An Experimental Study of the Efficiency of Unanimity Rule and Majority Rule*

Keith Dougherty
Brian Pitts
Justin Moeller
Robi Ragan

Submitted for the Panels on "Empirical Social Choice,"
2012 World Public Choice Conference.

Abstract. Scholars have traditionally claimed that unanimity rule is more capable of producing Pareto optimal outcomes than majority rule. Dougherty and Edward (2009) make the opposite claim assuming proposals are either random, sincere, or strategic. We test these competing hypotheses in a two-dimensional framework using laboratory experiments. Our primary results suggest: 1) majority rule enters the Pareto set more quickly than unanimity rule, 2) majority rule leaves the Pareto set at the same rate as unanimity rule, and 3) majority rule is more likely to select a Pareto optimal outcome than unanimity rule at the end of the game.

* Dougherty, Pitts, and Moeller, Department of Political Science, University of Georgia. Ragan, Department of Political Science, Emory University. Please direct correspondences to Dougherty, (706) 542-2989, <dougherk@uga.edu>. We thank T.K. Ahn for careful comments on both the experimental design and the presentation of the results. Bill Bianco, Joe Oppenheimer, Oleg Smirnov, and Jimmy Walker provided useful comments as well.

1. Introduction

Voting thresholds, such as majority rule, supermajority rule, and unanimity rule, can facilitate change or maintain the status quo; harness the power of the masses or favor elites; and even dictate the types of policies enacted. With such effects in mind, legislatures and committees often re-adjust their voting thresholds between majority rule and unanimity rule.[1] For example, from 1960 to 2000 more than a dozen state legislatures increased their voting threshold for tax increases from a majority to a supermajority (Heckelman and Dougherty 2010). The Treaty Establishing a Constitution for Europe (2004) proposed reducing its unanimity rule requirement in the Council of Ministers to a qualified majority in 26 issue areas. And the Financial Accounting Standards Board (FASB) reduced its threshold from a supermajority to a majority in 1977 only to increase it back to a different supermajority in 1991 (King 1994). Each of these changes were supposed to establish a more desirable voting threshold.

Most theoretical work claims that unanimity rule is the best k-majority rule,[2] for promoting Pareto optimality[3] (Chen and Ordeshook 1998; Brennan and Buchanan 2000: 151-55; Mueller 1996, 2003). Traditionally viewed, unanimity rule guarantees more efficient outcomes than other voting rules because unanimity rule cannot pass proposals that make some individuals better off at the expense of others. Other k-majority rules can replace Pareto optimal outcomes with Pareto sub-optimal ones.

Dougherty and Edward (2009) challenge this claim.[4] They analyze a series of two-dimensional spatial voting models with a finite number of rounds and conclude that majority rule is usually more likely to select a Pareto-optimal outcome than unanimity rule if voting is sincere and proposals are random. They also prove that majority rule is at least as likely to select a Pareto optimal outcome if behavior is sincere or strategic.

We test these theories using laboratory experiments on subjects voting over policies in a two-dimensional issue space. In particular, we test six hypotheses, which are detailed later in the paper: 1) groups using majority rule are more likely to enter the Pareto set in fewer rounds than groups using unanimity rule; 2) groups using majority rule are at least as likely to leave the Pareto set as groups using unanimity rule; 3) groups using majority rule are at least as likely to select Pareto optimal outcomes at the end of the game as groups using unanimity rule; 4) groups with complete information are more likely to select a Pareto optimal outcome at the end of the game than groups with incomplete information; 5) unanimity rule groups are at least as likely as majority rule groups to select outcomes that are both Pareto optimal and Pareto preferred to the initial status quo, and 6) if certain conditions are met, subjects will propose "observationally rational" alternatives in the final round of voting.

We find evidence in favor of our first three hypotheses. Groups using majority rule enter the Pareto set in fewer rounds than groups using unanimity rule, they tend to leave the Pareto set at roughly the same rate as groups using unanimity rule, and they are *more* likely than unanimity rule groups to select a Pareto optimal outcome. The explanation for these results may be multifaceted. In some cases, subjects in unanimity rule groups seem to reject Pareto preferred proposals in order to attain more Pareto preferred outcomes later in the game. When the final round occurs, Pareto preferred proposals are occasionally not made. In other cases, proposers in unanimity rule groups appear to have problems formulating proposals that pass. Such results provide strong evidence in favor of the theoretical claims of Dougherty and Edward (2009). We also find that incomplete information does not significantly affect the results, unanimity rule and majority rule are equally likely to select outcomes which are both Pareto preferred to the initial status quo and Pareto optimal, and subjects do not propose "observationally rational" proposals in the final round.

Our results suggests that the widely held relationship between unanimity rule and Pareto optimality needs to be treated more carefully. Since majority rule is clearly more efficient in terms of process, and our results suggest it may perform well in terms of achieving efficient outcomes, majority rule may be the more efficient voting rule overall. This may vindicate the ubiquitous use of majority rule in committees, conventions, and legislatures, where its efficiency has been questioned (Niou and Ordeshook 1985; Aldrich 1995; Tsebelis 2002).

2. Experimental literature

A plethora of experimental research has been conducted on majority-rule (Fiorina and Plott 1978; McKelvey and Ordeshook 1981, 1984a, 1984b; Wilson 1986; Bianco et al. 2006, 2008). Some of the earliest works find that groups voting under majority rule are much more predictable than McKelvey and Schofield's "chaos theorem" might imply (Riker 1980).[5] For example, in a two-dimensional study, McKelvey and Ordeshook (1984a) find that if members of a committee are allowed to vote on one dimension at a time, then groups using majority rule are likely to select the outcome at the median of the ideal points in each separate dimension. This might explain stability in some settings, but it avoids multidimensional voting and the brunt of the chaos theorem. Fiorina and Plott (1978) examine the more general case where alternatives are chosen over multiple dimensions simultaneously. They find that the majority rule core[6] is a good predictor of committee behavior when the core is non-empty (i.e., when majority rule has at least one standard equilibrium). They also find that majority rule outcomes tend toward the center of the ideal points when the core is empty (i.e., when majority rule does *not* have a standard equilibrium).[7]

Bianco et al. (2006, 2008) argue that the uncovered set[8] helps explain the centralizing behavior of majority rule, particularly in cases with empty cores. Their first paper surveys eight experiments on majority rule and reports that roughly 94% of the experimental outcomes fall within the uncovered set. Conducting similar experiments of their own, their second study finds that the fraction of outcomes in the uncovered set range from 59% to 100% depending on the configuration of ideal points. Since the uncovered set is always a subset of the Pareto set (Miller 1980: 80), their results support Dougherty and Edward's (2009) claim that majority rule will consistently select Pareto optimal outcomes.[9] Nevertheless, it does not make the important comparison to unanimity rule that allows us to determine which voting rule is more likely to produce an efficient result.

Fewer experiments have been conducted on unanimity rule. Laing and Slotznick (1991) describe a series of single round, unanimity rule experiments in which the core performs better than the Condorcet alternative or the Nash-Harsanyi arbitration solution.[10] However, they note that several of their results deviate sharply from the core when the initial status quo is not in equilibrium.

Walker et al. (2000) conduct experiments on two-stage games where experimental groups first select a voting rule (majority rule or unanimity rule), then vote on the allocation of a resource using the voting rule selected. Control groups are assigned one of the two voting rules by the experimenter then vote on the allocation of resources using the rule assigned. They find that groups that are allowed to choose their voting rule are more likely to select an allocation that maximizes the sum of the payoffs than groups assigned a voting rule. Furthermore among the groups allowed to choose, if preferences are symmetric, unanimity rule produces outcomes closer to the maximum sum of payoffs than majority rule.

3. Theory

To demonstrate the theoretical differences between the claims of Buchanan and Tullock (1962), Mueller (1996, 2003), and Brennan and Buchanan (2000), on the one hand, and the claims of Dougherty and Edward (2009), on the other, consider a two-dimensional spatial voting model.

