of over 15% for more charismatic leaders. A series of papers examine the role of leaders as first movers in group settings, including Komai, Grossman, and Deters (2010)[65], Moxnes and Van der Heijden (2003)[66], and Güth, Müller, and Spiegel (2002)[67]. All of these papers find that costly, binding actions by leaders acting as first movers are an effective means of coordinating behavior. The last of those papers examines this in a sequential duopoly game and find that the threat of followers' actions effectively provides a deterrent that reduces the advantage of the first mover.

Several studies focus on different leadership roles in experimental settings, whether leaders act through communication or by being first movers in minimum effort and public goods games, including Dong, Montero and Possajennikov (2017)[68] and Sahin, Eckel and Komai (2015)[69]. In general, the exact type of leadership is not a substantial causal factor on differences of group performance. Finally, for a more extensive review of the various types of experiments focused exclusively on the impact of communication in laboratory experiments, see Brandts, Cooper, and Rott (2019)[70]. In work similar to ours, Levy et al. (2011)[71] tests the impact of leaders being selected randomly or being elected by group measures and measures how this impacts group performance. They find that non-binding communication is equally effective regardless of selection mechanism, and were significantly better than even a computer makes similar decision suggestions, lending credence to the idea that the legitimacy of a leader may play an important role in group decision making. For further reading on the theoretical role of leaders in different settings, see Foss (2001)[72] for a discussion of settings and channels by which leaders can act as information aggregators and coordinators. While we do not run specific treatments for computerized or leaderless communication in this study, evidence in the literature seems to suggest that 1) computerized communication is less efficient and 2) two-way rather than one-way communication in coordination games are more efficient.

3.3 Theoretical Background

Here we outline a path dependent model of dishonesty, in which the cost of lying is influenced by two primary factors that include: 1) the previous performance of their group during the group task and 2) the mechanism by which the individual was selected to be the leader of their group. In our experimental setting, subjects are asked to make a series of choices regarding their group's performance on a group task. Subjects are presented a list of choices A and B and asked to choose between each one. Option A is always the true value of the average group earnings. Option B is always the value of the average group earnings plus 50 (so this performance is inflated)). Because the magnitude of the dishonesty is held constant across all group outcomes and treatments we can largely ignore how the size of a lie (in terms of how much a reported value differs from the actual value) affects honest behavior. Subjects are asked to make a decision between choices A and B at a variety of incentive levels with the first choice being a high incentive level and the last choice having the same payoff for telling the truth or misreporting the higher value.

Our model for costs of dishonesty draws from the "Reputation for Honesty + LC" model described in Abeler, Nosenzo, and Raymond (2019)[56]. From this paper, utility is given by:

$$\phi(r, c(r, \omega), \Lambda(r); \phi^{LC}, \phi^{RH}) = u(r) - \phi^{LC} c(r, \omega) - \phi^{RH} v(\Lambda(r))$$

where r is defined as the reporting level, $\Lambda(r)$ is defined as the fraction of liars at r with $v(\Lambda(r)) > 0$, and $c(r, \omega)$ is the cost of lying at r with $c(\omega, \omega) = 0$. We also assume that ϕ is increasing in r, w, ϕ^{LC}, and ϕ^{RH}.

In our reporting task there are only two possible choices labeled A for truthful reporting and B for misreporting. The comments below are for the general case of r being a number that is determined by the A and B options, and we make a slight abuse of notation and let $r \in \{A, B\}$.

Our approach involves applying the general ordered response model of Cameron and Heckman (1998)[73] to the utility function given above.

With the reporting task, at each point $\mathrm{j} \in \{1, \ldots, 5\}$ of a treatment $t \in \{C, R, V\}$ the leader solves the problem:

$$\max_{r \in \{A_{\mathrm{j}}, B_{\mathrm{j}}\}} \{\phi(r, c_t(r, \omega), \Lambda_t(r); \phi_t^{LC}, \phi_t^{RH})\} \tag{3.1}$$

where $c_t(r, \omega)$, $\Lambda_t(r)$, ϕ_t^{LC}, and ϕ_t^{RH} may all depend on t.

If at point $\mathrm{j} \in \{1, \ldots, 5\}$ the leader switches from lying to truth telling, then we know the two following facts:

$$u(A_{\mathrm{j}}) - \phi_t^{RH} v_t(\Lambda(A_{\mathrm{j}})) \geq u(B_{\mathrm{j}}) - \phi_t^{LC} c_t(B_{\mathrm{j}}, \omega) - \phi_t^{RH} v_t(\Lambda(B_{\mathrm{j}}))$$

and

$$u(A_{\mathrm{j}-1}) - \phi_t^{RH} v_t(\Lambda(A_{\mathrm{j}-1})) \leq u(B_{\mathrm{j}-1}) - \phi_t^{LC} c_t(B_{\mathrm{j}-1}, \omega) - \phi_t^{RH} v_t(\Lambda(B_{\mathrm{j}-1}))$$

Then, because

$$u(B_{\mathrm{j}-1}) - u(A_{\mathrm{j}-1}) \geq u(B_{\mathrm{j}}) - u(A_{\mathrm{j}})$$

we know that

$$\begin{aligned} u(B_{\mathrm{j}-1}) - u(A_{\mathrm{j}-1}) &\geq \phi_t^{LC} c_t(B_{\mathrm{j}-1}, \omega) + \phi_t^{RH} v_t(\Lambda(B_{\mathrm{j}-1})) - \phi_t^{RH} v_t(\Lambda(A_{\mathrm{j}-1})) \\ &\geq \phi_t^{LC} c_t(B_{\mathrm{j}}, \omega) + \phi_t^{RH} v_t(\Lambda(B_{\mathrm{j}})) - \phi_t^{RH} v_t(\Lambda(A_{\mathrm{j}})) \\ &\geq u(B_{\mathrm{j}}) - u(A_{\mathrm{j}}) \end{aligned} \tag{3.2}$$

we also know that

$$\begin{aligned} u(A_{\mathrm{j}}) - u(A_{\mathrm{j}-1}) &\geq \phi_t^{LC} c_t(B_{\mathrm{j}-1}, \omega) + \phi_t^{RH} v_t(\Lambda(B_{\mathrm{j}-1})) - \phi_t^{RH} v_t(\Lambda(A_{\mathrm{j}-1})) \\ &- \left[\phi_t^{LC} c_t(B_{\mathrm{j}}, \omega) + \phi_t^{RH} v_t(\Lambda(B_{\mathrm{j}})) - \phi_t^{RH} v_t(\Lambda(A_{\mathrm{j}}))\right] \\ &\geq 0 \end{aligned} \tag{3.3}$$

Now we add in the omitted variable ϵ which is a person-specific shifter that is independent of other characteristics, and we assume that ϵ is continuously distributed according to a distribution F.

Let X be the set of possible profiles of observable characteristics, where $x \in X$ denotes an arbitrary profile of characteristics. We assume that the parameters ϕ_t^{LC} and ϕ_t^{RH} are depend on $x \in X$, i.e. replace the constants ϕ_t^{LC} and ϕ_t^{RH} with $\phi_t^{LC}|x$ and $\phi_t^{RH}|x$. Futhermore, we assume that $\phi_t^{LC}|x$ and $\phi_t^{RH}|x$ depend on x and ϵ (observed and unobserved effects, respectively) in a multiplicatively separable way. That is, there exists a function $\mu(x)$ and constants $\widetilde{\phi}_t^{LC}$ and $\widetilde{\phi}_t^{RH}$ such that:

$$\phi_t^{LC}|x = \widetilde{\phi}_t^{LC} \mu(x) \epsilon$$

and

$$\phi_t^{RH}|x = \widetilde{\phi}_t^{RH} \mu(x) \epsilon$$

Thus, the probability that a leader with observable characteristics x switches at point $\mathrm{j} \in \{1, \ldots, 5\}$ is:

$$\Pr(\text{switch at j}|x) = \\ \Pr\Bigg[\frac{u(B_{\mathrm{j}-1}) - u(A_{\mathrm{j}-1})}{\Big(\widetilde{\phi}_t^{LC} c_t(B_{\mathrm{j}-1}, \omega) + \widetilde{\phi}_t^{RH} v_t(\Lambda(B_{\mathrm{j}-1})) - \widetilde{\phi}_t^{RH} v_t(\Lambda(A_{\mathrm{j}-1}))\Big)\,\mu(x)} \geq \epsilon \geq \\ \frac{u(B_{\mathrm{j}}) - u(A_{\mathrm{j}})}{\Big(\widetilde{\phi}_t^{LC} c_t(B_{\mathrm{j}}, \omega) + \widetilde{\phi}_t^{RH} v_t(\Lambda(B_{\mathrm{j}})) - \widetilde{\phi}_t^{RH} v_t(\Lambda(A_{\mathrm{j}}))\Big)\,\mu(x)}\Bigg] \tag{3.4}$$

Defining $l(\mathrm{j})$ as

$$\exp(l(\mathrm{j})) := \frac{u(B_{\mathrm{j}}) - u(A_{\mathrm{j}})}{\Big(\widetilde{\phi}_t^{LC} c_t(B_{\mathrm{j}}, \omega) + \widetilde{\phi}_t^{RH} v_t(\Lambda(B_{\mathrm{j}})) - \widetilde{\phi}_t^{RH} v_t(\Lambda(A_{\mathrm{j}}))\Big)}$$

we may rewrite equation 4 as:

$$\Pr(\text{switch at j}|x) = \Pr\left[\frac{\exp(l(\mathrm{j}-1))}{\mu(x)} \geq \epsilon \geq \frac{\exp(l(\mathrm{j}))}{\mu(x)}\right] \tag{3.5}$$

Then we can assume that $\mu(x) = \exp(-x\beta)$ which implies that

$$\Pr(\text{switch at j}|x) = \int_{l(\mathrm{j})+x\beta}^{l(\mathrm{j}-1)+x\beta} f(\log\epsilon)\,d\epsilon \tag{3.6}$$

where f is the density of $\log\epsilon$. Estimation of $x\beta$ is given in the results section 5 along with various robustness checks that support the use of an ordered logistic regression to measure treatment effects. An overview of our estimation and how we address several issues and assumptions required of an ordinal logistic regression are provided in sections 5.2 and 5.3.

3.4 Experimental Design

This experiment tested the impact of different leadership selection mechanisms both on group efficiency and measures of honesty on the selected leader. A total of 340 subjects were used in this experiments and were drawn from the population of graduate and undergraduate students at Purdue University. Computerized experimental sessions were run using oTree (Chen, et al. 2016) at the Vernon Smith Experimental Economics Laboratory. We ran 21 experimental sessions with all three main treatments in each session. Between 12 and 24 subjects participated in the lab each session. Each experimental session involved three parts. Subjects were given a set of instructions, which are available in Appendix B, at the beginning of each part of the experiment the experimenter read the instructions for that part aloud. Subjects were paid in USD for a single decision made in one task, determined randomly, in addition to a $10 participation payment for an average payment of $18.14

This experiment consisted of 8 different tasks. The main task of this experiment consisted of a minimum effort coordination game taken from Brandts, Cooper, and Weber (2015)[38], in which subjects were placed in a group and asked to select "effort" levels that determined both the group and individual payoffs. This was done with and without a leader. Subjects were asked to do 7 additional tasks as well, with one of these tasks taking place before the coordination game, 2 of these tasks occurring between different rounds of the coordination game, and 4 of these tasks occurring after completion of this minimum effort coordination game. Subjects completed a multiple choice quiz as the first task before any other part of the experiment. Tasks occurring between different rounds include an honesty task for group leaders and a group self evaluation for all group members. Tasks following the minimum effort coordination game include a leadership style self-evaluation, risk and ambiguity aversion multiple price list (MPL) tasks, and a demographics questionnaire.

3.4.1 Coordination game and honesty tasks

The main two tasks used for this experiment involved a group minimum effort coordination task and a subsequent honesty task conducted by group leaders. This part of the experiment was broken up into three different treatments, each consisting of 10 rounds. The first of these tasks was taken largely from Brandts, Cooper, and Weber (2015)[38]. In the first round of each treatment, subjects were placed in groups of 4. The task involved each group member selecting a discrete "effort" level from one of 5 choices. During the experiment this was framed as each individual selecting how many hours during a workweek they wanted to spend working on a certain task.

After all group members had selected an effort level, each individuals' payoff was calculated as a function of their chosen effort level and the minimum effort level choice of all group members as well as a "bonus rate" parameter determined during the experiment. The formula used during the experimental sessions is given below:

$$Payoff = 200 - 5 * HA_{\text{i}} + min(HA) * B$$

Where HA_{i} is the individual's chosen effort level, $min(HA)$ is the minimum of all group members' effort levels, and B is the "bonus rate". The value chosen for B across all treatment was 8. This value was taken from one of the treatments of the original Brandts, Cooper, and Weber (2015)[38] paper. After each group had submitted an effort level, a results screen displayed their choice, the minimum effort level of any other group member, and the payoff from that round in points.

After the first 4 rounds of each treatment, a leader was selected from among the 4 group members. How this leader was selected differed by treatment, with three total treatments being used. All group members were informed of which selection mechanism would take place during this treatment. In the *random* treatment, leaders were selected randomly, with each group member being equally likely to be selected as the leader. In the *voting* treatment, each individual group member voted on which member of the group they wanted to be the leader. Each group member had one vote they could cast and the individual with the most votes was chosen to be the leader. Any ties were broken randomly. The last of these treatments was referred to as the *competition* treatment, which is explained in the following paragraph.

In the competition treatment, leader selection took the form of a Tullock competition. Each group member was given 100 "tickets" which they could elect to spend on increasing their probability of becoming the group leader. Any unused tickets were added to their potential earnings for the experiment. Subsequently, after all players decided how many tickets to spend, their probability of being picked to be the leader was the quotient of how many tickets they chose to spend in the competition and the sum total of all tickets spent by all group members.

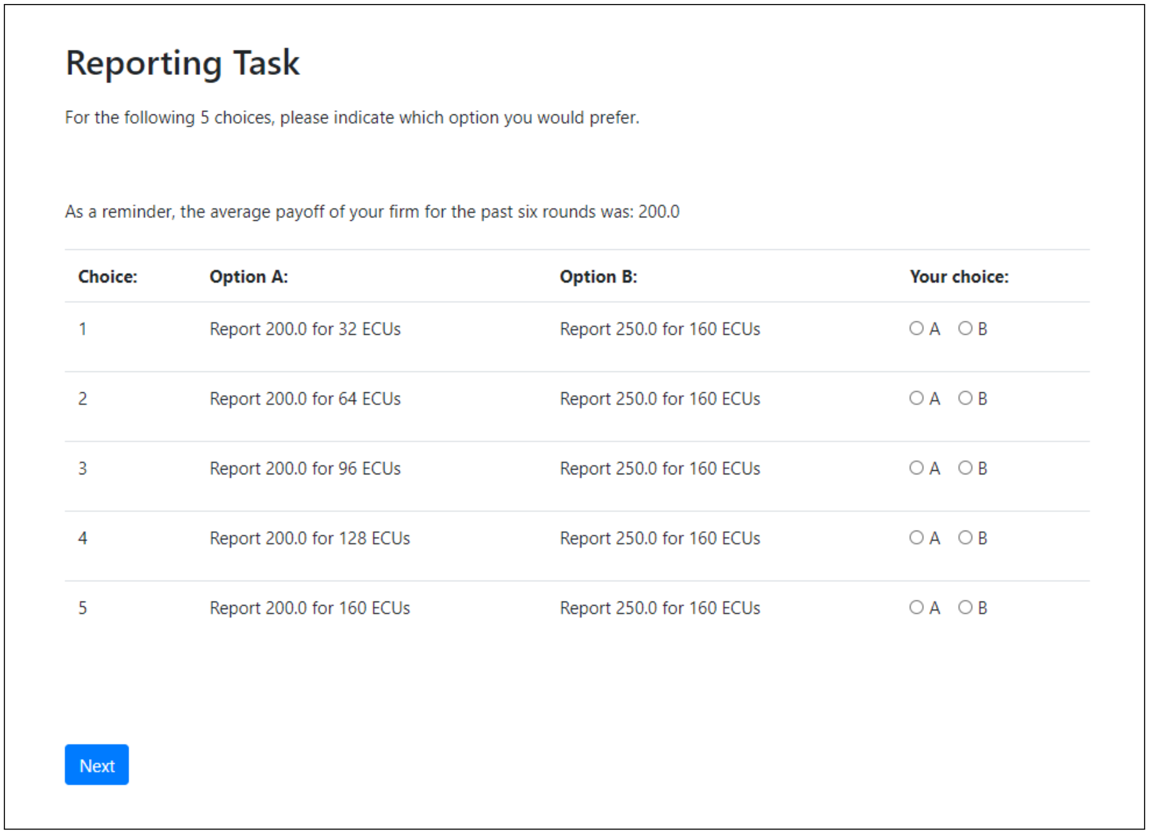
During the leader selection process, group members could also observe several characteristics of each of the group members. This included how many questions each group member answered correctly on a previously completed quiz from the start of the experiment. Additionally included was the average effort chosen in the first four rounds of the treatment by each of the group members. Subjects were informed ahead of time that this information would be shared among all group members during the leader selection process.

One of the key differences between the voting and competition treatment is the way in which those leaders that are selected interact with the selection mechanism. In the voting treatment, the leaders are selected by others. In the competition treatment, individuals essentially indicate how much they individually want to be the leader. For the voting treatment it may be important to consider what influences a group member to vote for a specific group member to be leader. The most important behavioral consideration for this is perhaps the degree by which they engage in pro-social behavior such as the amount of effort chosen during the leaderless rounds. This information is provided during leader selection and seems to be the case empirically; the coefficient of a logistic regression of being selected leader in the voting round on an individual's average effort during the leaderless rounds is 0.0100 (p-value 0.033).

For the competition it is important behavioral consideration for why an individual themselves wishes to become a leader. The two obvious main drivers are this are the rewards generated from being the leader through the reporting task and idiosyncratic personality traits for individuals who prefer to be leaders. To the former point, subjects are informed that the subsequent reporting task that leaders participate in is potentially used for payment but are not informed of this payment. However, it is possible that a subject could have been a manager in an earlier selection mechanism and observed the payoff schedule for the reporting task, and was then motivated later to a higher degree to become the manager again during the competition treatment. We find this to be the most plausible explanation of behavior. There is little evidence to suggest personality type as measured by the 'leadership sum" measure is a strong predictor of behavior of the selection of tickets during the competition treatment. Furthermore, those subjects who had not already participated as a manager before the competition mechanism treatment did not choose significantly more tickets than those who hadn't been a manager previously. However, those subjects who had previously been managers during a previous treatment before the competition selection treatment were estimated to have a coefficient estimate on the number of tickets selected of 16.000 (p-value 0.001) compared to those who had not previously been selected as a manager. This seems to indicate that the potential payoffs from the reporting task were a primary driver of desire to be a group's manager only after a subject had previously participated in this task and financial incentives were known.

After a leader was selected, the rest of the remaining six rounds of the treatment proceeded similarly to the preceding 4 rounds. The key difference for the remaining rounds was that before all group members selected their effort level choices, the group leader could send any number of chat messages to all group members. All group members were unable to advance past this chat screen for at least 30 seconds and an automated message informed all group members when the leader had finished sending messages. Sending these messages before individual effort levels were chosen is the main avenue by which the leader could affect coordination or other outcomes related to group behavior. One important consideration is the amount of chat activity the group leader participated in can serve as a measurement of "real effort" on the part of the leader, with more chat messages potentially resulting in more favorable outcomes. For this reason, the total number of chat messages sent by individual subjects is included in the analysis and results of our experiment.

After the 10th round of each treatment, the leader of the group was asked to complete an additional task. This task was framed as the leader reporting the results of their groups task to an external body, similar to that found in Gibson, et al. (2013)[74]. In the task, the leader was presented a series of choices in which they could report the average value that their group earned over the past 6 rounds or they could "misreport" this value for a higher payoff. The "misreport value" was always 50 points higher than the true value that the group earned, though the payoff for misreporting this value changed depending on the decision being made, similar to multiple price listing tasks used to assess risk aversion. Decisions on this honesty task only affected the payoffs for the leader. The payoffs of all other group members were not affected by decisions in this task. An example of this task is shown in Figure 3.1.



Reporting Task

For the following 5 choices, please indicate which option you would prefer.

As a reminder, the average payoff of your firm for the past six rounds was: 200.0

Choice:	Option A:	Option B:	Your choice:
1	Report 200.0 for 32 ECUs	Report 250.0 for 160 ECUs	A B
2	Report 200.0 for 64 ECUs	Report 250.0 for 160 ECUs	A B
3	Report 200.0 for 96 ECUs	Report 250.0 for 160 ECUs	A B
4	Report 200.0 for 128 ECUs	Report 250.0 for 160 ECUs	A B
5	Report 200.0 for 160 ECUs	Report 250.0 for 160 ECUs	A B

Next

Figure 3.1. Reporting Task

Again, it is important to highlight that this task stands in contrast to much of the related literature regarding measuring honesty, which often use a die roll task. Typically, the distribution of reported die roll values is compared to the expected distribution of these die rolls to measure levels of honesty implicitly. Here we primarily are focused on an incentive threshold at which individuals switch from being dishonest to honest regarding their group's performance. This allows us to both observe these honesty decisions directly and analyze the degree of dishonesty, while potentially leaving open the option to analyze the interaction between different levels of incentives and subsequent honesty decisions.

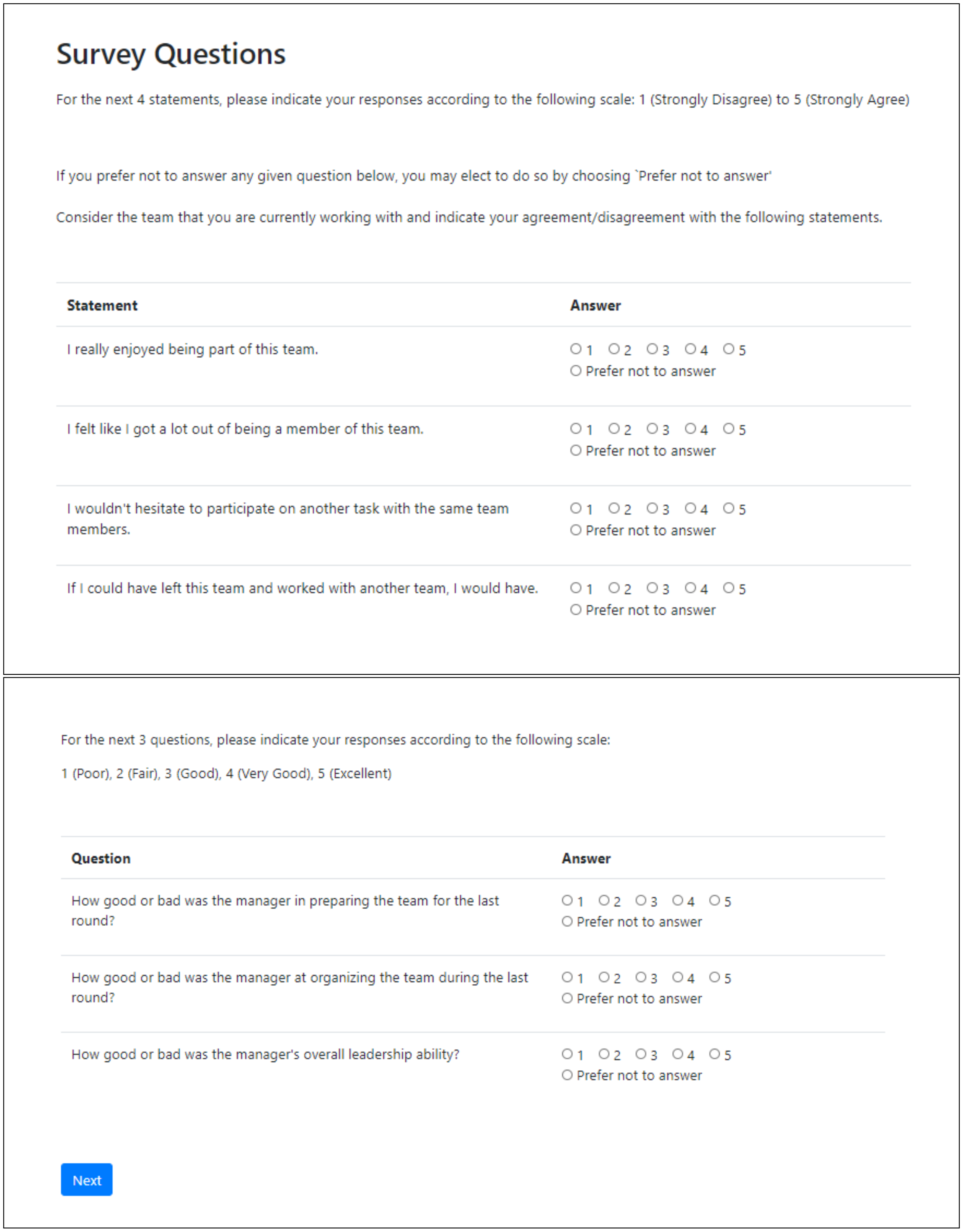
At the end of the treatment and all tasks for that treatment had been completed, subjects were then regrouped into new groups using random re-matching. All three treatments (random, voting, and competition) were used in every session performed. While every treatment was performed within-subject, the order in which these treatments were performed differed across sessions in every possible combination in order to produce a balanced sample and minimize order effects present in the data.

3.4.2 Additional tasks

As previously stated, subjects were asked to do 6 tasks in addition to the misreporting and minimum effort coordination tasks. One of these tasks took place before the coordination game, one of these tasks occurred between different rounds of the coordination game, and four of of these tasks occurred after completion of this minimum effort coordination game. These tasks included a general knowledge quiz, two different surveys of group leadership and performance, a risk aversion elicitation task, an ambiguity aversion elicitation task, and finally a basic demographics survey.

The first of these tasks was a multiple choice quiz which consisted of 5 total questions. This task was completed first before any other tasks in the experiment. The questions and wording have been taken directly from Brandts, Cooper, and Weber (2015)[38]. As stated previously, how many questions each subject got correct was shared with all group members during the leader selection process.

After the 10th round of each treatment during the minimum effort coordination task, each subject was asked to complete a survey which evaluated both their satisfaction with being involved with the group and their assessment of the effectiveness of their group's leader. A total of 4 questions were asked about the group as a whole and 3 questions were asked regarding the leader's performance. The full list of questions can be seen in Figure 3.2. These questions were not used for subject payment.



Survey Questions

For the next 4 statements, please indicate your responses according to the following scale: 1 (Strongly Disagree) to 5 (Strongly Agree)

If you prefer not to answer any given question below, you may elect to do so by choosing `Prefer not to answer'

Consider the team that you are currently working with and indicate your agreement/disagreement with the following statements.

Statement	Answer
I really enjoyed being part of this team.	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer
I felt like I got a lot out of being a member of this team.	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer
I wouldn't hesitate to participate on another task with the same team members.	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer
If I could have left this team and worked with another team, I would have.	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer

For the next 3 questions, please indicate your responses according to the following scale:

1 (Poor), 2 (Fair), 3 (Good), 4 (Very Good), 5 (Excellent)

Question	Answer
How good or bad was the manager in preparing the team for the last round?	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer
How good or bad was the manager at organizing the team during the last round?	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer
How good or bad was the manager's overall leadership ability?	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer

Next

Figure 3.2. Group and leader performance questions

After all rounds of the group effort coordination task were completed, subjected completed 4 additional tasks. The first of these was a survey in which subjects answered a series of questions designed to evaluate how assertive each subject was and how much they desired leadership positions. This survey also asked questions regarding how much these subjects preferred to work in groups in general. A total of 10 questions addressed the former topic, and 15 questions dealt with the latter topic. A full list of questions asked can be found in Appendix A.

The second and third task involved subjects completing both a risk aversion and an ambiguity aversion task using a multiple price list. Both tasks involved 20 questions in which the subject was asked to choose between a certain payoff or uncertain/risky payoff. This was conducted similarly to previous risk aversion tasks conducted first in Holt and Laury (2002)[75]. The list of risk aversion questions can be viewed in Figure 3.3. The remaining ambiguity aversion questions can be viewed in Appendix A.

Choice Task

For the following 20 choices, please indicate which option you would prefer. All values are in points which are worth the same as they were in the earlier search tasks.

Choice:	Option A:	Option B:	Your choice:
1	0.00 or 160.00 with a 50% chance	8.00 for sure	○ A ○ B
2	0.00 or 160.00 with a 50% chance	16.00 for sure	○ A ○ B
3	0.00 or 160.00 with a 50% chance	24.00 for sure	○ A ○ B
4	0.00 or 160.00 with a 50% chance	32.00 for sure	○ A ○ B
5	0.00 or 160.00 with a 50% chance	40.00 for sure	○ A ○ B
6	0.00 or 160.00 with a 50% chance	48.00 for sure	○ A ○ B
7	0.00 or 160.00 with a 50% chance	56.00 for sure	○ A ○ B
8	0.00 or 160.00 with a 50% chance	64.00 for sure	○ A ○ B
9	0.00 or 160.00 with a 50% chance	72.00 for sure	○ A ○ B
10	0.00 or 160.00 with a 50% chance	80.00 for sure	○ A ○ B
11	0.00 or 160.00 with a 50% chance	88.00 for sure	○ A ○ B
12	0.00 or 160.00 with a 50% chance	96.00 for sure	○ A ○ B

Figure 3.3. Risk aversion menu task

Finally, subjects were asked to complete a basic demographics questionnaire. Questions asked included college major, gender, and how many previous experiments the subject participated in. The full list of questions is viewable along with the rest of the experimental UI in Appendix A. After the completion of all tasks, subjects were informed how much they had earned during the experimental session and were paid privately in USD.

3.5 Results

Our study is concerned with the effect of selection mechanisms on two primary outcomes. The first of these outcomes is the impact of these different leadership selection mechanisms on group efficiency, performance, and coordination. The second outcome is the impact on leader honesty in the subsequent reporting task. Our findings indicate that the presence of having a leader to coordinate group effort is highly beneficial when considering group efficiency, though there is little variance in group performance when comparing how leaders are selected. When considering the effect of leadership selection on honesty, however, there exists evidence that leaders selected randomly behave more dishonestly when compared to those leaders selected through either voting or competition. Additionally, there exists some evidence suggesting that those leaders selected through a voting process have the highest tendency to behave honestly. In total, 312 student at Purdue University participated in this experiment across 30 individual sessions. Summary statistics for this experiment can be found in the appendix

3.5.1 Group Efficiency and Coordination

As previously stated, the effect of a leader acting as a coordination mechanism is highly beneficial when measuring group performance. However, the means by which that leader was selected seems to have little if any impact on this dimension. As observed in Figure 3.4, there is a large and statistically significant difference between rounds which lacked a leader and those rounds that had some sort of leader in terms of average minimum group effort.

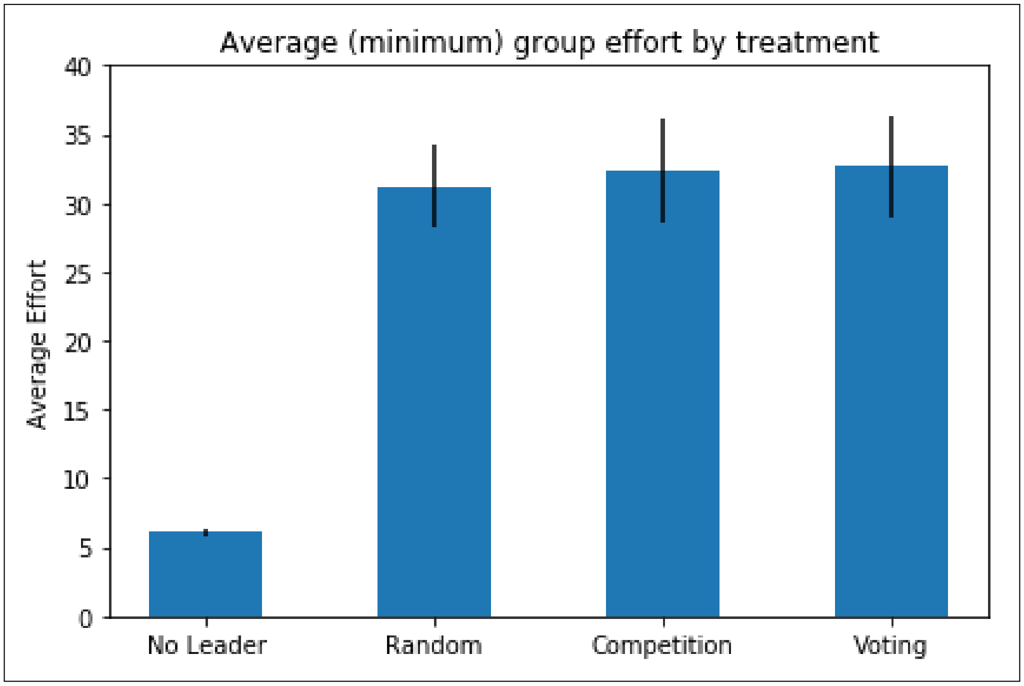
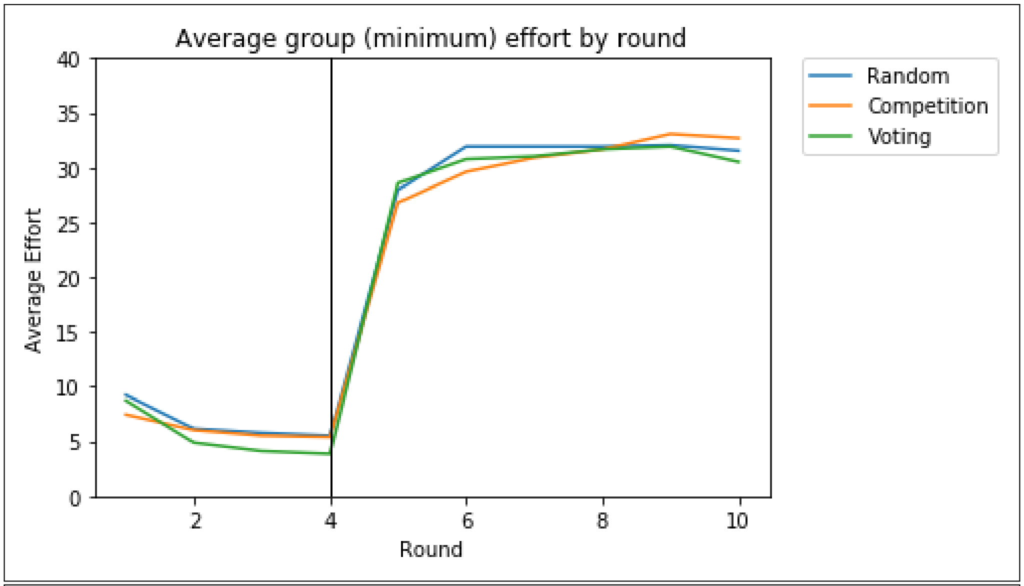


Figure 3.4. Group Minimum Effort. Black bars represent 95% confidence intervals.

The contrast between those round without and without leaders is stark; regardless of the mechanism used to choose leaders, the difference created when a leader is introduced are all roughly 25 hours selected. However, average minimum effort in all treatments with leaders all comes out to be in the low 30's.

Furthermore, it is important to consider how effort levels converge over rounds. Again, as seen in Figure 3.5, the impact of a leader on group effort is quite clear. After the imposition of a leader after round 4, average minimum group effort rises sharply and stabilizes above 30. This trend again persists across all treatment with little evidence that how the leader is selected causes much difference between treatments. This also carries through when broadening observation to all effort in general rather than just minimum effort. Though the impact of having any leader is quite clear, the impact of differences in leader selection makes little difference.