Each individual has an ideal point and prefers an alternative closer to that ideal point to an alternative farther away. Voting proceeds using a forward agenda. This means that the initial status quo q_1 is paired against a proposal p_1 in round 1. The winning alternative in round 1 is then paired against a new proposal p_2 in round 2, p_r in round r, and so on, for a total of R rounds. In what follows, we will refer to both the proposal and its corresponding location in the two-dimensional space as p_r. Similarly, q_r refers to the status quo and its location in round r. Forward agendas are consistent with Tullock (1998: 70-74) and Mueller's (2003) descriptions of how unanimity rule produces Pareto optimal results. A fixed number of rounds is common in assemblies that limit the number of amendments or limit the time allowed to make decisions (for example the U.S. Congress). It is also implicit in backward agendas.[11]

In two-dimensional space with circular indifference curves (assumed here), the Pareto set is the set of alternatives within the convex hull of ideal points, including alternatives on the edges of the hull (Ordeshook 1986; Duggan 2006). In Figure 1, this is the triangle outlining the perimeter of the ideal points. The Pareto set is the set of all Pareto optimal (*PO*) alternatives.

This set can be compared to the set of alternatives that are both Pareto preferred to the initial status quo and Pareto optimal ($PP(q_1)\&PO$). For any fixed set of ideal points, the location of the $PP(q_1)\&PO$ set depends on the location of the initial status quo. For example, if $q = q_1$ in Figure 1b, then the $PP(q_1)\&PO$ set is the area shaded. In Figure 1a, the $PP(q_1)\&PO$ set is empty because the status quo is Pareto optimal.

Which criteria is more appropriate may depend upon the context. Pareto optimality is common in the social choice and legislative decision making literatures (Fiorina and Plott 1978; Aldrich 1995; Mueller 2003,:138-43; Bianco et al. 2008), while $PP(q_1)\&PO$ is common in public economics and the study of common pool resources (Buchanan and Tullock 1965; Walker et al. 2000; Mueller 2003: 67-72; Weimer and Vining 2005: 56). For many studies in public economics, it is important to know whether voluntary contributions improve upon the initial allocation of no one contributing. For studies of government decision making, requiring that Pareto optimal outcomes are also Pareto improvements from the initial status quo restricts judgments to status quos from previous regimes and may give those regimes undue influence on policy. Although we describe our results with respect to both criteria, we focus our attention on Pareto optimal outcomes that may or may not be Pareto improvements from the initial status quo simply because the literature contains opposing views on this criterion. We do not value one criterion more than the other.

3.1 Traditional claims.

Under unanimity rule, all points in the Pareto set (*PO*) are in the unanimity rule core, and all points in the unanimity rule core must be in the Pareto set (Ordeshook 1986; Colomer 2001). Alternative *x* is an element of the unanimity rule core if there does not exist another alternative *y* that a unanimity of individuals prefer to *x*. Consequently, since no proposal can beat a Pareto optimal q_r in a single round of voting, no proposal can beat the same q_r in a series of voting. In this sense, there is a one-to-one relationship between the unanimity rule core, i.e., points in equilibrium under unanimity rule, and the Pareto set (*PO*).

Now compare these predictions to majority rule. Researchers have demonstrated that unless the distribution of ideal points satisfies radial symmetry (Plott 1967), the majority rule core will be empty (McKelvey 1976; Schofield 1978). In other words, for every alternative there will always be another alternative that a majority prefers to it. With a flexible agenda, majority rule can produce any alternative. An outcome would be in the Pareto set only by coincidence.

Figure 1a helps illustrate the point. Here, seven individuals choose between the status quo *q* (inside the Pareto set) and the proposal *p* (outside the Pareto set). As indicated by the cut line,[12] if the group votes under unanimity rule, it will select the Pareto optimal alternative *q*. If the group votes under majority rule, it will select the Pareto sub-optimal alternative *p*. Since many scholars assume that alternatives are in equilibrium when such equilibria exist, and unanimity rule is in equilibrium in the Pareto set while majority rule is not, it is easy to see why scholars believe unanimity rule is better at producing Pareto optimal outcomes than majority rule.

3.2 An alternative theory

Dougherty and Edward (2009) do not question these results, but they arrive at different conclusions for Pareto optimality (*PO*) *assuming the number of rounds is finite*. They base their argument on two key observations: 1) alternatives may not start in the core,[13] and 2) the proposal process affects the outcome. They consider three types of proposals in their study: random, sincere, and strategic. We briefly summarize their reasoning for each.

First, using simulations, Dougherty and Edward demonstrate that if proposals are random and voting is sincere, then majority rule is typically more likely to select a Pareto optimal outcome than unanimity rule for a finite series of votes.[14] This is because, although unanimity rule is better at retaining policies in the Pareto set (as illustrated in Figure 1a), majority rule requires a lower threshold than unanimity rule to move policy into the Pareto set (consider Figure 1b). When the forces are combined over a finite number of rounds, Dougherty and Edward find that majority rule typically benefits more from its attractive property than unanimity rule does from its retentive property. Since proposals are random and voting is sincere, complete or incomplete information should have no affect on the results.

Second, Dougherty and Edward analyze sincere proposals and sincere voting using a simple deductive argument. If individuals propose and vote sincerely, then they will always propose their ideal point, which is within the Pareto set by definition. Therefore, the only cases that distinguish the performance of the two voting rules are the cases where q_1 is Pareto sub-optimal. In these cases, majority rule would be at least as likely to move policies into the Pareto set as unanimity rule because the unanimity rule win set is a subset of the majority rule win set. Again, the information condition has no affect.

Third, Dougherty and Edward prove that if information is complete, individuals propose and vote strategically, the number of rounds is finite, and indifferent voters vote in favor of proposals, then any k-majority rule will produce a Pareto optimal outcome in subgame perfect equilibrium.[15] Majority rule and unanimity rule are simply special cases. The intuition behind this proposition is that in the final round of voting, rational proposers will propose the alternative closest to their ideal point that will defeat the current status quo. Using a geometric argument, Dougherty and Edward show that such proposals must be in the Pareto set. If the win set[16] is empty or the proposer is closest to q_R, then the proposer will propose a "throw away" alternative making q_R the outcome. In both cases the outcome must be Pareto optimal. Since their argument applies to any status quo in the final round of voting (whether Pareto optimal or Pareto sub-optimal), earlier rounds of voting are irrelevant to their proof.

Finally, for $PP(q_1)\&PO$ outcomes Dougherty and Edward show that if behavior is strategic or sincere, unanimity rule is at least as likely as majority rule to select a $PP(q_1)\&PO$ outcome. They also show that unanimity rule typically outperforms majority rule if proposals are random and voting is sincere. These results are largely consistent with the claims of the traditional literature.

3.3 Experimental hypotheses

The two sets of theories suggest six testable hypotheses that we evaluate in our experiment:

> *H1: Groups using majority rule require fewer rounds to enter the Pareto set than groups using unanimity rule.*

This hypothesis is a straightforward implication of Dougherty and Edward's random proposal hypothesis, though it can apply to sincere or strategic proposers as well. Dougherty and Edward claim that groups using majority rule will have an easier time moving policies into the Pareto set than those using unanimity rule.

H2: Groups using majority rule will be at least as likely to leave the Pareto set as groups using unanimity rule.

Traditional theory suggests that if a group of rational individuals uses unanimity rule, then they will never leave the Pareto set once they enter it. It also suggests that if the majority rule core is empty, then every alternative can be beaten by at least another alternative in the space. As a result, we should expect majority rule groups to be at least as likely to *leave* the Pareto set as unanimity rule groups, consistent with the arguments of both sets of theorists.

H3: Groups using majority rule will be at least as likely to select a Pareto optimal outcome at the end of the game as groups using unanimity rule.

This is our primary hypothesis, and it is the one which most strongly tests the competing claims. Evidence in support of the hypothesis provides evidence in favor of Dougherty and Edward's (2009) argument. Evidence against the hypothesis provides evidence in favor of the more traditional claims.

H4: Groups with complete information are more likely to select a Pareto optimal outcome at the end of the game than groups with incomplete information.

This claim is *not* explicitly made by Dougherty and Edward nor authors in the traditional literature. We include it to evaluate whether the transaction costs associated with identifying a successful proposal affect group performance. Our complete information condition should provide enough information for subjects to formulate successful proposals, while our incomplete information condition may require them to gather information about preferences through play. We expect complete information groups to be more likely to produce Pareto optimal results because they have less transaction costs.

H5: Groups using unanimity rule will be at least as likely to select a $PP(q_1)$&PO outcome at the end of the game as groups using majority rule.