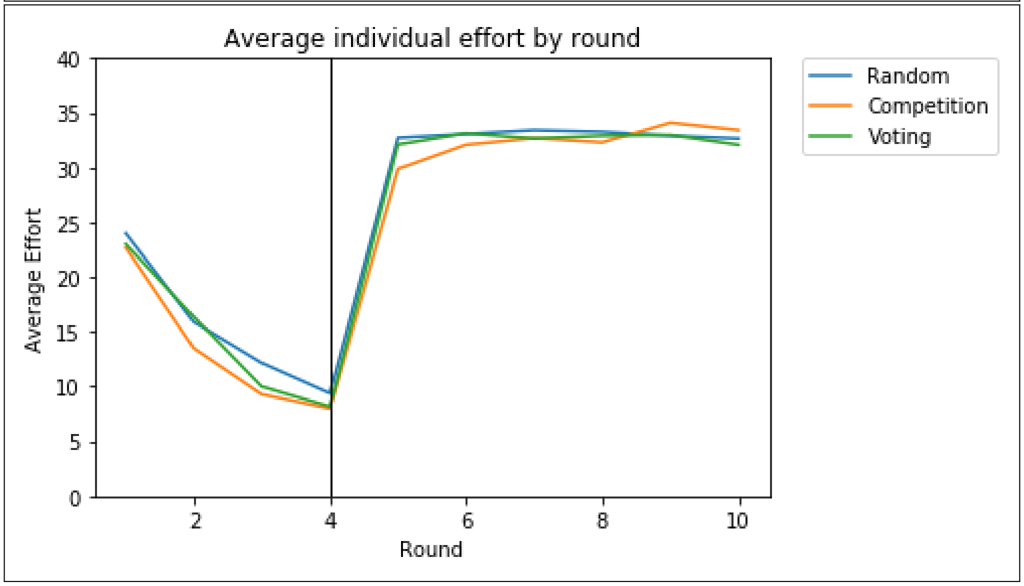


Figure 3.5. Group effort by round

Table 3.1. Group Effort Estimates

	(1)	(2)	(3)	(4)	(5)
VARIABLES	Min group effort	Ind effort	Ind effort	Min group effort	Ind effort
Leader	24.55***	17.65***	17.63***		
	(2.000)	(1.827)	(1.831)		
Num Messages				0.200**	0.178***
				(0.083)	(0.063)
Competition	-0.577	-1.995*	-2.061*	-0.6143	-0.621
	(1.018)	(1.097)	(1.067)	(2.364)	(1.899)
Voting	-1.282	-0.970	-1.000	-0.808	-0.585
	(1.245)	(1.238)	(1.224)	(2.029)	(1.549)
Competition*leader	0.150	1.397	1.548		
	(2.640)	(2.429)	(2.383)		
Voting*leader	0.812	0.606	0.639		
	(2.532)	(2.275)	(2.242)		
Leadership sum			0.215***		0.202***
			(0.0599)		(0.065)
Tullock bid			0.0231		0.022
			(0.0205)		(0.0216)
Quiz score			0.651***		-0.528**
			(0.174)		(0.200)
Constant	6.667***	15.36***	7.287***	28.981***	23.659***
	(1.288)	(1.315)	(2.375)	(2.561)	(3.602)
Observations	9,360	9,360	9,270	5,328	5,292
R-squared	0.440	0.273	0.0188	0.0304	0.0186

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

The estimations in Table 3.1 come from a standard linear estimation using cluster-robust standard errors. In Table 3.1 we see that, in all estimations, leaders have a large and statistically significant impact on both minimum group effort and average individual effort within a group. However, we again see that the type of leader seems to be less important with coefficient estimates involving the different leadership selection mechanisms (competition and voting) being small and not statistically significant. The exception here seems to be that those leaders selected through competition have a minor but statistically significant impact on individual effort among group members. What also seems to matter a great deal is the measure “leadership sum”, which was an aggregate score taken from a self evaluation questionnaire about individual leadership styles. Results here seem to indicate that individuals with more proactive leadership styles and attitudes contribute positively to average effort of individual group members. Individual quiz scores are also positively and significantly correlated with individual effort contributions.

For columns 4 and 5, we have replaced estimates of having a leader at all with the amount of chat activity conducted by the leader during the experiment. Evidence from this estimation method indicates that there is evidence that the amount of activity a group’s manager participated in (measured by number of chat messages) had a positive impact on minimum group effort. However, there is strong evidence to indicate that number of chat messages correlates positively to increases in individual group member effort. One can conclude from these results that the presence of the leader is important, but so is their active role in encouraging and facilitating coordination.

The other important dimension to consider for group behavior is the level of coordination achieved by the groups in each of the various treatments. Here we measure group coordination through “wasted effort”. This is optimal as any group member selecting a higher group level than any other group member pays a cost for selecting this higher effort level with no individual payoff benefit. Wasted effort here is defined as the difference between the average group effort contributed to the coordination game and the minimum effort of the group. Additional examples of using wasted effort as a measure of group coordination can be found in Cason, et al (2012)[76]. As we can see in Figure 3.6, coordination follows a similar trend to that of general effort levels. The presence of a leader is seemingly important; it is observed that those rounds where a leader is present increase the rate of coordination and decrease wasted effort significantly. However, how the leader is picked causes little difference between treatments. The exception to this is that leaders who are selected through a competition mechanism produce the least wasted effort as compared to the other selection mechanisms.

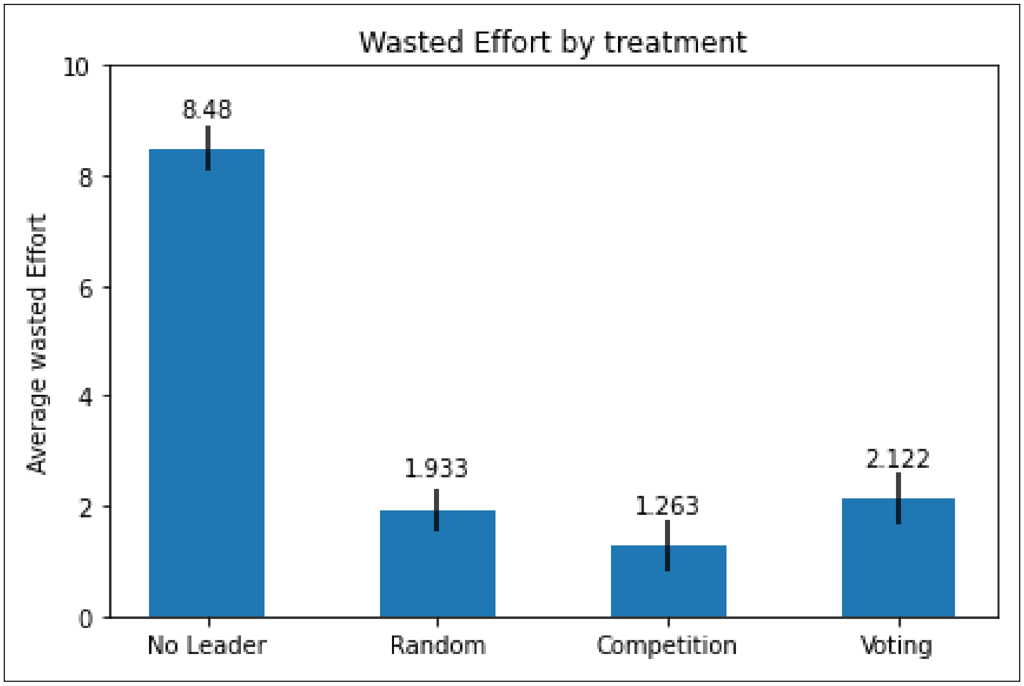


Figure 3.6. Wasted effort by treatment. Black bars represent 95% confidence intervals.

Observing how coordination rates evolve over time follow a similar pattern as discussed previously, which can be seen in Figure 3.7. It does appear that coordination in general is increasing rather continuously across rounds in a treatment. This can be explained by the fact that in rounds without a leader, group members tend do coordinate on the risk dominated effort choice of "0" but switch to coordination of higher effort levels in rounds where a leader is present.

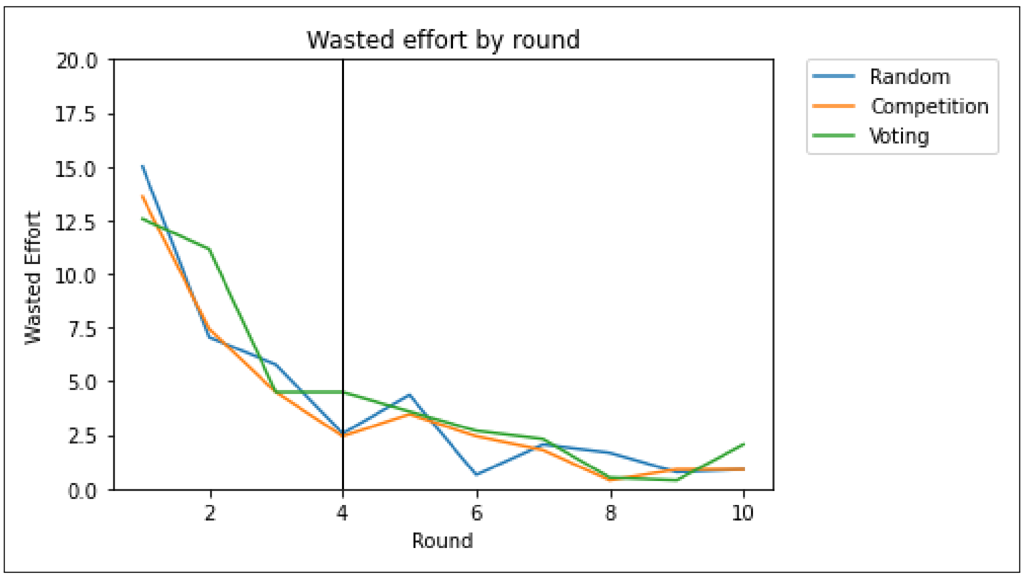


Figure 3.7. Wasted effort by round

Table 3.2. Coordination estimates

	(1)	(2)	(3)	(4)	(5)
VARIABLES	Wasted Effort	Wasted Effort	Wasted Effort	Wasted Effort	Wasted Effort
Leader	-6.551***	-6.899***	-7.110***		
	(0.429)	(0.529)	(0.501)		
Num Messages				-0.006	-0.004
				(0.0239)	(0.023)
Competition	-0.670*	-1.418***	-1.427***	-0.688	-0.694*
	(.388)	(0.425)	(0.390)	(0.410)	(0.398)
Voting	0.189	-0.970	0.282	0.283	0.259
	(0.502)	(0.604)	(0.559)	(0.516)	(0.492)
Competition*leader		1.247**	1.222**		
		(0.546)	(0.546)		
Voting*leader		-0.205	-0.201		
		(0.674)	(0.6955)		
Leadership sum			-0.017		-0.027
			(0.019)		(0.018)
Tullock bid			0.016**		0.018***
			(0.006)		(0.006)
Quiz score			1.283***		0.819***
			(0.213)		(0.231)
Constant	8.485***	8.693***	8.753***	4.665***	4.982***
	(0.523)	(0.515)	(0.828)	(0.5170)	(0.736)
Observations	9,360	9,360	9,270	5,328	5,292
R-squared	0.1059	0.1069	0.1190	0.0014	0.0164

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

The above OLS estimates in Table 3.2 are estimated in the same way the earlier estimates in Table 3.1, including using the same controls. Again, similar conclusions can be drawn but with important caveats. The presence of a leader itself is by far the largest contributing factor to groups being well-coordinated on effort levels. In this case, however, groups with leaders that were selected through a competition selection mechanism appear to have lower and statistically significant differences in wasted effort compared to the random leader and voting treatments. Leadership score seems to have no impact on the level of wasted effort, and quiz scores are positively related. Furthermore, th

It is important to again highlight that these results stand in contrast to existing experimental evidence shows in studies such as Brandts, Cooper, and Weber (2015)[38]. Overall, we find little to no impact of how leaders are selected on various methods such as effort, or group payoff which differs from earlier results that indicate that leaders picked through a voting process improved group outcomes. Some evidence indicates that those leaders picked through competition produce results that have less wasted effort. We find some evidence, seen in tables 3.1 and 3.2, that an announcement of a competition treatment may decrease effort but increase coordination level as measured by decreases in wasted effort. This may have to do with the pro-social perception of potential leaders being less important in a competition setting, though this is a common factor in both the competition and random treatments.

3.5.2 Leader honesty

As a reminder about the leader honesty task, subjects are asked to make decisions between a series of choices, A and B framed as reporting their team's performance on the preceding coordination task. Choice A was always the average payoff earned by the group over the 6 rounds where there was a leader, similar to that found in Gibson, et al. (2103)[74]. Choice B was this average payoff with 50 points added to it. These choices were at various levels of incentive, starting from a high incentive level for the first choice and ending with a last choice where payoffs for both choices are identical. There are two ways to think about strategies involving decisions in this task. The first involves a subject choosing option B until the incentive level drops below a point where the cost of lying is no longer less than the payoff of lying, after which the subject switches to telling the truth for all subsequent choices. We refer to this as the cutoff strategy. The second is a naive analysis of aggregate decision-making at all different incentive levels of reporting, from which we may be able to uncover some sort of heterogeneity in behavior. We start this section with the former before moving onto the latter type of analysis.

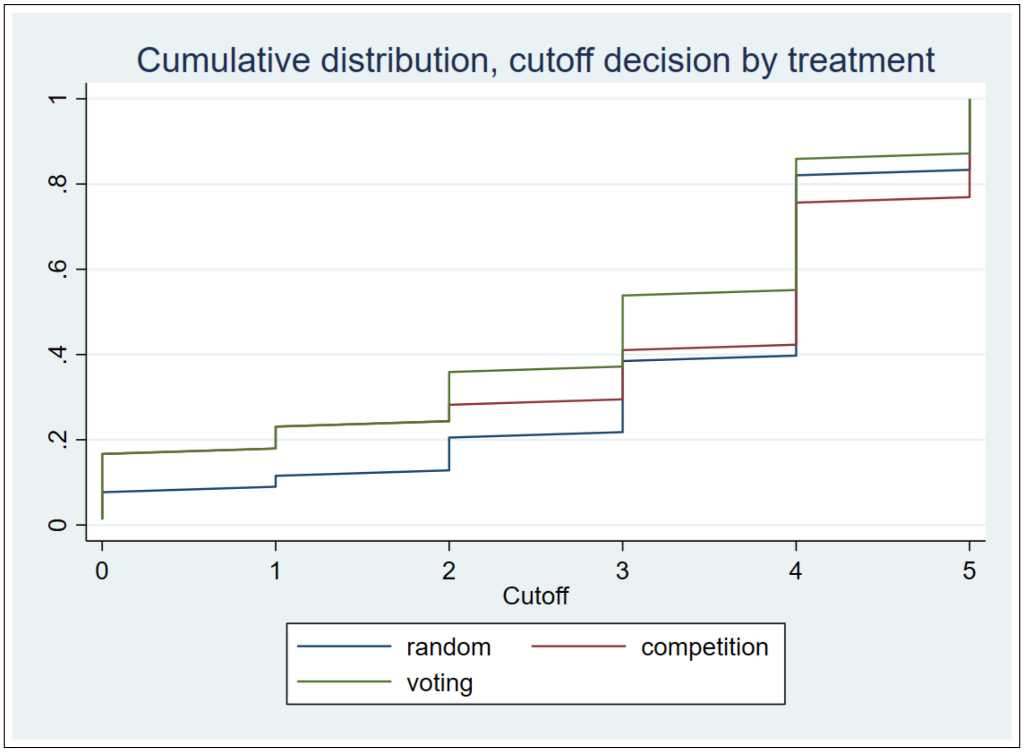


Figure 3.8. Cumulative distribution of cutoff decisions

As previously stated, one way of analyzing this data is by focusing on where subjects made a switch from misreporting to reporting honestly about group performance across these different incentive levels. In this way, we can treat our analysis similarly to risk and ambiguity aversion multiple price listing tasks as seen in the existing literature. Furthermore, we can observe that the overwhelming majority of subjects making these sorts of switching strategies, with over 84% of subjects adopting a strategy in which they choose to switch from misreporting to reporting honestly at a given incentive level and do not switch back. Figure 3.8 shows the cumulative distribution of these decisions across our different treatments. We can see by Figure 3.8 that subjects are generally switching earlier in the voting treatment compared to both the competition and random treatments. Furthermore, subjects made earlier switching decisions in the competition treatment as compared to the random treatment in all but the lowest incentive level.

In order to approach the data from this angle, we estimate an ordered logit model, motivated by our model of honesty in section 3, where subjects changed their behavior from misreporting the higher group payoff to the truthful reporting of their group's actual performance. Table 3.3 provides an estimation of this model. Columns 1 and 2 estimate this model from the full set of data, with and without controls respectively. Columns 3 and 4 do the same but only using data from subjects who used a strict cutoff strategy. For the full sample, we can see that the voting treatment is significantly and negatively correlated with a decrease in the cutoff point used in a subjects strategy. Interpreted another way, this estimation shows that subjects switch from misreporting to reporting truthfully earlier compared to both competition and random selection. Competition is estimated to be positive though not statistically significant.

One consideration that might be necessary is how this analysis looks when only looking at behavior from subjects who strictly use cutoff strategies (i.e. those subjects who do not switch back and forth between misreporting and reporting truthfully at different levels). This is done in Table 3.3 in columns 3 and 4. While the level of significance of these results is not as strong as the full sample analysis, anaylsis of this sample also shows similar trends where leaders selected through the voting treatment switch from misreporting to reporting truthfully sooner than those in the random treatment. They also appear to switch sooner compared to the competition selection treatment, though this difference in means is not statistically significant.

Again, with regards to the results found in related literature, the results here stand in contrast to results found in other studies. Most specifically, the results of this paper reject the conclusions of Schurr and Ritov (2016)[39] that indicate that competition results drive individuals to be more dishonest. Results of our study indicate that those leaders who where chosen by a competition were at worst no more dishonest than those chosen completely by random, with some small but statistically insignificant evidence to indicate that, under certain circumstances, leaders may in fact be *more* honest than those picked at random. Furthermore we find consistent evidence that indicates leaders picked by voting are at least as honest as those picked by competition with some evidence they may be more honest than leaders picked either randomly or through a competition mechanism. As mentioned

Table 3.3. Misreporting ordered Logit estimates

VARIABLES	(1) cutoff	(2) cutoff	(3) cutoff	(4) cutoff
Competition	-0.0772	0.0148	-0.284	-0.250
	(0.269)	(0.284)	(0.289)	(0.307)
Voting	-0.549**	-0.509**	-0.537*	-0.462
	(0.239)	(0.253)	(0.274)	(0.291)
Mean group payoff		-0.00620**		-0.00562*
		(0.00279)		(0.00326)
Leadership sum		0.0250		0.0367
		(0.0248)		(0.0292)
Tullock bid		-0.00296		-0.000228
		(0.00504)		(0.00559)
/cut1	-2.075***	-2.998***	-1.933***	-2.236**
	(0.248)	(0.837)	(0.257)	(1.113)
/cut2	-1.664***	-2.579***	-1.596***	-1.891*
	(0.219)	(0.824)	(0.240)	(1.096)
/cut3	-1.158***	-2.083**	-1.134***	-1.442
	(0.200)	(0.817)	(0.223)	(1.093)
/cut4	-0.434**	-1.342*	-0.470**	-0.761
	(0.191)	(0.814)	(0.212)	(1.091)
/cut5	1.274***	0.405	1.554***	1.321
	(0.222)	(0.805)	(0.267)	(1.102)
Observations	234	231	198	196

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

earlier, one potential concern is that different types of people are being selected rather than the difference in outcome being caused by the selection mechanism itself. We attempt to avoid this confounding factor by controlling for personality type using the "leadership sum" measure in our estimations. From a policy standpoint, it is a potentially interesting avenue to pursue on this "filtering" vs causal view of leader selection, despite the practical outcomes being very similar.

Despite this top line difference in results, it is important also to highlight that the context of these competitions and the relationship to the measures of dishonesty probably makes a substantial difference. Leaders in this study are measured regarding their ethical behavior in a task related to their own group's performance, and ownership over these results may play a significant role in the leader's relationship to this information and their own honesty about it. Furthermore, this competition is framed in the context of a leadership promotion event rather than a competition that results in a pure monetary gain to the subject. The relationship between the utility derived from winning this competition as well as the relationship the individual has to the information that is being used to measure honesty likely plays an important role that may explain some of the disparity between these results.

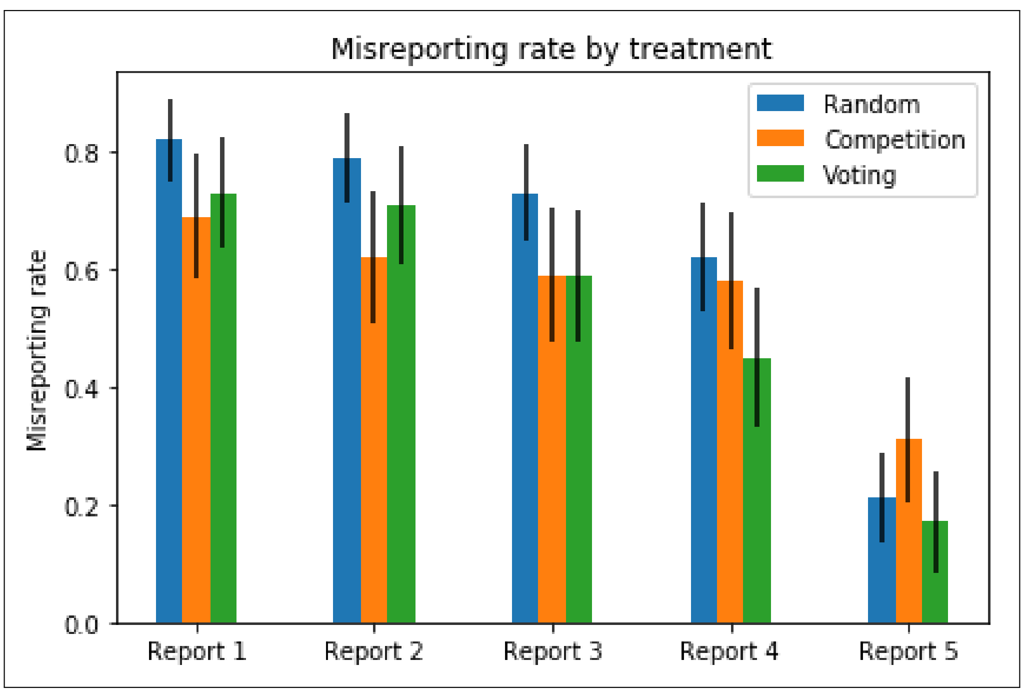


Figure 3.9. Misreporting Rates. Black bars represent 95% confidence intervals.

As a naive overview of the impact of different leadership choice mechanisms, Figure 3.9 displays the mean reporting rate for each of the three mechanisms used for selecting a leader, witch each colored bar representing a different treatment. The 95% confidence interval for these estimates are displayed as vertical black lines. These means are grouped by "report level" corresponding to each choice a subject had to select the truthful level of output done by the group or the higher value that does not accurately reflect the mean group earnings. These are ordered from highest incentive (report 1) to the lowest incentive (report 5). It is worth noting that report 1 carries a potential payoff of 128 ECU, or potentially $8 incentive to report the higher choice, which decreased gradually by 32 ECU's until these choices were indifferent in terms of payoff with report 5.

Two trends emerge from this data. The first is that the mean reporting of the higher, dishonest value is higher among those leaders picked randomly for all categories with the exception of the indifferent report 5 category. In several cases, these differences are even statistically significant at p-values less than 0.05 both individually for the voting and competition treatments and occasionally jointly. This seems to suggest that how leaders are selected does in fact have an impact on their subsequent honesty regarding their groups performance.

The other overall trend that can be observed here is the marginal impact of changes in incentives is smallest among the competition treatment. While those leaders selected through competition are observed to have generally lower rates of reporting their group's output dishonestly at the highest incentive levels, this propensity to misreport group output changes relatively less when incentives are decreased.

To further illustrate the effect of various factors on the different reporting levels, Table 3.4 contains a set of logit estimates for reports 1 through 5. Covariates. Standard errors have been clustered at the participant level. When analysing the effect of the various factors on honesty, in most cases we find that both voting and competition treatments cause a statistically significant decrease in the propensity to be dishonest. While most other covariates do not show statistically significant effects, one that is interesting is the estimated impact of the mean group output on honesty, which changes signs with statistical significance at either end of the extremes for incentives to behave dishonestly. In other words, when there are large incentives to misreport actual group performance, increasing that group performance leads to relatively more estimated misreporting by group leaders when incentives are high. However, when there is no incentive to provide a misreported result, increased group performance decreases the probability of misreporting the higher group output.

Table 3.4. Misreporting Logit estimates

	(1)	(2)	(3)	(4)	(5)
VARIABLES	Report 1	Report 2	Report 3	Report 4	Report 5
Competition	-0.856**	-0.973***	-0.698**	-0.121	0.490
	(0.385)	(0.360)	(0.329)	(0.316)	(0.407)
Voting	-0.604*	-0.451	-0.625*	-0.633**	-0.253
	(0.360)	(0.342)	(0.325)	(0.297)	(0.370)
Mean group payoff	0.00572*	0.00235	0.00124	-0.00416	-0.0101***
	(0.00324)	(0.00315)	(0.00297)	(0.00281)	(0.00313)
Leadership sum	0.0439	0.0317	0.0388	0.0167	0.0251
	(0.0316)	(0.0290)	(0.0270)	(0.0263)	(0.0274)
Tullock bid	0.000962	0.00341	-0.000194	-0.00165	0.00187
	(0.00661)	(0.00596)	(0.00615)	(0.00603)	(0.00659)
Constant	-1.560	-0.529	-0.694	1.071	0.505
	(1.121)	(1.071)	(1.042)	(1.024)	(1.044)
Observations	231	231	231	231	231

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Figure 3.10 presents this trend visually as well. Here we can clearly observe that in all three treatments, the relationship between mean group output and misreporting is positive initially in high incentive environments but this relationship reverses as incentives decreases.

It is also worth noting that at the highest group performance levels, misreporting behavior seems to be similar across all treatment groups.

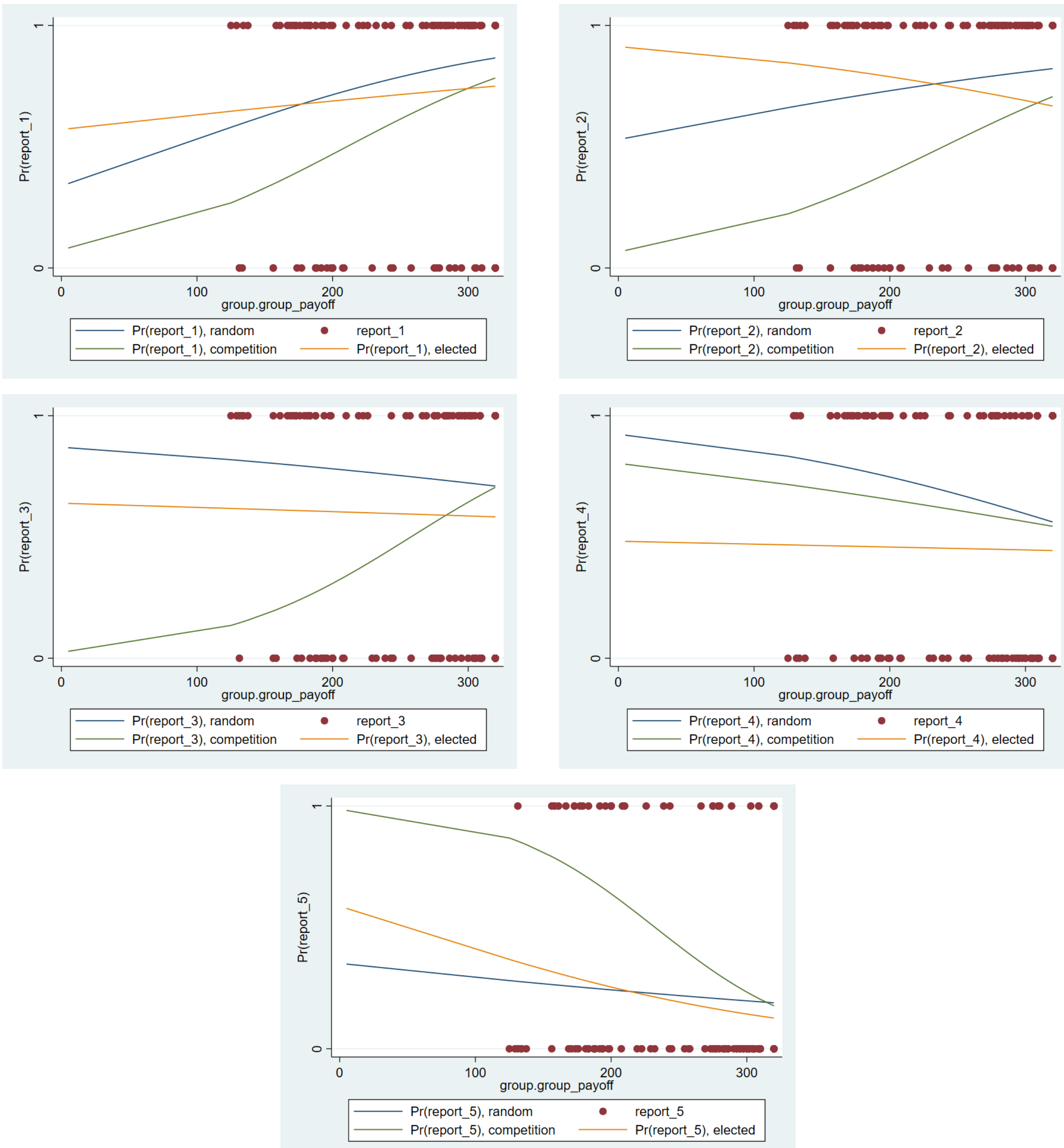


Figure 3.10. Misreporting and group output, Report 1-5

3.5.3 Robustness Checks

Regarding the ordered logistic estimation used in the previous section, there are a number of factors that need to be checked in order to justify this estimation procedure and provide further support for the results therein. This justification extends beyond the theoretical model already previously provided. Ordered logistic models rely on a number of underlying assumptions about our data set. Additionally, there have been a number of concerns raised in related literature regarding measuring these sorts of discrete cutoff decisions. This section provides further justification and support of both our ordered logistic estimation as well as our estimated treatment effects.

The most common assumption used for all ordered logit estimation is the proportional odds or parallel regression assumption. This assumption states that the relationship between each pair of outcome group is the same. Another way of interpreting this is when estimating this model, we assume that when comparing the lowest against all higher categories of the response variable, the relationship between these variables must be the same as compared to the next lowest category and all higher categories of response variables. To verify this assumption, the results of the Brant test is given in Table 3.5 for our full model with the full data-set and all controls. Since the alternative hypothesis of the Brant test is a rejection of the parallel regression assumption, results shown in this table support this assumption in our data and thus the use of an ordered logit model estimation.

Table 3.5. Brant test for ordered logistic model

	(1)	(2)	(3)
	chi2	p>chi2	df
All	15.49	0.75	20
Competition	5.07	0.28	4
Voting	0.85	0.93	4
Mean group payoff	4.30	0.37	4
Leadership sum	5.89	0.20	4
Tullock bid	0.92	0.92	4

In addition to making sure that our model satisfies the important assumption of an ordered logit estimation, we must also address some of the concerns associated with estimating treatment effects from discrete ordered data. In a paper related to a critique of research done on happiness scales, Bond and Lang (2019)[36] express concerns related to the functional form of utility assumed in the happiness literature and the problems it may create. Namely, when dealing with the sorts of decisions related to self identifying happiness levels, transformations of the assumed utility function underlying these decisions have the potential to reverse treatment effects around the mean.

Because reported happiness levels are similar to the types of cutoff decisions assumed when estimating our ordered logit model, the data in this study is subject to similar potential issues. Thus we analyze our estimations and our data using two different perspectives which aim to alleviate these concerns. The first is investigating to see if our data and results satisfy first order stochastic dominance (FOSD). The second involves estimating treatment effects around the *median* rather than the mean.

Bond and Lang (2019)[36] states the the concerns about functional transformations are alleviated if estimated treatment effects satisfy FOSD. Again, Figure 3.11 plots the cumulative distribution of the cutoff decisions of subjects in our data separated by treatment group. We can see in this figure that the cutoff decisions made by individuals in the voting treatment that both the random and competition first order stochastically dominate the competition treatment, providing some support that our estimated treatment effect of the voting selection mechanism increasing honesty (earlier cutoffs) still holds. Neither competition nor random has FOSD over the other, though this is of less a concern as the treatment effect of competition was small and non-significant in all ordered logit estimates.

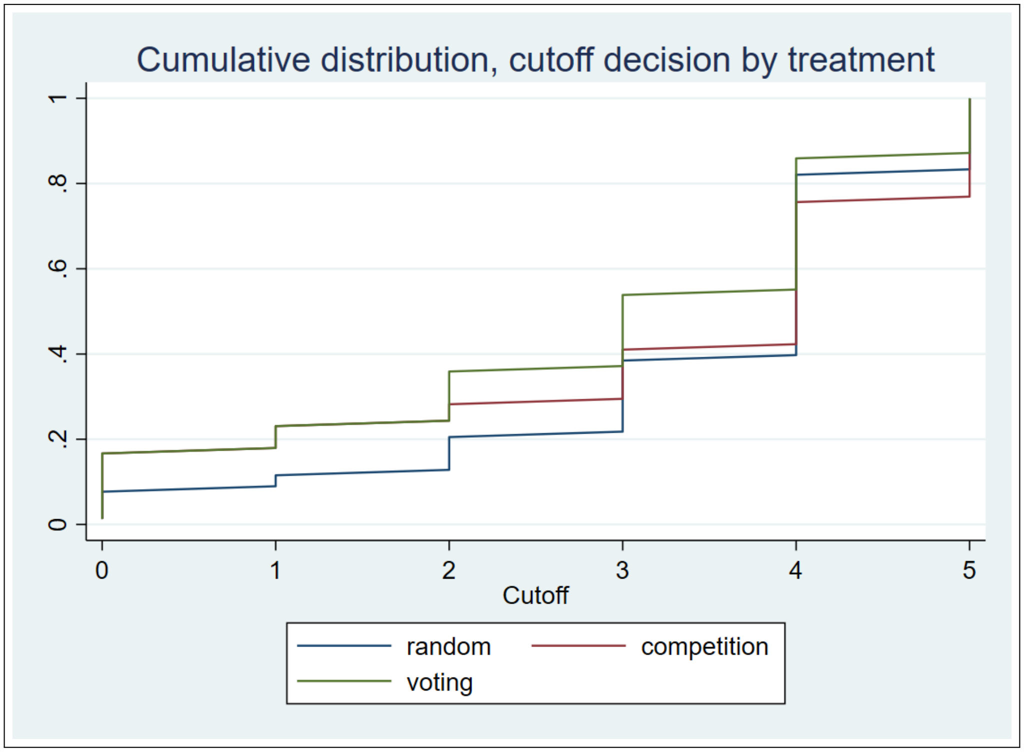


Figure 3.11. Cumulative distribution of cutoff decisions

Furthermore, we estimate a difference in variances between treatments. The results of a difference in variances using a variance ratio test in the different treatment groups can be seen in Table 3.6. When comparing voting and competition, there is no significance in the difference of variances. A similar result is found when comparing the random treatment and voting treatment. There is some evidence that suggests that there is a difference in variance between the random treatment and the competition treatment.

Table 3.6. Variance ratio tests

	(1)	(2)	(3)
	ratio<1	ratio != 1	ratio>1
Random & Competition	0.0195	0.0389	0.9805
Random & Voting	0.0626	0.1252	0.9374
Competition & Voting	0.7044	0.5911	0.2956

Moving on from FOSD, one potential avenue to also strengthen the results presented in the previous section is through analysis of treatment effects on the *median* of the distribution rather than the *mean*. Since the median is not subject to the same concerns related to the functional transformation of any underlying distribution, estimated treatment effects on the median minimize concerns that may arise from transformations of the utility function, like those addressed in Bond and Lang (2019)[36]. Chen, et al. (2019)[37] presents a process of estimating median effects using a mixed integer linear programming approach. According to this original paper, the following linear programming problem can be solved to uncover these median effects:

$$\min_{(b,c)\in\theta} \sum_{\mathrm{i}=1}^{n} \sum_{\mathrm{j}=1}^{J-1} [|Y_{\mathrm{i}} - \mathrm{j}| - |Y_{\mathrm{i}} - \mathrm{j} - 1] \times d_{\mathrm{i,j}}$$

subject to

$$(d_{\mathrm{i,j}} - 1)M_{\mathrm{i,j}} \leq c_{\mathrm{j}} - X_{1\mathrm{i}} - \widetilde{X}_{\mathrm{i}}^{\intercal} b < d_{\mathrm{i,j}}(M_{\mathrm{i,j}} + \delta), (\mathrm{i,j}) \in \{1, ..., n\} \times \{1, ...J - 1\}$$

$$c_{\mathrm{j}} < c_{\mathrm{j}+1}(\mathrm{j}) \in \{1, ...J - 2\}$$

$$d_{\mathrm{i,j}} \leq d_{\mathrm{i,j}+1}, (\mathrm{i,j}) \in \{1, ..., n\} \times \{1, ...J - 2\}$$

$$d_{\mathrm{i,j}} \in \{0, 1\}, (\mathrm{i,j}) \in \{1, ..., n\} \times \{1, ...J - 1\}$$

where $\delta > 0$ is a user-chosen tolerance level ($\delta = 10^{-6}$ for this study) and

$$M_{\mathrm{i,j}} \equiv \max_{(b,c)\in\theta} |c_{\mathrm{j}} - X_{1\mathrm{i}} - \widetilde{X}_{\mathrm{i}}^{\intercal} b|, (\mathrm{i,j}) \in \{1, ..., n\} \times \{1, ...J - 1\}$$

In our study, Y_{i} is a given cutoff level chosen by an individual subject, while b and c can be positive or negative valued in a finite parameter space, n is the number of obseravations in our data and $\mathrm{j} \in \{1, 2, 3, 4, 5, 6\}$ for every possible cutoff point decision. This estimation is a two-stage process, wherein the $M_{\mathrm{i,j}}$ terms are solved for in the maximization problem above in the first stage and then used to solve the MILP problem in the second stage. Furthermore, note the first covariate term in this model has a fixed coefficient value of "1". For our estimation, we use the negative of mean group payoff as the first covariate term. This is because the effect of this covariate in our parametric ordered logit is known to be positive and significant in our data. This model can efficiently solved by modern optimization solvers and our model was estimated using Gurobi. For a more technical explanation and theoretical motivation behind this model, see Chen, et al. (2019)[37].