Both Dougherty and Edward and the traditional literature claim that unanimity rule is particularly adept at passing outcomes that are Pareto preferred to the initial status quo q_1. Since unanimity rule retains Pareto preferred and Pareto optimal outcomes, and majority rule typically has no reason to move toward the $PP(q_1)$ part of the Pareto set, unanimity rule is at least as likely to select a *$PP(q_1)$&PO outcome* as majority rule.

For our final hypothesis, we assume: (1) information is complete, (2) q_R has a non-empty win set, and (3) q_R is not at the same location as the proposer's ideal point. Furthermore, we consider a proposal observationally rational if and only if in the final round the proposer proposes the alternative that is closest to his/her ideal point and is also in the win set of q_R, or is q_R if q_R is closest to his/her ideal point. The first three conditions remove cases that do not produce clear predictions about the proposer's behavior. This leads to *H6*.

H6: Given conditions 1-3, subjects will propose observationally rational alternatives in the final round of voting.

We focus on the final round because it is more difficult to determine whether subjects propose rationally in earlier rounds. *H6* should apply to both majority rule and unanimity rule groups.

4. Experimental design

Our experimental design is similar to the paper-and-pencil designs of Fiorina and Plott (1978), McKelvey and Ordeshook (1984a), and Bianco et al. (2008). Specifically, subjects are assigned to small groups, motions are made by the subjects, the initial status quo is always outside the Pareto set, and voting is conducted in a forward agenda by a show of hands. Two of our procedures differ noticeably from these earlier studies. We allowed no communication and we allowed the game to last exactly ten rounds. Previous experiments used no communication as a treatment, which Fiorina and Plott (1978) found to have no effect. We prohibited communication because neither of the theories we test assume communication and because we want to avoid confounding effects, such as vote trading.[17]

Previous experiments allowed subjects to vote for adjournment between rounds with a time limit on the experiment. We require a fixed number of rounds because it is a necessary assumption for Dougherty and Edward's proposition for strategic voters, which is one of the theories we would like to test. We briefly discuss the choice of stopping rules in the conclusion. Even though Bianco et al. (2008) allow subjects to vote for adjournment, the average number of rounds in our experiment, ten, exceeds the average number of rounds in both their small-N experiments, eight, and large-N experiments, slightly more than five.[18]

Subjects were recruited from various sections of Introduction to American Government at the University of Georgia and participated during their regular class time. Participating classes were divided into four groups of seven subjects each and assigned a voting rule (either majority rule or unanimity rule) and an information condition (complete or incomplete). Hence, a typical class contained four groups: majority, complete (mc); majority, incomplete (mi); unanimity, complete (uc); and unanimity, incomplete (ui). Subjects receiving complete information were provided a two-dimensional graph that contained the ideal points of the other subjects as well as their own ideal points and the location of the initial status quo. Subjects receiving incomplete information were given a similar graph that contained only their own ideal point and the location of the initial status quo. A set of seven ideal points was randomly drawn for each group from a uniform distribution on a 100 x 100 square. The set was redrawn until the initial status quo, always (10,10), was Pareto sub-optimal. For groups 17-28, we also excluded draws that contained (50,50) in the Pareto set. The latter prevented a natural focal point from affecting the results. We then assigned ideal points in matched sets. That is, each set of four groups (mc, mi, uc, ui) were assigned the same set of ideal points so that ideal points matched across treatments. This practice was maintained even if there were not enough students in a class to run four groups on the same day. The experiment included 32 groups with seven subjects each and eight different sets of ideal points (see Figure 2).

At the start of each class, the principal investigator read general instructions which described the purpose of the experiment and what subjects would do if they participated (see section 7.1). Subjects were informed of the minimum payment ($1), the maximum payment ($15), and the fact that payment depended on the distance between the final outcome and their ideal point. They were further informed that there was no chance of losing money. Subjects agreeing to participate in the experiment were randomly assigned to one of the four groups, and received a manila envelope containing instructions for the experimental rounds, a brief questionnaire,[19] and a payment form. Attached to the back of the envelope were instructions for the practice rounds and a piece of string (to measure distance to ideal points). Students declining to participate were asked to stay and observe the proceedings for educational purposes or to volunteer as a time keeper or a data recorder. Participating subjects then followed their group leader (one of the authors) to a separate room where the experiment was conducted. Each group of seven participated in a different room.

After relocating, subjects were asked to read the directions on the back of the manila envelope for the practice rounds (these directions were similar to those in section 7.2). Subjects were reminded there should be no talking during the experiment and were given five minutes to read the instructions for the practice rounds. After the subjects read the instructions, the group leader re-described proposing, voting, payment, and other experimental procedures (see section 7.1). Subjects were then given another opportunity to ask questions.

The practice rounds were identical to the experimental rounds except that experimental rounds lasted ten rounds (the practice rounds lasted four rounds), the experimental rounds started with a different status quo ((10, 10) instead of (80, 80)), and the experimental rounds utilized different ideal points. To start the experiment, the group leader stated the initial status quo and asked if anyone wanted to make a proposal. Subjects could propose any (x, y) pair between 0 and 100 inclusive, in increments of .01. A subject could propose in future rounds, but only after everyone in the group was given the opportunity to propose first, if they desired. Subjects were given 30 seconds to consider the two alternatives (the proposal and the status quo). They then voted by a show of hands that all subjects could see, which almost always occurred simultaneously. If the proposal passed, the proposal would become the new status quo for the next round of voting. As proposing and voting proceeded, the group leader recorded the subject's identification number, their proposal, and the status quo on a chalk board in the front of the room.

At the end of the practice rounds, students were instructed to return the materials for the practice rounds to the group leader. Subjects were then asked to open their sealed envelope and read over the three page instructions detailing the experimental rounds (see section 7.2). The questionnaire and payment form remained in the packet. Subjects were allowed three to five minutes to read through these instructions and to locate their new ideal point. The third page of the instructions contained the subject's new ideal point and, depending on the information condition, the ideal points of the other participants. After the subjects examined the materials, the group leader reemphasized that payment was based on the distance between the subject's ideal point and the final outcome after ten rounds of voting. The experimental rounds were then conducted following the procedure described previously.

After the experimental rounds, subjects were asked to complete the two remaining sheets in the envelope – the payment form and the subject questionnaire. The payment form asked information needed to pay the subjects by check. The subject questionnaire asked for general biographic information such as gender, ethnicity, academic major, and year of college. When subjects completed these forms they returned all materials to the manila envelope and gave it to their group leader. Subjects were then given the option of returning to the main classroom where they could learn the exact amount of their earnings, or to leave the experiment and learn their payment when they received it by mail.

5. Results

The results of the experiment are displayed in Figure 2.[20] Each frame contains one of the eight sets of ideal points used in the experiment, an asymmetric box outlining the Pareto set, a shaded area outlining the $PP(q_1)\&PO$ set, the location of the initial status quo (q), and the location of the final outcome for each of the four conditions: mc, mi, uc, ui. The most striking result is that all of the majority rule groups selected an outcome in the Pareto set. Some of the unanimity rule groups did not.

H1: Rounds to Enter the Pareto Set. As shown in Figure 3, the majority rule groups entered the Pareto set more quickly than the unanimity rule groups. After the first round, the majority rule groups were ten times more likely to be in the Pareto set than the unanimity rule groups, and they were at least 5 times more likely to be in the Pareto set as unanimity rule groups in the next three rounds. Furthermore, of the 24 groups that entered the Pareto set for at least one round, those using majority rule entered the Pareto set in an average of 1.7 rounds. Groups using unanimity rule entered the Pareto set in an average of 5 rounds. This difference is statistically significant at the .01 level. Such data provide strong evidence in favor of Hypothesis 1.

H2: Leaving the Pareto Set. We also found evidence in favor of Hypothesis 2. As the traditional literature would predict, none of the groups using unanimity rule left the Pareto set after they entered it. More surprisingly, however, only one of the groups using majority rule left the Pareto set after they entered it. This finding is contrary to the predictions of both the traditional theorists and Dougherty and Edward.