The results of this semi-parametric estimation can be seen below in Table 3.8. The first column again presents our parametric ordered logit estimates. The second column provides scaled estimates for the parametric estimation, which have been scaled to coincide with the value of $\beta_1 = 1$. The third column provides the semi-parametric estimate as a comparison.

Table 3.7. Parametric and semi-parametric estimations

	Parametric Estimates		Semi-parametric
	Logit	(scaled)	estimates
-1*Mean group payoff	0.006	1.000	1.000
Competition	0.014	2.383	8.676
Voting	-0.509	-82.196	-9.99
Leadership sum	0.025	4.033	8.138
Tullock bid	-0.002	-0.478	-0.6153
/cut1	-2.998	-483.942	-73.938
/cut2	-2.579	-416.295	-73.938
/cut3	-2.083	-336.237	-73.938
/cut4	-1.342	-216.604	-37.015
/cut5	0.405	65.415	44.923
Observations	231	231	231

While estimates between the parametric and semi-parametric results differ in magnitude, they do not differ in sign. This again provides further support to the direction of the treatment effect of the different selection mechanisms and other covariates on the cutoff decision. Again we see that the voting treatment causes a lower cutoff point, which can be interpreted as more honest decision-making. As a further comparison between our parametric and semiparametric estimates, the fitted value of these estimated models are plotted in Figure 3.12. Scaled parametric estimates are consistently lower than our semiparametric estimates, but the direction of the relationship between (negative) group output and these fitted values are the same in both models.

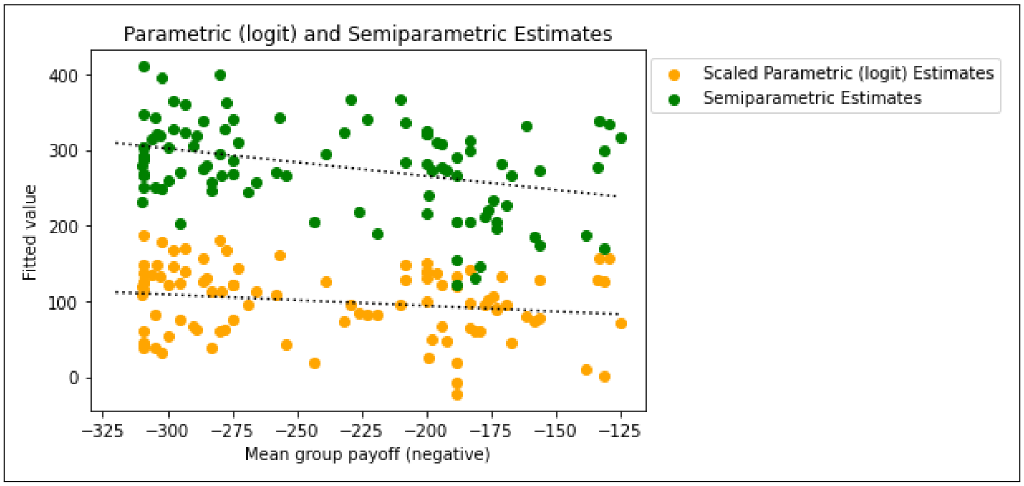


Figure 3.12. Fitted values of parametric (logit) estimates and semiparametric estimates. Negative of mean group payoff is located on the horizontal axis.

3.6 Discussion

While evidence from this study and previous literature is far from conclusive, it can be reasonably asserted that how leaders are selected does indeed have a material impact on a variety of factors. Understanding this is key to planning the development of organizational structure and culture. Many leadership structures and their promotion mechanisms emerge organically. However, understanding the consequences of different promotion structures should be a key aspect when choosing which organizational structure best aligns with an organization's larger goals.

We have observed a few key conclusions in this study. First, having leaders in general matters greatly in a material way. They act as key aspects of facilitating coordination among groups even when that coordination is non-binding and non-incentivized. The presence of a leader is highly and positively correlated to all measures of group efficiency and performance by any metric. Related to this is that, in terms of group performance, how leaders are selected in certain tasks doesn't seem to provide a meaningful variance in group outcomes. By all measures of group performance, including individual effort, coordination, and group payoffs, differences in these measures are either not statistically significant or, if they are, they are economically very small. This stands in contrast to earlier related studies that showed that randomly selected leaders under-performed compared to other selection mechanisms.

When it comes to measures of honesty, how leaders are picked for their positions does seem to matter. Consistently the worst performing mechanism for all measures of honesty are those leaders picked completely randomly. Being selected through competition does seem to positively correlate with some measures of honesty. Being selected through a voting procedure consistently outperforms random selection regardless of how this treatment effect is measured and even outperforms the competition selection mechanism using the ordered logistic estimation. This difference in treatment effect is not consistent in all of our estimation methods, however. Some evidence in this study suggests that voting may induce more honest behavior while other evidence suggests there may be little difference between these two mechanisms in terms of outcomes. Furthermore, using procedures similar to a generalized ordered logit approach indicate there may be heterogeneous effects of these treatments at different incentive levels, specifically how ex-post group performance interacts with these different selection mechanisms. It can be seen in our data, for instance, that the marginal effect of group performance on misreporting behavior is small for all incentive levels in the voting treatment, while the effect of this group performance may have a strong positive effect on misreporting under high incentives and a moderate negative effect on misreporting under low or no incentive settings. Or general (conservative) conclusion related to these measures of honesty is that being selected by voting weakly outperforms being selected by competition, which in turn weakly outperforms being selected at random.

Additionally, this study contributes to the growing literature that addresses many of the concerns related to the use of ordinal cutoff decisions when analyzing treatment effects. Recent important criticism has been made of analyzing discrete ordinal data, much of it applied to the literature regarding happiness scales but similar criticism can be made of the sorts of cutoff decisions in tasks such as the way in which honesty is measured in this paper.

Future research must place an emphasis on addressing these concerns. We hope that some of the tools used in this paper to address those potential criticisms can be used for other research in analogous settings.

From a policy perspective, what is clear is that among the systems studied here, voting at least weakly outperforms both competition and random leadership selection mechanisms in regards to ethical decision making. In settings where accountability is important and leaders have the opportunity to behave unethically, electoral mechanisms are more likely to produce more honest decisions. This is of special consideration where a leader's actions are hidden and unverifiable. Furthermore, voting selection mechanisms are much less prone to influence from different levels of incentives to behave dishonestly, which creates an environment much more robust and consistent with producing honest decisions. The study of different types of leadership selection mechanisms in different tasks and different types of incentive structures provides a future path for further development of research on this topic.

What has yet to be explored in this literature is the important topic of the underlying cause of these outcomes. One possible explanation for a difference in outcome in terms of honesty between random selection and the other two mechanisms could, for instance, be a sense of ownership of a group's outcomes created by the more deliberate selection of leaders through competition or voting. It could be the case that this close sense of accountability to a group induces more direct ownership of group outcomes leading to more honest behavior in terms of reporting these outcomes. Previous literature also has stated that it is a sense of entitlement regarding competitions that lead to more dishonest behavior among competition winners. While we do not attempt to isolate such underlying causes in this study, such motivating factors are important. Understanding these causes of behavior help to move towards the ability to design systems and mechanisms that produce desired outcomes. While much has been done in the literature to explore the consequences of different mechanisms, much space in future research exists in investigating these underlying behavioral forces which cause a disparity in outcomes.

4. FREE RIDING IN DYNAMIC INNOVATION CONTESTS

This paper provides an investigation into the factors and conditions that drive "free riding" behavior in dynamic innovation contests. Starting from a dynamic innovation contest model from Halac, et al. (2017)[4], I construct a two period dynamic innovation contest game. From there, I provide a theoretical background and derivation of mixed strategies that can be interpreted as an agent's degree to which they engage in free riding behavior, namely allowing their opponent to exert effort in order to uncover information about an uncertain state of the world. I show certain conditions must be fulfilled in order to induce free riding in equilibrium, and also analytically show the impact of changing contest prize structures on the degree of free riding. I end this paper with an experimental design to test these various theoretical conclusions in a laboratory setting while also considering the behavioral observations recorded in studies investigating similar contest models as well as a plan to analyze the data collected by this laboratory experiment.

4.1 Introduction

Behavior in various innovation and research and development settings has long been an important topic of interest for both policy makers and social scientists. One of the most important considerations of innovation settings is the threat of free riding by participants in these settings; that is, the ability of agents to reap the benefits of these innovations while under-investing or not participating in the costs associated with producing innovations such as through R&D. This under investment is chief among the concerns associated with innovation, perhaps second only to the risk involved in these ventures. Many settings, such as R&D contests and joint ventures, are often designed to minimize this sort of free riding behavior and often vary in their intensity of cooperation or competition. However, the degree to which agents may engage in free riding may differ substantially even within these competing settings.

In this paper I examine the factors that drive free riding behavior in a simple, two period dynamic innovation contest setting. Building from a multi-armed bandit (MAB) contest setting introduced in Halac, et al. (2017)[4], I provide a mathematical foundation for how the contest setting differing in prize structure can have a large impact on both the degree of free riding in these settings. Additionally, I show how this prize structure impacts the interaction these contests have with their individual parameters. I demonstrate, for instance, that changing the marginal cost of effort potentially has opposite effects across the two different prize structures analyzed in this study. After providing a theoretical framework of predicted equilibrium behavior, I also construct an experimental design plan in which to test various hypotheses related to these theoretical predictions and other related behavioral considerations.

The main contributions of this paper to the existing body of research on this topic is two-fold. First is a strong fundamental evaluation of how free riding may evolve in this setting using an analytical approach. Through an application of mixed-strategy Nash equilibrium in this setting, I am able to expand on an understanding of how prize structure drives free riding behavior in these environments and how that prize structure interacts with the model parameters. This approach is currently missing from the existing literature. Furthermore, this study expands on existing experimental efforts to test behavior of individuals in similar contest settings. More specifically, I offer an experimental design based on Deck and Kimrough (2017)[5] with alternations made to specifically focus on measuring free riding behavior analogous to that outlined in the theoretical section.

The general tension of MAB environments is one of exploration vs exploitation. That is, agents in these settings must make choices which inform their prior information about the current state of the world and eventually commit to actions which maximize their individual payoffs. While the environment studied in this paper is a simplified, two period model of a multi-armed bandit problem, this tension still exists within the dynamic problem agents face. In period 1, agents must choose the intensity in which they take actions that may uncover the state of the world. In period 2, they make a more simple decision to maximize their payoffs based on what information was revealed. However, there are additional considerations made by agents in this setting which provide a further tension which is the main focus of study of this paper.

What sets this setting apart from some MAB problems is the addition of a second agent whose decisions and outcomes are public knowledge. This leads to the second key tension created in this environment: the incentive to avoid committing to a costly action and instead rely on the actions of others to costlessly reveal information about the state of the world. This is what I define here in this study as free riding. That is, not only are agents making decisions about their own actions which reveal important payoff relevant information but also further have the incentive to instead rely on the information generated by others without incurring personal cost. It is this key tension that is the primary motivator for both the focus of the theoretical conclusions and the main driver of the design elements found later in this study.

These theoretical results created the foundation of several key questions and related hypotheses intended to be tested in a laboratory environment. The first of these questions is how does changing the contest structure (winner-take-all vs equal-sharing) affect the level of free riding observed in this environment? In the winner-take-all (WTA) contest, the first agent to reach a success is rewarded with no further successes being rewarded for either agent. In the equal-sharing (ES) contest, rewards for successes are non-rivalrous. Second, how does adjusting individual parameters within each type of contest affect individual behavior and how does this differ from equilibrium predictions? Lastly, how do different behavioral considerations drive deviations from predicted equilibrium behavior? Specifically, this last question is concerned with the effects of probability misweighting, base rate neglect, and risk aversion.

Related to the first question, I predict that equal-share contests will generate higher free riding than winner-take-all contests, but the rate at which these two differ will be less than predicted, primarily driven by a preference for cooperation. Related to the second question, in the WTA treatment, I predict that free riding behavior increases in the cost of effort while decreases in the prior probability of the good state, the probability of success in the good state, and the side of the prize. In the ES treatment, I predict that free riding increases with respect to the prize, but decreases in all other parameters. Furthermore, I predict that subjects will not be as sensitive to changes in parameters as predicted, free riding less in environments where there is a high incentive to free ride and more than predicted in environments where there is a low incentive to free ride. Lastly, related to this third question, I predict that risk aversion will be the primary driver of off-equilibrium behavior as this is observed as well in the currently existing literature.

In order to test these predictions, an experimental design is provided in this study. While the experimental investigation of this topic is yet to be conducted, at the conclusion of this paper I provide a high level plan of how these variables are to be measured and how I intend to test the previously discussed predictions. For the most part, I plan to use a simple linear model for estimating treatment effects with measured variables from additional tasks both as controls and as instruments for testing treatment effects. In addition to the size and direction of treatment effects, the investigation of behavior that differs from equilibrium predictions is of particular interest.

The rest of this paper is organized as follows. Section 2 provides a short literature review of the existing research on dynamic innovation contests and provides context to how the content of this paper fits into this existing body of research. Section 3 provides a comprehensive theoretical overview of the problem along with several key hypotheses derived from this theory. Section 4 outlines an experimental design to test these theoretical predictions in the laboratory. Finally, section 5 lays out a fundamental data analysis plan of this study with some brief concluding remarks.

4.2 Literature Review

This paper relates to and builds on the existing body of literature in a number of notable areas. First, this paper adds to the growing theory developing for dynamic innovation and multi-armed bandit contests. Second, this paper adds to the existing literature examining free riding in different contexts, especially when interacting with different behavioral considerations. Lastly, this paper expands on important issues investigated by the broader experimental body of research on the analysis and development of multi-armed bandit problems.

Probably the most important paper that establishes the foundation of much of the current literature regarding the theory of experimental bandits and bandit competitions is Keller, et al. (2005)[77]. This paper establishes the much used framework of a 2 state bandit problem in which success in the good state returns benefits at some positive probabilistic rate while the bad state never yields positive results. Conclusions of their model are primarily in continuous time with discounting. One of the most important theoretical results of this paper is the presence of free-riding and a lack of equilbiria in cutoff strategies. Instead, their Markovian equilibrium involves decisions where agents switch between free-riding and experimentation over time. The threat of free riding reduces the efficiency of outcomes in these bandit settings in comparison to the optimal social planner solution or a single agent problem. Numerous papers expand on this model. Bonatti and Hörner (2011)[78] creates an environment where benefits are a public good, costs are private, and individual actions are hidden. Strulovici (2010)[79] applies a similar framework to a setting where constituents are voting on different policy implementations and benefits are heterogeneous. Klein and Rady (2011)[80] studies an environment where payoffs are negatively correlated rather than uniform across all agents. Höner, et al. (2021)[81] find support for Markovian mixed strategies in in a discrete time version of Keller, et al. (2005)[77].

The theoretical environment closest to this study comes from Halac, et al (2017)[4]. Here, these bandit problems are presented in both discrete and continuous time on finite time horizons without discounting. The authors study four different types of contests which differ on how public information is revealed and their their prize sharing scheme. The authors find that first best results come from contests where there is a "winner-take-all" prize structure with public information or with an "equal-sharing" prize stucture with private information about actions and outcomes. Halac, et al. (2016)[82] also provides a similar setting, examing optimal contracts in a principal agent setting. Guo (2016)[83] studies a similar principal agent problem which finds support for optimal cutoff strategies. What our study adds to this body of literature specifically is the further examination of free riding, mixed strategy equilibria, and associated theoretical predictions that are largely absent from Halac, et al. (2017)[4] and the related literature. While cutoff strategies in certain settings are dominant or present, in the two period model presented by Halac, et al. (2017)[4] it can be shown that certain parameterizations can lead to mixed, Markovian style equilibira as well.

This paper also adds to the body of literature examining the behavioral interactions between free riding and other underlying factors, both theoretically and experimentally. It is true that in general, subjects may have preferences for cooperation and free-ride substantially less than predicted (a survey on this observation on older literature is made in Fehr and Schmidt (1999)[84] for public goods games). However, there is some evidence to suggest that risk-aversion compounds with free-rider incentives, such as in Jindapond and Yang (2020)[85] and Teyssier (2012)[86]. This may not always be the case, however. Raub and Snijders (1997)[87] find theoretical support that risk aversion may increase cooperation and decrease free-riding where outcomes represent losses rather than gains. More generally speaking, Keller and Rady (2010)[88] also find theoretical support that less free-riding occurs in cooperative multi-agent MAB situations in certain Markov perfect equilibria.

While free riding is an emerging focus in the experimental bandit literature, it is a major focus of much of the public goods literature. A theoretical examination of free riding and collaboration in teams in a public goods environment can be found in Bonatti and Hörner (2011)[78]. Gächter (2006)[89] and Fischbacher, et al. (2012)[90] place a large emphasis on *conditional cooperators*, or individuals who continue to cooperate rather than free ride in public goods games so long as free riding by other agents isn't observed. Volk, et al. (2011)[91] examines the interaction between personality and preferences for cooperation vs free riding, and Fischbacher and Gächter (2011)[92] studies the interaction of social preferences and free riding in a public goods game. Marwell and Ames (1980)[93] examines how stakes and experience lend to free rider issues. For further examination of contemporary literature examining experimental results of experiments on free riding in public goods games, see both Chaudhuri (2011)[94] and Zelmer (2003)[95].

As previously stated, this experiment builds on the setting and theory proposed by Halac, et al. (2017)[4]. Several other papers use this or similar experimental bandit settings in related experimental and behavioral studies. Notably, Hudja (2021)[96], Hudja and Woods (2019)[97], Hudja, et al (2020)[98] and Hudja (2019)[99] examine both single and multi-agent bandits in an experimental setting. All of these papers find consistent evidence of under-experimentation of subjects in these bandit settings. Most evidence from these papers find evidence to support the idea that this under experimentation is driven primarily by risk aversion but may also be influenced by base-level neglect and probability misweighting by subjects, or other heuristic decision-making. Subjects consistently applied cutoff strategies even when not constrained to them. As noted later, there exists some evidence that risk-aversion may have non-monotonic interactions with potential free rider problems, which creates an important gap to be explored through the project being proposed.

Laboratory experiments conducted in similar contexts with experimental bandits can also be found in past and recent literature. An early example of a lab setting studying these problems include Banks, et al. (1996)[100], which finds evidence that supports that behavior is quantitatively different in two armed and one armed bandit settings. Hoelzemann and Klein (2017)[101] finds support for the theoretical predictions of Keller, et al. (2005)[77] with regards to predictions about free riding, while noting that subjects are unable to update beliefs precisely. This inability to accurately update beliefs is supported in an earlier paper by Payzan-LeNestour (2010)[102] as well. However, Payzan-LeNestour (2012)[103] finds evidence that supports the opposite conclusion, and that subjects are able to learn optimally in certain bandit settings despite the high difficulty of doing so. Anderson (2012)[104] finds laboratory evidence of ambiguity aversion driving decisions and undervaluing experimentation in bandit settings.

Additionally, this project is similar to Deck and Kimbrough (2017)[5] which compared the different mechanisms outlined in Halac, et al. (2017)[4]. Focus in this study simplified the environment to a two period model where subjects can choose to experiment in either the first or second period with both public and private information treatments of individual decisions about whether or not to experiment in each period. Evidence from this study seems to corroborate the underlying theory that public winner-take-all environments are more efficient than public equal-sharing contests, and that private equal-sharing contests dominate private winner-take-all contests. The standout behavioral observation from this study was the presence of a high amount of "copycat" behavior in subject decision making. While an informative study in its own right, the study proposed here seeks to expand on this analysis by introducing the behavioral dynamics created by creating a multi-period problem with longer opportunities to experiment during the task rather than being constrained to a two-period setting. Furthermore, this study seeks to find deeper motivations of decision-making in these environments. However, while first period effort is shown to decrease in the public equal-sharing contest when compared to public the winner-take-all contest, only some minor analysis is done to address this free riding behavior. Our study addresses this by 1) finding parameter spaces that theoretically induce free-riding in these contests and 2) creating an experimental environment that explicitly allows for subjects to create mixed strategies. This last point is the key design element that allows us to directly study the intensity of free riding in different experimental treatments.

4.3 Theoretical Motivation

The following is a description and some basic theoretical predictions taken from Halac, et al. (2017)[4] and Hudja (2021)[96]. The former paper outlines 4 different types of contest. This section focuses on two of the contests covered in Halac, et al. (2017)[4]: a public "winner-takes-all" contest and a public "equal-share" contest.

A principal wants to obtain a specific innovation, which depends on a binary state – either good or bad. This state is unobservable. The prior probability of the good state is $p_0 \in (0, 1)$. Time is discrete with decisions taking places across two periods $t = 0, 1$, no discounting, and two risk neutral agents. In each period, each agent independently and simultaneously chooses whether or not to exert effort. If an agent exerts effort in a period and the state is good, the agent succeeds in that period with probability $\lambda \in (0, 1)$; if either the agent doesn't exert effort or the state is bad, the agent does not succeed. Exerting effort in the period costs an agent $c > 0$. Successes are conditionally independent across agents given the state and are observed by a principal and both agents. Aggregate effort is observable by both agents. The principal wants to induce both agents to work until at least one agent succeeds; an additional success provides no extra benefit. The principal has a prize $\bar{w}$ to pay the agents.

As agents exert effort, each agent updates their belief according to Bayes' rule. Thus, if a success has been obtained, the agent knows that the state is good. If a success has not yet been achieved, the Bayesian update of the state (p_{t-1}) can be written as

$$\frac{p_0(1-\lambda)^{A^{t-1}}}{p_0(1-\lambda)^{A^{t-1}} + (1-p_0)}$$

where A^{t-1} is the aggregate number of innovation attempts in the contest in the first period.

For the *public winner-takes-all* competition, suppose the principal awards the entire prize $\bar{w}$ to the first agent who achieves a success, she publicly discloses all successes at the end of each period, and there is nothing awarded if a success is achieved after the first success. If both agents succeed simultaneously, the prize is equally divided. In this mechanism, neither agent will work in the second period if either succeeded in the first period. Thus, in any period, if there has been no earlier success and the opponent is exerting effort, an agent's expected reward for success is given by:

$$\hat{w} = \lambda\bar{w}/2 + (1-\lambda)\bar{w}$$

In other words, conditional on achieving a success, there is a probability of $(1-\lambda)$ that the agent is the only one who achieved a lone success and a probability of λ that their opponent also achieved a success, leading to an expected payoff of a success given by $\hat{w}$.

If $p_0\lambda\hat{w} > c$, it is a dominant strategy for an agent to work in the first period[1]. If neither agent succeeds in the first period, both agents work in the second period if and only if

$$\tilde{p_1}\lambda w \geq c \tag{4.1}$$

where

$$\tilde{p_1} = \frac{p_0(1-\lambda)^2}{p_0(1-\lambda)^2 + 1 - p_0}$$

In a *public equal-sharing* competition, the principal discloses all successes at the end of each period and awards the prize $\bar{w}$ to the first agent to achieve a success. If both agents succeed simultaneously, then a prize of $\bar{w}/2$ is awarded to both agents. An agent is still allocated the prize even if they are the only one to succeed. Furthermore, if one agent was successful in period 1, the other agent may still be awarded in period 2. If an agent is subsequently successful in period 2, both agents are awarded $\bar{w}/2$. If an agent succeeds in

[1]↑In a later section covering non-cutoff equilibria, I will demonstrate that this is not the case if this condition does not hold but other equilibira do exist.

an earlier period, the opposing agent is certain the state is good and will continue to exert effort in period 2 so long as $\lambda\bar{w}/2 > c$. When $\lambda\bar{w}/2 < c$, an agent does not work in the second period when his opponent succeed in the first period; in this case, the contest is equivalent to a public winner-takes-all (WTA). If agents still have an incentive to work after an initial success is achieved in period 1, there is a threat of free riding as an agent may put off working in hopes that their opponent will work and reveal information about the state of the world. This dynamic is the main focus of this study.

An equilibrium always exists in stopping strategies using pure strategies. Such an equilibrium exists where each agent exerts effort until $p_{t-1} < \frac{c}{\lambda\bar{w}}$ or until an innovation is obtained (or after the end of period 2 is reached). However, it is notable that these stopping strategies are not the only equilibira in this setting. From here I move on to an analysis of other strategies not classified as cutoff strategies using mixed-strategies[2]. The next section covers public winner-take-all competitions, starting from period two to demonstrate an equilibrium using mixed strategies and backward induction. The section following that examines similar dynamics in the public equal-sharing competition.

4.3.1 Public winner-take-all

Period 2

Suppose the principal awards the entire prize $\bar{w}$ to the first agent who achieves a success, she publicly discloses all successes at the end of each period, and there is nothing awarded if a success is achieved after the first success. If both agents succeed simultaneously, the prize is equally divided. In this mechanism, neither agent will work in the second period if either succeeded in the first period. Again, in any period, if there has been no earlier success and the opponent is exerting effort, an agent's expected reward for success is given by:

[2]↑The use of mixed strategies in this section is motivated theoretically as a measurement of the "intensity" of free riding in this setting (discussed more later in this section). There are multiple ways to define an equilibrium in this setting depending on the restrictions placed on the strategy set. Free riding may exist, for instance, in pure strategies for certain parameter values in this model. However, it is natural to think of free riding in this setting as a "percentage of times an agent choose to work or shirk" and thus a mixed strategy definition of free riding follows naturally as well.

$$\hat{w} = \lambda\bar{w}/2 + (1-\lambda)\bar{w}$$

In period 2, agents in this setting update their prior beliefs about the state in period 1 p_0 going into period 2 using Bayes' rule. Thus in period 2, there are three possible cases: both agents worked in period 1, both agents shirked in period 1, and one agent shirked in period 1 while one agent worked in period 1. I will refer to these as case 1, 2, and 3. Accordingly, in period 2, if no success has been yet achieved, the expected payoff of working in period two for cases 1, 2, and 3 are for case 1

$$E(work|nosuccesses) = \tilde{p_1}\lambda\hat{w} \tag{4.2}$$

where

$$\tilde{p_1} = \frac{p_0(1-\lambda)^2}{p_0(1-\lambda)^2 + (1-p_0)}$$

In case 2, neither agent worked and so the prior of the state does not update, and the expected payoff for working is

$$E(work|bothshirk) = p_1\lambda\hat{w} \tag{4.3}$$

where

$$p_1 = p_0$$

In case 3, one agent worked and the other does not. Since working is public knowledge, prior beliefs are updated for both agents conditional on only one agent working such that the expectation of working is

$$E(work|oneworkoneshirk) = \widehat{p_1}\lambda\hat{w} \tag{4.4}$$

where

$$\widehat{p_1} = \frac{p_0(1-\lambda)}{1-\lambda p_0}$$

Note that in period 2, if no success has yet been achieved there is no benefit to not working if the expected payoff from doing so is higher than the cost of working such that

$$p_1 \lambda \hat{w} \geq c \tag{4.5}$$

It is important to note that in these three cases, the value of c determines if working or shirking is better in expectations. Further note that

$$p_0 \geq \frac{p_0(1-\lambda)}{1-\lambda p_0} \geq \frac{p_0(1-\lambda)^2}{p_0(1-\lambda)^2 + (1-p_0)} \tag{4.6}$$

For the purposes of the simplification of this analysis and for the purpose of dynamics discussed later, I consider only the scenario where the expected payoff of working is less than or equal to the cost of working. Furthermore, I consider only cases in which the cost of working is higher than the payoff of working in expectation. That is, where

$$c \geq p_0 \lambda \hat{w} \geq \frac{p_0(1-\lambda)\lambda \hat{w}}{1-\lambda p_0} \geq \frac{p_0(1-\lambda)^2 \lambda \hat{w}}{p_0(1-\lambda)^2 + (1-p_0)} \tag{4.7}$$

Again, this condition sets that in period 2, in expectation, neither agent will want to choose to work rather than shirk. I This restriction is placed on c as in all other cases working instead of shirking is a dominant strategy.

Period 1

Suppose in period 1, each agent chooses some mixed strategy $s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})$ where $\sigma_{\mathrm{i}} \in (0,1)$ such that they work with probability σ_{i} and shirk with probability $1-\sigma_{\mathrm{i}}$. $\sigma_{\mathrm{i}} = 1$ is identical to a pure strategy of working while $\sigma_{\mathrm{i}} = 0$ is identical to a pure strategy of shirking. We can use this mixed strategy to measure the intensity of "free riding" as σ_{i} approaches 0. In a single agent problem, because updating only occurs if at least one agent works, there is no incentive to shirk since $p_0 \lambda \hat{w} \geq c$ but agents may have an incentive under certain circumstances to choose a value of $\sigma_{\mathrm{i}} < 1$ in order to benefit from information revealed by another agent working.

In expectation (with the abuse of some notation), an agent's expected payoff from strategy $s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})$ is

$$\begin{aligned} E_0(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})) = \sigma(E(work|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}}) + E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|work))+ \\ (1-\sigma_{\mathrm{i}})(c + E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|shirk)) \end{aligned} \tag{4.8}$$

Where the first element is the expected payoff of working in period 1 given the other agents strategy, the second is the expected payoff of the next period conditional on working this period, the third term is the payoff c for shirking this period and the fourth therm is the expected payoff of period 2 conditional on shirking in period 1. This can be mathematically expressed as:

$$\begin{aligned} E(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}})) = \sigma_{\mathrm{i}}(\bar{w}p_0\lambda[1-\frac{\lambda\sigma_{-\mathrm{i}}}{2}] + c(1+\lambda p_0\sigma_{-\mathrm{i}} - \lambda^2 p_0))+ \\ (1-\sigma_{\mathrm{i}})(c + p_0\lambda\hat{w}(1-\sigma_{-\mathrm{i}}) + c\sigma_{-\mathrm{i}}) \end{aligned} \tag{4.9}$$

Some simplification done to group the σ_{i} and $\sigma_{-\mathrm{i}}$ terms

$$E(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}})) = \sigma_{\mathrm{i}}(\kappa\sigma_{-\mathrm{i}} + \Phi) + (1-\sigma_{\mathrm{i}})(\eta\sigma_{-\mathrm{i}} + \Psi) \tag{4.10}$$

where

$$\kappa = c\lambda p_0 - \lambda^2\bar{w}p_0/2$$

$$\Phi = \bar{w}p_0\lambda + c - c\lambda^2 p_0$$

$$\eta = c - p_0\lambda\hat{w}$$

$$\Psi = c + p_0 \lambda \hat{w}$$

A full derivation of this is offered in the appendix. The first order condition of this expectation with respect to σ_{i} is such that

$$\frac{\partial E(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}}))}{\partial \sigma} = (\kappa\sigma_{-\mathrm{i}} + \Phi) - (\eta\sigma_{-\mathrm{i}} + \Psi) \tag{4.11}$$

Setting this equal to zero and solving for σ_{i} leads to the Nash equilibrium strategy for σ_{i}

$$\sigma_{-\mathrm{i}} = \frac{\Phi - \Psi}{\eta - \kappa} \tag{4.12}$$

where $\sigma_{-\mathrm{i}} = \sigma_{\mathrm{i}} = \sigma^*$ for both players due to symmetry.

Figure 4.1 below shows the equilibrium value of σ for a single player for various values of c, $\bar{w}$, λ, and p_0. We can see by this figure below that for our relevant case, σ^* is increasing in λ, p_0, and $\bar{w}$, and decreasing in c. For the purposes of a comparative statics comparison, we have fixed values for λ, c, p_0, and w at 0.3, 7, 0.8, and 25 respectively. To illustrate the effect each variable has on the equilibrium value of σ^*, three of these parameters are fixed while the fourth is varied.

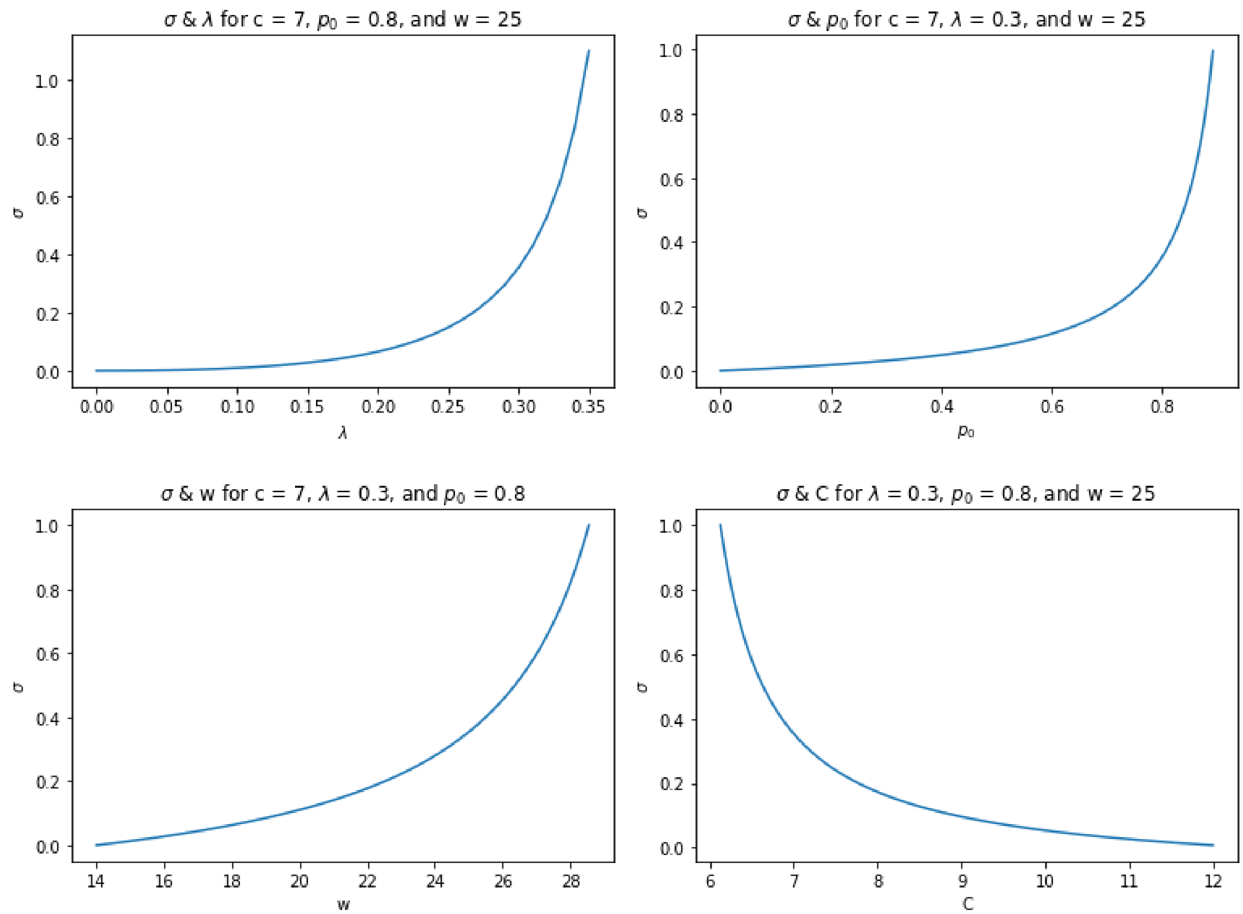


Figure 4.1. Comparative Statics for C, p_0, λ, and $\bar{w}$ in the WTA competition

The effect from these variables are intuitive in the WTA contest. Increases in λ, p_0, and w increase the expected payoff of working rather than shirking, while increases in c have the opposite effect, hence the movement of σ^* in the illustrated directions above. The conclusions drawn from these figures leads us to our first hypothesis related to this model. That is, in the WTA competition, free riding in this environment is decreasing in λ, p_0, and $\bar{w}$ but increases in c.

Hypothesis 1 In the WTA competition, free riding in this environment is increasing in λ, p_0, and $\bar{w}$ but decreases in c.

However, in any environment where $p_0\lambda\hat{w} > c$, then shirking is dominated by working as a strategy, and individuals should never free ride, leading us to our second hypothesis.

Hypothesis 1.1 In the WTA competition, if $p_0\lambda\hat{w} > c$, there should be no free-riding in this environment.

4.3.2 Public Equal-Sharing

Period 2

Suppose the principal awards the entire prize $\bar{w}$ to the first agent who achieves a success, and she publicly discloses all successes at the end of each period. If both agents succeed simultaneously, the prize is equally divided. If a second success is achieved after the first success, both agents are awarded $\bar{w}/2$. If an agent succeeds in the first period, the opponent is certain in the second period that the state is good and, due to the shared prize scheme, the opponent's reward for success is $\bar{w}/2$. Thus, when $\lambda\bar{w}/2 < c$, an agent does not work in the second period if his opponent succeeds in the first period; in this case the contest behaves equivalently to the public winner-takes all contest. On the other hand, when $\lambda\bar{w}/2 > c$, an agent will work in the second period if the opponent succeeds in the first period. Note that the duplication of effort does not benefit the principal because she values one one success and that compared to WTA, the incentive to work in the first period is lower due to two reasons. The first is a higher incentive to free-ride - an agent may want to wait for the other agent to experiment and reveal information about the state - and a lower expected reward for first period success due to the opponent's duplication of effort. Furthermore, if an agent achieves an earlier success in period 1, they will choose not to work in period 2 as a second success is not rewarded at an individual level.

From here, we analyze this setting starting in period 2. Again, in this setting update their prior beliefs about the state in period 1 p_0 going into period 2 using Bayes' rule identical to how they behaved in the public WTA contest. In period 2, there are 4 relevant cases to consider: 2 in which no success has been achieved by period 2, one in which the agent's opponent has achieved a success in period 1, and one in which neither agent worked in period 1. These will be referred to as cases 1, 2, 3, and 4 accordingly.

In case 1 both agents chose to work in period 1. Furthermore, neither agent achieved a success in period 1.

Case 1 is identical to the case in the WTA competition where both players worked and no success has yet to be achieved. In that case, the expected payoff from working is:

$$E(work) = \tilde{p_1}\lambda\hat{w}$$

where

$$\tilde{p_1} = \frac{p_0(1-\lambda)^2}{p_0(1-\lambda)^2 + (1-p_0)}$$

In case 2, no agent has achieved a success but only one agent worked in period 1. In this case, the expected payoff from working is again given by

$$E(work) = \widehat{p_1}\lambda\hat{w}$$

However, in this case p_1 is not updated for both agents working and takes a value of

$$\widehat{p_1} = \frac{p_0(1-\lambda)}{1-\lambda p_0}$$

In case 3, one or more agents worked in period 1, but only the agent's opponent achieved a success. In this case, in period 2 the agent know that the state is good and their expected payoff of working is:

$$E(work) = \lambda\bar{w}/2$$

In case 4, neither agent worked and so the prior of the state does not update, and the expected payoff for working is

$$E(work) = p_1\lambda\hat{w} \tag{4.13}$$

where

$$p_1 = p_0$$

Note that in period 2, if no success has yet been achieved there is no benefit to not working if the expected payoff from doing so is higher than the cost of working such that

$$p_1 \lambda \hat{w} \geq c \tag{4.14}$$

Furthermore, in period 2 and a success has been achieved, there is no benefit to not working if the expected payoff from doing is higher than the cost of working such that:

$$\lambda \bar{w}/2 \geq c \tag{4.15}$$

It is important to note that in these four cases, the value of c determines if working or shirking is better in expectations in period 2. Further note that

$$p_0 \geq \frac{p_0(1-\lambda)}{1-\lambda p_0} \geq \frac{p_0(1-\lambda)^2}{p_0(1-\lambda)^2 + (1-p_0)} \tag{4.16}$$

Furthermore, this paper only considers the cases in which

$$\lambda \bar{w}/2 \geq c$$

So that if the good state is ever observed in period 1 by a player's opponent achieving a success, it is better in expectation for a risk neutral agent to work rather than shirk.

The following sections consider three possible cases for the analysis of period 1. We define the three cases as follows:

In case 1 we consider the case in which there is incentive to work in period 1 but if any lack of success in period 1 is observed from any one agent, the payoff from shirking in period 2 exceeds the expected payoff from working. In other words

$$p_0 \lambda \hat{w} \geq \lambda \bar{w}/2 \geq c \geq \frac{p_0(1-\lambda)\lambda \hat{w}}{1-\lambda p_0} \geq \frac{p_0(1-\lambda)^2 \lambda \hat{w}}{p_0(1-\lambda)^2 + (1-p_0)} \tag{4.17}$$

In case 2 we consider the case in which there is incentive to work in period 1 and there is a higher expected payoff to working in round 2 regardless of how many successes there were in round 1, the payoff from shirking in period 2 exceeds the expected payoff from working. In other words

$$p_0\lambda\hat{w} \geq \frac{p_0(1-\lambda)\lambda\hat{w}}{1-\lambda p_0} \geq \frac{p_0(1-\lambda)^2\lambda\hat{w}}{p_0(1-\lambda)^2+(1-p_0)} \geq \lambda\bar{w}/2 \geq c \tag{4.18}$$

In case 3 we consider the case in which there is incentive to work in period 1 and there is a higher expected payoff to working compared to shirking in round 2 only if there have been 0 or 1 unsuccessful attempts to find a success by working in round 1. In other words

$$p_0\lambda\hat{w} \geq \frac{p_0(1-\lambda)\lambda\hat{w}}{1-\lambda p_0} \geq \lambda\bar{w}/2 \geq c \geq \frac{p_0(1-\lambda)^2\lambda\hat{w}}{p_0(1-\lambda)^2+(1-p_0)} \tag{4.19}$$

Period 1

In period 1, each agent chooses some mixed strategy $s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})$ where $\sigma_{\mathrm{i}} \in (0,1)$ such that they work with probability σ_{i} and shirk with probability $1 - sigma_{\mathrm{i}}$. $\sigma_{\mathrm{i}} = 1$ is identical to a pure strategy of working while $\sigma_{\mathrm{i}} = 0$ is identical to a pure strategy of shirking. We can use this mixed strategy to measure the intensity of "free riding" as σ_{i} approaches 0. In a single agent problem, because updating only occurs if at least one agent works, there is no incentive to shirk since $p_0\lambda\hat{w} \geq c$ but agents may have an incentive under certain circumstances to choose a value of $\sigma_{\mathrm{i}} < 1$ in order to benefit from information revealed by another agent working.

In expectation (with the abuse of some notation), an agent's expected payoff from strategy $s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})$ is

$$\begin{aligned} E_0(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})) = \sigma(E(work|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}}) + E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|work))+ \\ (1-\sigma_{\mathrm{i}})(c + E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|shirk)) \end{aligned} \tag{4.20}$$

Where the first element is the expected payoff of working in period 1 given the other agents strategy, the second is the expected payoff of the next period conditional on working this period, the third term is the payoff c for shirking this period and the fourth therm is

the expected payoff of period 2 conditional on shirking in period 1. For case 1, 2, and 3, this full term can be described by the following three expressions:

Case 1:

$$E(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}})) = \sigma_{\mathrm{i}}(\bar{w}p_0\lambda[1-\frac{\lambda\sigma_{-\mathrm{i}}}{2}] + \sigma_{-\mathrm{i}}[\lambda p_0(c+\lambda(c-\lambda\bar{w}/2)) \\ + (1-\lambda p_0)(p_0\lambda^2\bar{w}/2 + (1-\lambda p_0)c)] \\ + (1-\sigma_{-\mathrm{i}})[1-\lambda p_0]c + \lambda p_0(c-\lambda\bar{w}/2))+ \\ (1-\sigma_{\mathrm{i}})(c+\sigma_{-\mathrm{i}}[p_0\lambda(\lambda\bar{w}/2-c)+c-p_0\lambda\hat{w}] + p_0\lambda\hat{w}) \tag{4.21}$$

Case 2:

$$E(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}})) = \sigma_{\mathrm{i}}(\bar{w}p_0\lambda[1-\frac{\lambda\sigma_{-\mathrm{i}}}{2}] + \sigma_{-\mathrm{i}}[\lambda p_0(c+\lambda(c-\lambda\bar{w}/2)) \\ + (1-\lambda p_0)(p_0\lambda^2\bar{w}/2 + (1-\lambda p_0)\tilde{p_1}\lambda\hat{w})] \\ + (1-\sigma_{-\mathrm{i}})[1-\lambda p_0]\widehat{p_1}\lambda\hat{w} + \lambda p_0(c-\lambda\bar{w}/2))+ \\ (1-\sigma_{\mathrm{i}})(c+\sigma_{-\mathrm{i}}\lambda[p_0(\lambda\bar{w}/2+\hat{w}(\widehat{p_1}-p_0-p_0\widehat{p_1})] + p_0\lambda\hat{w}) \tag{4.22}$$

Case 3:

$$E(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}})) = \sigma_{\mathrm{i}}(\bar{w}p_0\lambda[1-\frac{\lambda\sigma_{-\mathrm{i}}}{2}] + \sigma_{-\mathrm{i}}[\lambda p_0(c+\lambda(c-\lambda\bar{w}/2)) \\ + (1-\lambda p_0)(p_0\lambda^2\bar{w}/2 + (1-\lambda p_0)c)] \\ + (1-\sigma_{-\mathrm{i}})[1-\lambda p_0]\widehat{p_1}\lambda\hat{w} + \lambda p_0(c-\lambda\bar{w}/2))+ \\ (1-\sigma_{\mathrm{i}})(c+\sigma_{-\mathrm{i}}\lambda[p_0(\lambda\bar{w}/2+\hat{w}(\widehat{p_1}-p_0-p_0\widehat{p_1})] + p_0\lambda\hat{w}) \tag{4.23}$$

In all three cases, these terms can be simplified and expressed as follows:

$$E(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}})) = \sigma_{\mathrm{i}}(\sigma_{-\mathrm{i}}\Phi + (1-\sigma_{-\mathrm{i}})\Psi + \kappa) + (1-\sigma_{\mathrm{i}})(\sigma_{-\mathrm{i}}\eta + \chi) \tag{4.24}$$

where for case 1,

$$\Phi = \lambda p_0(c + \lambda(c - \lambda\bar{w}/2)) + (1-\lambda p_0)(p_0\lambda^2\bar{w}/2 + (1-\lambda p_0)c) - \bar{w}p_0\lambda^2/2$$

$$\Psi = [1-\lambda p_0]c + \lambda p_0(c - \lambda\bar{w}/2)$$

$$\eta = p_0\lambda(\lambda\bar{w}/2 - c) + c - p_0\lambda\hat{w}$$

case 2,

$$\Phi = \lambda p_0(c + \lambda(c - \lambda\bar{w}/2)) + (1-\lambda p_0)(p_0\lambda^2\bar{w}/2 + (1-\lambda p_0)\tilde{p_1}\lambda\hat{w}) - \bar{w}p_0\lambda^2/2$$

$$\Psi = [1-\lambda p_0]\widehat{p_1}\lambda\hat{w} + \lambda p_0(c - \lambda\bar{w}/2)$$

$$\eta = \lambda[p_0(\lambda\bar{w}/2 + \hat{w}(\widehat{p_1} - p_0 - p_0\widehat{p_1}))]$$

and case 3,

$$\Phi = \lambda p_0(c + \lambda(c - \lambda\bar{w}/2)) + (1-\lambda p_0)(p_0\lambda^2\bar{w}/2 + (1-\lambda p_0)c) - \bar{w}p_0\lambda^2/2$$

$$\Psi = [1-\lambda p_0]\widehat{p_1}\lambda\hat{w} + \lambda p_0(c - \lambda\bar{w}/2)$$

$$\eta = \lambda[p_0(\lambda\bar{w}/2 + \hat{w}(\widehat{p_1} - p_0 - p_0\widehat{p_1}))]$$

and in all cases,

$$\chi = c + \hat{w} p_0 \lambda$$

$$\kappa = \lambda p_0 (\bar{w} + c - \lambda \bar{w}/2)$$

The first order condition of this expectation with respect to σ_{i} is such that

$$\frac{\partial E(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}}) | s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}}))}{\partial \sigma} = \sigma_{-\mathrm{i}} \Phi + (1-\sigma_{-\mathrm{i}}) \Psi + \kappa - (\sigma_{-\mathrm{i}} \eta + \chi) \tag{4.25}$$

Setting this equal to zero and solving for $\sigma_{-\mathrm{i}}$ leads to the Nash equilibrium strategy for $\sigma_{-\mathrm{i}}$

$$\sigma_{-\mathrm{i}} = \frac{\Psi + \kappa - \chi}{\eta + \Psi - \Phi} \tag{4.26}$$

where $\sigma_{-\mathrm{i}} = \sigma_{\mathrm{i}} = \sigma^*$ for both players due to symmetry.

Figure 4.2 below shows the equilibrium value of σ for a single player for various values of c, $\bar{w}$, λ, and p_0. To illustrate the effect each variable has on the equilibrium value of σ^*, three of these parameters are fixed while the fourth is varied. For the purposes of a comparative statics comparison, we have fixed values for λ, c, p_0, and w at 0.6, 5, 0.7, and 23 respectively. Pictures below are inclusive for all cases discussed above. We can see by this figure below that over a relevant range of values, σ^* is increasing in λ and c, and decreasing in p_0 and $\bar{w}$.

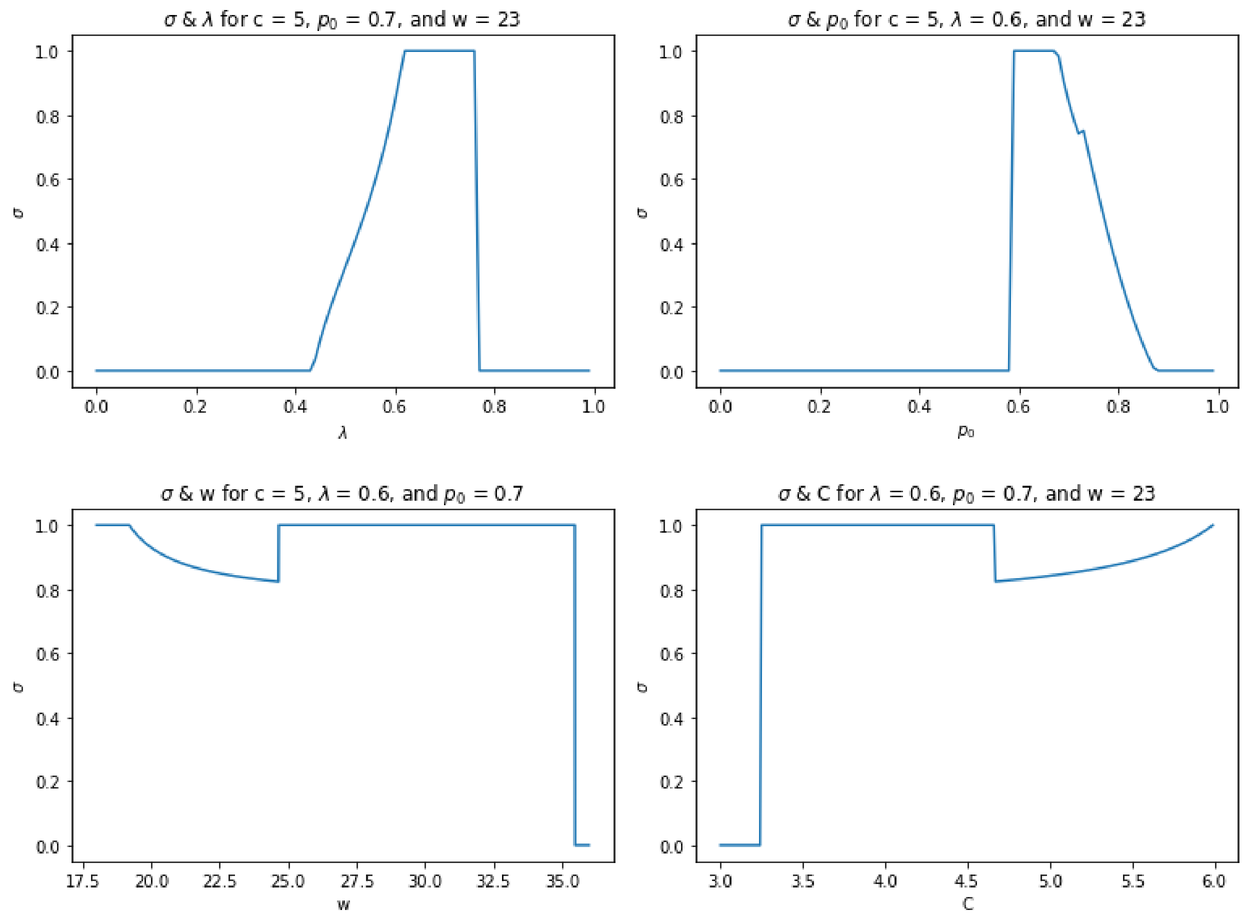


Figure 4.2. Comparative Statics for C, p_0, λ, and $\bar{w}$ in the ES competition

The interpretation of these figures is less simple than those found in the WTA case. Fundamentally, this is because there are two factors working against each other in the ES case: the temptation to free ride is much stronger in the ES competition. In some cases, as the expected value of working increases, so does the expected payoff of shirking. This explains the negative relationship between w and σ^*: the payoff (and threat) of free riding in the first period and working in the second period is has a larger effect than through the payoff of simply being the first person to succeed. This also explains the relationship between c and σ^*. The term p_0 is only relevant in updating beliefs about if the state is good or bad; however higher values of p_0 also means a higher likelihood of success in the second period for any given outcome of the first period, meaning decreasing working in the first period to work in the second period carries higher rewards under higher values of p_0. Finally the strongest channel that λ acts through is entirely with the probability of success only in the "good" state, and so has a strictly positive impact on σ^*.

These observations lead us to the following hypothesis prediction:

Hypothesis 2 In the ES competition, over a relevant range of values, free riding in this environment is decreasing in λ, and c but increases in $\bar{w}$ and p_0.

Furthermore, from the above figure we can also make the following prediction:

Hypothesis 2.1 In the ES competition, over a relevant range of values, the elastic of free riding for λ and p_0 is larger than that for than $\bar{w}$ or c.

4.4 Experimental Design

This section outlines a potential experimental design intended to test the model and previous hypotheses outlined in the previous section. This section is broken up into two subsections. The first outlines the main task, the contest game, with several characterizations and individual task treatments. The second section outlines some additional tasks to be conducted after the main task to measure subject characteristics to be later used as controls for measuring treatment effects in the main task.

4.4.1 Main task

The main task of this experiment involves the competition game outlined in section 3 along with that sections associated hypothesis predictions.

Subjects are seated at private cubicles with instructions for this first part of the experiment. These instructions are read aloud with the subjects at the beginning of the room. Subject are informed they will be making a series of decisions, with each decision being divided into two parts.

To these subjects, this task is presented as a opportunity to make choices regarding drawing poker chips from a bag containing a total of 20 chips with each bag containing green or black chips. Drawing a green chip corresponds with an innovation success (worth $\bar{w}$ points) and a black ship is an innovation failure. The cost of drawing a chip is implemented as an opportunity cost as subject would receive c points for not drawing a chip. Based on the value of p_0, subjects are informed that a random number will be drawn by the computer between 0 and 100. If the number meets or exceeds the value of p_0, a bag containing nothing but black chips would be used. If not, a bag containing a mix of green and black chips would be used. The instructions indicated the number of green chips located in that bag (based on λ).

Subjects are informed they will be paired with another individual room and each individual in that pair will make two choices. In the first choice, each individual is presented with the choice of picking a probability that they will choose to draw from the bag. It is explained that a computer will draw a random number between 0 and 100, and if that number exceeds the number they have chosen, they will not draw from the bag and instead receive c. For the second choice, they are asked whether or not to draw from the bag using a pure strategy of either choosing to draw or not draw using the same bag. Pure strategies are imposed in this second choice for two reasons. First, the choice to draw or not draw from the bag in the second choice is deterministic from a theoretical standpoint and based solely on how much information about the state of the world is revealed from the outcomes of the first period choices. There is no incentive to free-ride and thus this decision should only be made completely based on the expected payoff of these actions in comparison to the cost of drawing. Second, this helps to simplify an already complex environment for subjects without sacrificing the main dynamics of interest for this experiment, which are the mixed strategy choices for the first decision.

After both of these decisions are made, subjects are randomly re-matched with new partners. It is explained that this process will then repeat for 32 total decision pairs. Subjects are informed of the results of their decisions, their partner's decision, and the result of their partner's decision after each decision made. Visualizations illustrating the different types of bags as well as the probability of these actions are provided on-screen as these decisions are being made.

For the WTA treatment, it is explained that the first person to draw a green chip receives $\bar{w}$ points. If this occurs in the first choice, there is no second choice and both subjects automatically receive c as well. Furthermore, if both partners draw a green chip at the same time for the same choice, both then receive $\bar{w}/2$ points.

For the ES treatment, it is explained that the first person to draw a green chip receives $\bar{w}$ points. If this occurs in the first choice, the individual who drew the green chip receives an additional c points, and the other individual may still choose to draw a chip. If this second individual then draws a subsequent green chip, both partners receive $\bar{w}/2$ points instead (in addition to any points gained from choosing not to draw a chip). Furthermore, if both partners draw a green chip at the same time for the same choice, both then receive $\bar{w}/2$ points.

Table 4.1 illustrates the parameter values intended to be used across a total of 4 different treatments for each the WTA and ES game. As seen in this table, this study plans to use a 4-by-2 factorial design, with 4 different parameter sets and two types of contests games. The two contest games, the winner-take-all (WTA) and equal-sharing (ES) games, are intended to be conducted between subject. The parameter sets are conducted within subject.

Table 4.1. Contest game parameter values

			Between Subject	
			WTA Game	ES Game
Within Subject	Baseline	$\bar{w} =$	26	26
		$c =$	6	6
		$\lambda =$	0.3	0.3
		$p_0 =$	0.8	0.8
		$\sigma^* =$	1	1
	Treatment 1	$\bar{w} =$	25	25
		$c =$	7	5
		$\lambda =$	0.3	0.6
		$p_0 =$	0.8	0.8
		$\sigma^* =$	0.354	0.358
	Treatment 2	$\bar{w} =$	28	25
		$c =$	7	3
		$\lambda =$	0.3	0.6
		$p_0 =$	0.8	0.8
		$\sigma^* =$	0.818	0.878
	Treatment 3	$\bar{w} =$	25	25
		c	7	3
		$\lambda =$	0.3	0.6
		$p_0 =$	0.6	0.85
		$\sigma^* =$	0.115	0.203

The above treatment parameters are designed to capitalize on different parameter changes to see if there are heterogeneous treatment effects from different types of parameters. For instance, comparing Treatment 1 and Treatment 2 in the WTA game can measure the effects of changing $\bar{w}$ while comparing Treatment 1 and Treatment 3 in the WTA game measure treatment effects resulting from changing parameter p_0. In each session, each treatment is conducted for 8 decision pairs called a "block". At the end of a block, subjects are informed of the new values of p_0, $\bar{w}$, λ, and c and proceed to make 8 more pairs of decisions with the new parameter values. Additionally, each pairs of treatment across the WTA and ES game provide analogous equilibrium predictions of σ^*

Furthermore, both the WTA and ES game have one treatment, dubbed the "Baseline" treatment. This treatment creates conditions such that exerting effort is a dominant strategy for both types of game. This allows us to establish a baseline measurement of behavior in each task where there is no equilibrium predicted level of free-riding in each type of game.

When conducting this experiment, the baseline treatment is always conducted first. However, the order of the treatments are varied across treatments. With three different treatments, this requires 8 different treatment orderings for each type of game, for a minimum of 16 experimental sessions accounting for all possible orderings to minimize order effects.

The next section outlines several additional tasks designed to control for various subject qualities. These tasks are intended to be completed after conducting the initial main task.

4.4.2 Additional Tasks

This section overviews three additional tasks to be completed in addition to the main task. These tasks are intended to be conducted in order to measure factors that potentially or have empirically have been shown to be related to tasks similar to the main task. As such, this section covers a social value orientation task, a task intended to measure risk aversion, and a task intended to measure Bayesian updating. New instructions for each of these tasks are distributed between tasks.

The first of these tasks is a social value orientation task, implemented very similarly to Murphy, et al., (2011)[31]. This is done to measure individuals' motivations for making decisions that are potentially pro- or anti-social. Decisions to free ride and benefit of off the effort of others likely has links to values individuals hold about cooperation and other regarding preferences, thus potentially correlated with the personality types measured in the SVO task. The implementation of this task is aimed to help control for this in later analysis.

Subjects are placed in pairs with a partner and asked to choose an allocation dividing 150 points between the pair in a slider task identical to Murphy, et al., 2011. Once both partners selected an allocation, both subjects are informed how many points they earned for this task. Subjects are then randomly re-matched with new partners and asked to complete a new SVO task. A total of 6 SVO tasks are done which were made up of the six primary SVO slider items from Murphy, et al, (2011)[31].

The second task involves subjects completing both a risk aversion aversion task using a multiple price list. This task involves 20 questions in which the subject is asked to choose between a certain payoff or risky payoff. This is conducted similarly to previous risk aversion tasks conducted first in Holt and Laury (2002)[75], though instead subjects are asked to choose a cutoff point in this menu of choices in order to filter out potential switching between choices further down the price list. Here, the certain payoff takes a reward of 25, with the risky payoff awards 0 with some probability p and 25 with probability $1 - p$ at changing levels of p. The value of 25 is to address the salience of risk aversion around values similar to the reward levels in the main innovation game task.

The last task administered is the Bayesian update task from Charness and Levin (2005)[105]. In this task, subjects may draw from one of two urns that give different payoffs depending on an unknown state of the world. Subjects are instructed to draw twice from these urns, with the state of the world staying constant between draws. In the case of its use in this study, I plan to use treatment 1 from the original experiment and conduct the task 10 times. The variable of interest in this task is the error rate of decision making based on draws from each urn. This error rate will then be used in subsequent regression analysis for the main task.

4.5 Data Analysis Plan and Conclusions

This section focuses on the planned statistical tests and variables of interests regarding the experimental data to be collected, followed by a short conclusion summarizing this paper. First, I outline the data analysis plan followed by concluding remarks.

The primary variable of interest for this study is the degree of free-riding taking place across various treatments. This is done by analyzing the choice of σ_{i} (the probability of choosing to draw from the bag) in the experiment. σ_{i} is a continuous variable that takes a value between 0 and 1. As a reminder, there are several hypotheses related to this value stated in section 2:

Hypotheses

Hypothesis 1 In the WTA competition, free riding in this environment is increasing in λ, p_0, and $\bar{w}$ but decreases in c.

Hypothesis 1.1 In the WTA competition, if $p_0\lambda\hat{w} > c$, there should be no free-riding in this environment.

Hypothesis 2 In the ES competition, over a relevant range of values, free riding in this environment is decreasing in λ, and c but increases in $\bar{w}$ and p_0.

Hypothesis 2.1 In the ES competition, over a relevant range of values, the elastic of free riding for λ and p_0 is larger than that for than $\bar{w}$ or c.

Furthermore, perhaps of principal interest to this investigation, is how subject behavior differs between incentive structures, i.e. comparing behavior between the WTA and ES treatments. This is best directly captured from the baseline treatment, where both treatments have a predicted equilibrium value of $\sigma^* = 1$ and have identical treatment parameters. More generally, we can compare the observed difference in behavior across all treatments using a standard OLS estimation with the control variables later mentioned in this section. In general, I predict that the ES treatment will result in relatively higher levels of free-riding when compared to the WTA treatment, which is largely driven by the large salient benefit carried by being able to delay effort but potentially still receive $\bar{w}/2$.

From the previously mentioned hypotheses we can conduct two different tests of interest. The first is to see if the difference between behavior between the WTA and ES game diverges from the predicted equilibrium difference as well. The second is to test to see how much these decisions on average diverge from equilibrium predictions (which I will refer to as the "error rate").

For various treatment differences we can test this using the differences in treatment outcomes depending on which variables that were changed. If we define the following variable as:

$$difference = \sigma_{T1} - \sigma_{T2}$$

where σ_T terms represent the observed value of σ in different treatments. Suppose we observe the difference in treatment outcomes for a single choice by a subject as defined by the following equation

$$difference_{\mathrm{i}} = \sigma^{\mathrm{i}}_{T1} - \sigma^{\mathrm{i}}_{T2}$$

If we wish to estimate the underlying factors driving this difference to find the unbiased treatment effect, we can model this variable using a simple linear relationship, such that:

$$difference_{\mathrm{i}} = \beta_0 + \beta X + \epsilon_{\mathrm{i}} \tag{4.27}$$

Where β_0 is an intercept term, X is a 1xK vector of K co-variate terms, and ϵ is a random error term with mean 0. This can estimated using a simple linear regression model where

$$\widehat{difference} = \hat{\beta}_0 + \hat{\beta} X \tag{4.28}$$

For the co-variate terms we can use the data collected from the additional tasks conducted at the end of the experiment. This includes the classification of an individual as "pro-social" from the SVO task (which is a 0, 1 indicator variable taking on a value of 1 if indicated to be that type), the individual's estimate for their risk aversion parameter from the risk aversion task (an unbounded continuous variable), and the "error rate" of decisions made in the Bayesian updating task (a positive-valued continuous variable between 0 and 100). As such, equation 28 can be fully modeled as:

$$\widehat{difference} = \hat{\beta}_0 + \hat{\beta}_1 ProSocial + \hat{\beta}_2 RiskAversion + \hat{\beta}_3 BayesianError \tag{4.29}$$

If we know the directionality that $difference$ should take, we can conduct a 1-sided hypothesis test of the above regression model in equation 29. This sort of analysis can be conducted both *within* contest types and *between* contest types. It may be of particular interest to see if the relationship between the change in parameters or change in contest structure produce larger differences in subject behavior, especially when compared to the predicted outcomes.

A secondary variable of interest relates to **Hypothesis 2.1**. That is we wish to test to see if subject behavior is more sensitive to changes in certain parameters compared to others in terms of elasticity. As mentioned in the experimental design section, the choice of parameters in the experiment is designed to facilitate this.

Suppose we have three different treatments. For example, consider comparing treatments 1, 2 and 3 in the WTA competition. Using the above notation, define the elasticity of the response of σ to changes in parameters between treatments 1 and 2 as

$$\epsilon_{1,2} = \frac{\frac{\sigma_{T1}-\sigma_{T2}}{(\sigma_{T1}+\sigma_{T2})/2}}{\frac{w_{T1}-w_{T2}}{(w_{T1}+w_{T2})/2}}$$

and the elasticity between treatments 1 and 3 as:

$$\epsilon_{1,3} = \frac{\frac{\sigma_{T1}-\sigma_{T2}}{(\sigma_{T1}+\sigma_{T2})/2}}{\frac{p_{T1}-p_{T2}}{(p_{T1}+p_{T2})/2}}$$

If we wish to test the hypothesis that the difference generated by the change in parameters between treatments 1 and 2 was for instance smaller than that caused by a change in parameters in treatments 1 and 3, we can define a new variable as

$$D\text{i}D = \epsilon_{1,2} - \epsilon_{1,3}$$

Which should be positive according to our theoretical predictions. Again, we can use a similar regression model with the same controls as mentioned before as

$$D\hat{\text{i}}D = \hat{\beta}_0 + \hat{\beta}_1 ProSocial + \hat{\beta}_2 RiskAversion + \hat{\beta}_3 BayesianError \tag{4.30}$$

Which can then again be tested using a standard 1-sided hypothesis to determine the amount of evidence supporting the direction and magnitude of this observed variable. Thus we can test the elasticity response for changes in different parameters in different treatments. Again, it is of some interest to see how these elasticises behave both within and between competition types and how those align with the theoretical predictions of these elasticities.

For testing deviations basic from equilibrium, suppose we define the "error" rate as follows:

$$error_{\text{i}} = \sigma^{\text{i}}_{predicted} - \sigma^{\text{i}}_{observed}$$

Or the difference between the theoretically predicted value of σ^* and the observed choice of σ for a subject in one decision during the experiment. We can model this variable using a simple linear relationship, such that:

$$error_{\text{i}} = \beta_0 + \beta X + \epsilon_{\text{i}} \tag{4.31}$$

Similar to equation 29, this can be modeled using the same covariate controls to uncover which factors drive differences in equilibrium behavior

$$\widehat{error} = \hat{\beta}_0 + \hat{\beta}_1 ProSocial + \hat{\beta}_2 RiskAversion + \hat{\beta}_3 BayesianError \tag{4.32}$$

Which can be tested using the normal two-sided t-test for a difference in means.

In this study I have established a framework to analyze the intensity of free riding in an innovation contest through a mixed-strategy framework. I have provided an analysis that solves for the conditions necessary for Nash equilibrium in this framework and demonstrated how the different parameters interact with predicted levels of free riding in these different environments. I have demonstrated, for instance, that these parameters may even have heterogeneous effects across both the WTA and ES contest environments.

From there I have established several hypotheses to be tested in an experimental environment as well as a plan for procedures to conduct a laboratory experiment to test these hypotheses. Finally, in this section I have provided a plan by which this experimental data is to be analyzed effectively to test the stated hypotheses. Future work on this project involves several steps. Beyond simply the refining and conducting of this experiment to test these theoretical predictions, an analysis of predicted behavior under non-standard utility assumptions (such as risk aversion) is a worthwhile avenue to pursue. In the long term, extensions of this project include a general analysis of this framework in discrete time in more than two periods, which involves solving for a Markov-perfect equilibrium. This second extension provides an exciting direction to analyze behavior in a complex but highly dynamic environment which is largely understudied in the literature. For now, I leave this task for a future promising extension that may be pursued by this author or other researchers down the line.

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A. APPENDIX FOR: THE EFFECT OF COMPLEXITY IN AN ELECTORATE: EXPERIMENTAL EVIDENCE

A.A Preference Sets

Plurality Vote

	Player 1	Player 2	Player 3
Votes	3	4	2
A	20	15	10
B	10	20	20
C	5	10	15
D	15	5	5

	Player 1	Player 2	Player 3
Votes	5	2	4
A	20	10	15
B	15	20	5
C	5	15	20
D	10	5	10

	Player 1	Player 2	Player 3
Votes	3	6	4
A	15	20	10
B	10	10	5
C	5	15	20
D	20	5	15

	Player 1	Player 2	Player 3
Votes	2	5	4
A	5	15	10
B	15	5	20
C	10	20	15
D	20	10	5

	Player 1	Player 2	Player 3
Votes	5	4	2
A	10	20	10
B	20	10	15
C	5	15	20
D	15	5	5

IRV

	Player 1	Player 2	Player 3
Votes	5	2	4
A	5	15	10
B	10	20	5
C	20	10	15
D	15	5	20

	Player 1	Player 2	Player 3
Votes	4	2	5
A	20	5	15
B	15	20	5
C	10	15	20
D	5	10	10

	Player 1	Player 2	Player 3
Votes	3	2	4
A	10	5	20
B	5	20	15
C	15	10	5
D	20	15	10

	Player 1	Player 2	Player 3
Votes	3	4	6
A	5	20	10
B	10	5	15
C	15	10	20
D	20	15	5

	Player 1	Player 2	Player 3
Votes	4	2	5
A	15	5	5
B	20	15	10
C	5	20	15
D	10	10	20

<u>STAR</u>

	Player 1	Player 2	Player 3
Votes	4	5	2
A	5	10	5
B	10	15	20
C	20	5	10
D	15	20	15

	Player 1	Player 2	Player 3
Votes	5	2	4
A	20	15	10
B	15	10	5
C	10	5	20
D	5	20	15

	Player 1	Player 2	Player 3
Votes	5	6	3
A	15	5	20
B	5	15	10
C	10	20	15
D	20	10	5

	Player 1	Player 2	Player 3
Votes	4	2	5
A	20	5	10
B	10	15	20
C	5	10	15
D	15	20	5

	Player 1	Player 2	Player 3
Votes	2	4	5
A	5	20	10
B	15	10	20
C	10	5	15
D	20	15	5

A.B Experimental UI

Welcome

Please wait for the experiment to begin.

Practice Page

This screen displays the tools and information below in a similar manner to when you are making decisions for payment. Decisions here will not be used for payment in this experiment.

The below table lists both your and your group members' payoffs for selecting the various alternatives, as well as how many votes each as been allocated this round. Your player number, votes, and payoffs are highlighted in yellow:

Player:	1	2 (You)	3
Votes:	5	4	3
Alternatives	**Players' Payoffs**		
A	20	15	5
B	5	10	10
C	10	20	20
D	15	5	15

Suppose players 1 and 3 have selected to vote for "B" and "D" respectively. Input your voting decision below and then press the "Test" button to see the outcome of the group selection, including how many points you would have earned for your decision.

B

Practice Page

This screen displays the tools and information below in a similar manner to when you are making decisions for payment. Decisions here will not be used for payment in this experiment.