One might conjecture that our subjects did not have ample opportunity to leave the Pareto set because Pareto sub-optimal alternatives were rarely within the win set of q_r. However, this is not the case. Of the 135 rounds where a status quo for a majority rule group was in the Pareto set, the win set extended beyond the Pareto set in 106 cases (79% of the time). In these 135 cases, the proposer proposed an alternative outside the Pareto set only 18 times (13%).[21] In other words, proposers in majority rule groups had ample opportunity to propose a sub-optimal alternative that could defeat a Pareto optimal status quo, but they rarely proposed such alternative.

Three mechanisms help to explain this phenomenon. First, if subjects proposed sincerely, then they would always propose their ideal point which would be optimal. Second, if subjects proposed randomly (and voted sincerely), then they could propose Pareto sub-optimal alternatives that could pass, but that does not mean that such proposals would be likely. For each round of voting, the area where the win set intersects the Pareto sub-optimal set is smaller than the area where the win set intersects the Pareto set. This makes it unlikely that a random proposal would be both sub-optimal and pass. Third, if subjects proposed strategically as if each round were the last round and they assumed that other subjects voted sincerely as if it was the last round, then it would be rational for the proposer to propose an alternative within the Pareto set (similar to Dougherty and Edward's propositions for strategic behavior). All three explanations can explain why proposers in majority rule groups almost never proposed an alternative that would move their group outside the Pareto set despite having the opportunity to do so.

H3: Majority Rule is at Least as Likely to Select Optimal Outcomes. We found strong support for our primary hypothesis. As mentioned previously, all of the majority rule groups ended in the Pareto set. Only half of the unanimity rule groups ended there. The difference is statistically significant at the .01 level, indicating that majority rule is more likely to select a Pareto optimal outcome than unanimity rule.

This occurred because unanimity rule groups frequently get stuck at the initial status quo or a status quo they arrived at in a subsequent round. Among the 16 unanimity rule groups, six remained at the initial status quo (which was sub-optimal) while two more moved to a different sub-optimal point and remained at that point for the remainder of the game. As a result, half of the unanimity rule groups never entered the Pareto set, compared to the majority rule groups which all entered the Pareto set and were there at the end of the game.

This point can be seen more clearly in Figure 4. This figure maps the movement of majority rule group 17 and unanimity rule group 19. Both had complete information and the same set of ideal points. The arrows indicate the rounds in which the groups moved through the space. Missing numbers indicate rounds where the proposal did not pass. As was typical for our majority rule and unanimity rule groups, group 17 (majority rule) moved into the Pareto set quickly then moved within the Pareto set. Group 19 (unanimity rule) did not propose an alternative that passed until the final round, and the proposal that did pass was sub-optimal.

It is not clear why groups using unanimity rule got stuck outside the Pareto set, and there may be no single reason that applies to all subjects, but we have some conjectures. Subjects might have lacked the skills needed to propose within the win set. Although this is a reasonable conjecture, it was clearly not the case for group 19. Group 19 proposed within the winset nine out of the ten rounds.[22] Hence, failing to propose winning alternatives was not the reason why group 19 got stuck at the status quo for nine rounds. Two other conjectures might explain why subjects did not vote for Pareto preferred proposals, leading them to get stuck at an early status quo. Either subjects could not determine which alternative made them better off or they voted against Pareto superior alternatives to hold out for a better propsoal in later rounds. There are several reasons to believe the latter may be a more accurate description of group 19. First, most of the proposals from group 19 were in positions that clearly made all of the subjects better off. For example, the proposal of (20,50) was rejected by two voters over the status quo of (10,10). Second, all the subjects, except one, proposed alternatives within the win set. Unless they got lucky, these subjects had to know that the same locations made themselves better off. Third, sophisticated voters should know that accepting a Pareto preferred proposal too early would only reduce the size of the winset in later rounds, and reduce their chances of getting a more preferred outcome. Responses to the subject questionaire suggest that at least two subjects thought another subject rejected proposals for this reason. One of them wrote "there was one member who wouldn't cooperate. He just was going to vote for the last one, even when other points benefitted him more."

Nevertheless, other groups showed greater signs of incompetence. For example, only one of the proposers in group 27 (a complete information group) proposed within the winset, which was rejected. Furthermore, a subject in group 15 described the experiment as "going nowhere because I don't believe everyone understood the experiment. Unfortunately because we were doing unanimous voting, the few that didn't understand ruined the vote for everyone." Hence, there may have been a mix of sophisticated behavior and incompetent behavior that prevented some unanimity rule groups from entering the Pareto set.

To see if the relationship between majority rule and Pareto optimality holds when other factors are controlled, we also regressed a dummy variable for whether the final outcome was in the Pareto set (= 1 in, 0 if not) on dummies for the voting rule (= 1 if majority, 0 if unanimity), information condition (= 1 if complete, 0 if incomplete), and whether alternative (50, 50) was in the Pareto set (= 1 if an element, 0 if not). The (50, 50) dummy controls for a natural focal point that subjects might use to formulate proposals. To control for a claimed demographic effect on cooperation, we also included the percentage of female subjects in the group. To account for the possibility that the performance of a majority rule group is conditioned upon the information condition, we interacted the majority rule dummy with the complete information dummy.

Least squares results are presented in Table 1.[23] Since the interaction term is insignificant (as shown in the first column of the table), it is easier to interpret results without an interaction term (in the second column of the table).[24] Although the signs of the coefficients are in the expected directions, the only significant variables are the majority rule dummy and the dummy for (50, 50). The former suggests that majority rule groups are more likely to enter the Pareto set than the unanimity groups when other factors, such as the information condition, are controlled. The latter suggests that it may be easier for groups to choose an outcome in the Pareto set if (50, 50) is an element.[25]

These results provide evidence against the long standing notion that unanimity rule is particularly adept at producing Pareto optimal outcomes. Even though the majority rule core was always empty, subjects in our majority rule groups left the Pareto set only once and they returned to the Pareto set in that one case. Furthermore, even though unanimity rule is in equilibrium within the Pareto set (i.e., the unanimity rule core is the Pareto set), our results suggest that subjects using unanimity rule will not always attain equilibrium.

H4: Information and the Pareto Set. We do not find evidence in favor of our hypothesis that complete information helps groups select a Pareto optimal outcome. On the one hand, 13 of the 16 *complete* information groups ended the experiment in the Pareto set (81%). On the other hand, 11 of the 16 *incomplete* information groups ended the experiment in that set (69%). This difference is not statistically significant, with a one tailed p-value of 0.22.

Surprisingly, providing subjects with the information needed to formulate proposals and anticipate the voting behavior of others only weakly improves a subject's ability to propose alternatives that pass. As Figure 5 illustrates, both complete and incomplete information groups were moderately likely to propose alternatives in the win set in rounds 1-2. This is because the win set is larger for Pareto sub-optimal status quos than for Pareto optimal ones. When groups move towards the set of ideal points, the win set for majority rule shrinks and the information condition appears to matter. Complete information groups tend to find proposals that pass in rounds 3-5 better than incomplete information groups. By round 6, the incomplete information groups are increasingly successful at proposing in the win set, perhaps because subjects have learned the approximate location of the ideal points of the other players through play. As a result, the information condition has almost no affect on the final outcome.

H5: Unanimity Rule is at Least as Likely to Select a $PP(q_1)\&PO$ *Outcome.* As shown by the shaded regions in the frames of Figure 2, majority rule and unanimity rule groups were *equally* likely to select an outcome that was both Pareto preferred to the initial status quo and Pareto optimal. This is a bit surprising because unanimity rule only allows a proposal to pass if no one objects, which should give it advantage in selecting $PP(q_1)\&PO$ outcomes.

Five of the unanimity rule groups (3, 4, 7, 8, and 31) selected a *PP*(q_1)*&PO* outcome at the end of the game. Of the remaining eleven unanimity rule groups, seven either remained at the initial status quo or moved to a Pareto preferred location that was not Pareto optimal. Those seven cases can be explained by the retentive qualities of unanimity rule. The four remaining unanimity rule groups ended outside the *PP*(q_1) set because at least one individual from each of those groups voted against their preferences -- perhaps in a failed attempt to manipulate the outcome strategically.

Similarly, five of the majority rule groups (5, 6, 17, 21, and 22) selected a *PP*(q_1)*&PO* outcome at the end of the game. Most of the majority rule groups tended toward the center of the ideal points, as measured by the yolk.[26] This placed all the majority rule groups in the Pareto set but outside the *PP*(q_1) region in some of the cases.