The below table lists both your and your group members' payoffs for selecting the various alternatives, as well as how many votes each has been allocated this round. Your player number, votes, and payoffs are highlighted in yellow:

Player:	1	2	3
Votes:	5	5 (You)	3
Alternatives	**Players' Payoffs**		
A	20	15	5
B	5	10	10
C	10	20	20
D	15	5	15

Practice Page

This screen displays the tools and information below in a similar manner to when you are making decisions for payment. Decisions here will not be used for payment in this experiment.

The below table lists both your and your group members' payoffs for selecting the various alternatives, as well as how many votes each has been allocated this round. Your player number, votes, and payoffs are highlighted in yellow:

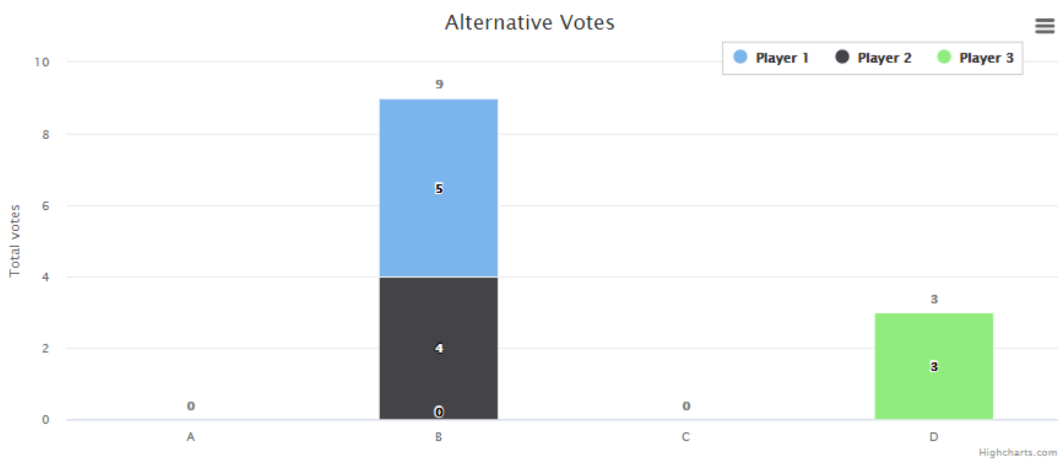
Player:	1	2 (You)	3
Votes:	5	5	3
Alternatives	**Players' Payoffs**		
A	20	15	5
B	5	10	10
C	10	20	20
D	15	5	15

Suppose players 1 and 3 have selected to vote for "B" and "D" respectively. Input your voting decision below and then press the "Test" button to see the outcome of the group selection, including how many points you would have earned for your decision.

B

Test

The chart below summarizes the voting decisions for each player and how many votes each alternative received



Chosen alternative: B
Payoff: 10

When you are finished, press the "next" button below to proceed to the rest of the experiment.

Next

Suppose players 1 and 3 have selected to vote in the following manner:

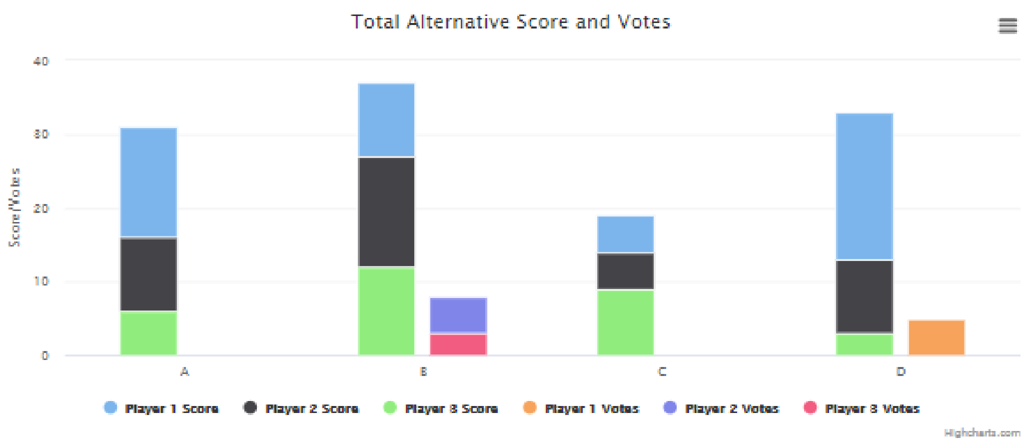
Player 1: A = 3, B = 2, C = 1, D = 4

Player 3: A = 2, B = 4, C = 3, D = 1

Input your voting decision below and then press the "Test" button to see the outcome of the group selection, including how many points you would have earned for your decision.

A:	B:	C:	D:
2	3	1	2

Test



The chart above summarizes the voting decisions for each player. The first column for every alternative is the total score for that alternative while the second is the total number of votes that alternative received in the runoff.

Chosen alternative: B
Payoff: 10

When you are finished, press the "next" button below to proceed to the rest of the experiment.

Next

Suppose players 1 and 3 have selected to vote in the following manner:

Player 1: A = 3, B = 2, C = 1, D = 4

Player 3: A = 2, B = 4, C = 3, D = 1

Input your voting decision below and then press the "Test" button to see the outcome of the group selection, including how many points you would have earned for your decision.

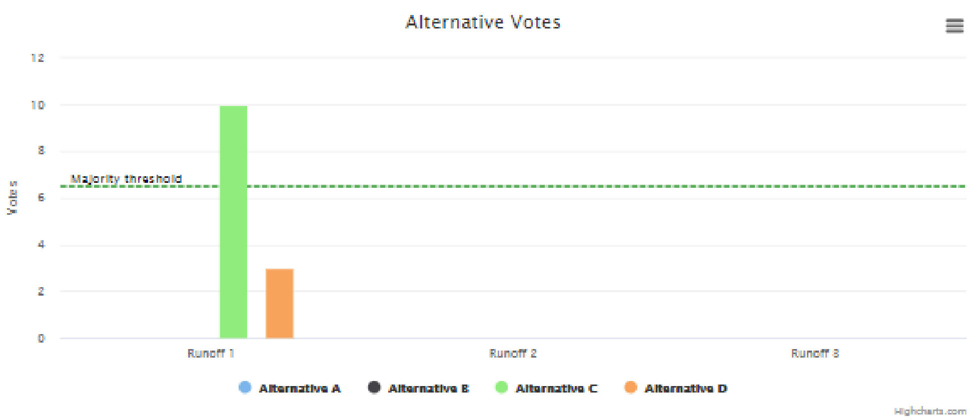
A: 3

B: 2

C: 1

D: 4

Test



The chart above summarizes the series of runoffs and votes for each alternative. Each group of columns represents each runoff. Remember, once an alternative reaches a majority of votes there are no further rounds of voting.

Chosen alternative: C
Payoff: 20

When you are finished, press the "next" button below to proceed to the rest of the experiment.

Next

Alternative Selection
Round 1 of 40

The below table lists both your and your group members' payoffs for selecting the various alternatives, as well as how many votes each has been allocated this round. Your player number, votes, and payoffs are highlighted in yellow:

Player:	1 (You)	2	3
Votes:	3	6	4
Alternatives	**Players' Payoffs**		
A	15	20	10
B	10	10	5
C	5	15	20
D	20	5	15

Please indicate which alternative you would like to assign all of your votes to:

Vote Choice:

○ A ○ B ○ C ○ D

Next

Alternative Selection
Round 1 of 40

The below table lists both your and your group members' payoffs for selecting the various alternatives, as well as how many each has been allocated this round. Your player number, votes, and payoffs are highlighted in yellow:

Player:	1 (You)	2	3
Votes:	5	6	3
Alternatives	**Players' Payoffs**		
A	15	5	20
B	5	15	10
C	10	20	15
D	20	10	5

Please indicate how many points you wish to assign to each alternative (1 to 4)

A: --------- B: --------- C: --------- D: ---------

Next

Alternative Selection
Round 1 of 40

The below table lists both your and your group members' payoffs for selecting the various alternatives, as well as how many votes each has been allocated this round. Your player number, votes, and payoffs are highlighted in yellow:

Player:	1 (You)	2	3
Votes:	3	2	4
Alternatives	**Players' Payoffs**		
A	10	5	20
B	5	20	15
C	15	10	5
D	20	15	10

Please indicate your ranking of the above alternatives from highest (1) to lowest (4):

A: ---------

B: ---------

C: ---------

D: ---------

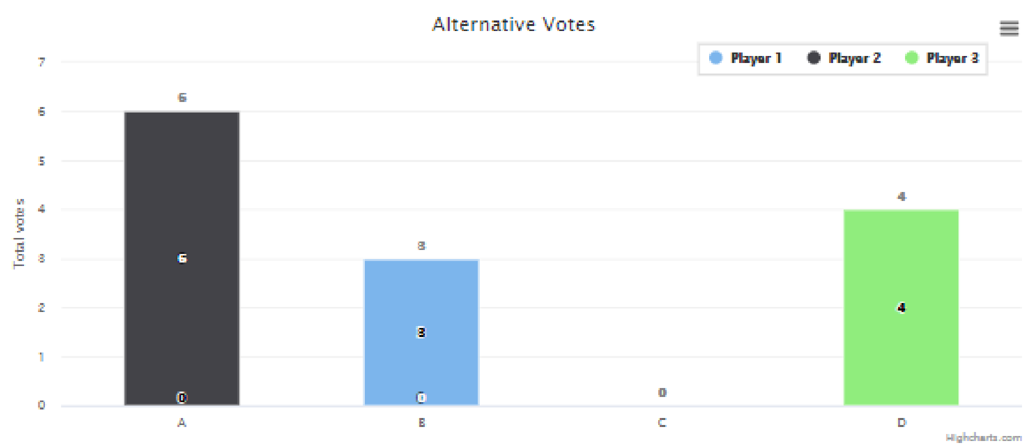
Next

Round Results
Round 2 of 40

The below table lists both your and your group members' payoffs for selecting the various alternatives, as well as how many votes each has been allocated this round. Your player number, votes, and payoffs are highlighted in yellow. The alternative that has been selected has been highlighted in blue. All players' choices have been bordered in black:

Player:	1	2	3 (You)
Votes:	3	6	4
Alternatives	**Players' Payoffs**		
A	15	20	10
B	10	10	5
C	5	15	20
D	20	5	15

The chart below summarizes the voting decisions for each player and how many votes each alternative received



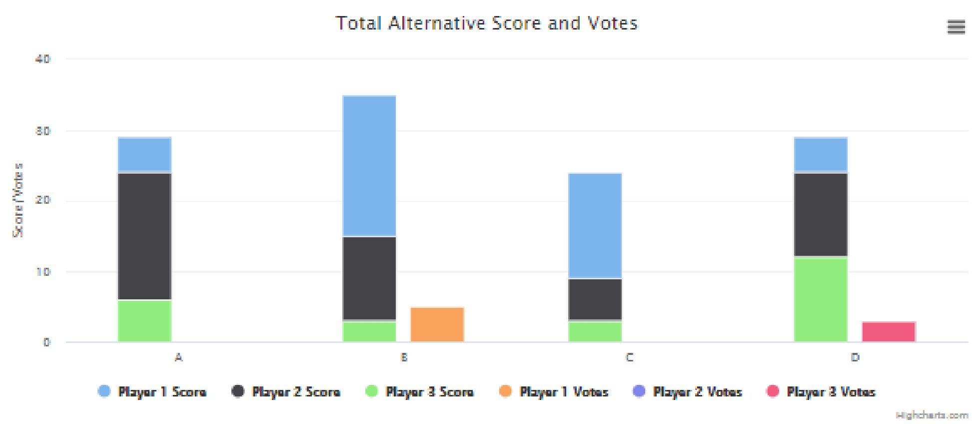
The chosen alternative for this round was A and your payoff was 10 points

Next

Round Results
Round 1 of 40

The below table lists both your and your group members' payoffs for selecting the various alternatives, as well as how many votes each has been allocated this round. Your player number, votes, and payoffs are highlighted in yellow. The alternative that has been selected has been highlighted in blue. The score each player chose for each alternative is listed in bold next to that alternative's payoff:

Player:	1	2	3 (You)
Votes:	5	6	3
Alternatives	**Players' Payoffs**		
A	15 **(1)**	5 (3)	20 **(2)**
B	5 **(4)**	15 **(2)**	10 **(1)**
C	10 **(3)**	20 **(1)**	15 **(1)**
D	20 **(1)**	10 **(2)**	5 **(4)**



The chart above summarizes the voting decisions for each player. The first column for every alternative is the total score for that alternative while the second is the total number of votes that alternative received in the runoff.

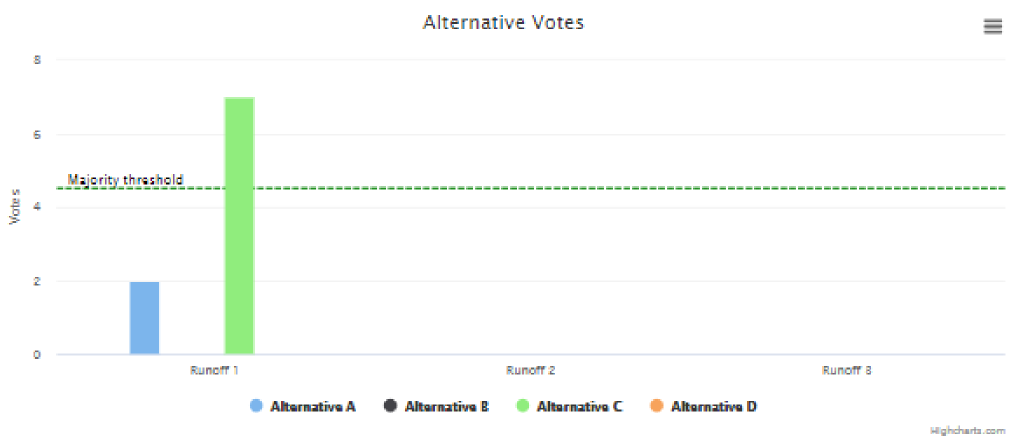
The chosen alternative for this round was B and your payoff was 10 points

Next

Round Results
Round 1 of 40

The below table lists both your and your group members' payoffs for selecting the various alternatives, as well as how many votes each has been allocated this round. Your player number, votes, and payoffs are highlighted in yellow. The alternative that has been selected has been highlighted in blue. The rank each player chose for each alternative is listed in bold next to that alternative's payoff:

Player:	1	2	3 (You)
Votes:	3	2	4
Alternatives	**Players' Payoffs**		
A	10 **(3)**	5 **(1)**	20 **(4)**
B	5 **(2)**	20 **(3)**	15 **(3)**
C	15 **(1)**	10 **(2)**	5 **(1)**
D	20 **(4)**	15 **(4)**	10 **(2)**



The chart above summarizes the series of runoffs and votes for each alternative. Each group of columns represents each runoff. Remember, once an alternative reaches a majority of votes there are no further rounds of voting.

The chosen alternative for this round was C and your payoff was 5 points

Next

New Block

This is the start of a new block. Please pay attention as the number of votes each player has received may have changed. The amount of points each player receives from each alternative being selected may have changed as well.

Next

Task 2

This next task will ask you and another participant to select an action. This task will last for 8 rounds. You will complete the same task for 8 rounds. After each round, you will be randomly rematched with a new, other participant.

Each round you will be presented with a table. The table used today for this task is presented below.

	Other's actions	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Your actions								
1		(12,12)	(21,1)	(11,11)	(11,11)	(11,11)	(11,11)	(0,11)
2		(1,21)	(11,11)	(21,1)	(11,11)	(11,11)	(11,11)	(11,11)
3		(11,11)	(1,21)	(11,11)	(21,1)	(11,11)	(11,11)	(11,11)
4		(11,11)	(11,11)	(1,21)	(11,11)	(21,1)	(21,1)	(21,1)
5		(11,11)	(11,11)	(11,11)	(1,21)	(11,11)	(11,11)	(11,11)
6		(11,11)	(11,11)	(11,11)	(1,21)	(11,11)	(11,11)	(11,11)
7		(11,0)	(11,11)	(11,11)	(1,21)	(11,11)	(11,11)	(0,0)

The actions available to you in this task will be presented along the left hand side of this table and the other participants possible actions will be listed along the top of the table. The payoff you receive in each round depends both on your action as well as the action the other participant picks.

The rest of this table is made of a series of cells. These cells correspond with the pair of actions taken by you and the other participant. For instance, if you picked action "4" and the other participant picked action "3", the cell corresponding to the actions you and the other participant took would lie on the 4th row and 3rd column of the table.

Inside each cell is listed a pair of numbers formatted in a manner of (x,y). This represents the payoffs you and the other participant would receive from the pair of actions for that cell, with x being your payoff for this round and y being the other participant's payoff. In the example above where you had picked action "4" and the other participant picked action "3", you would have received 1 point for this round and the other participant would receive 21 points for this round.

After you select which action you would like to take, click the "next" button on that page. Once both you and the other participant have selected an action, a results screen will display which actions you and the other participant took as well as your payoff for that round.

You will be paid the value of all points earned for this task. Points earned in this task will be converted to USD at a rate of 80 points = 1 USD

Please click the button below to proceed to Task 2.

Next

Decision Page (Round 1 of 8)

	Other's actions	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Your actions								
1		(12,12)	(21,1)	(11,11)	(11,11)	(11,11)	(11,11)	(0,11)
2		(1,21)	(11,11)	(21,1)	(11,11)	(11,11)	(11,11)	(11,11)
3		(11,11)	(1,21)	(11,11)	(21,1)	(11,11)	(11,11)	(11,11)
4		(11,11)	(11,11)	(1,21)	(11,11)	(21,1)	(21,1)	(21,1)
5		(11,11)	(11,11)	(11,11)	(1,21)	(11,11)	(11,11)	(11,11)
6		(11,11)	(11,11)	(11,11)	(1,21)	(11,11)	(11,11)	(11,11)
7		(11,0)	(11,11)	(11,11)	(1,21)	(11,11)	(11,11)	(0,0)

Please choose which action you would like to take. As a reminder, your possible actions are listed along the left hand side of the table, while the other participant's actions are listed along the top of the table.

Please select which action you would like to take:

Next

Results (Round 1 of 8)

	Other's actions	1	2	3	4	5	6	7
Your actions								
1		(12,12)	(21,1)	(11,11)	(11,11)	(11,11)	(11,11)	(0,11)
2		(1,21)	(11,11)	(21,1)	(11,11)	(11,11)	(11,11)	(11,11)
3		(11,11)	(1,21)	(11,11)	(21,1)	(11,11)	(11,11)	(11,11)
4		(11,11)	(11,11)	(1,21)	(11,11)	(21,1)	(21,1)	(21,1)
5		(11,11)	(11,11)	(11,11)	(1,21)	(11,11)	(11,11)	(11,11)
6		(11,11)	(11,11)	(11,11)	(1,21)	(11,11)	(11,11)	(11,11)
7		(11,0)	(11,11)	(11,11)	(1,21)	(11,11)	(11,11)	(0,0)

The action you chose is highlighted in blue in the corresponding row of the above table. The action taken by the other participant is highlighted in red of the corresponding column.

Your payoff for this round is 12 points.

Next

Questionnaire 1

In this questionnaire, you have been randomly paired with another person, whom we will refer to as the other.
You will be asked to make a series of decisions about allocating resources (in points) between you and the other person.
For each of the following questions, please indicate the distribution you would prefer the most.

All of your answers to this questionnaire will be used in your payment today.
For each question you will be paired up with another participant. Each of you will answer the same question. Your payment for that question will be based on both players' choice of distributions. In other words, you will earn that value distributed to yourself as chosen by you as well as the value the other person has distributed to you as chosen by the other person.
After answering each question you will be randomly re-paired with a new other person. There are a total of 6 questions.

In this questionnaire, we will use the following exchange rate: 240 points = 1 USD

At any time during the questionnaire, if you have any questions, please raise your hand and the experimenter will come over to answer them.

Please click the button below to proceed to the questionnaire.

Next

Question 1 of 6

Please indicate which of the following allocations you would like to select:

Allocation	1	2	3	4	5	6	7	8	9
You receive	85	85	85	85	85	85	85	85	85
Other receives	85	76	68	59	50	41	33	24	15

Select Allocation:

○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9

Next

Question 2 of 6

Please indicate which of the following allocations you would like to select:

Allocation	1	2	3	4	5	6	7	8	9
You receive	85	87	89	91	93	94	96	98	100
Other receives	15	19	24	28	33	37	41	46	50

Select Allocation:

○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9

Next

Question 3 of 6

Please indicate which of the following allocations you would like to select:

Allocation	1	2	3	4	5	6	7	8	9
You receive	50	54	59	63	68	72	76	81	85
Other receives	100	98	96	94	93	91	89	87	85

Select Allocation:

○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9

Next

Question 4 of 6

Please indicate which of the following allocations you would like to select:

Allocation	1	2	3	4	5	6	7	8	9
You receive	50	54	59	63	68	72	76	81	85
Other receives	100	89	79	68	58	47	36	26	15

Select Allocation:

○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9

Next

Question 5 of 6

Please indicate which of the following allocations you would like to select:

Allocation	1	2	3	4	5	6	7	8	9
You receive	100	94	88	81	75	69	63	56	50
Other receives	50	56	63	69	75	81	88	94	100

Select Allocation:

○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9

Next

Question 6 of 6

Please indicate which of the following allocations you would like to select:

Allocation	1	2	3	4	5	6	7	8	9
You receive	100	98	96	94	93	91	89	87	85
Other receives	50	54	59	63	68	72	76	81	85

Select Allocation:

○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9

Next

Questionnaire 2

The following questionnaire asks you to answer a series of questions. Questions may take the form of either multiple choice style questions or may ask you to enter a value into a box provided.

For each question answered correctly, you will earn a total of $0.25 to be added to all other earnings in the experiment today. You will be paid for all questions correctly answered.

At any time during the questionnaire, if you have any questions, please raise your hand and the experimenter will come over to answer them.

Please click the button below to proceed to the questionnaire.

Next

Questionnaire 2

1. A bat and a ball costs $1.10 in total. A bat costs $1.00 more than a ball.
How much does the ball cost in cents?

2. If it takes 5 machines 5 minutes to make 5 widgets, how long would it take 100 machines to make 100 widgets in minutes?

3. In a lake there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half the lake in days?

4. A man buys a pig for $60, sells it for $70, buys it back for $80, and sells it finally for $90.
How much money has he made in dollars?

5. Jerry received both the 15th highest and 15th lowest mark in the class. How many students are in the class?

6. Emily's father has three daughters. The first two are named April and May. What is the third daughter's name?

7. How many cubic feet of dirt are there in a hole that is 3 feet deep, 3 feet wide, and 3 feet long?

8. If John can drink one barrel of water in 6 days, and Mary can drink one barrel of water in 12 days, how long would it take them to drink one barrel of water together in days?

Next

Demograhpics Survey

The below survey asks you to answer several questions. Your answers to these questions will remain anonymous and are not used for payment in today's session. Answering any of the following questions is optional; if you do not wish to answer a question, please enter "prefer not to answer" among the list of choices provided or enter it into the text box provided.

Question	Answer
What is/are your college major(s)?	
How many economics courses have you taken?	---------
Have you taken a course in game theory before?	---------
How many political science courses have you taken?	---------
How many economics laboratory experiments have you participated in?	---------
What gender do you identify as?	---------
Which of the following races do you identify as?	---------

Final Results

Thank you for participation in today's experiment. From your participation today, you have earned the following: $12.05
Please remain silent as others around you may not have finished. The experimenter will be around to distribute your payment to you.
Once you have received your payment, you are free to leave.

A.C Experimental Instructions

A.C.1 Plurality Voting Instructions

Instructions

Introduction

Welcome!

Thank you for your participation in today's experiment. This is an experiment in decision-making. In addition to a $5 participation payment, you will be paid any additional money you accumulate during the experiment at the conclusion of today's session.

All payoffs during the experiment are denominated in points. At the end of the experiment, points will be converted into cash at the rate of $1 per 80 points. You will be paid privately in cash. The exact amount you receive will be determined during the experiment and will depend on your decisions as well as the decisions of others. At the end of the experiment today, we will pay you based on the total number of points you have earned across all rounds.

If you have any questions during your experiment, please raise your hand and wait for an experimenter to come to you. Please do not talk, exclaim, or try to communicate in ways other than instructed to with other participants during the experiment. Participants intentionally violating the rules may be asked to leave the experiment and may not get paid. Additionally, please put away all electronic devices not provided to you by the experimenter in this session today.

Experiment Overview

In part 1 of this experiment you will be asked to make a group decision among a set of 4 different alternatives. The alternatives are labeled as alternative A, alternative B, alternative C, and alternative D. The amount of points you earn in each round is determined by which alternative your group picks; the amount you earn for the chosen alternative may be different than what others in your group earn. Between rounds, your group members may change. Additionally, how many points you earn for each alternative may change as well. The process by which your group chooses alternatives will not change and this experiment will last for a total of 40 rounds.

Part 2 follows part 1 of this experiment. Additional instructions for part 2 will be provided after part 1.

Blocks and Rounds

Part 1 will consist of five (5) different blocks, each made up of a series of choices. Each block will consist of eight (8) rounds for a total of 40 rounds.. Each round will ask you and your group members to make decisions which will determine how many points each of you receive for that round.

Task

Your task today involves making a group decision. You will be in a group consisting of yourself and two other participants and your group will be randomly rematched each round. For each round, you and your fellow group members will be asked to make individual choices that determine the choice the group makes.

In each round you will be presented with a list of alternatives. Your group will be asked to choose one alternative for the group to select by voting on the various alternatives. That is, you will select which alternative you would like to vote for. You will vote for only one alternative. The alternative that receives the most votes from your group members will be selected by the group.

You will also be presented with your and your group members' alternatives and the respective (corresponding) payoffs. Additionally, you and each member of your group may have a different amount of votes. When you select which alternative you would like to vote for, all of your votes will be assigned to that alternative. For instance, if you have 5 votes for this round and you select alternative "B", alternative B would receive 5 votes from you. You are not able to split your votes between more than one alternative. At any time you are asked to vote on an alternative, you will be able to observe how many votes you have as well as how many votes other members of your group have as well.

The picture below displays how this information will be presented to you:

Alternative Selection
Round 1 of 40

The below table lists both your and your group members' payoffs for selecting the various alternatives, as well as how many votes each has been allocated this round. Your player number, votes, and payoffs are highlighted in yellow:

Player:	1 (You)	2	3
Votes:	3	4	2
Alternatives	**Players' Payoffs**		
A	20	15	10
B	10	20	20
C	5	10	15
D	15	5	5

Please indicate which alternative you would like to assign all of your votes to:

Vote Choice:

○ A ○ B ○ C ○ D

After all group members have selected the alternative that they wish to vote for, you are rewarded based on the alternative that received the most votes by the group. A page will be displayed that shows how many votes each alternative received and the payoffs you and your group members have received. Additionally, this results page displays the decisions you and the other members of your group made, which alternative was selected, and how many points you received this round.

An example of this screen is shown below:

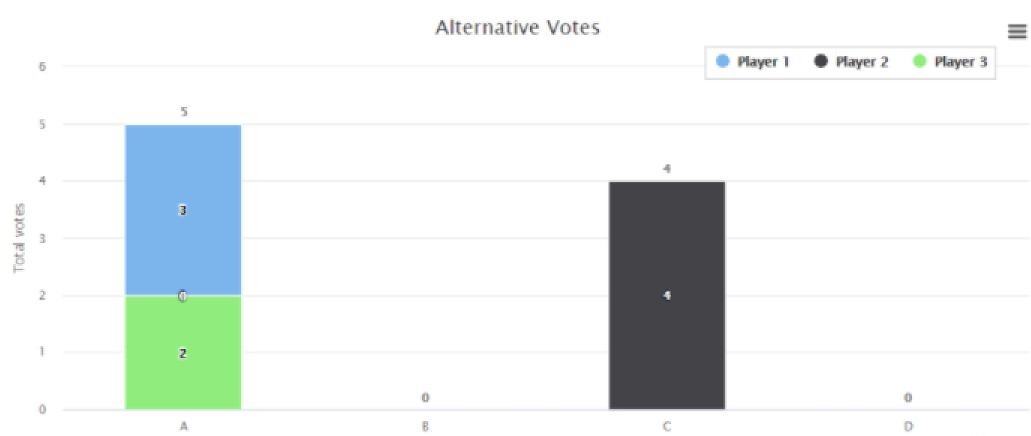
Round Results
Round 1 of 40

The below table lists both your and your group members' payoffs for selecting the various alternatives, as well as how many votes each has been allocated this round. Your player number, votes, and payoffs are highlighted in yellow. The alternative that has been selected has been highlighted in blue. All players' choices have been bordered in black:

Player:	1 (You)	2	3
Votes:	3	4	2
Alternatives	**Players' Payoffs**		
A	20	15	10
B	10	20	20
C	5	10	15
D	15	5	5

Finally, to help you understand your group members' decisions in the current round, a chart is also provided in the results screen that summarizes the results in another way. An example of this chart is provided below:

The chart below summarizes the voting decisions for each player and how many votes each alternative received



The chosen alternative for this round was A and your payoff was 20 points

The height of each column shows the total votes that each alternative receives. Within each column it displays from which group member the total votes came from. **Roles and blocks**

Your role in each round determines the number of votes you receive as well as the points you would receive from each of the available alternatives being selected. Note from the above screenshots, each member of the group has a different role (players 1, 2, and 3). For the 8 rounds of each block, each group will be made up of the same 3 roles. However, after each round, you will be randomly regrouped into a new group of participants and may be assigned a new role. That is, each round your group may be made up of different participants and you individually may have a different role, but the three roles of each group across rounds of a block will not change. A group will change which roles it consists of at the start of every new block or, in other words, every 8 rounds.

Part 2

Part 2 consists of 3 additional tasks and one set of survey questions that follow part 1. Additional instructions for each of the tasks in part 2 will be provided to you before each task. If you have any questions during this part of the experiment, please raise your hand and an experimenter will come to clarify any questions you may have.

Summary

A summary of the instructions above are provided below:

1. This experiment consists of five (5) blocks
    (a) Each block consists of eight (8) rounds
2. In each round you will be assigned to a role in a group consisting of yourself and 2 other participants
    (a) The roles in each group do not change for the entirety of one block, but will change between blocks
    (b) The role you are assigned to individually may change between rounds
    (c) Your group will be randomly reassigned each round
3. You will be asked to vote on one of four alternatives to be selected by the group. You will choose to vote for only one alternative.

(a) You will be informed how many votes you and your group members have, as well as you and your groups payoffs for selecting each alternative.

(b) The alternative that receives the most votes will be selected by the group

4. Each round you will be informed which alternative was selected by the group and the number of points you received that round

5. Part 2 will ask you to complete 3 additional tasks and one set of survey questions. Additional instructions for these tasks will be provided at the time you are asked to complete them.

6. At the end of the experiment, you will be paid for the points you have earned across all decisions you made during the course of the experiment in addition to your $5 show-up payment.

A.C.2 IRV Voting Instructions

Instructions

<u>Introduction</u>

Welcome!

Thank you for your participation in today's experiment. This is an experiment in decision-making. In addition to a $5 participation payment, you will be paid any additional money you accumulate during the experiment at the conclusion of today's session.

All payoffs during the experiment are denominated in points. At the end of the experiment, points will be converted into cash at the rate of $1 per 80 points. You will be paid privately in cash. The exact amount you receive will be determined during the experiment and will depend on your decisions as well as the decisions of others. At the end of the experiment today, we will pay you based on the total number of points you have earned across all rounds.

If you have any questions during your experiment, please raise your hand and wait for an experimenter to come to you. Please do not talk, exclaim, or try to communicate in ways other than instructed to with other participants during the experiment. Participants intentionally violating the rules may be asked to leave the experiment and may not get paid. Additionally, please put away all electronic devices not provided to you by the experimenter in this session today.

Experiment Overview

In part 1 of this experiment you will be asked to make a group decision among a set of 4 different alternatives. The alternatives are labeled as alternative A, alternative B, alternative C, and alternative D. The amount of points you earn in each round is determined by which alternative your group picks; the amount you earn for the chosen alternative may be different than what others in your group earn. Between rounds, your group members may change. Additionally, how many points you earn for each alternative may change as well. The process by which your group chooses alternatives will not change and this experiment will last for a total of 40 rounds.

Part 2 follows part 1 of this experiment. Additional instructions for part 2 will be provided after part 1.

Blocks and Rounds

Part 1 will consist of five (5) different blocks, each made up of a series of choices. Each block will consist of eight (8) rounds for a total of 40 rounds. Each round will ask you and your group members to make decisions which will determine how many points each of you receive for that round.

Task

Your task today involves making a group decision. You will be in a group consisting of yourself and two other participants and your group will be randomly rematched each round. For each round, you and your fellow group members will be asked to make individual choices that determine the choice the group makes.

In each round you will be presented with a list of alternatives. Your group will be asked to choose one alternative for the group to select by voting on the various alternatives. The voting system used for today's experiment is explained in the following paragraph.

The voting system works as follows: first you are asked to provide a ranking of the alternatives, with 1 being the highest and 4 being the lowest. This is the only point in which you are asked to make a decision. What follows is a series of automatic runoffs.

The computer will assign your votes for whichever alternative you ranked first with a “1”. Following this, the computer checks to see if any alternative has received a majority of all possible votes. If any alternative has received a majority of votes, that alternative is selected by the group. If it has not, the alternative with the fewest votes is eliminated. If any group member had ranked that alternative with a “1”, the computer will then assign their votes to whichever alternative they ranked with a “2” (or next highest ranking if their “2” ranked alternative has already been eliminated). The computer then checks again to see if any alternative has a majority of votes, choosing that alternative to be the one selected by the group if this is satisfied. If not, the elimination process continues until one alternative has received a majority of all votes from the group members. In the event of a tie, one of the tied alternatives will be picked randomly.

You will also be presented with your and your group members’ alternatives and the respective (corresponding) payoffs. Additionally, you and each member of your group may have a different amount of votes. When you submit the rankings of the alternatives, all of your votes will initially be assigned to the alternative you ranked with a “1”. For instance, if you have 5 votes for this round and you ranked alternative “B” with a “1”, alternative B would receive 5 votes from you. You are not able to split your votes between more than one alternative. At any time you are asked to vote on an alternative, you will be able to observe how many votes you have as well as how many votes other members of your group have as well.

Extended example

Suppose three group members with 3, 4, and 4 votes ranked four alternatives, A, B, C, and D in the following manner as described in the table on the next page:

	Player 1	Player 2	Player 3
Votes	3	4	4
A	1	2	4
B	2	1	3
C	3	3	2
D	4	4	1

First the computer checks to see if any alternative received a majority of votes. Currently, A would have received 3 votes from player 1, B would have received 4 votes from player 2, and D would have received 4 votes from player 3. Since the total number of votes is 11, one alternative must receive at least 6 total votes to be selected. None of these alternatives have at least 6 votes yet, so the alternative with the fewest votes is eliminated; in this case alternative C since it currently has 0 votes. The computer then checks to see what the totals are, which remain unchanged since no player ranked C with a "1". It then eliminates the alternative with the next fewest votes; in this case the computer eliminates alternative A since it only has 3 votes compared to B and D which both have 4. Since Player 1 had ranked A first, and A was eliminated, their votes then go to whatever alternative they ranked second, which is alternative B. Alternative B now has 7 total votes (3 from player 1 and 4 from player 2). Since it has at least a majority of the total votes, alternative B would be the alternative selected by the group.

The picture on the next page displays how information will be presented to you during your decision making:

Alternative Selection
Round 1 of 40

The below table lists both your and your group members' payoffs for selecting the various alternatives, as well as how many votes each has been allocated this round. Your player number, votes, and payoffs are highlighted in yellow:

Player:	1	2 (You)	3
Votes:	5	2	4
Alternatives	**Players' Payoffs**		
A	5	15	10
B	10	20	5
C	20	10	15
D	15	5	20

Please indicate your ranking of the above alternatives from highest (1) to lowest (4):

A:	B:	C:	D:
--------- ▾	--------- ▾	--------- ▾	--------- ▾

After all group members have submitted their voting decision, you are rewarded based on the alternative that was chosen by the previously explained voting system. A page will be displayed that shows how many votes each alternative received and the payoffs you and your group members have received. Additionally, this results page displays the decisions you and the other members of your group made, which alternative was selected, and how many points you received this round.

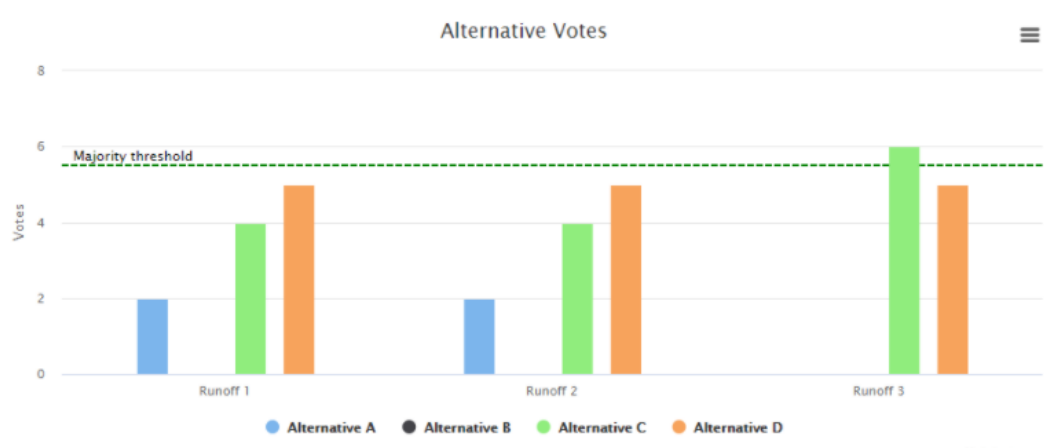
An example of this screen is shown on the next page:

Round Results
Round 1 of 40

The below table lists both your and your group members' payoffs for selecting the various alternatives, as well as how many votes each has been allocated this round. Your player number, votes, and payoffs are highlighted in yellow. The alternative that has been selected has been highlighted in blue. The rank each player chose for each alternative is listed in bold next to that alternative's payoff:

Player:	1	2	3 (You)
Votes:	5	2	4
Alternatives	**Players' Payoffs**		
A	5 **(4)**	15 **(1)**	10 **(3)**
B	10 **(3)**	20 **(2)**	5 **(2)**
C	20 **(2)**	10 **(3)**	15 **(1)**
D	15 **(1)**	5 **(4)**	20 **(4)**

Finally, to help you understand your group members' decisions in the current round, a chart is also provided in the results screen that summarizes the results in another way. An example of this chart is provided below:



The chart above summarizes the series of runoffs and votes for each alternative. Each group of columns represents each runoff. Remember, once an alternative reaches a majority of votes there are no further rounds of voting.

The chosen alternative for this round was C and your payoff was 20 points

Roles and blocks

Your role in each round determines the number of votes you receive as well as the points you would receive from each of the available alternatives being selected. Note from the above screenshots, each member of the group has a different role (players 1, 2, and 3). For the 8 rounds of each block, each group will be made up of the same 3 roles. However, after each round, you will be randomly regrouped into a new group of participants and may be assigned a new role. That is, each round your group may be made up of different participants and you individually may have a different role, but the three roles of each group across rounds of a block will not change. A group will change which roles it consists of at the start of every new block or, in other words, every 8 rounds.

Part 2

Part 2 consists of 3 additional tasks and one set of survey questions that follow part 1. Additional instructions for each of the tasks in part 2 will be provided to you before each task. If you have any questions during this part of the experiment, please raise your hand and an experimenter will come to clarify any questions you may have.

Summary

A summary of the instructions above are provided below:

1. This experiment consists of five (5) blocks
   (a) Each block consists of eight (8) rounds
2. In each round you will be assigned to a role in a group consisting of yourself and 2 other participants
   (a) The roles in each group do not change for the entirety of one block, but will change between blocks
   (b) The role you are assigned to individually may change between rounds
   (c) Your group will be randomly reassigned each round
3. You will be asked to vote on a set of alternatives for one to be selected by the group:
   (a) You will be informed how many votes you and your group members have, as well as you and your groups payoffs for selecting each alternative.

(b) You will be asked to provide a ranking of alternatives with “1” (highest) to “4” (lowest)

(c) The alternative that is chosen is the one that receives a majority of votes, potentially after a series of runoffs

4. Each round you will be informed which alternative was selected by the group and the number of points you received that round

5. Part 2 will ask you to complete 3 additional tasks and one set of survey questions. Additional instructions for these tasks will be provided at the time you are asked to complete them.

6. At the end of the experiment, you will be paid for the points you have earned across all decisions you made during the course of the experiment in addition to your $5 show-up payment.

A.C.3 STAR Voting Instructions

Instructions

<u>Introduction</u>

Welcome!

Thank you for your participation in today’s experiment. This is an experiment in decision-making. In addition to a $5 participation payment, you will be paid any additional money you accumulate during the experiment at the conclusion of today’s session.

All payoffs during the experiment are denominated in points. At the end of the experiment, points will be converted into cash at the rate of $1 per 80 points. You will be paid privately in cash. The exact amount you receive will be determined during the experiment and will depend on your decisions as well as the decisions of others. At the end of the experiment today, we will pay you based on the total number of points you have earned across all rounds.

If you have any questions during your experiment, please raise your hand and wait for an experimenter to come to you. Please do not talk, exclaim, or try to communicate in ways other than instructed to with other participants during the experiment. Participants intentionally violating the rules may be asked to leave the experiment and may not get paid. Additionally, please put away all electronic devices not provided to you by the experimenter in this session today.

Experiment Overview

In part 1 of this experiment you will be asked to make a group decision among a set of 4 different alternatives. The alternatives are labeled as alternative A, alternative B, alternative C, and alternative D. The amount of points you earn in each round is determined by which alternative your group picks; the amount you earn for the chosen alternative may be different than what others in your group earn. Between rounds, your group members may change. Additionally, how many points you earn for each alternative may change as well. The process by which your group chooses alternatives will not change and this experiment will last for a total of 40 rounds.

Part 2 follows part 1 of this experiment. Additional instructions for part 2 will be provided after part 1.

Blocks and Rounds

Part 1 will consist of five (5) different blocks, each made up of a series of choices. Each block will consist of eight (8) rounds for a total of 40 rounds. Each round will ask you and your group members to make decisions which will determine how many points each of you receive for that round.

Task

Your task today involves making a group decision. You will be in a group consisting of yourself and two other participants and your group will be randomly rematched each round. For each round, you and your fellow group members will be asked to make individual choices that determine the choice the group makes.

In each round you will be presented with a list of alternatives. Your group will be asked to choose one alternative for the group to select by voting on the various alternatives. The voting system used for today's experiment is explained in the following paragraphs.

The voting system works as follows. First you are asked to score each alternative on a numerical scale from 1 to 4, with 4 being the highest score and 1 being the lowest score. You are allowed to score two alternatives with the same score if you wish. This is the only point in which you are asked to make a decision. The computer then calculates the score for all alternatives by adding up the score each voter gave each alternative. The two alternatives with the highest cumulative scores are selected to participate in a runoff stage. In the event of a tie in scores among more than 2 alternatives, alternatives are selected randomly among the tied alternatives. The computer then automatically submits votes for whichever alternative each voter had scored higher, or votes for neither alternative if the voter had scored both of these alternatives equally. The computer then calculates which alternative received the most votes and this is the alternative chosen for the group. In the case that these two alternatives are tied, one is chosen at random. Please note that it is not the alternative with the highest score but instead the one that receives the most votes in the runoff stage that is picked. The total score an alternative receives is only used to determine which alternatives proceed to the runoff stage. It is possible for the alternative with the highest possible score to subsequently not be selected by the group in the runoff stage.

You will also be presented with your and your group members' alternatives and the respective (corresponding) payoffs. Additionally, you and each member of your group may have a different amount of votes. When you have selected which score to give to each alternative, the total score contributed to that alternative will equal that score multiplied by the number of votes you have. For instance, if you have 5 votes for this round and you scored alternative "B" with a "4", alternative B would receive a total score of 20 from you. Additionally, during the runoff step, the number of votes that you contribute towards an alternative is equal to the number of votes you received this round. For instance, if alternatives A and C were in the runoff, you have 4 votes this round, and you had scored A higher than C, A would receive 4 votes from you. At any time you are asked to vote on an alternative, you will be able to observe how many votes you have as well as how many votes other members of your group have as well.

Extended Example

Suppose three group members with 3, 4, and 4 votes scored four alternatives, A, B, C, and D as described in the table below:

	Player 1	Player 2	Player 3
Votes	3	4	4
A	1	2	4
B	2	1	3
C	3	3	2
D	4	4	1

First the computer calculates the total score each alternative receives, which is equal to the score each player gave that alternative multiplied by the number of votes. In this case, alternative A would have a total score of 3 + 8 + 16 = 27. In the same manner, B would have a total score of 22, C would have a total score of 29, and D would have a total score of 32. Because C and D have the highest total scores, these are then the two alternatives selected to participate in the runoff stage.

Because Player 1 scored alternative D higher than alternative C, alternative D automatically receives Player 1's 3 votes. In the same manner, alternative D receives 4 votes from player 2, and alternative C receives 4 votes from player 3. D would have 7 total votes and C would have 4 total votes. Alternative D is selected by the group since it has more votes than alternative C.

The picture on the next page displays how this information during your decision making will be presented to you:

Alternative Selection
Round 1 of 40

The below table lists both your and your group members' payoffs for selecting the various alternatives, as well as how many each has been allocated this round. Your player number, votes, and payoffs are highlighted in yellow:

Player:	1	2 (You)	3
Votes:	4	5	2
Alternatives	**Players' Payoffs**		
A	5	10	5
B	10	15	20
C	20	5	10
D	15	20	15

Please indicate how many points you wish to assign to each alternative (1 to 4)

A: --------- B: --------- C: --------- D: ---------

After all group members have submitted their voting decision, you are rewarded based on the alternative that was chosen by the previously explained voting system. A page will be displayed that shows how many votes each alternative received and the payoffs you and your group members have received. Additionally, this results page displays the decisions you and the other members of your group made, which alternative was selected, and how many points you received this round.

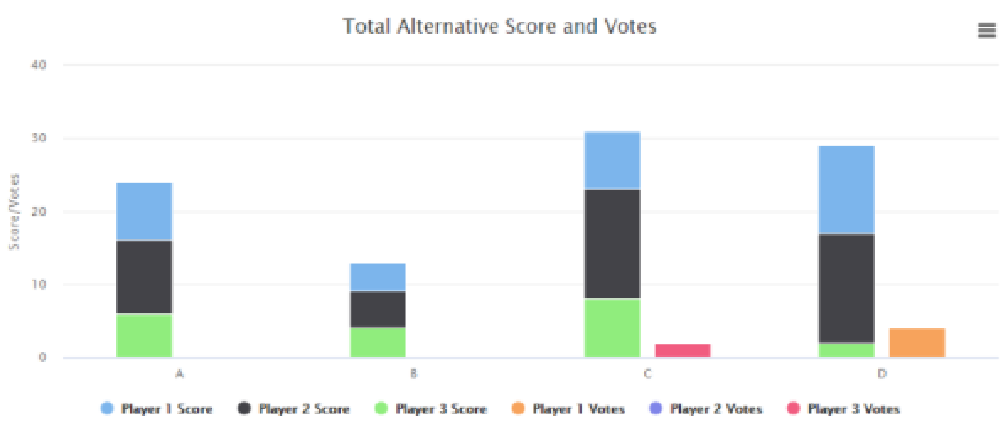
An example of this screen is shown on the next page:

Round Results
Round 1 of 40

The below table lists both your and your group members' payoffs for selecting the various alternatives, as well as how many votes each has been allocated this round. Your player number, votes, and payoffs are highlighted in yellow. The alternative that has been selected has been highlighted in blue. The score each player chose for each alternative is listed in bold next to that alternative's payoff:

Player:	1	2 (You)	3
Votes:	4	5	2
Alternatives	**Players' Payoffs**		
A	5 **(2)**	10 **(2)**	5 **(3)**
B	10 **(1)**	15 **(1)**	20 **(2)**
C	20 **(2)**	5 **(3)**	10 **(4)**
D	15 **(3)**	20 **(3)**	15 **(1)**

Finally, to help you understand your group members' decisions in the current round, a chart is also provided in the results screen that summarizes the results in another way. An example of this chart is provided below:



The chart above summarizes the voting decisions for each player. The first column for every alternative is the total score for that alternative while the second is the total number of votes that alternative received in the runoff.

The chosen alternative for this round was D and your payoff was 20 points

<u>Roles and blocks</u>

Your role in each round determines the number of votes you receive as well as the points you would receive from each of the available alternatives being selected. Note from the above screenshots, each member of the group has a different role (players 1, 2, and 3). For the 8 rounds of each block, each group will be made up of the same 3 roles. However, after each round, you will be randomly regrouped into a new group of participants and may be assigned a new role. That is, each round your group may be made up of different participants and you individually may have a different role, but the three roles of each group across rounds of a block will not change. A group will change which roles it consists of at the start of every new block or, in other words, every 8 rounds.

Part 2

Part 2 consists of 3 additional tasks and one set of survey questions. Additional instructions for each of the tasks in part 2 will be provided to you before each task. If you have any questions during this part of the experiment, please raise your hand and an experimenter will come to clarify any questions you may have.

Summary

A summary of the instructions above are provided below:

1. This experiment consists of five (5) blocks
   (a) Each block consists of eight (8) rounds
2. In each round you will be assigned to a role in a group consisting of yourself and 2 other participants
   (a) The roles in each group do not change for the entirety of one block, but will change between blocks
   (b) The role you are assigned to individually may change between rounds
   (c) Your group will be randomly reassigned each round
3. You will be asked to vote on a set of alternatives for one to be selected by the group:
   (a) You will be informed how many votes you and your group members have, as well as you and your groups payoffs for selecting each alternative.

(b) You will submit a score for each alternative from “1” (lowest) to “4” (highest)

(c) The two highest scored alternatives are selected for a runoff stage

(d) Your votes are submitted to whichever alternative you scored higher between the two alternatives in the runoff stage (or to neither if scored equally)

(e) The alternative that receives the most votes will be selected by the group

4. Each round you will be informed which alternative was selected by the group and the number of points you received that round

5. Part 2 will ask you to complete 3 additional tasks and one set of survey questions. Additional instructions for these tasks will be provided at the time you are asked to complete them.

6. At the end of the experiment, you will be paid for the points you have earned across all decisions you made during the course of the experiment in addition to your $5 show-up payment.

A.D QRE Estimates

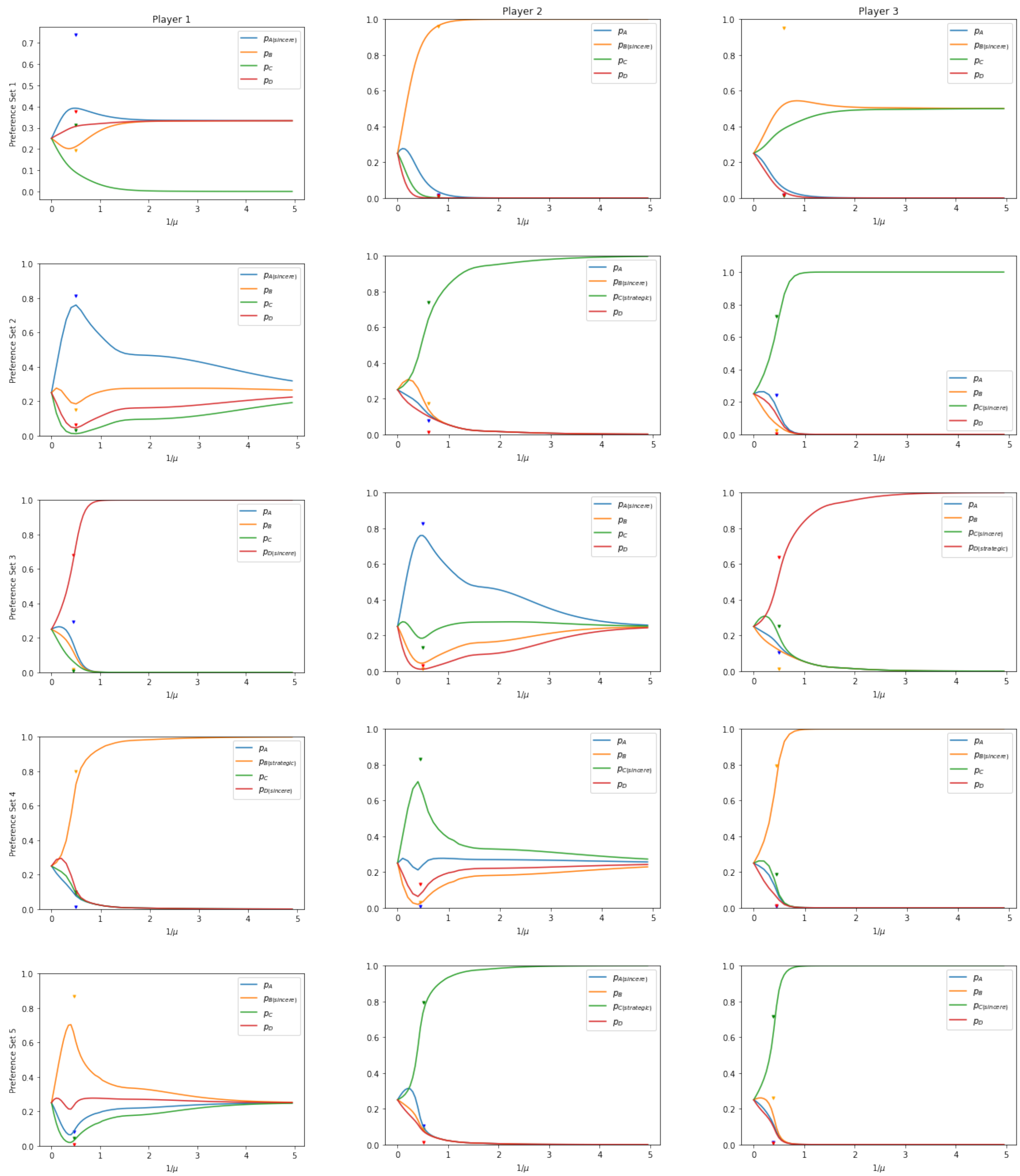


Figure A.1. Plurality QRE Estimates

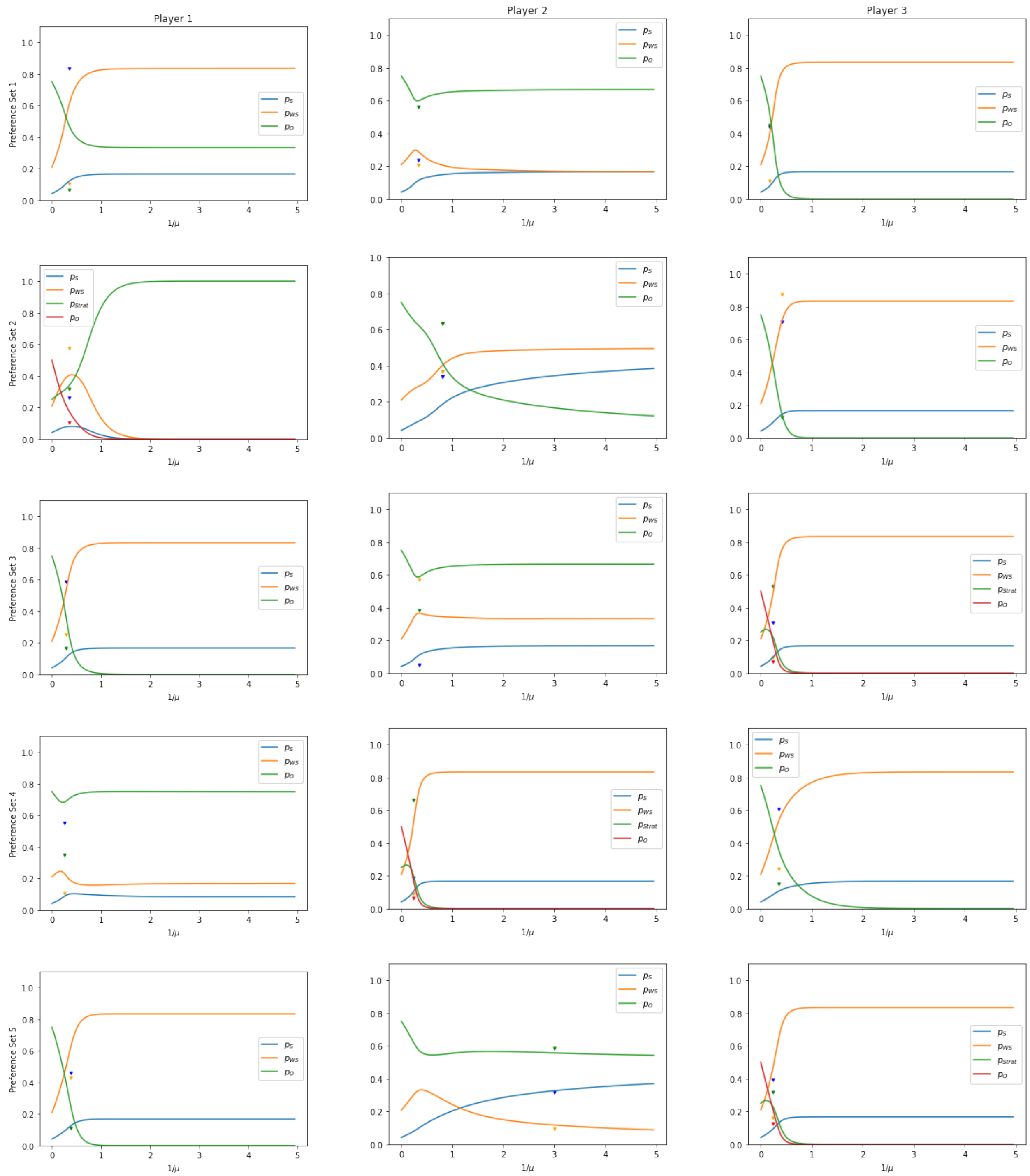


Figure A.2. IRV QRE Estimates

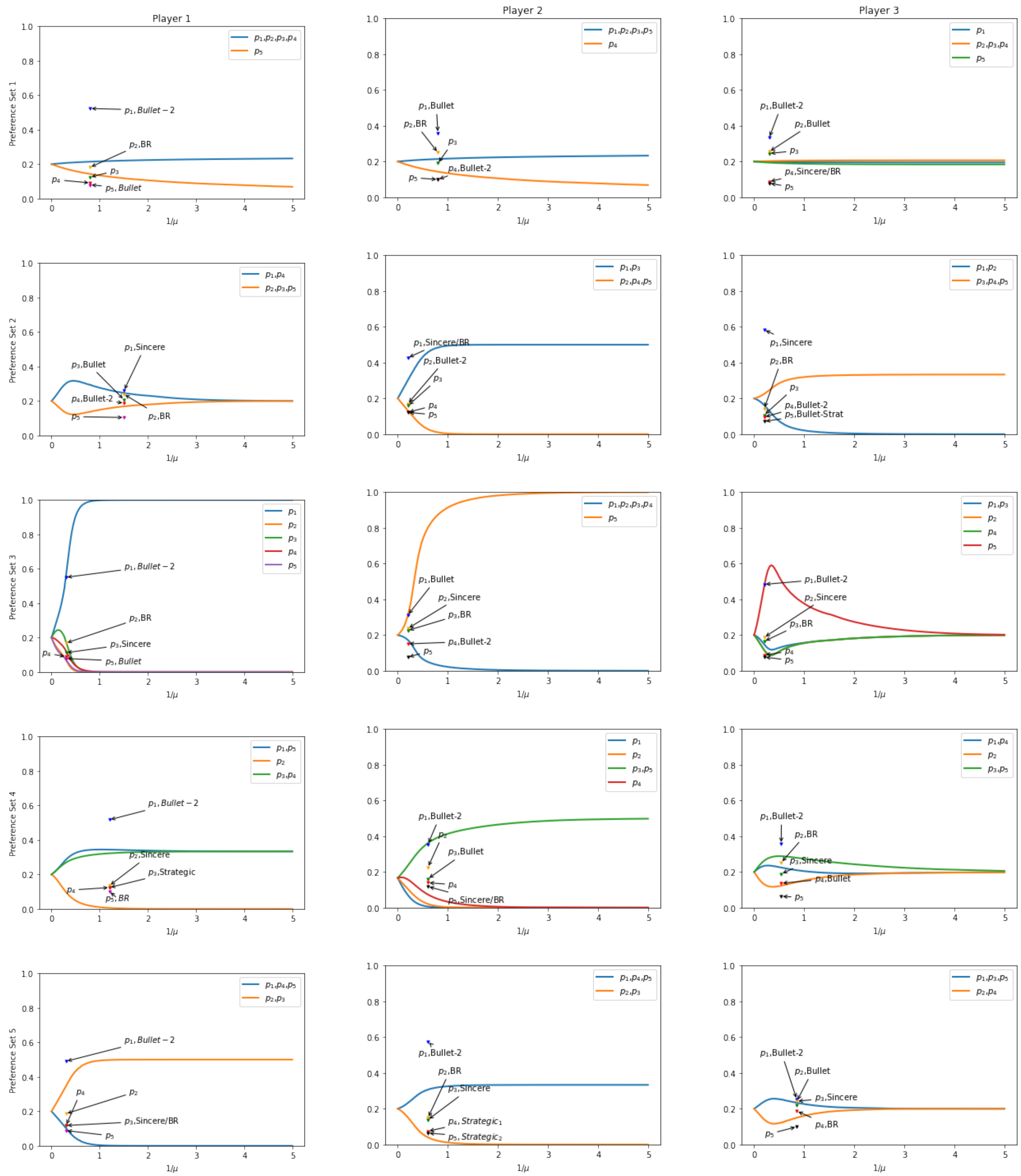


Figure A.3. STAR QRE Estimates

A.E Empirical QRE Estimates by player and preference set

Table A.1. Plurality QRE Estimates

$\frac{1}{\mu}$ Estimates	Player 1	Player 2	Player 3
Pref 1	5.241	0.684	2.410
	(3.6249, 7.4823)	(0.5363, 1.000)	(0.4984, 12.955)
Pref 2	0.7079	0.8646	0.4202
	(0.5769, 0.8854)	(0.7327, 1.0189)	(0.3583, 0.4917)
Pref 3	0.4481	0.5959	0.6517
	(0.3757, 0.5253)	(0.4902, 0.7355)	(0.5341, 0.7885)
Pref 4	0.8548	0.7399	0.4861
	(0.7296, 0.9917)	(0.5865, 0.9453)	(0.4206, 0.5709)
Pref 5	0.7079	0.8337	0.4804
	(0.5596, 0.9200)	(0.7002, 0.9677)	(0.4066, 0.5559)

Table A.2. IRV QRE Estimates

$\frac{1}{\mu}$ Estimates	Player 1	Player 2	Player 3
Pref 1	0.8138	1.1727	0.9548
	(0.6275, 1.1668)	(0.92136, 1.6131)	(0.6866, 1.4537)
Pref 2	0.4472	0.5899	0.4153
	(0.3627, 0.53425)	(0.4938, 0.71216)	(0.34953, 0.51688)
Pref 3	0.4352	0.7023	0.4996
	(0.3646, 0.5311)	(0.60816, 0.81476)	(0.416722, 0.5903)
Pref 4	0.6502	0.6821	0.4917
	(0.5517, 0.7757)	(0.5777, 0.81674)	(0.40901, 0.60287)
Pref 5	0.3843	0.8385	0.6158
	(0.32636, 0.45674)	(0.71608, 0.97506)	(0.48894, 0.75848)

Table A.3. STAR QRE Estimates

$\frac{1}{\mu}$ Estimates	Player 1	Player 2	Player 3
Pref 1	0	$1.129 * 10^{-6}$	$1.235 * 10^{-9}$
	$(0, 0)$	$(1.12 * 10^{-6}, 1.12 * 10^{-6})$	$(1.23 * 10^{-9}, 1.23 * 10^{-9})$
Pref 2	0	$3.221 * 10^{-7}$	$4.111 * 10^{-8}$
	$(0, 0)$	$(3.22 * 10^{-7}, 3.22 * 10^{-7})$	$(4.11 * 10^{-8}, 4.11 * 10^{-8})$
Pref 3	0	$7.386 * 10^{-7}$	0
	$(0, 0)$	$(7.38 * 10^{-7}, 7.38 * 10^{-7})$	$(0, 0)$
Pref 4	$3.697 * 10^{-9}$	0	0
	$(3.69 * 10^{-9}, 3.69 * 10^{-9})$	$(0, 0)$	$(0, 0)$
Pref 5	$1.715 * 10^{-7}$	0	$1.229 * 10^{-6}$
	$(1.71 * 10^{-7}, 1.71 * 10^{-7})$	$(0, 0)$	$(1.22 * 10^{-6}, 1.22 * 10^{-6})$

B. APPENDIX FOR: THE EFFECT OF LEADER SELECTION ON HONESTY AND GROUP PERFORMANCE: EXPERIMENTAL EVIDENCE

B.A Summary statistics

Table B.1. Summary Statistics (standard deviation in parentheses)

	(1)
	mean/sd
Payoff	240.94
	(87.18)
Effort	25.36
	(17.20)
Tullock Bid	21.26
	(25.23)
Leadership Sum	34.86
	(6.29)
Minimum group effort	32.89
	(85.55)
Coordination rate	.60
	(.49)
N	9360

B.B Experimental UI

Introduction

This is an experiment in decision-making. In addition to a $10 participation fee, you will be paid any additional money you accumulate during the experiment at the conclusion of today's session.

All payoffs during the experiment are denominated in an artificial currency, experimental currency units (ECU). At the end of the experiment, ECU will be converted into cash at the rate of $1 per 16 ECU. Upon completion of the experiment, your earnings will be converted to dollars and you will be paid privately in cash. The exact amount you receive will be determined during the experiment and will depend on your decisions as well as the decisions of others.

If you have any questions during the experiment or these instructions, please raise your hand and wait for an experimenter to come to you. Please do not talk, exclaim, or try to communicate in ways other than instructed with other participants during the experiment. Participants intentionally violating the rules may be asked to leave the experiment and may not be paid. Additionally, please put away all electronic devices not provided to you by the experimenter in this session today.

Next

Introduction

This experiment will consist of three stages (I, II, and III), each made up of a series of choices. Each stage will have several parts. We will first proceed through Stage I, and you will then receive new instructions for Stage II, and finally one last set of instructions for Stage III.

At the end of the experiment, we will randomly select one choice among all your choices made in Stages I, II, and III (as determined by a random number). The earnings from this choice will be the only choice used for payment for the experiment today. That is, each of you will make choices in Stage I, II, and III. At the end of the experiment, we will randomly select one choice from Stage I, II or III, and this will be the choice from all three stages that count as payment for the experiment. However, since you will not know which choice this will be, you should treat your choices in these three stages as if they counted, since one of your choices will count.

We will now proceed to instructions for Stage I.

Next

Introduction

In Stage I, you will each answer five multiple-choice general trivia questions. Everyone receives the same five questions. These questions were randomly selected from a large database of questions dealing with the general knowledge of varied topics. Each question will ask you to select the correct answer from one of four options. For each question answered correctly, there is potentially a 80 ECU ($5.00) prize.

As a reminder, one of these choices (one answer to one question) will potentially be chosen for payment in the experiment today.

Next

Stage I

Below are the five questions for Stage I of the experiment. For each question, click on the answer that you believe is correct. Once you are done, please check your answers before clicking "next"

Question	Answer
1. Which of the following countries in Africa is totally land-locked?	○ Sudan ○ Gabon ○ Botswana ○ Mauritania
2. What was the first U.S. state to enter the Union?	○ New Jersey ○ Georgia ○ Pennsylvania ○ Delaware
3. Which Irish city's name means 'black pool'?	○ Dublin ○ Blackburn ○ Belfast ○ Cobb
4. Which planet once had a 'Great Dark Spot' before it disappeared in 1995?	○ Jupiter ○ Mars ○ Saturn ○ Neptune
5. The mathematical term 'e' stands for what number, to two decimal places?	○ 1.72 ○ 2.71 ○ 1.27 ○ 2.17

Stage II

Parts, Rounds, and Firms: Stage II consists of 3 sets. Each set consists of two parts, with the first part of each set consisting of 4 rounds and the second part of each set consisting of 6 rounds.

For the remainder of this experiment you will be randomly assigned to a firm consisting of four (4) participants. You will be grouped with the same three other participants for one set. At the beginning of each set you will be randomly regrouped into new groups consisting of a different set of participants.

The following instructions are for the first part of a set from Stage II -- the first four rounds of each set. After we have given you the instructions for the first part of the set, we will present to you the instructions for the second part of the set.

Next

Stage II

Task: there are four employees in each firm. Each round of the experiment can be thought of as a workweek. Each of the four employees spends 40 hours per week at their firm. In each round, there will be a bonus rate for all employees. The bonus rate is the same for all employees in the firm.

After seeing the bonus rate, each employee has to choose how to allocate his or her time between two activities, Activity A and Activity B. Specifically, each employee will be asked to choose how much time to devote to Activity A. The available choices are 0 hours, 10 hours, 20 hours, 30 hours, and 40 hours. That employee's remaining hours will be put towards Activity B. For example, if an employee devotes 30 hours to Activity A, this means that 10 hours will be put towards Activity B. Weekly payoffs for employees depends on a bonus rate and on the number of hours allocated to Activity A by the employees.

Next

Stage II

Employee Payoffs: The payoff for an employee of the firm is determined in each round by the bonus rate (B), how many hours that employee spends on activity A, and the minimum number of hours employees in his or her firm spend on Activity A. The employee's payoff is reduced by 5 ECUs per hour that he or she spends on Activity A. Each employee also receives the bonus rate multiplied by the minimum number of hours any employee in his or her firm spends on Activity A. Each employee also automatically gets a flat payoff of 200 ECUs each round.

For example, suppose an employee spends 10 hours on Activity A. Suppose the other three workers in his or her firm spend 20, 40 and 40 hours and their bonus rate equals 8. The minimum hours spent on Activity A is 10 hours. The employee's payoff equals 200 - 5*10 + 8*10 = 230 ECUs.

These payoffs are summarized by the formula below. The variable HA(i) gives the number of hours spent on Activity A by employee i. The variable B gives the bonus rate. Finally, min(HA) is the smallest or minimum number of hours any employee of the firm spends on Activity A.

Payoff = 200 - 5*HA(i) + min(HA)*B

If you do not find this formula useful, don't worry about it. It is given to you as an additional way to understand the payoffs. The computer always shows your payoff table at any point where you need to make a decision. These tables will include all the information you will need to make your decision. The program calculates your payoff for you as part of the feedback you receive after each round.

Feedback as an employee: At the end of each round, you will receive a summary of what happened in the round including the number of hours you spent on Activity A, the minimum number of hours spent on Activity A by your firm, the bonus rate, and your payoff for the latest round.

On the next page, you can practice with the interface that you will be using for the rest of Stage II.

Next

Stage II

Below is an example of the interface you will use for the rest of Stage II. Keep in mind that no values used here on this page will be used for payment and is only here for your convenience.

You are free to enter any value available to you to spend on Activity A. Additionally, you may enter in a value that represents the minimum time spent on Activity A by any other employee in your firm as well. Finally, you can click the "Test" button, and the payoff you would receive for both the time you spent on Activity as well the minimum time spent by others on Activity A entered will be displayed.

The bonus rate is: 6

Please select your amount of time devoted to Activity A:

20

As a reminder, your payoff is determined by your choice of time on Activity A and your group's time spent on Activity A as shown below:

Your time spent on Activity A	**Minimum time spent on Activity A by all other group members**				
	0	**10**	**20**	**30**	**40**
0	200	200	200	200	200
10	150	210	210	210	210
20	100	160	220	220	220
30	50	110	170	230	230
40	0	60	120	180	240

Enter the minimum amount of time spent on Activity A by all other employees in your group:

10

Payoff: 160

Test

Stage II

Firm Managers: In the second part of each set, there will be a firm manager. The manager will be selected from among the four employees in the firm. Each firm will have four employees who perform the same task as in the first part of Stage II. However, one employee will also serve as the firm manager. For the remainder of the set, one of the four people in your firm will be the manager. The manager is always the same person.
At the beginning of each round, the manager will be able to type messages to the other employees in his or her firm. Except for the following restrictions, the manager may type whatever he or she wants. All firm managers and employees will not be able to move onto the next screen for a short time (30 seconds) during this part of the set. Once given the option and after all messages have been sent, you may proceed to the following page to make your decision about how much time to spend on Activity A. Once the manager has proceeded to the next page, a message will be sent to all firm employees that the manager has finished sending messages for this round.
Restrictions on Messages:

1. Please do not identify yourself or send any information that could be used to identify you (e.g. age, race, gender, etc.)
2. Please refrain from using obscene or offensive language

When it is time for the manager to enter a message, the computer will display a box into which the manager can type their messages. Note when the manager enters a message, he or she will not know how many hours the other firm employees will devote to Activity A.

Next

Stage II

Selection system: At the beginning of each set, you will be informed of the system that will be used to select the manager of your firm. The selection system will take one of three forms:

1. Random: Your manager will be randomly selected among one employee of the firm, with each employee having an equal probability of being selected.

2. Voting: All employees will vote for one employee to serve as the manager of the firm. Ties between different employees will be broken randomly.