H6: Observationally-Rational Proposing. We fail to find evidence that proposers behave in an observationally rational way in the final round. Of our 16 complete information groups, 11 had status quos in the final round that contained a non-empty win set and were not at the same location as the proposer's ideal point.[27] In other words, 11 met the conditions required for observational rationality. Among these, none of the final round proposers proposed an alternative that would be deemed observationally-rational. Few even came close. If we define close as within five units of the observationally-rational proposal, then only two final round proposals can be deemed close. If individuals were universally rational, we would expect all 11 of the final round proposers who met our conditions to propose within the vicinity of an observationally rational proposal. This provides fairly strong evidence against *H6*. It also raises questions about the rationality of proposers in earlier rounds where rational proposing is more difficult to observe but equally important.

Other Predictions. Finally, to facilitate comparisons with other experiments, we characterize our results with respect to other solution concepts and regions of the space (see Table 2). This table reports the percentage of groups within one of four regions at the end of the game, many of which overlap. The Nash-Harsanyi solution maximizes the product of individual payoffs in the game and might be considered a utilitarian efficient point. Laing and Slotznick (1991) describe it as a fair point because of its location in the center of the ideal points. Since this solution is always a singleton, we consider any outcome within five units of the Nash-Harsanyi solution as part of the Nash-Harsanyi set (our nomenclature). 31% of our majority rule groups produced outcomes in the Nash-Harsanyi set, compared to none of the unanimity rule groups. The difference is statistically significant at the .05 level. In this sense, majority rule might be deemed more likely to produce a "fair" or "strongly efficient" outcome than unanimity rule.

Similarly, 69% of our majority rule groups selected outcomes in the yolk or within one unit of yolk, while none of the unanimity rule groups selected such locations. The yolk is another measure of the centrality. It typically covers a larger region than the Nash-Harsanyi set which partly explains why it is a better predictor.

Our results also produce slightly weaker support for the uncovered set than previous work by Bianco et al. (2006, 2008). Bianco et al. (2008) found that 59% to 100% of their majority rule groups produced outcomes in the uncovered set, depending upon the number of players and the configuration of ideal points. Less than half of our majority rule groups (43.8%) produced outcomes in the uncovered set. The difference might be due to different configurations of ideal points.[28]

6. Conclusion

Since Arrow's seminal work (1951), unanimity rule and Pareto optimality have been treated as practically synonymous. Arrow described the Pareto principle as a unanimity principle. Fishburn (1973) referred to the Pareto criterion as strong unanimity. And Buchanan (1967: 285) described unanimity rule as the "the political counterpart of the Pareto criterion for optimality."[29] The claim has been reinforced by equilibrium analyses in the multidimensional spatial voting literature, where it has been shown that the unanimity rule core is Pareto optimal and the majority rule core is typically empty. Since Shepsle (1979, 1986), the dominant explanation for the stability of majority rule has been institutional, not something related to the voting rule itself or to the incentives of the proposer. Combined, the common understanding among scholars is that unanimity rule produces efficient outcomes and, without institutional constraints, majority rule produces just about anything (Riker 1980).

Our experiments suggest differently. We demonstrate that unanimity rule may not be particularly adept at selecting Pareto optimal outcomes if the starting point is not in equilibrium. Furthermore, majority rule enters the Pareto set fairly quickly and typically does not leave as one might expect. Testing groups of subjects with forward agendas, changing proposers, and finite rounds of voting, we find that all of our majority rule groups were in the Pareto set in the final round of the game. In contrast, our unanimity rule groups were less likely to enter the Pareto set than our majority rule groups because members of our unanimity rule groups were either voting strategically, as may be the case for group 19, or did not propose alternatives that everyone preferred to the status quo. In other words, majority rule groups did not "wander anywhere" and unanimity rule groups did not make it to their standard equilibria. These results hold for a diverse distribution of ideal points and different information conditions. They corroborate Dougherty and Edward's (2009) claim that out-of-equilibrium behavior can affect the results.

We also found that majority rule groups were at least as likely as unanimity rule groups to select outcomes that are both Pareto preferred to the initial status quo and Pareto optimal. Hence, even in terms of this more restrictive criterion, unanimity rule may not be superior.

Of course, every institution and every set of instructions can affect an experiment. In comparing our experiment to other majority rule experiments, it is important to note the difference in stopping rules. Fiorina and Plott (1978), McKelvey and Ordeshook (1984a), and Bianco et al. (2008) stop their groups when a majority of a group's members vote to adjourn. We stopped our groups after exactly ten rounds to test a conjecture that assumes a fixed number of rounds. We fully admit this institution may affect the results. Nevertheless, subjects voting to stop a game should be constantly concerned about the game ending prior to a fixed stopping point, such as prior to our tenth round, and they may have less opportunity to propose and vote strategically with such expectations in mind. These factors might explain why the average number of rounds was shorter in the experiments of Bianco et al. (2008) than in ours.

Furthermore, voting for adjournment allows subjects to behave strategically over adjournment which is typically not part of the theoretical model tested. Hence, the effect of allowing such an institution is unclear. A fixed stopping rule avoids this problem. It facilitates strategic voting and proposing, without extending strategic behavior to votes for adjournment.

Standard game theory makes it clear that unanimity rule is the ideal voting rule for maintaining Pareto-optimal outcomes (Colomer 2001: 71–73). However, our experiment suggests that majority rule is much better at attaining Pareto-optimal outcomes than unanimity rule, and is also surprisingly effective at maintaining them. Both considerations are important. If institutional framers want Pareto efficiency (or perhaps even Pareto efficiency that is Pareto superiority to the status quo), then they may want to consider both the properties of attraction and retention before they require consensus for votes on optimal quantities of public goods (Cornes and Sandler 1996), legislative outcomes (Aldrich 1995; Niou and Ordeshook 1985), or assembly rules (Buchanan and Tullock 1962).

7. Appendix

What follows are the verbal and written instructions provided to subjects prior to play. The use of these instruments is described in the text.

7.1 General instructions (before breaking into groups).

We are going to conduct an experiment on the properties of voting rules in two-dimensional spatial voting models. This should help us test some theories about the differences between majority rule and unanimity rule and help you get exposure to some of the science behind political science.

Subjects who choose to participate will be randomly assigned to one of _(4)_ groups. We will run our experiments in these groups – one voting under majority rule, another voting under unanimity rule – for 10 rounds. When the experiments are done, you will fill out a brief questionnaire and payment form. You will get paid based on the distance between the final outcome and your ideal point as outlined in the instructions. The maximum you can get paid is $15. The least you will get paid is $1. We will tell you how much you will get paid at the end of the experiment.

We will now pass out two consent forms (one for you and one for us). If you are interested in participating, please read and fill out the consent forms.

We will now go around the room and assign subjects to groups. Please keep your packets face down until we ask you to turn them over. Your participation is entirely voluntary. If you do not want to participate, please say so when we come to you, and we will pick up your forms. We can only use ___ of you today, so unfortunately we will have to skip some of you. We ask that students who do not participate stay in the class and observe the proceedings for educational purposes. You might even be able to help us keep time or record information in the experiment, if you'd like. If you do help us, then we will give you your choice of a candy bar or a breakfast bar as a token of our appreciation.

The leader of your group will describe the method of proposing alternatives and how voting will proceed. We hope you enjoy the experiment.

7.1.1 Majority rule instructions (group leader: upon arrival in the experimental room). Please turn over your packets and read the instructions for the practice rounds. We will be voting for 4 rounds so that you can get the hang of what we will be doing in the experimental rounds. There should be no talking, or other communication, during the experiment [pause: roughly 5 minutes for instruction reading].

Voting will proceed as follows. Any one of you can raise your hand and propose an alternative, which is identified by any pair of numbers between 0 and 100 inclusive (real numbers in increments of .01 are acceptable). For example, you may propose (50, 0) or you may propose (.01, .81). Proposal values can be repeated as many times as the group wants but ***each person will be allowed to propose once before anyone is allowed to propose a second or a third time***. To propose, first state your identification number (on the top left hand corner of the payoff page), then the x and y values of your proposal (between 0 and 100 inclusive). After a proposal is made we will allow 30 seconds for members of your group to think about the choices. We will then vote on the proposal versus the status quo (the alternative we have now) by a show of hands. ***A proposal passes if more subjects vote yea than nay***. If the proposal passes, it will become the new status quo. If it does *not* pass, then the status quo remains the same. In the practice rounds, voting continues for exactly 4 rounds. In the 4^{th} round, voting stops. If this were the actual experiment, you would be paid based on the distance between the alternative selected at the end of the game and your ideal point. The closer the final alternative is to your ideal point, the more you will get paid. The exact amount you will get paid will be presented before the experimental rounds. Any questions?