3. Competition: This will be done as a lottery competition. In the first round of this selection system, you will be given 100 ECUs and asked to make a choice regarding a number of "tickets" you wish to select. These tickets affect your chances of being selected to be the manager. After you and all other firm employees have selected the number of tickets you would like, your probability of being selected as the manager will be determined by the following formula:

(number of tickets you selected)/(number of total tickets selected by all firm employees, including yourself).

However, your payoff for this set will also include an amount equal to 2*(100-(# tickets you selected)). That is, increasing your chance of becoming the manager will also reduce the amount of ECU's you will gain from this competition selection system. Note this is one decision you could potentially be paid for in the experiment today.

During the selection process, information will be provided to you about the other members of your firm, including their score on the quiz as well as the average amount of time they committed to task A during the first part of the set.

Next

Stage II

Confidentiality and Payoff: At no point in time will we identify any employees in the firm. In other words, the action you will take will remain confidential. Remember that any one decision in Stage II could be chosen and converted from ECUs at a rate of $1 per 16 ECUs. You will be paid these converted earnings in cash along with the show-up fee of $10. You will be paid privately and we will not disclose your payoff to the other participants in the experiment.

Survey Questions: At the end of each set you will receive a series of survey questions that ask you to evaluate various aspects of your group. The answer to these questions are confidential and the answers to them will not be used for payment in your session today.

Manager Task: Additionally, the manager will have a task to complete at the end of each set. The manager will be asked to make payoff relevant decisions related to your firm's performance in this set. The manager will be asked to make choices between two different options and will be potentially paid for one of these choices, determined randomly. This amount will potentially be earned just like any other decisions from other sections of this experiment (i.e. it is one decision that could potentially be used for payment). Further instructions for this task will be provided at the time that the manager is asked to complete this task.

Next

Selection Rule

For this set, the following selection rule will be put in place: Random Selection

As a reminder, all employees of the firm have an equal probability of being chosen as the firm manager for the second part of this set.

Next

Time Allocation

The bonus rate is: 8
Please select your amount of time devoted to Activity A:

0

As a reminder, your payoff is determined by your choice of time on Activity A and your group's time spent on Activity A as shown below:

Your time spent on Activity A	Minimum time spent on Activity A by all other group members				
	0	**10**	**20**	**30**	**40**
0	200	200	200	200	200
10	150	230	230	230	230
20	100	180	260	260	260
30	50	130	210	290	290
40	0	80	160	240	320

Next

Round Results

The amount of time you assigned to Activity A was 30

The minimum time assigned to Activity A by any member of your firm was 10

Therefore, your payoff for this round was 130

Next

Manager Selection

Selection of the Manager: We will now select which participant will be the manager for each firm.

The manager will be selected randomly among all employees of the firm. As one of you will be chosen at random, no other factors in the previous rounds will impact the chance you are selected. Please select continue, and your role will be displayed on the following page.

Additionally, you may find below a summary about the other members of your firm, which include the number of correct answers in Stage I and their average amount of time on Activity A in the first part of Stage II for this set (the previous four rounds).

As a reminder, you are Employee 1

Employee ID	Correct Answers in Stage I	Average Time Spent on Activity A
1	0	7.5
2	0	5.0
3	0	2.5
4	0	2.5

Next

Manager Selection

Selection of the Manager: We will now select which participant will be the manager for each firm.
The manager will be selected based on a vote by the employees in the firm. Additionally, you may find below a summary about the other members of your firm, which include the number of correct answers in Stage I and their average amount of time on Activity A in the first part of Stage II for this set (the previous four rounds).

As a reminder, you are Employee 1

Employee ID	Correct Answers in Stage I	Average Time Spent on Activity A
1	0	0.0
2	0	0.0
3	0	0.0
4	0	0.0

Please select which employee you would like to vote for:

- ○ Employee 1
- ○ Employee 2
- ○ Employee 3
- ○ Employee 4

Using the buttons under the table, please elect which participant you wish to play the role of manager for your firm. The participant who receives the most votes will be selected as the manager. Ties will be broken randomly.

Next

Manager Selection

Selection of the Manager: We will now select which participant will be the manager for each firm.
As a reminder, this will be done as a lottery competition. In the first round of this selection system, you will be given 100 ECUs and asked to make a choice regarding a number of "tickets" you wish to select. These tickets affect your chances of being selected to be the manager. After you and all other firm employees have selected the number of tickets you would like, your probability of being selected as the manager will be determined by the following formula:

(number of tickets you selected)/(number of total tickets selected by all firm employees, including yourself).

However, your payoff for this set will also increase by: 100-(# tickets you selected). That is, increasing your chance of becoming the manager will also reduce the amount of ECU's you will gain from this competition selection system.

You have been endowed with 100 ECUs. Please choose the number of tickets you would like to select:

50

Below is a summary about the other members of your firm, which include the number of correct answers in Stage I and their average amount of time on Activity A in the first part of Stage II for this set (the previous four rounds).

As a reminder, you are Employee 1

Employee ID	Correct Answers in Stage I	Average Time Spent on Activity A
1	0	0.0
2	0	0.0
3	0	0.0
4	0	0.0

Next

Introduction

Your role for the next 6 rounds is: employee

Next

Firm Message

The bonus rate is: 8

You now have the opportunity to send messages to all the firm's employees. Once you have sent the message, it will be sent out to all employee's and appear in the box below. All employees in your firm will see the same message.

Once you have finished sending messages, click "next" to proceed. Please do not click "next" until you have finished sending messages to the employees in your firm.

Send

Firm Message

The bonus rate is: 8

The manager in your firm will now have the opportunity to send messages to all the firm's employees. Once the manager has sent the message, it will appear to all employees and appear in the box below. All employees in your firm will see the same message.

Once you have read the messages, click "next" to proceed. Please do not click "next" until you have read the message from the manager.

Participant 4	wasdfasdfa
Participant 4	The manager is finished sending messages this round

Next

Time Allocation

The bonus rate is: 8
Please select your amount of time devoted to Activity A:

As a reminder, your payoff is determined by your choice of time on Activity A and your group's time spent on Activity A as shown below:

Your time spent on Activity A	**Minimum time spent on Activity A by all other group members**				
	0	**10**	**20**	**30**	**40**
0	200	200	200	200	200
10	150	230	230	230	230
20	100	180	260	260	260
30	50	130	210	290	290
40	0	80	160	240	320

Participant 4 wasdfasdfa
Participant 4 The manager is finished sending messages this round

Next

Survey Questions

For the next 4 statements, please indicate your responses according to the following scale: 1 (Strongly Disagree) to 5 (Strongly Agree)

If you prefer not to answer any given question below, you may elect to do so by choosing `Prefer not to answer'

Consider the team that you are currently working with and indicate your agreement/disagreement with the following statements.

Statement	Answer
I really enjoyed being part of this team.	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer
I felt like I got a lot out of being a member of this team.	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer
I wouldn't hesitate to participate on another task with the same team members.	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer
If I could have left this team and worked with another team, I would have.	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer

For the next 3 questions, please indicate your responses according to the following scale:

1 (Poor), 2 (Fair), 3 (Good), 4 (Very Good), 5 (Excellent)

Question	Answer
How good or bad was the manager in preparing the team for the last round?	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer
How good or bad was the manager at organizing the team during the last round?	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer
How good or bad was the manager's overall leadership ability?	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer

Next

Reporting Task

Suppose as the manager of this firm, you may have to report the earnings of your firm (in this case the average earnings of your firm over the past six rounds) to some external body as a pubic earnings report.

The following task asks you to make a decision about what earnings figures to announce. For the following choice task, please select an option for each choice. Note that each option has a corresponding payment amount for that choice.

As a reminder, one of your decisions made in this task could potentially be selected for your payment in the experiment today. Points in this task are worth the same as in the time allocation task ($1 per 16 ECUs).

As a reminder, the average payoff of your firm for the past six rounds was: 200.0

Next

Reporting Task

For the following 5 choices, please indicate which option you would prefer.

As a reminder, the average payoff of your firm for the past six rounds was: 200.0

Choice:	**Option A:**	**Option B:**	**Your choice:**
1	Report 200.0 for 32 ECUs	Report 250.0 for 160 ECUs	○ A ○ B
2	Report 200.0 for 64 ECUs	Report 250.0 for 160 ECUs	○ A ○ B
3	Report 200.0 for 96 ECUs	Report 250.0 for 160 ECUs	○ A ○ B
4	Report 200.0 for 128 ECUs	Report 250.0 for 160 ECUs	○ A ○ B
5	Report 200.0 for 160 ECUs	Report 250.0 for 160 ECUs	○ A ○ B

Next

Stage III

This last stage consists of four parts: 2 sets of survey questions and 2 lottery selection tasks. For the sets of survey questions, we will ask you to answer several questions about yourself. All answers are confidential and none of these answers will be used for payment.

For the two lottery selection tasks, you will be asked to choose between different lotteries that have different probabilities of paying out various amounts. These amounts are displayed in points that will use the same conversion rate of $1 per 16 ECUs. Each choice you make during these two lottery tasks is potentially one that could be used for payment in today's experiment At the conclusion of this experiment, in the event that one of these decisions is chosen for payment, how much you earn will depend on your choice as well as the result of the lottery which is decided by the probability provided.

Once you have completed Stage III, your payoff for your decisions in Stages I, II, and III will be displayed. Please wait patiently as others around you may not have finished and the experimenter will be by to give you payment for your participation today. Once you have received payment for your participation today, you are free to quietly leave the room.

Next

Survey Questions

For all following statements, please indicate your responses according to the following scale: 1 (Strongly Disagree) to 5 (Strongly Agree)

If you prefer not to answer any given question below, you may elect to do so by choosing `Prefer not to answer'

Statement	**Answer**
I like having authority over others	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer
I see myself as a good leader.	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer
I try to lead others.	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer
I want to be in charge	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer
I have a strong need for power.	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer
I find it easy to manipulate others.	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer
I dislike having authority over others.	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer
I dislike taking responsibility for making decisions.	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer
I am not highly motivated to succeed.	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer
I wait for others to lead the way.	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer

Think about the work groups in which you currently belong (outside the current study), and have belonged to in the past. The items below ask about your relationship with, and thoughts about, those particular groups. Respond to the following questions, using the response scale provided.

Statement	Answer
I preferred to work in those groups rather than working alone.	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer
Working in those groups was better than working alone.	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer
I wanted to work with those groups as opposed to working alone.	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer
I felt comfortable counting on group members to do their part.	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer
I was not bothered by the need to rely on group members.	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer
I felt comfortable trusting group members to handle their tasks.	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer
The health of those groups was important to me.	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer
I cared about the well-being of those groups.	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer
I was concerned with the needs of those groups.	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer
I followed the norms of those groups.	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer
I followed the procedures used by those groups.	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer
I accepted the rules of those groups.	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer
I cared more about the goals of those groups than my own goals.	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer
I emphasized the goals of those groups more than my individual goals.	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer
Group goals were more important to me than my personal goals.	○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ Prefer not to answer

Next

Choice Task

For the following 20 choices, please indicate which option you would prefer. All values are in points which are worth the same as they were in the earlier search tasks.

Choice:	Option A:	Option B:	Your choice:
1	0.00 or 160.00 with a 50% chance	8.00 for sure	○ A ○ B
2	0.00 or 160.00 with a 50% chance	16.00 for sure	○ A ○ B
3	0.00 or 160.00 with a 50% chance	24.00 for sure	○ A ○ B
4	0.00 or 160.00 with a 50% chance	32.00 for sure	○ A ○ B
5	0.00 or 160.00 with a 50% chance	40.00 for sure	○ A ○ B
6	0.00 or 160.00 with a 50% chance	48.00 for sure	○ A ○ B
7	0.00 or 160.00 with a 50% chance	56.00 for sure	○ A ○ B
8	0.00 or 160.00 with a 50% chance	64.00 for sure	○ A ○ B
9	0.00 or 160.00 with a 50% chance	72.00 for sure	○ A ○ B
10	0.00 or 160.00 with a 50% chance	80.00 for sure	○ A ○ B
11	0.00 or 160.00 with a 50% chance	88.00 for sure	○ A ○ B
12	0.00 or 160.00 with a 50% chance	96.00 for sure	○ A ○ B

Choice Task

For the following 20 choices, please indicate which option you would prefer. All values are in points which are worth the same as they were in the earlier search tasks.

Choice:	Option A:	Option B:	Your choice:
1	0.00 or 160.00 with an unknown chance	8.00 for sure	○ A ○ B
2	0.00 or 160.00 with an unknown chance	16.00 for sure	○ A ○ B
3	0.00 or 160.00 with an unknown chance	24.00 for sure	○ A ○ B
4	0.00 or 160.00 with an unknown chance	32.00 for sure	○ A ○ B
5	0.00 or 160.00 with an unknown chance	40.00 for sure	○ A ○ B
6	0.00 or 160.00 with an unknown chance	48.00 for sure	○ A ○ B
7	0.00 or 160.00 with an unknown chance	56.00 for sure	○ A ○ B
8	0.00 or 160.00 with an unknown chance	64.00 for sure	○ A ○ B
9	0.00 or 160.00 with an unknown chance	72.00 for sure	○ A ○ B
10	0.00 or 160.00 with an unknown chance	80.00 for sure	○ A ○ B
11	0.00 or 160.00 with an unknown chance	88.00 for sure	○ A ○ B
12	0.00 or 160.00 with an unknown chance	96.00 for sure	○ A ○ B

Demograhpics Survey

The below survey asks you to answer several questions. Your answers to these questions will remain anonymous and are not used for payment in today's session. Answering any of the following questions is optional; if you do not wish to answer a question, please enter "prefer not to answer" among the list of choices provided or enter it into the text box provided.

Question	Answer
What is/are your college major(s)?	
How many economics courses have you taken?	---------
Have you taken a course in game theory before?	---------
How many economics laboratory experiments have you participated in?	---------
What gender do you identify as?	---------
Which of the following races do you identify as?	---------

Next

Final Results

Thank you for participation in today's experiment. From your participation today, you have earned the following: $16.25
Please remain silent as others around you may not have finished. The experimenter will be around to distribute your payment to you.
Once you have received your payment, you are free to leave.

B.C Experimental Instructions

Instructions

Introduction

Welcome!

Thank you for your participation in today's experiment. This is an experiment in decision-making. In addition to a $10 participation fee, you will be paid any additional money you accumulate during the experiment at the conclusion of today's session.

All payoffs during the experiment are denominated in an artificial currency, experimental currency units (ECU). At the end of the experiment, ECU will be converted into cash at the rate of $1 per 16 ECU. Upon completion of the experiment, your earnings will be converted to dollars and you will be paid privately in cash. The exact amount you receive will be determined during the experiment and will depend on your decisions as well as the decisions of others.

If you have any questions during your experiment, please raise your hand and wait for an experimenter to come to you. Please do not talk, exclaim, or try to communicate in ways other than instructed with other participants during the experiment. Participants intentionally violating the rules may be asked to leave the experiment and may not get paid. Additionally, please put away all electronic devices not provided to you by the experimenter in this session today.

Stages and Payment

The experiment will consist of three stages (I, II, and III), each made up of a series of choices. Each stage will have several parts. We will first proceed through Stage I, and you will then receive new instructions for Stage II, and finally one least set of instructions for Stage III.

At the end of the experiment, we will randomly select one choice from all your choices made in Stages I, II, and III (as determined by a random number). The earnings from this choice will be the only choice used for payment for the experiment today. That is, each of you will make choices in Stage I, II, and II. At the end of the experiment, we will randomly select one choice from Stage I, II, or III and this will be the choice from these three stages that count as payment for the experiment. However, since you will not know which choice this will be, you should treat each of your choices in these three stages as if they counted, since one of your choices will count.

Stage I

In Stage I, you will each answer five multiple-choice general trivia questions. Everyone receives the same five questions. These questions were randomly selected from a large database of questions dealing with the general knowledge of varied topics. Each question will ask you to select the correct answer from one of four options. For each question answered correctly, there is potentially a 80 ECU ($5.00) prize.

As a reminder, one of these choices (one answer to one question) will potentially be chosen for payment in the experiment today.

Stage II

Parts, Rounds, and Firms

Stage II consists of 3 sets. Each set consists of 2 parts, with the first part of each set consists of 4 rounds and the second part consisting of 6 rounds.

For the remainder of this experiment you will be randomly assigned to a firm consisting of four (4) participants. You will be grouped with the same three other participants for one set. At the beginning of each set you will be randomly regrouped into new groups consisting of a different set of participants.

The following instructions are for the first part of a set from Stage II – the first four rounds of each set. After we have given you the instructions for the first part of the set, we will present to you the instructions for the second part of the set.

Task

There are four employees in each firm. Each round of the experiment can be thought of as a workweek. Each of the four employees spends 40 hours per week at their firm. In each round, there will be a bonus rate for all employees. The bonus rate is the same for all employees in a firm.

After seeing the bonus rate, each employee has to choose how to allocate his or her time between two activities, Activity A or Activity B. Specifically, each employee will be asked to choose how much time to devote to Activity A. The available choices are 0 hours, 10 hours, 20 hours, 30 hours, and 40 hours. That employee's remaining hours will be put towards Activity B. For example, if an employee devotes 30 hours to Activity A, this means that 10 hours will be put towards Activity B. Weekly payoffs for employees depends on a bonus rate and on the number of hours allocated to Activity A by the employee.

Employee Payoffs

The payoff for an employee of the firm is determined in each round by the bonus rate (B), how many hours that employee spends on Activity A, and the minimum number of hours employees in his or her firm spend on Activity A. The employee's payoff is reduced by 5 ECU's per hour that he or she spends on Activity A. Each employee also receives the bonus rate multiplied by the minimum number of hours any employee in his or her firm spends on Activity A. Each employee also automatically gets a flat payoff of 200 ECU's each round.

For example, suppose an employee spends 10 hours on Activity A. Suppose the other three workers in his or her firm spend 20, 40, and 40 hours and their bonus rate equals 8. The minimum hours spend on Activity A is 10 hours. The employees payoff equals

$$200 - 5 * 10 + 8 * 10 = 230$$

The payoffs are summarized by the formula below. The variable HA(i) gives the number of hours spent on Activity A by employee i. The variable B gives the bonus rate. Finally, min(HA) is the smallest or minimum number of hours any employee of the firm spends on Activity A.

$$Payoff = 200 - 5 * HA(\mathrm{i}) + min(HA) * B$$

If you do not find this formula useful, don't worry about it. It is given to you as an additional way to understand the payoffs.The computer always shows you a payoff table at any point where you need to make a decision. These tables will include all the information you will need to make your decision. The program calculates your payoff for you as part of the feedback you receive after each round.

At the end of each round, you will receive a summary of what happened in the round, including the number of hours you spent on Activity A, the minimum number of hours spent on Activity A by your firm, the bonus rate, and your payoff for that round.

Firm Managers

In the second part of each set, there will be a firm manager. The manager will be selected from among the four employees in the firm. Each firm will have four employees who perform the same task as in the first part of Stage II. However, one employee will also serve as the firm manager. For the remainder of the set, one of the four people in your firm will be the manager. The manager is always the same person.

At the beginning of each round, the manager will be able to type messages to the other employees in his or her firm. Except for the following restrictions, the manager may type whatever he or she wants. All firm managers and employees will not be able to move onto the next screen for a short time (30 seconds) during this part of the set. Once given the option and after all messages have been sent, you may proceed to the following page to make your decision about how much time to spend on Activity A. Once the manager has proceeded to the next page, a message will be sent to all firm employees that the manager has finished sending messages for this round.

Restrictions on Messages:

Please do not identify yourself or send any information that could be used to identify you (e.g. age, race, gender, etc.) Please refrain from using obscene or offensive language

When it is time for the manager to enter a message, the computer will display a box into which the manager can type their messages. Note when the manager enters a message, he or she will not know how many hours the other firm employees will devote to Activity A.

Selection System

At the beginning of each set, you will be informed of the system that will be used to select the manager of your firm. The selection will take one of three forms:

- Random: Your manager will be randomly selected among one employee of the firm, with each employee having an equal probability of being selected.

- Voting: All employees will vote for one employee to serve as the manager of the firm. Ties between different employees will be broken randomly.
- Competition: This will be done as a lottery competition. In the first round of the selection system, you will be given 100 ECUs and asked to make a choice regarding a number of "tickets" you wish to select. These tickets affect your chance of being selected to be the manager. After you and all other firm employees have selected the number of tickets you would like, your probability of being selected as the manager will be determined by the following formula:

  (number of tickets you selected)/(number of total tickets selected by all firm employees, including yourself)

  However, your payoff for this set will also include an amount equal to 2*(100-(# tickets you selected)). That is, increasing your chance of becoming the manager will also reduce the amount of ECU's you will gain from this competition selection system. Note this is one decision you could potentially be paid for in the experiment today.

During the selection process, information will be provided to you about the other members of your firm, including their score on the quiz as well as the average amount of time they committed to task A during the first part of the set.

Confidentiality and Payoff

At no point in time will we identify any employees in the firm. In other words, the action you will take will remain confidential. Remember that any one decision from Stage II could be chosen and your payoff will be converted from ECU's at a rate of $1 to 16 ECU's. You will be paid these converted earning in cash along with the show-up fee of $10. You will be paid privately and we will not disclose your payoff to other participants in the experiment.

Survey Questions

At the end of each set you will receive a series of survey questions that ask you to evaluate various aspects of your group. The answer to these questions are confidential and the answers to them will not be used for payment in your session today.

Manager Task

Additionally, the manager will have a task to complete at the end of each set. The manager will be asked to make payoff relevant decisions related to your firm's performance in this set. The manager will be asked to make choices between two different options and will be potentially paid for one of these choices, determined randomly. This amount will potentially be earned just like any other decisions from other sections of this experiment (i.e. it is one decision that could be potentially used for payment). Further instructions for this task will be provided at the time that the manager is asked to complete this task.

Stage III

This last stage consists of four parts: 2 sets of survey questions and 2 lottery selection tasks. For the sets of survey questions, we will ask you to answer several questions about yourself. All answers are confidential and none of these answers will be used for payment.

For the two lottery selection tasks, you will be asked to choose between different lotteries that have different probabilities of paying out various amounts. These amounts are displayed in points that will use the same conversion rate of $1 per 16 ECU's. Each choice you make during these two lottery tasks is potentially one that could be used for payment in today's experiment. At the conclusion of this experiment,in the event that one of these decisions is chosen for payment, how much you earn will depend on your choice as well as the result of the lottery which is decided by the probability provided.

One you have completed Stage III, your payoff for your decisions in Stages I, II, and III will be displayed. Please wait patiently as others around you may not have finished and the experimenter will be by to give you payment for your participation today. Once you have received payment for your participation today, you are free to quietly leave the room.

Summary

A summary of the instructions above are provided below:

- This experiment consists of Three (3) Stages
- Payment in each stage will take the form of ECU's, which will be converted to dollars at a rate of 16 ECU's to $1.00

- Stage I consists of a multiple choice general knowledge quiz. A correct answer in this quiz entitles you to a possibility of winning 80 ECU's ($5.00)
- Stage II consists of Three (3) sets each made of two (2) parts
- In all sets and all parts, you will be an employee of a firm consisting of 4 people (including yourself)
- Part 1 of each set will consist of 4 rounds, and part 2 will consist of 6 rounds. In each part, you will choose how much time to commit between two activities, A and B
- Your payment for each round will be determined by the amount of time devoted to Activity A and the minimum of all time spent on Activity A across all group members, determined by the following formula:

$$Payoff = 200 - 5 * HA(\mathrm{i}) + min(HA) * B$$

- In the second part of each set, each firm will have a manager that can send messages to all employees of the firm
- The manager is selected from using a variety of selection systems, including: random, voting, and competition
- The manager will also have a special decision task at the end of each set
- Stage III consists of four (4) tasks, a survey task and a lottery task. The survey tasks will not be used for payment.
- At the end of the experiment, you will be paid for one decision you made during the course of the experiment in addition to your $10 show-up fee.

Appendix: Full model derivations

B.D Public winner-take-all

The following are derivations for all relevant cases for the WTA competition found in this paper. Note that for all cases where $\tilde{p_1}\lambda\hat{w} > c$, working in is a dominant strategy and $\sigma \geq 1$

Suppose the principal awards the entire prize $\bar{w}$ to the first agent who achieves a success, she publicly discloses all successes at the end of each period, and there is nothing awarded if a success is achieved after the first success. If both agents succeed simultaneously, the prize is equally divided. In this mechanism, neither agent will work in the second period if either succeeded in the first period. Thus, in any period, if there has been no earlier success and the opponent is exerting effort, an agent's expected reward for success is given by:

$$\hat{w} = \lambda\bar{w}/2 + (1-\lambda)\bar{w}$$

From here, we analyze this setting starting in period 2. Agents in this setting update their prior beliefs about the state in period 1 p_0 going into period 2 using Bayes' rule. This in period 2, there are three possible cases: both agents worked in period 1, both agents shirked in period 1, and one agent shirked in period 1 while one agent worked in period 1. I will refer to these as case 1, 2, and 3. Accordingly, in period 2, if no success has been yet achieved, the expected payoff of working in period two for cases 1, 2, and 3 are

$$E(work) = \tilde{p_1}\lambda\hat{w} \tag{B.1}$$

where

$$\tilde{p_1} = \frac{p_0(1-\lambda)^2}{p_0(1-\lambda)^2 + (1-p_0)}$$

In case 2, neither agent worked and so the prior of the state does not update, and the expected payoff for working is

$$E(work) = p_1 \lambda \hat{w} \tag{B.2}$$

where

$$p_1 = p_0$$

In case 3, one agent worked and the other does not. Since working is public knowledge, prior beliefs are updated for both agents conditional on only one agent working such that the expectation of working is

$$E(work) = \hat{p_1} \lambda \hat{w} \tag{B.3}$$

where

$$\hat{p_1} = \frac{p_0(1-\lambda)^2}{1-\lambda p_0}$$

Note that in period 2, if no success has yet been achieved there is no benefit to not working if the expected payoff from doing so is higher than the cost of working such that

$$p_1 \lambda \hat{w} \geq c \tag{B.4}$$

It is important to note that in these three cases, the value of c determines if working or shirking is better in expectations. Further note that

$$\frac{p_0(1-\lambda)}{1-\lambda p_0} \geq \frac{p_0(1-\lambda)^2}{p_0(1-\lambda)^2 + (1-p_0)} \tag{B.5}$$

B.D.1 Case 1

Consider the scenario where the expectation of working is better than shirking only in the case where no *lack of success from working* has been observed. That is, where

$$p_0 \lambda \hat{w} \geq c \geq \frac{p_0(1-\lambda)}{1-\lambda p_0} \geq \frac{p_0(1-\lambda)^2}{p_0(1-\lambda)^2 + (1-p_0)} \tag{B.6}$$

Again, this condition sets that in period 2 if both agents shirked in period 1, it is better in expectation for them to work than shirk in period 2. If one or both agents work in period 1 and either one or both are not successful, then in expectation it is better to shirk in period 2. This creates a tension in period 1 where agents may want to shirk in period 1 in order to potentially gain information about the state of the world where they would be compelled to shirk again in period 2.

In period 1, each agent chooses some mixed strategy $s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})$ where $\sigma_{\mathrm{i}} \in (0,1)$ such that they work with probability σ and shirk with probability $1-\sigma$. $\sigma = 1$ is identical to a pure strategy of working while $\sigma = 0$ is identical to a pure strategy of shirking. We can use this mixed strategy to measure the intensity of "free riding" as σ approaches 0. In a single agent problem, because updating only occurs if at least one agent works, there is no incentive to shirk since $p_0 \lambda \hat{w} \geq c$ but agents may have an incentive under certain circumstances to choose a value of $\sigma < 1$ in order to benefit from information revealed by another agent working.

In expectation (with the abuse of some notation), an agent's expected payoff from strategy $s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})$ is

$$\begin{aligned} E_0(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})) = \sigma(E(work|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}}) + E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|work))+ \\ (1-\sigma_{\mathrm{i}})(c + E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|shirk)) \end{aligned} \tag{B.7}$$

Where the first element is the expected payoff of working in period 1 given the other agents strategy, the second is the expected payoff of the next period conditional on working this period, the third term is the payoff c for shirking this period and the fourth therm is

the expected payoff of period 2 conditional on shirking in period 1. Defining each of these elements, the first element can be expressed as:

$$E(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}})) = p_0\lambda\bar{w}(1-\sigma_{-\mathrm{i}}) + p_0\lambda(1-\lambda)\bar{w}\sigma_{-\mathrm{i}} + p_0\lambda^2\bar{w}\sigma_{-\mathrm{i}}/2 \quad \text{(B.8)}$$

$$E(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}})) = \bar{w}p_0\lambda[(1-\sigma_{-\mathrm{i}} + (1-\lambda)\sigma_{-\mathrm{i}} + \lambda\sigma_{-\mathrm{i}}/2]$$

$$E(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}})) = \bar{w}p_0\lambda[1-\frac{\lambda\sigma_{-\mathrm{i}}}{2}]$$

The second term can be expressed as:

$$E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|work) = \lambda p_0 c + (1-\lambda)\lambda p_0 c\sigma_{-\mathrm{i}} + c(1-\sigma_{-\mathrm{i}})(1-\lambda p_0) + c\sigma_{-\mathrm{i}}(1-\lambda p_0) \quad \text{(B.9)}$$

$$E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|work) = c(1+\lambda p_0\sigma_{-\mathrm{i}} - \lambda^2 p_0\sigma_{-\mathrm{i}})$$

Finally, the last term in this expectation can be expressed as

$$E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|shirk) = p_0\lambda c\sigma_{-\mathrm{i}} + p_0\lambda\hat{w}(1-\sigma_{-\mathrm{i}}) + c\sigma_{-\mathrm{i}}[1-\lambda p_0] \quad \text{(B.10)}$$

$$E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|shirk) = p_0\lambda\hat{w}(1-\sigma_{-\mathrm{i}}) + c\sigma_{-\mathrm{i}} \quad \text{(B.11)}$$

Which leads to the full expression

$$\begin{aligned} E(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}})) = \sigma_{\mathrm{i}}(\bar{w}p_0\lambda[1-\frac{\lambda\sigma_{-\mathrm{i}}}{2}] + c(1+\lambda p_0\sigma_{-\mathrm{i}} - \lambda^2 p_0)) + \\ (1-\sigma_{\mathrm{i}})(c + p_0\lambda\hat{w}(1-\sigma_{-\mathrm{i}}) + c\sigma_{-\mathrm{i}}) \end{aligned} \quad \text{(B.12)}$$

Some simplification done to group the σ_{i} and $\sigma_{-\mathrm{i}}$ terms

$$E(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}})) = \sigma_{\mathrm{i}}(\kappa\sigma_{-\mathrm{i}} + \Phi) + (1-\sigma_{\mathrm{i}})(\eta\sigma_{-\mathrm{i}} + \Psi) \tag{B.13}$$

where

$$\kappa = c\lambda p_0 - \lambda^2 \bar{w} p_0/2$$

$$\Phi = \bar{w} p_0 \lambda + c - c\lambda^2 p_0$$

$$\eta = c - p_0 \lambda \hat{w}$$

$$\Psi = c + p_0 \lambda \hat{w}$$

The first order condition of this expectation with respect to σ_{i} is such that

$$\frac{\partial E(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}}))}{\partial \sigma} = (\kappa\sigma_{-\mathrm{i}} + \Phi) - (\eta\sigma_{-\mathrm{i}} + \Psi) \tag{B.14}$$

Setting this equal to zero and solving for σ leads to the Nash equilibrium strategy for σ

$$0 = (\kappa\sigma_{-\mathrm{i}} + \Phi) - (\eta\sigma_{-\mathrm{i}} + \Psi)$$

$$\eta\sigma_{-\mathrm{i}} - \kappa\sigma_{-\mathrm{i}} = \Phi - \Psi$$

$$\sigma_{-\mathrm{i}} = \frac{\Phi - \Psi}{\eta - \kappa} \tag{B.15}$$

where $\sigma_{-\mathrm{i}} = \sigma_{\mathrm{i}} = \sigma^*$ for both players due to symmetry.

B.D.2 Case 2

Consider the scenario where the expectation of working is better than shirking only in the case where no *only one or fewer lack of successes* has been observed. That is, where

$$p_0 \lambda \hat{w} \geq \frac{p_0(1-\lambda)}{1-\lambda p_0} \geq c \geq \frac{p_0(1-\lambda)^2}{p_0(1-\lambda)^2 + (1-p_0)} \tag{B.16}$$

Again, this condition sets that in period 2 if both agents shirked in period 1, it is better in expectation for them to work than shirk in period 2. If both agents work in period 1 and both are not successful, then in expectation it is better to shirk in period 2. This creates a tension in period 1 where agents may want to shirk in period 1 in order to potentially gain information about the state of the world where they would be compelled to shirk again in period 2.

In period 1, each agent chooses some mixed strategy $s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})$ where $\sigma_{\mathrm{i}} \in (0,1)$ such that they work with probability σ and shirk with probability $1-\sigma$. $\sigma = 1$ is identical to a pure strategy of working while $\sigma = 0$ is identical to a pure strategy of shirking. We can use this mixed strategy to measure the intensity of "free riding" as σ approaches 0. In a single agent problem, because updating only occurs if at least one agent works, there is no incentive to shirk since $p_0 \lambda \hat{w} \geq c$ but agents may have an incentive under certain circumstances to choose a value of $\sigma < 1$ in order to benefit from information revealed by another agent working.

In expectation (with the abuse of some notation), an agent's expected payoff from strategy $s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})$ is

$$\begin{aligned} E_0(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})) = \sigma(E(work|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}}) + E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|work))+ \\ (1-\sigma_{\mathrm{i}})(c + E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|shirk)) \end{aligned} \tag{B.17}$$

Where the first element is the expected payoff of working in period 1 given the other agents strategy, the second is the expected payoff of the next period conditional on working this period, the third term is the payoff c for shirking this period and the fourth therm is

the expected payoff of period 2 conditional on shirking in period 1. Defining each of these elements, the first element can be expressed as:

$$E(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}})) = p_0\lambda\bar{w}(1-\sigma_{-\mathrm{i}}) + p_0\lambda(1-\lambda)\bar{w}\sigma_{-\mathrm{i}} + p_0\lambda^2\bar{w}\sigma_{-\mathrm{i}}/2 \quad \text{(B.18)}$$

$$E(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}})) = \bar{w}p_0\lambda[(1-\sigma_{-\mathrm{i}} + (1-\lambda)\sigma_{-\mathrm{i}} + \lambda\sigma_{-\mathrm{i}}/2]$$

$$E(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}})) = \bar{w}p_0\lambda[1-\frac{\lambda\sigma_{-\mathrm{i}}}{2}]$$

The second term can be expressed as:

$$E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|work) = \lambda p_0 c + (1-\lambda)\lambda p_0 c\sigma_{-\mathrm{i}} + \lambda(1-\lambda)\hat{w}p_0(1-\sigma_{-\mathrm{i}}) + c\sigma_{-\mathrm{i}}(1-\lambda p_0) \quad \text{(B.19)}$$

$$E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|work) = \sigma_{-\mathrm{i}}[c-\lambda^2 p_0 c] + (1-\sigma_{-\mathrm{i}})[\lambda(1-\lambda)\hat{w}p_0] + \lambda p_0 c$$

Finally, the last term in this expectation can be expressed as

$$E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|shirk) = p_0\lambda c\sigma_{-\mathrm{i}} + p_0\lambda\hat{w}(1-\sigma_{-\mathrm{i}}) + \lambda(1-\lambda)\hat{w}p_0\sigma_{-\mathrm{i}} \quad \text{(B.20)}$$

$$E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|shirk) = p_0\lambda[c\sigma_{-\mathrm{i}} + \hat{w} - \lambda\hat{w}\sigma_{-\mathrm{i}}] \quad \text{(B.21)}$$

Which leads to the full expression

$$\begin{aligned} E(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}})) = \sigma_{\mathrm{i}}(\bar{w}p_0\lambda[1-\frac{\lambda\sigma_{-\mathrm{i}}}{2}]+ \\ \sigma_{-\mathrm{i}}[c-\lambda^2 p_0 c] + (1-\sigma_{-\mathrm{i}})[\lambda(1-\lambda)\hat{w}p_0] + \lambda p_0 c)+ \\ (1-\sigma_{\mathrm{i}})(c + p_0\lambda[c\sigma_{-\mathrm{i}} + \hat{w} - \lambda\hat{w}\sigma_{-\mathrm{i}}]) \end{aligned} \quad \text{(B.22)}$$

Some simplification done to group the σ_{i} and $\sigma_{-\mathrm{i}}$ terms

$$E(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}})) = \sigma_{\mathrm{i}}(\sigma_{-\mathrm{i}}\Phi + (1-\sigma_{-\mathrm{i}})\Psi + \kappa) + (1-\sigma_{\mathrm{i}})(\sigma_{-\mathrm{i}}\eta + \chi) \quad \text{(B.23)}$$

where

$$\Phi = c - \lambda^2 p_0 c - \bar{w} p_0 \lambda^2/2$$

$$\Psi = \lambda(1-\lambda)\hat{w}p_0$$

$$\kappa = \lambda p_0(\bar{w} + c)$$

$$\eta = \lambda p_0 c - \lambda^2 p_0 \hat{w}$$

$$\chi = c + \hat{w}p_0\lambda$$

The first order condition of this expectation with respect to σ_{i} is such that

$$\frac{\partial E(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}}))}{\partial \sigma} = \sigma_{-\mathrm{i}}\Phi + (1-\sigma_{-\mathrm{i}})\Psi + \kappa - (\sigma_{-\mathrm{i}}\eta + \chi) \quad \text{(B.24)}$$

Setting this equal to zero and solving for σ leads to the Nash equilibrium strategy for σ

$$0 = \sigma_{-\mathrm{i}}\Phi + (1-\sigma_{-\mathrm{i}})\Psi + \kappa - (\sigma_{-\mathrm{i}}\eta + \chi)$$

$$\sigma_{-\mathrm{i}}\eta + \sigma_{-\mathrm{i}}\Psi - \sigma_{-\mathrm{i}}\Phi = \Psi + \kappa - \chi$$

$$\sigma_{-\mathrm{i}} = \frac{\Psi + \kappa - \chi}{\eta + \Psi - \Phi} \tag{B.25}$$

where $\sigma_{-\mathrm{i}} = \sigma_{\mathrm{i}} = \sigma^*$ for both players due to symmetry.