There is no talking or communication during the experiment. We also ask that you cover-up your paper so that others don't see your ideal point. [run 4 practice rounds]

Please pass your papers related to the practice rounds to the front of the room. [after collecting] Please open your manila envelopes and pull out the stapled papers (this should be the first of three forms in the envelope. The other two are a brief questionnaire and a payment form that you will fill out later). Please take a moment and read over the instructions on the stapled sheet. [pause: roughly 3 minutes].

We will now vote in the experimental rounds following the same procedures as we did before. However, voting will continue for exactly 10 rounds, and you have probably received a new ideal point. Your ideal point is on the third page, not the second page. The second page only helps you to understand the payment schedule. You will get paid based on the distance between the alternative selected at the end of the game (on the third page) and your ideal point. The closer the final alternative is to your ideal point, the more you will get paid. If the final outcome is at your ideal point, you will receive the maximum amount which is $15. If the final outcome is extremely far away from your ideal point, you will receive the minimum payment of $1. Any questions?

[run experimental rounds – 10]. Now that the experiment is over, there are two things that we need you to do before we return to the original room. *First*, pull out the remaining sheets of paper from the envelope and answer the questions on the brief questionnaire. Your responses are voluntary. [pause momentarily]. *Second*, please fill out your payment form completely, including your group number and subject id number on the top. If you would like to get paid, we need your social security number for tax purposes. Ten digit student id numbers cannot be used for this purpose. We go to great lengths to protect your social security number. For example, as soon as your payment is processed, this form will be shredded, and no record of your personal information will be kept with experimental information.

[when finished] Please put all your materials back into your manila envelope. If you would like to know how much you will be paid, please follow me back to your classroom. If you want to leave now, please hand me your packet. In either case, you will receive a check in the mail shortly. Thanks for participating.

7.2. Written instructions (experimental rounds).

General Structure:

Each subject is assigned an ideal point, which is a point of greatest payoff on a square. As a group, you will vote on alternatives (points in the square) in a pair-wise fashion using ***simple majority rule***. At the end of voting, you will receive payment based on how close the final alternative is to your ideal point. ***The closer the final alternative is to your ideal point, the more you get paid***.

Specifics:

Voting will proceed as follows. When we start, the original alternative or status quo on the floor will be ***(10, 10)***. Any one of you can then raise your hand and propose another alternative, which is identified by any pair of numbers between 0 and 100 inclusive (real numbers in increments of .01 are acceptable). For example, you may propose (50, 0) or you may propose (.01, .81). Proposal values can be repeated as many times as the group wants, but ***each person will be allowed to propose once before anyone is allowed to propose a second or a third time***. To propose, first state your identification number (on the top left hand corner of the third page), then the x and y values of your proposal (between 0 and 100 inclusive). After a proposal is made, we will allow 30 seconds for members of your group to think about the choices. We will then vote on the proposal versus the alternative on the floor. ***If the proposal wins a simple majority (i.e., more subjects vote yea than nay), then it will become the new alternative on the floor.*** If it does *not* win a majority, or there is a tie, then the alternative on the floor remains the same. Voting continues for exactly 10 rounds. In the 10^{th} round, voting stops and subjects are paid based on the distance between the alternative selected at the end of the game and their ideal point. The closer the final alternative is to your ideal point, the more you get paid. See the attached page for specifics.

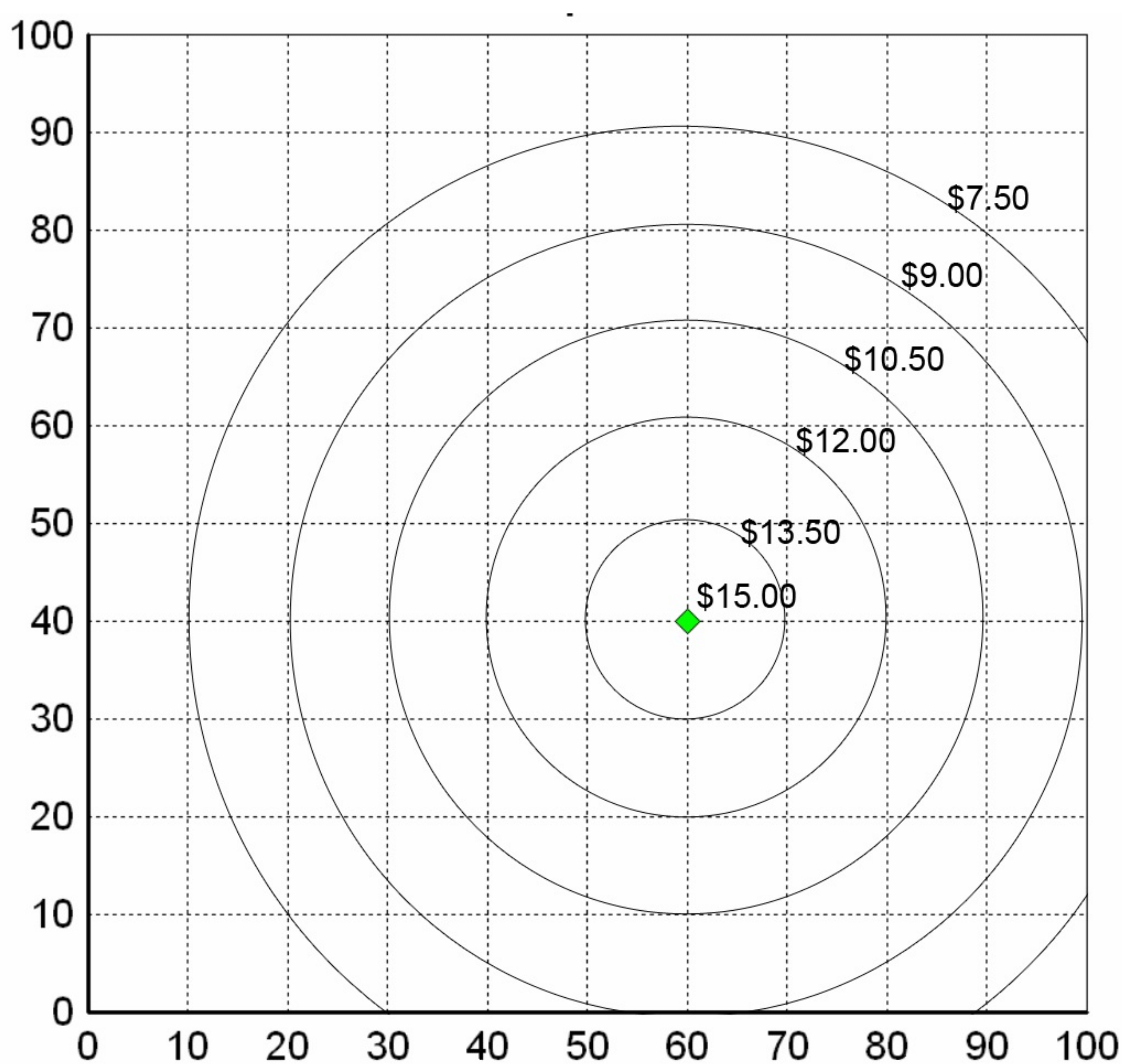
All activities that occur during the experiment are described on this page and the subsequent pages which detail the payment schedule. A very brief exit questionnaire will also be handed out at the end of the experiment. There will be no coercion, and you have the right to leave at any time.

PLEASE, NO TALKING DURING THE EXPERIMENT!

Payment Schedule

Each of you will receive payment based on the distance between your ideal point and the alternative prevailing at the end of the game. You will receive $15.00 for an outcome exactly on your ideal point, $13.50 for an outcome 10 units away from your ideal point, $12.00 for an outcome 20 units away from your ideal point, etc. Payments will be in dollars and cents. Hence, an outcome 9 units away from your ideal point will give you $13.65.

To get a better feel for the payment schedule, consider the graph presented below. This individual has an ideal point at (60, 40) – probably different than yours. He/she would receive $15 for an outcome exactly at (60, 40); $13.50 for an outcome at (70, 40), etc. Note that payments are based on the final outcome of the game. Intermediary steps are not considered in the payment. Further note that each of you will receive ***at least*** $1 for participating and there is no chance that anyone will lose money.

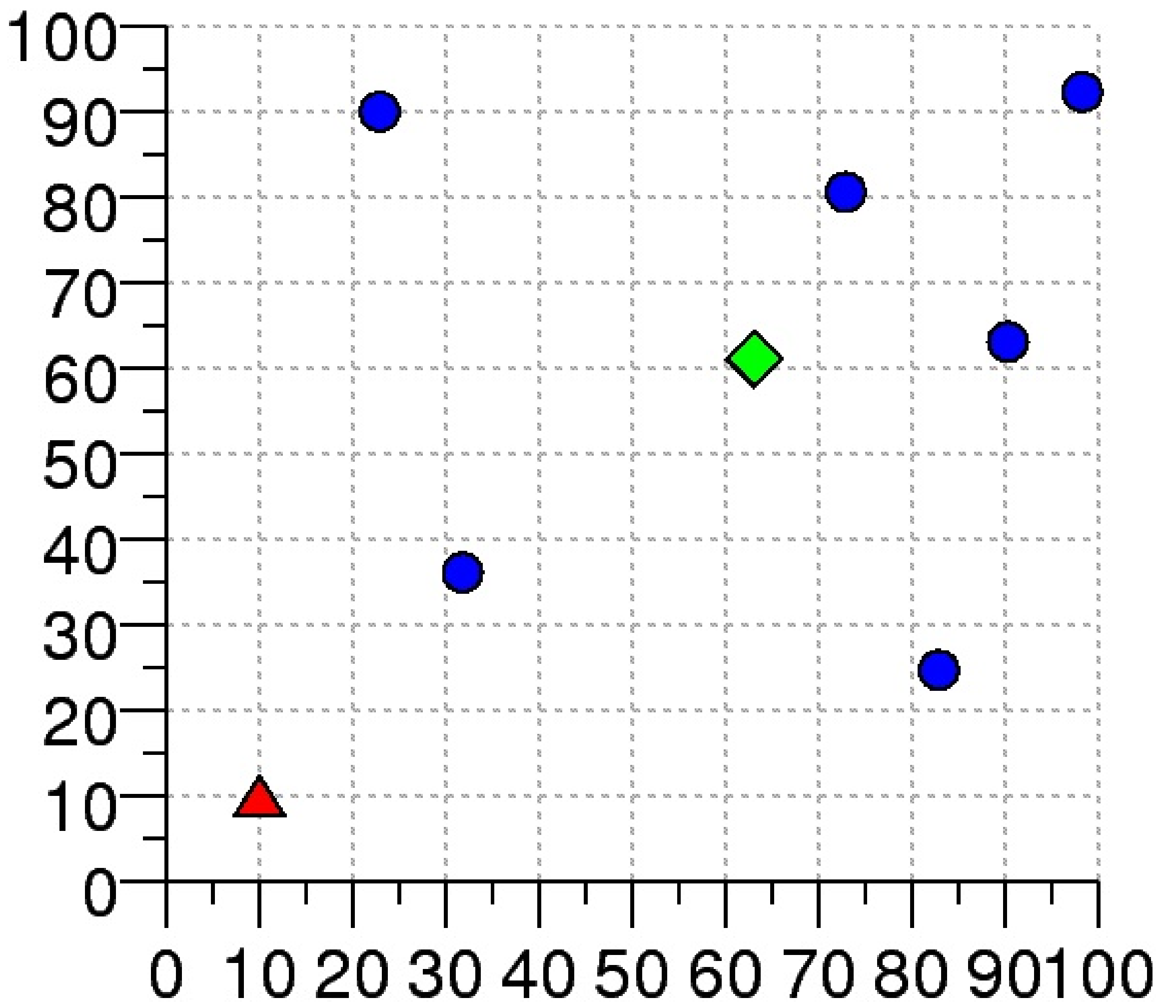


Experimental Round

YOUR GROUP NUMBER: 1 YOUR IDENTIFICATION NUMBER: 1

YOUR IDEAL POINT: (63.1, 61.1)

Each member of your group is assigned an ideal point on a 100 x 100 square as indicated in the first graph below. Your ideal point is indicated by the green diamond. The ideal points of the other members are indicated by the blue circles. The initial alternative (status quo) is indicated by the red triangle.



Endnotes

1. Throughout the paper, we use the term "majority rule" to refer to simple majority rule (a proposal passes if and only if the yeas exceed the nays) and "unanimity rule" to refer to simple unanimity rule (a proposal passes if and only if the yeas > 0 and the nays = 0). See Riker (1982) for details.

2. Assuming that all individuals vote yea or nay, a k-majority rule requires at least k individuals to vote in favor of a proposal in order for the proposal to pass, where $N/2 < k \leq N$ and N is the number of individuals; otherwise the status quo is chosen. Two special cases of k-majority rule are majority rule ($k = (N+1)/2$, for N odd) and unanimity rule ($k = N$). See Dougherty and Edward (2004) for more precise definitions when non-voters and "votes to abstain" are permitted.

3. Pareto optimality, also known as Pareto efficiency, is the most widely accepted criterion for evaluating efficiency. Technically, an alternative is Pareto optimal if no other alternative is Pareto preferred to it. That is, no other alternative can make at least one individual better off without making another individual worse off.

4. See Dougherty and Edward (2005) for a similar analysis in one dimension.

5. The "chaos theorem" states that in n-dimensional space, unless ideal points are radially symmetric, no alternative is in equilibrium using pairwise majority rule. In other words, for every alternative in the space, there is another alternative that a majority of individuals prefer to it. Ideal points are radially symmetric around an alternative x if there is an ordinal, pairwise symmetry of all the ideal points along any vector passing through x -- a rare condition (Hinich & Munger 1997: 65).

6. The core is the set of alternatives that cannot be defeated using the specified voting rule. More specifically, alternative *x* is an element of the majority rule core if there does not exist another alternative *y* that a majority prefers at least as much as *x*.

7. For experiments suggesting that distributive fairness may affect majority rule voting behavior, see Miller and Oppenheimer (1982). For a related theoretical argument, see Oppenheimer and Frohlich (2007).

8. Loosely, an uncovered alternative is any alternative that can defeat any other alternative, using majority rule, in two or fewer steps (Penn 2006). More precisely, Bianco et al. (2006, 2008) define the uncovered set as the set of all points not covered by other points. A point *x* is covered by point *y* if more than half of the individuals prefer *y* to *x* (i.e., find *y* closer to their ideal points than *x*) and any point *z* that more than half of individuals prefer to *y* is also preferred by more than half of the individuals to *x*. We use the same definition in section 5.

9. Note that Fiorina and Plott (1978), Bianco et al. (2008), and other authors found cases where majority rule groups did not select Pareto optimal outcomes at the end of their game.

10. Under unanimity rule, the Condorcet alternative (if it exists) is the alternative that is unanimously preferred to all other alternatives. If *q* is the status quo, the Nash-Harsanyi arbitration solution is the alternative *z* that maximizes the product $\prod_{i \in N} [u_i(z) - u_i(q)]$. For Euclidean preferences, assumed here, such an alternative is in the "middle" of the ideal points (Laing and Slotznick 1991).

11. Wilson (1986) conducts a series of majority rule experiments on backward and forward agendas. In a backward agenda, individuals propose alternatives $p_1, \ldots, p_R$ and the voting proceeds p_R against p_{R-1}, winner against p_{R-2}, etc., with the remaining proposal paired against the

status quo, q_1. Wilson finds that majority rule is more likely to deviate from the initial status quo under a forward agenda than under a backward agenda, consistent with the theory of structurally induced equilibria (Shepsle 1979).

12. A cut line demarcates the space between individuals who prefer the status quo and individuals who prefer the proposal. With Euclidean preferences, the cut line is perpendicular to a line connecting *p* and *q* and it intersects such a line at its midpoint.