B.D.3 Case 3

Consider only the scenario where the expectation of working is better than shirking regardless of how many lack of successes is observed. That is, where

$$p_0 \lambda \hat{w} \geq \frac{p_0(1-\lambda)}{1-\lambda p_0} \geq \frac{p_0(1-\lambda)^2}{p_0(1-\lambda)^2 + (1-p_0)} \geq c \tag{B.26}$$

In period 1, each agent chooses some mixed strategy $s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})$ where $\sigma_{\mathrm{i}} \in (0,1)$ such that they work with probability σ and shirk with probability $1-\sigma$. $\sigma = 1$ is identical to a pure strategy of working while $\sigma = 0$ is identical to a pure strategy of shirking. We can use this mixed strategy to measure the intensity of "free riding" as σ approaches 0. In a single agent problem, because updating only occurs if at least one agent works, there is no incentive to shirk since $p_0 \lambda \hat{w} \geq c$ but agents may have an incentive under certain circumstances to choose a value of $\sigma < 1$ in order to benefit from information revealed by another agent working.

In expectation (with the abuse of some notation), an agent's expected payoff from strategy $s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})$ is

$$\begin{aligned} E_0(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})) = \sigma(E(work|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}}) + E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|work))+ \\ (1-\sigma_{\mathrm{i}})(c + E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|shirk)) \end{aligned} \tag{B.27}$$

Where the first element is the expected payoff of working in period 1 given the other agents strategy, the second is the expected payoff of the next period conditional on working this period, the third term is the payoff c for shirking this period and the fourth therm is

the expected payoff of period 2 conditional on shirking in period 1. Defining each of these elements, the first element can be expressed as:

$$E(s_{\mathrm{i}}(\sigma_{\mathrm{i}},1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}},1-\sigma_{-\mathrm{i}})) = p_0\lambda\bar{w}(1-\sigma_{-\mathrm{i}}) + p_0\lambda(1-\lambda)\bar{w}\sigma_{-\mathrm{i}} + p_0\lambda^2\bar{w}\sigma_{-\mathrm{i}}/2 \quad \text{(B.28)}$$

$$E(s_{\mathrm{i}}(\sigma_{\mathrm{i}},1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}},1-\sigma_{-\mathrm{i}})) = \bar{w}p_0\lambda[(1-\sigma_{-\mathrm{i}} + (1-\lambda)\sigma_{-\mathrm{i}} + \lambda\sigma_{-\mathrm{i}}/2]$$

$$E(s_{\mathrm{i}}(\sigma_{\mathrm{i}},1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}},1-\sigma_{-\mathrm{i}})) = \bar{w}p_0\lambda[1-\frac{\lambda\sigma_{-\mathrm{i}}}{2}]$$

The second term can be expressed as:

$$E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}},1-\sigma_{\mathrm{i}})|work) = \lambda p_0 c + (1-\lambda)\lambda p_0 c\sigma_{-\mathrm{i}} + \lambda(1-\lambda)\hat{w}p_0(1-\sigma_{-\mathrm{i}}) + (1-\lambda p_0)\sigma p_1\lambda\hat{w} \quad \text{(B.29)}$$

$$E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}},1-\sigma_{\mathrm{i}})|work) = \sigma_{-\mathrm{i}}[p_0(1-\lambda)\lambda c + (1-\lambda p_0)p_1\lambda\hat{w}) + (1-\sigma_{-\mathrm{i}})[\lambda(1-\lambda)\hat{w}p_0] + \lambda p_0 c$$

where

$$\tilde{p_1} = \frac{p_0(1-\lambda)^2}{p_0(1-\lambda)^2 + (1-p_0)} \quad \text{(B.30)}$$

Finally, the last term in this expectation can be expressed as

$$E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}},1-\sigma_{\mathrm{i}})|shirk) = p_0\lambda c\sigma_{-\mathrm{i}} + p_0\lambda\hat{w}(1-\sigma_{-\mathrm{i}}) + \lambda(1-\lambda)\hat{w}p_0\sigma_{-\mathrm{i}} \quad \text{(B.31)}$$

$$E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}},1-\sigma_{\mathrm{i}})|shirk) = p_0\lambda[c\sigma_{-\mathrm{i}} + \hat{w} - \lambda\hat{w}\sigma_{-\mathrm{i}}] \quad \text{(B.32)}$$

Which leads to the full expression

$$E(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}})) = \sigma_{\mathrm{i}}(\bar{w}p_0\lambda[1-\frac{\lambda\sigma_{-\mathrm{i}}}{2}] + \sigma_{-\mathrm{i}}[p_0(1-\lambda)\lambda c + (1-\lambda p_0)p_1\lambda\hat{w})+$$
$$(1-\sigma_{-\mathrm{i}})[\lambda(1-\lambda)\hat{w}p_0] + \lambda p_0 c)+$$
$$(1-\sigma_{\mathrm{i}})(c + p_0\lambda[c\sigma_{-\mathrm{i}} + \hat{w} - \lambda\hat{w}\sigma_{-\mathrm{i}}]) \tag{B.33}$$

Some simplification done to group the σ_{i} and $\sigma_{-\mathrm{i}}$ terms

$$E(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}})) = \sigma_{\mathrm{i}}(\sigma_{-\mathrm{i}}\Phi + (1-\sigma_{-\mathrm{i}})\Psi + \kappa) + (1-\sigma_{\mathrm{i}})(\sigma_{-\mathrm{i}}\eta + \chi) \tag{B.34}$$

where

$$\Phi = p_0(1-\lambda)\lambda c + (1-\lambda p_0)p_1\lambda\hat{w} - \bar{w}p_0\lambda^2/2$$

$$\Psi = \lambda(1-\lambda)\hat{w}p_0$$

$$\kappa = \lambda p_0(\bar{w} + c)$$

$$\eta = \lambda p_0 c - \lambda^2 p_0\hat{w}$$

$$\chi = c + \hat{w}p_0\lambda$$

The first order condition of this expectation with respect to σ_{i} is such that

$$\frac{\partial E(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}}))}{\partial\sigma} = \sigma_{-\mathrm{i}}\Phi + (1-\sigma_{-\mathrm{i}})\Psi + \kappa - (\sigma_{-\mathrm{i}}\eta + \chi) \tag{B.35}$$

Setting this equal to zero and solving for σ leads to the Nash equilibrium strategy for σ

$$0 = \sigma_{-\mathrm{i}}\Phi + (1 - \sigma_{-\mathrm{i}})\Psi + \kappa - (\sigma_{-\mathrm{i}}\eta + \chi)$$

$$\sigma_{-\mathrm{i}}\eta + \sigma_{-\mathrm{i}}\Psi - \sigma_{-\mathrm{i}}\Phi = \Psi + \kappa - \chi$$

$$\sigma_{-\mathrm{i}} = \frac{\Psi + \kappa - \chi}{\eta + \Psi - \Phi} \tag{B.36}$$

where $\sigma_{-\mathrm{i}} = \sigma_{\mathrm{i}} = \sigma^*$ for both players due to symmetry.

B.E Public Equal Sharing

Suppose the principal awards the entire prize $\bar{w}$ to the first agent who achieves a success, and she publicly discloses all successes at the end of each period. If both agents succeed simultaneously, the prize is equally divided. If a second success is achieved after the first success, both agents are awarded $\bar{w}/2$. If an agent succeeds in the first period, the opponent is certain in the second period that the state is good and, due to the shared prize scheme, the opponent's reward for success is $\bar{w}/2$. Thus, when $\lambda\bar{w}/2 < c$, an agent does not work in the second period if his opponent succeeds in the first period; in this case the contest behaves equivalently to the public winner-takes all contest. On the other hand, when $\lambda\bar{w}/2 > c$, an agent will work in the second period if the opponent succeeds in the first period. Note that the duplication of effort does not benefit the principal because she values one one success and that compared to WTA, the incentive to work in the first period is lower due to two reasons. The first is a higher incentive to free-ride - an agent may want to wait for the other agent to experiment and reveal information about the state - and a lower expected reward for first period success due to the opponent's duplication of effort. Furthermore, if an agent achieves an earlier success in period 1, they will choose not to work in period 2 as a second success is not rewarded at an individual level.

From here, we analyze this setting starting in period 2. Again, in this setting update their prior beliefs about the state in period 1 p_0 going into period 2 using Bayes' rule identical to how they behaved in the public WTA contest. In period 2, there are 4 relevant cases to consider: 2 in which no success has been achieved by period 2, one in which the agent's opponent has achieved a success in period 1, and one in which neither agent worked in period 1. The public WTA contest contains the same 3 cases for the state in which an agent is making the decision to work on shirk in period 2. However, there is one additional case which considers if the agent will work in period 2 despite their opponent's success in period 1. In this case, in period 2 the agent know that the state is good and their expected payoff of working is:

$$E(work) = \lambda \bar{w}/2$$

Note that in period 2, if no success has yet been achieved there is no benefit to not working if the expected payoff from doing so is higher than the cost of working such that

$$p_1 \lambda \hat{w} \geq c \tag{B.37}$$

Furthermore, in period 2 and a success has been achieved, there is no benefit to not working if the expected payoff from doing is higher than the cost of working such that:

$$\lambda \bar{w}/2 \geq c \tag{B.38}$$

It is important to note that in all potential cases, the value of c determines if working or shirking is better in expectations. Further note that

$$p_0 \geq \frac{p_0(1-\lambda)}{1-\lambda p_0} \geq \frac{p_0(1-\lambda)^2}{p_0(1-\lambda)^2 + (1-p_0)} \tag{B.39}$$

Furthermore, this paper only considers the cases in which

$$\lambda \bar{w}/2 \geq c$$

So that if the good state is ever observed in period 1 by a player's opponent achieving a success, it is better in expectation for a risk neutral agent to work rather than shirk.

The following section considers three possible cases for the analysis of period 1.

B.E.1 Case 1

In case 1 we consider the case in which there is incentive to work in period 1 but if any lack of success in period 1 is observed from any one agent, the payoff from shirking in period 2 exceeds the expected payoff from working. In other words

$$p_0\lambda\hat{w} \geq \lambda\bar{w}/2 \geq c \geq \frac{p_0(1-\lambda)\lambda\hat{w}}{1-\lambda p_0} \geq \frac{p_0(1-\lambda)^2\lambda\hat{w}}{p_0(1-\lambda)^2+(1-p_0)} \tag{B.40}$$

In period 1, each agent chooses some mixed strategy $s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})$ where $\sigma_{\mathrm{i}} \in (0,1)$ such that they work with probability σ and shirk with probability $1-\sigma$. $\sigma = 1$ is identical to a pure strategy of working while $\sigma = 0$ is identical to a pure strategy of shirking. We can use this mixed strategy to measure the intensity of "free riding" as σ approaches 0. In a single agent problem, because updating only occurs if at least one agent works, there is no incentive to shirk since $p_0\lambda\hat{w} \geq c$ but agents may have an incentive under certain circumstances to choose a value of $\sigma < 1$ in order to benefit from information revealed by another agent working.

In expectation (with the abuse of some notation), an agent's expected payoff from strategy $s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})$ is

$$\begin{aligned} E_0(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})) = \sigma(E(work|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}}) + E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|work))+ \\ (1-\sigma_{\mathrm{i}})(c + E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|shirk)) \end{aligned} \tag{B.41}$$

Where the first element is the expected payoff of working in period 1 given the other agents strategy, the second is the expected payoff of the next period conditional on working this period, the third term is the payoff c for shirking this period and the fourth therm is

the expected payoff of period 2 conditional on shirking in period 1. Defining each of these elements, the first element can be expressed as:

$$E(s_{\mathrm{i}}(\sigma_{\mathrm{i}},1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}},1-\sigma_{-\mathrm{i}})) = p_0\lambda\bar{w}(1-\sigma_{-\mathrm{i}}) + p_0\lambda(1-\lambda)\bar{w}\sigma_{-\mathrm{i}} + p_0\lambda^2\bar{w}\sigma_{-\mathrm{i}}/2 \quad \text{(B.42)}$$

$$E(s_{\mathrm{i}}(\sigma_{\mathrm{i}},1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}},1-\sigma_{-\mathrm{i}})) = \bar{w}p_0\lambda[(1-\sigma_{-\mathrm{i}} + (1-\lambda)\sigma_{-\mathrm{i}} + \lambda\sigma_{-\mathrm{i}}/2]$$

$$E(s_{\mathrm{i}}(\sigma_{\mathrm{i}},1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}},1-\sigma_{-\mathrm{i}})) = \bar{w}p_0\lambda[1-\frac{\lambda\sigma_{-\mathrm{i}}}{2}]$$

The second term can be expressed as:

$$\begin{aligned} E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}},1-\sigma_{\mathrm{i}})|work) &= \sigma_{-\mathrm{i}}\lambda p_0 c + \lambda p_0(c-\lambda\bar{w}/2) \\ &- \lambda^2\sigma_{-\mathrm{i}}p_0(c-\lambda\bar{w}/2) \\ &+ \sigma_{-\mathrm{i}}\lambda p_0[1-\lambda p_0]\lambda\bar{w}/2 + [1-\lambda p_0]^2\sigma_{-\mathrm{i}}c \\ &+ [1-\lambda p_0](1-\sigma_{-\mathrm{i}})c \end{aligned} \quad \text{(B.43)}$$

$$\begin{aligned} E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}},1-\sigma_{\mathrm{i}})|work) &= \sigma_{-\mathrm{i}}[\lambda p_0(c+\lambda(c-\lambda\bar{w}/2)) \\ &+ (1-\lambda p_0)(p_0\lambda^2\bar{w}/2 + (1-\lambda p_0)c)] \\ &+ (1-\sigma_{-\mathrm{i}})[1-\lambda p_0]c + \lambda p_0(c-\lambda\bar{w}/2) \end{aligned}$$

Finally, the last term in this expectation can be expressed as

$$E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}},1-\sigma_{\mathrm{i}})|shirk) = p_0\lambda^2\bar{w}\sigma_{-\mathrm{i}}/2 + p_0\lambda\hat{w}(1-\sigma_{-\mathrm{i}}) + c\sigma_{-\mathrm{i}}[1-\lambda p_0] \quad \text{(B.44)}$$

$$E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}},1-\sigma_{\mathrm{i}})|shirk) = \sigma_{-\mathrm{i}}[p_0\lambda(\lambda\bar{w}/2-c) + c - p_0\lambda\hat{w}] + p_0\lambda\hat{w} \quad \text{(B.45)}$$

Which leads to the full expression

$$
\begin{aligned}
E(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}})) = \sigma_{\mathrm{i}}(\bar{w}p_0\lambda[1-\frac{\lambda\sigma_{-\mathrm{i}}}{2}] + \sigma_{-\mathrm{i}}[\lambda p_0(c+\lambda(c-\lambda\bar{w}/2)) \\
+ (1-\lambda p_0)(p_0\lambda^2\bar{w}/2 + (1-\lambda p_0)c)] \\
+ (1-\sigma_{-\mathrm{i}})[1-\lambda p_0]c + \lambda p_0(c-\lambda\bar{w}/2))+ \\
(1-\sigma_{\mathrm{i}})(c+\sigma_{-\mathrm{i}}[p_0\lambda(\lambda\bar{w}/2-c)+c-p_0\lambda\hat{w}] + p_0\lambda\hat{w})
\end{aligned}
\tag{B.46}
$$

Some simplification done to group the σ_{i} and $\sigma_{-\mathrm{i}}$ terms

$$
\begin{aligned}
E(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}})) = \sigma_{\mathrm{i}}(\sigma_{-\mathrm{i}}\Phi + (1-\sigma_{-\mathrm{i}})\Psi + \kappa)+ \\
(1-\sigma_{\mathrm{i}})(\sigma_{-\mathrm{i}}\eta + \chi)
\end{aligned}
\tag{B.47}
$$

where

$$
\begin{aligned}
\Phi = \lambda p_0(c+\lambda(c-\lambda\bar{w}/2)) \\
+ (1-\lambda p_0)(p_0\lambda^2\bar{w}/2 + (1-\lambda p_0)c) - \bar{w}p_0\lambda^2/2
\end{aligned}
$$

$$\Psi = [1-\lambda p_0]c + \lambda p_0(c-\lambda\bar{w}/2)$$

$$\kappa = \lambda p_0(\bar{w} + c - \lambda\bar{w}/2)$$

$$\eta = p_0\lambda(\lambda\bar{w}/2 - c) + c - p_0\lambda\hat{w}$$

$$\chi = c + \hat{w}p_0\lambda$$

The first order condition of this expectation with respect to σ_{i} is such that

$$\frac{\partial E(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}}))}{\partial \sigma} = \sigma_{-\mathrm{i}}\Phi + (1-\sigma_{-\mathrm{i}})\Psi + \kappa - (\sigma_{-\mathrm{i}}\eta + \chi) \tag{B.48}$$

Setting this equal to zero and solving for σ leads to the Nash equilibrium strategy for σ

$$0 = \sigma_{-\mathrm{i}}\Phi + (1-\sigma_{-\mathrm{i}})\Psi + \kappa - (\sigma_{-\mathrm{i}}\eta + \chi)$$

$$\sigma_{-\mathrm{i}}\eta + \sigma_{-\mathrm{i}}\Psi - \sigma_{-\mathrm{i}}\Phi = \Psi + \kappa - \chi$$

$$\sigma_{-\mathrm{i}} = \frac{\Psi + \kappa - \chi}{\eta + \Psi - \Phi} \tag{B.49}$$

where $\sigma_{-\mathrm{i}} = \sigma_{\mathrm{i}} = \sigma^*$ for both players due to symmetry.

B.E.2 Case 2

In case 2 we consider the case in which there is incentive to work in period 1 and there is a higher expected payoff to working in round 2 regardless of how many successes there were in round 1, the payoff from shirking in period 2 exceeds the expected payoff from working. In other words

$$p_0\lambda\hat{w} \geq \frac{p_0(1-\lambda)\lambda\hat{w}}{1-\lambda p_0} \geq \frac{p_0(1-\lambda)^2\lambda\hat{w}}{p_0(1-\lambda)^2 + (1-p_0)} \geq \lambda\bar{w}/2 \geq c \tag{B.50}$$

In period 1, each agent chooses some mixed strategy $s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})$ where $\sigma_{\mathrm{i}} \in (0,1)$ such that they work with probability σ and shirk with probability $1-\sigma$. $\sigma = 1$ is identical to a pure strategy of working while $\sigma = 0$ is identical to a pure strategy of shirking. We can use this mixed strategy to measure the intensity of "free riding" as σ approaches 0. In a single agent problem, because updating only occurs if at least one agent works, there is no incentive to shirk since $p_0\lambda\hat{w} \geq c$ but agents may have an incentive under certain circumstances to choose a value of $\sigma < 1$ in order to benefit from information revealed by another agent working.

In expectation (with the abuse of some notation), an agent's expected payoff from strategy $s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})$ is

$$\begin{aligned} E_0(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})) = \sigma(E(work|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}}) + E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|work))+ \\ (1-\sigma_{\mathrm{i}})(c + E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|shirk)) \end{aligned} \tag{B.51}$$

Where the first element is the expected payoff of working in period 1 given the other agents strategy, the second is the expected payoff of the next period conditional on working this period, the third term is the payoff c for shirking this period and the fourth therm is the expected payoff of period 2 conditional on shirking in period 1. Defining each of these elements, the first element can be expressed as:

$$E(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}})) = p_0\lambda\bar{w}(1-\sigma_{-\mathrm{i}}) + p_0\lambda(1-\lambda)\bar{w}\sigma_{-\mathrm{i}} + p_0\lambda^2\bar{w}\sigma_{-\mathrm{i}}/2 \tag{B.52}$$

$$E(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}})) = \bar{w}p_0\lambda[(1-\sigma_{-\mathrm{i}} + (1-\lambda)\sigma_{-\mathrm{i}} + \lambda\sigma_{-\mathrm{i}}/2]$$

$$E(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}})) = \bar{w}p_0\lambda[1 - \frac{\lambda\sigma_{-\mathrm{i}}}{2}]$$

The second term can be expressed as:

$$\begin{aligned} E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|work) = \sigma_{-\mathrm{i}}\lambda p_0 c + \lambda p_0(c - \lambda\bar{w}/2) \\ - \lambda^2\sigma_{-\mathrm{i}}p_0(c - \lambda\bar{w}/2) \\ + \sigma_{-\mathrm{i}}\lambda p_0[1-\lambda p_0]\lambda\bar{w}/2 + [1-\lambda p_0]^2\sigma_{-\mathrm{i}}\tilde{p_1}\lambda\hat{w} \\ + [1-\lambda p_0](1-\sigma_{-\mathrm{i}})\hat{p_1}\lambda\hat{w} \end{aligned} \tag{B.53}$$

$$
\begin{aligned}
E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|work) = \sigma_{-\mathrm{i}}[\lambda p_0(c+\lambda(c-\lambda\bar{w}/2)) \\
+ (1-\lambda p_0)(p_0\lambda^2\bar{w}/2 + (1-\lambda p_0)\tilde{p_1}\lambda\hat{w})] \\
+ (1-\sigma_{-\mathrm{i}})[1-\lambda p_0]\hat{p_1}\lambda\hat{w} + \lambda p_0(c-\lambda\bar{w}/2)
\end{aligned}
$$

where

$$\hat{p_1} = \frac{p_0(1-\lambda)}{1-\lambda p_0}$$

and

$$\tilde{p_1} = \frac{p_0(1-\lambda)^2}{p_0(1-\lambda)^2 + 1 - p_0}$$

Finally, the last term in this expectation can be expressed as

$$E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|shirk) = p_0\lambda^2\bar{w}\sigma_{-\mathrm{i}}/2 + p_0\lambda\hat{w}(1-\sigma_{-\mathrm{i}}) + \hat{p_1}\lambda\hat{w}\sigma_{-\mathrm{i}}[1-\lambda p_0] \tag{B.54}$$

$$E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|shirk) = \sigma_{-\mathrm{i}}\lambda[p_0(\lambda\bar{w}/2 + \hat{w}(\hat{p_1} - p_0 - p_0\hat{p_1})] + p_0\lambda\hat{w} \tag{B.55}$$

where

$$\hat{p_1} = \frac{p_0(1-\lambda)}{1-\lambda p_0}$$

Which leads to the full expression

$$
\begin{aligned}
E(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}})) = \sigma_{\mathrm{i}}(\bar{w}p_0\lambda[1-\frac{\lambda\sigma_{-\mathrm{i}}}{2}] + \sigma_{-\mathrm{i}}[\lambda p_0(c+\lambda(c-\lambda\bar{w}/2)) \\
+ (1-\lambda p_0)(p_0\lambda^2\bar{w}/2 + (1-\lambda p_0)\tilde{p_1}\lambda\hat{w})] \\
+ (1-\sigma_{-\mathrm{i}})[1-\lambda p_0]\hat{p_1}\lambda\hat{w} + \lambda p_0(c-\lambda\bar{w}/2)) + \\
(1-\sigma_{\mathrm{i}})(c + \sigma_{-\mathrm{i}}\lambda[p_0(\lambda\bar{w}/2 + \hat{w}(\hat{p_1} - p_0 - p_0\hat{p_1})] + p_0\lambda\hat{w})
\end{aligned}
\tag{B.56}
$$

Some simplification done to group the σ_{i} and $\sigma_{-\mathrm{i}}$ terms

$$E(s_{\mathrm{i}}(\sigma_{\mathrm{i}},1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}},1-\sigma_{-\mathrm{i}})) = \sigma_{\mathrm{i}}(\sigma_{-\mathrm{i}}\Phi + (1-\sigma_{-\mathrm{i}})\Psi + \kappa) + (1-\sigma_{\mathrm{i}})(\sigma_{-\mathrm{i}}\eta + \chi) \tag{B.57}$$

where

$$\Phi = \lambda p_0(c + \lambda(c - \lambda\bar{w}/2)) + (1-\lambda p_0)(p_0\lambda^2\bar{w}/2 + (1-\lambda p_0)\tilde{p_1}\lambda\hat{w}) - \bar{w}p_0\lambda^2/2$$

$$\Psi = [1-\lambda p_0]\hat{p_1}\lambda\hat{w} + \lambda p_0(c - \lambda\bar{w}/2)$$

$$\kappa = \lambda p_0(\bar{w} + c - \lambda\bar{w}/2)$$

$$\eta = \lambda[p_0(\lambda\bar{w}/2 + \hat{w}(\hat{p_1} - p_0 - p_0\hat{p_1}))]$$

$$\chi = c + \hat{w}p_0\lambda$$

The first order condition of this expectation with respect to σ_{i} is such that

$$\frac{\partial E(s_{\mathrm{i}}(\sigma_{\mathrm{i}},1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}},1-\sigma_{-\mathrm{i}}))}{\partial\sigma} = \sigma_{-\mathrm{i}}\Phi + (1-\sigma_{-\mathrm{i}})\Psi + \kappa - (\sigma_{-\mathrm{i}}\eta + \chi) \tag{B.58}$$

Setting this equal to zero and solving for σ leads to the Nash equilibrium strategy for σ

$$0 = \sigma_{-\mathrm{i}}\Phi + (1-\sigma_{-\mathrm{i}})\Psi + \kappa - (\sigma_{-\mathrm{i}}\eta + \chi)$$

$$\sigma_{-\mathrm{i}}\eta + \sigma_{-\mathrm{i}}\Psi - \sigma_{-\mathrm{i}}\Phi = \Psi + \kappa - \chi$$

$$\sigma_{-\mathrm{i}} = \frac{\Psi + \kappa - \chi}{\eta + \Psi - \Phi} \tag{B.59}$$

where $\sigma_{-\mathrm{i}} = \sigma_{\mathrm{i}} = \sigma^*$ for both players due to symmetry.

B.E.3 Case 3

In case 3 we consider the case in which there is incentive to work in period 1 and there is a higher expected payoff to working compared to shirking in round 2 only if there have been 0 or 1 unsuccessful attempts to find a success by working in round 1, . In other words

$$p_0\lambda\hat{w} \geq \frac{p_0(1-\lambda)\lambda\hat{w}}{1-\lambda p_0} \geq \lambda\bar{w}/2 \geq c \geq \frac{p_0(1-\lambda)^2\lambda\hat{w}}{p_0(1-\lambda)^2 + (1-p_0)} \tag{B.60}$$

In period 1, each agent chooses some mixed strategy $s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})$ where $\sigma_{\mathrm{i}} \in (0,1)$ such that they work with probability σ and shirk with probability $1-\sigma$. $\sigma = 1$ is identical to a pure strategy of working while $\sigma = 0$ is identical to a pure strategy of shirking. We can use this mixed strategy to measure the intensity of "free riding" as σ approaches 0. In a single agent problem, because updating only occurs if at least one agent works, there is no incentive to shirk since $p_0\lambda\hat{w} \geq c$ but agents may have an incentive under certain circumstances to choose a value of $\sigma < 1$ in order to benefit from information revealed by another agent working.

In expectation (with the abuse of some notation), an agent's expected payoff from strategy $s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})$ is

$$\begin{aligned} E_0(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})) = \sigma(E(work|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}}) + E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|work))+ \\ (1-\sigma_{\mathrm{i}})(c + E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|shirk)) \end{aligned} \tag{B.61}$$

Where the first element is the expected payoff of working in period 1 given the other agents strategy, the second is the expected payoff of the next period conditional on working this period, the third term is the payoff c for shirking this period and the fourth therm is

the expected payoff of period 2 conditional on shirking in period 1. Defining each of these elements, the first element can be expressed as:

$$E(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}})) = p_0\lambda\bar{w}(1-\sigma_{-\mathrm{i}}) + p_0\lambda(1-\lambda)\bar{w}\sigma_{-\mathrm{i}} + p_0\lambda^2\bar{w}\sigma_{-\mathrm{i}}/2 \quad \text{(B.62)}$$

$$E(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}})) = \bar{w}p_0\lambda[(1-\sigma_{-\mathrm{i}} + (1-\lambda)\sigma_{-\mathrm{i}} + \lambda\sigma_{-\mathrm{i}}/2]$$

$$E(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}})) = \bar{w}p_0\lambda[1-\frac{\lambda\sigma_{-\mathrm{i}}}{2}]$$

The second term can be expressed as:

$$\begin{aligned} E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|work) = \sigma_{-\mathrm{i}}\lambda p_0 c + \lambda p_0(c - \lambda\bar{w}/2) \\ - \lambda^2\sigma_{-\mathrm{i}}p_0(c-\lambda\bar{w}/2) \\ + \sigma_{-\mathrm{i}}\lambda p_0[1-\lambda p_0]\lambda\bar{w}/2 + [1-\lambda p_0]^2\sigma_{-\mathrm{i}}c \\ + [1-\lambda p_0](1-\sigma_{-\mathrm{i}})\hat{p_1}\lambda\hat{w} \end{aligned} \quad \text{(B.63)}$$

$$\begin{aligned} E_1(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|work) = \sigma_{-\mathrm{i}}[\lambda p_0(c + \lambda(c-\lambda\bar{w}/2)) \\ + (1-\lambda p_0)(p_0\lambda^2\bar{w}/2 + (1-\lambda p_0)c)] \\ + (1-\sigma_{-\mathrm{i}})[1-\lambda p_0]\hat{p_1}\lambda\hat{w} + \lambda p_0(c-\lambda\bar{w}/2) \end{aligned}$$

where

$$\hat{p_1} = \frac{p_0(1-\lambda)}{1-\lambda p_0}$$

and

$$\tilde{p_1} = \frac{p_0(1-\lambda)^2}{p_0(1-\lambda)^2 + 1 - p_0}$$

Finally, the last term in this expectation can be expressed as

$$E_1(s_{\rm i}(\sigma_{\rm i}, 1-\sigma_{\rm i})|shirk) = p_0\lambda^2\bar{w}\sigma_{-\rm i}/2 + p_0\lambda\hat{w}(1-\sigma_{-\rm i}) + \hat{p_1}\lambda\hat{w}\sigma_{-\rm i}[1-\lambda p_0] \tag{B.64}$$

$$E_1(s_{\rm i}(\sigma_{\rm i}, 1-\sigma_{\rm i})|shirk) = \sigma_{-\rm i}\lambda[p_0(\lambda\bar{w}/2 + \hat{w}(\hat{p_1} - p_0 - p_0\hat{p_1})] + p_0\lambda\hat{w} \tag{B.65}$$

where

$$\hat{p_1} = \frac{p_0(1-\lambda)}{1-\lambda p_0}$$

Which leads to the full expression

$$\begin{aligned} E(s_{\rm i}(\sigma_{\rm i}, 1-\sigma_{\rm i})|s_{-\rm i}(\sigma_{-\rm i}, 1-\sigma_{-\rm i})) = \sigma_{\rm i}(\bar{w}p_0\lambda[1 - \frac{\lambda\sigma_{-\rm i}}{2}] + \sigma_{-\rm i}[\lambda p_0(c + \lambda(c - \lambda\bar{w}/2)) \\ + (1-\lambda p_0)(p_0\lambda^2\bar{w}/2 + (1-\lambda p_0)c)] \\ + (1-\sigma_{-\rm i})[1-\lambda p_0]\hat{p_1}\lambda\hat{w} + \lambda p_0(c - \lambda\bar{w}/2)) + \\ (1-\sigma_{\rm i})(c + \sigma_{-\rm i}\lambda[p_0(\lambda\bar{w}/2 + \hat{w}(\hat{p_1} - p_0 - p_0\hat{p_1})] + p_0\lambda\hat{w}) \end{aligned} \tag{B.66}$$

Some simplification done to group the $\sigma_{\rm i}$ and $\sigma_{-\rm i}$ terms

$$\begin{aligned} E(s_{\rm i}(\sigma_{\rm i}, 1-\sigma_{\rm i})|s_{-\rm i}(\sigma_{-\rm i}, 1-\sigma_{-\rm i})) = \sigma_{\rm i}(\sigma_{-\rm i}\Phi + (1-\sigma_{-\rm i})\Psi + \kappa) + \\ (1-\sigma_{\rm i})(\sigma_{-\rm i}\eta + \chi) \end{aligned} \tag{B.67}$$

where

$$\begin{aligned} \Phi = {} & \lambda p_0(c + \lambda(c - \lambda\bar{w}/2)) \\ & + (1-\lambda p_0)(p_0\lambda^2\bar{w}/2 + (1-\lambda p_0)c) - \bar{w}p_0\lambda^2/2 \end{aligned}$$

$$\Psi = [1-\lambda p_0]\hat{p_1}\lambda\hat{w} + \lambda p_0(c - \lambda\bar{w}/2)$$

$$\kappa = \lambda p_0(\bar{w} + c - \lambda\bar{w}/2)$$

$$\eta = \lambda[p_0(\lambda\bar{w}/2 + \hat{w}(\hat{p_1} - p_0 - p_0\hat{p_1}))]$$

$$\chi = c + \hat{w}p_0\lambda$$

The first order condition of this expectation with respect to σ_{i} is such that

$$\frac{\partial E(s_{\mathrm{i}}(\sigma_{\mathrm{i}}, 1-\sigma_{\mathrm{i}})|s_{-\mathrm{i}}(\sigma_{-\mathrm{i}}, 1-\sigma_{-\mathrm{i}}))}{\partial\sigma} = \sigma_{-\mathrm{i}}\Phi + (1-\sigma_{-\mathrm{i}})\Psi + \kappa - (\sigma_{-\mathrm{i}}\eta + \chi) \tag{B.68}$$

Setting this equal to zero and solving for σ leads to the Nash equilibrium strategy for σ

$$0 = \sigma_{-\mathrm{i}}\Phi + (1-\sigma_{-\mathrm{i}})\Psi + \kappa - (\sigma_{-\mathrm{i}}\eta + \chi)$$

$$\sigma_{-\mathrm{i}}\eta + \sigma_{-\mathrm{i}}\Psi - \sigma_{-\mathrm{i}}\Phi = \Psi + \kappa - \chi$$

$$\sigma_{-\mathrm{i}} = \frac{\Psi + \kappa - \chi}{\eta + \Psi - \Phi} \tag{B.69}$$

where $\sigma_{-\mathrm{i}} = \sigma_{\mathrm{i}} = \sigma^*$ for both players due to symmetry.

VITA

Education

Ph.D Economics, Department of Economics, Purdue University 2021

M.S. Economics, Purdue University 2017

B.S. Economics, B.S. Management, Purdue University 2016

Fields of Research

Experimental Economics, Game Theory, Political Economy, Behavioral Economics, Public Economics

Working Papers

"The Effect of Complexity in an Electorate: Experimental Evidence"

"The Effect of Leader Selection on Honesty and Group Performance: An Experimental Study" (With Brian Roberson andn Raquel Asencio)

Seminar, Workshop, and Conference Participation

2020 ESA job-market candidate seminar series 2020

Purdue University 2020

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Chapman University IFREE Graduate Student Workshop 2019

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Teaching Experience and Awards

Instructor

Introduction to Microeconomics (undergraduate, online) Summer 2019

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Game Theory (undergraduate) Summer 2018

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Principles of Economics (undergraduate, recitation) Fall 2016

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Teaching Assistant

Intermediate Macroeconomics (undergraduate)	Fall 2020
Bayesian Econometrics (PhD)	Fall 2020
Econometrics II (Masters)	Summer 2020
Personnel Economics (Masters)	Spring 2018
Game Theory (undergraduate)	Fall 2017
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Skills

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