13. There is a long tradition in the behavioral/evolutionary game theory literature, and especially in the agent based modeling literature, of examining the importance of out-of-equilibrium outcomes (Mailath 1998; Arthur 2006). Camerer et al. (2004: 121) capture the sentiment by writing, "[I]n the modern view, equilibrium should be thought of as the limiting outcome of an unspecified learning or evolutionary process that unfolds over time. In this view, equilibrium is the end of the story of how strategic thinking, optimization, and equilibration (or learning) work, not the beginning (one-shot) or the middle (equilibration)."

14. The finite series can be any length R. However, Dougherty and Edward examine $R \leq 1{,}000$.

15. Dougherty and Edward conjecture that if indifferent voters abstain, then any k-majority rule would produce an outcome in the Pareto set or one infinitesimally close to the Pareto set. See Duggan (2006) for a similar treatment of indifferent voters and a similar result.

16. The win set is the set of alternatives that can beat the status quo q_r in round r given the voting procedure and sincere voters.

17. Walker et al. argue that the absence of communication may help subjects in unanimity rule groups reach agreement because "no one could threaten the others or hold them hostage" (2000: 232).

18. Like most experiments, we pay subjects at the end of the game. Our maximum payoff is three dollars greater than the maximum payoff offered by Bianco et al. (2008) for their large-N treatments and three dollars less then the maximum payoff of their *S1*, small-N treatment.

19. Subject responses to the questionaire are available upon request.

20. A total of 224 subjects participated in the study: 64% were freshman, 24% sophomores, 8% juniors, and 4% seniors. Since American Government is required of all students at the university, majors varied greatly. The modal major was in the category of health, medicine, or veterinary sciences (42 subjects), while only 17 subjects majored in a social science. Women were 70% of the participants in a university comprised of 57% females.

21. In 17 of the 18 cases where a sub-optimal alternative was proposed, the proposer failed to propose inside the win set. In the one remaining case, the proposer proposed a sub-optimal proposal that passed but the group ultimately returned to the Pareto set before the game ended.

22. The one exception was the subject in the top left corner of the figure who proposed her ideal point.

23. For dichotomous dependent variables using least squares regression can produced theoretically inadmissable predicted values – greater than one or less than zero. It can also lead to heteroskedasticity. Although logit or probit would be more appropriate, neither were used here because *majority* (= 1) predicted the dependent variable (= 1) perfectly. Such perfect predictions prevent maximum likelihood estimates from converging. As a result, we estimate our regressions using least squares with robust standard errors. However, we caution readers not to over-interpret the marginal effects of these results.

24. Regressing the dummy for ending in the Pareto set on the complete information dummy, the

focal point dummy, and the percent female *using the unanimity rule groups alone* (N=16), further suggests that complete information does not significantly affect unanimity rule's ability to select Pareto optimal outcomes.

25. The Pareto set was typically larger in cases where (50, 50) was an element. Hence, there may be multiple explanations for this relationship.

26. In two dimensions, the yolk is the smallest circle that intersects all “median” lines. A median line demarcates the space such that the exact same number of voters on are opposite sides of the median line (McKelvey 1986; Feld et. al 1988). Eleven of the sixteen majority rule groups ended in the yolk or within one unit of the yolk.

27. The remaining 5 were unanimity rule groups that were within the Pareto set in the final round. Hence, their win sets were empty.

28. It is not surprising that our unanimity rule groups were less likely to end in the uncovered set because the set of uncovered points varies by voting rule. The unanimity rule uncovered set appears to be the Pareto set.

29. See Dougherty and Edward (2011) for a list of differences between unanimity rule and the weak Pareto criterion.

8. References

Aldrich, J. (1995). *Why parties?: the origin and transformation of party politics in America.* Chicago: University of Chicago Press.

Arthur, W. B. (2006). Out-of-equilibrium economics and agent-based modeling. In K.L. Judd and L. Tesfatsion (Eds.), *Handbook of computational economics, vol. 2: agent-based computational economics*. Amsterdam: North-Holland.

Bianco, W. T., Lynch, M. S., Miller, G. J., & Sened, I. (2006). 'A theory waiting to be discovered and used': a reanalysis of canonical experiments on majority rule decision making. *Journal of Politics*, 68(4), 837-850.

Bianco, W. T., Lynch, M. S., Miller, G. J., & Sened, I. (2008). The constrained instability of majority rule: experiments on the robustness of the uncovered set. *Political Analysis*, 16(2),115-137.

Brennan, G. & Buchanan, J. M. (2000). *The reason of rules*. Indianapolis: Liberty Fund.

Buchanan, J. M. (1967). *Public finance in democratic process*. Chapel Hill: The University of North Carolina Press.

Buchanan, J. M. & Tullock, G. (1962). *The calculus of consent*. Ann Arbor: The University of Michigan Press.

Chen, Y., and Ordeshook, P. C. (1998). 'Veto games: spatial committees under unanimity rule.' *Public Choice*, 97(4), 617–43.

Colomer, J. H. (2001). *Political institutions: democracy and social choice*. New York: Oxford University Press.

Cornes, R. & Sandler, T. (1996). *The theory of externalities, public goods, and club goods*, 2nd ed. New York: Cambridge University Press.

Camerer, C., Ho, T., & Chong, J. (2004). Behavioral Game Theory: Thinking, Learning, and Teaching. In S. Huck (Ed.), *Advances in understanding strategic behaviour: game theory, experiments, and bounded rationality: essays in honour of Werner Güth*. Basingstoke: Palgrave.

Dougherty, K. L. & Edward, J. (2004). 'The Pareto efficiency and expected costs of k-majority rules. *Politics Philosophy and Economics*, 3(2), 161–89.

Dougherty, K. L. & Edward, J. (2005). A non-equilibrium analysis of unanimity rule, majority rule, and two Pareto concepts. *Economic Inquiry*, 43(4), 855-64.

Dougherty, K. L. & Edward, J. (2009). Voting for a Pareto efficient constitution. Mimeo. University of Georgia.

Dougherty, K. L. & Edward, J. (2010). *The calculus of consent and constitutional design*. New York: Springer Publishing.

Feld, S. L., Grofman, B., & Miller, N. (1988). Centripetal forces in spatial voting: on the Size of the yolk. *Public Choice*, 59(1), 37-50.

Fiorina, M. P., & Plott, C. R. (1978). Committee decisions under majority rule: an experimental study. *American Political Science Review,* 72(2), 575–98.

Fishburn, P. C. (1973). *The theory of social choice*. Princeton: Princeton University Press.

Heckelman, J. C. & Dougherty, K. L. (2010). Majority rule versus supermajority rules, their effects on narrow and broad taxes. *Public Finance Review*, 38(6), 738-761.

Hinich, M. J. & Munger, M. C. (1997). *Analytical politics*. New York: Cambridge University Press.

King, R. R. (1994). An experimental investigation of super majority voting rules, implications for the financial accounting standards board. *Journal of Economic Behavior and Organization,* 25(2), 197-217.

Laing, J. D. & Slotznick, B. (1991). When anyone can veto, a laboratory study of committees governed by unanimous rule. *Behavioral Science*, 36(3), 179-95.

Lindahl, E. ([1919] 1967). Just taxation—a positive solution. In R. Musgrave & A. Peacock (Eds.), *Classics in the theory of public finance*, (pp. 168–76). New York: St. Martin's Press.

Mailath, G. J. (1998). Do people play nash equilibrium? Lessons from evolutionary game theory. *Journal of Economic Literature*, 36 (3), 1347-74.

McKelvey, R. D. (1976). Intransitivities in mulitdimensional voting models and some implications for agenda control. *Journal of Economic Theory,* 12, 472–82.

McKelvey, R. D. (1986). Covering, dominance, and institution-free properties of social choice. *American Journal of Political Science,* 30(2), 283-314.

McKelvey, R. D. & Ordeshook, P. C. (1981). Experiments on the core, some disconcerting results for majority rule voting games. *The Journal of Conflict Resolution*, 25(4), 709-24.

McKelvey, R. D. & Ordeshook, P. C. (1984a). An experimental study of the effects of procedural rules on committee behavior. *Journal of Politics*, 46(1), 182–205.

McKelvey, R. D. & Ordeshook, P. C. (1984b). Rational expectations in elections, some experimental results based on a multidimensional model. *Public Choice*, 44(1), 182-205.

Miller, G. J., & Oppenheimer, J. A. (1982). Universalism in experimental committees. *American Political Science Review*, 76(3), 561–74.

Miller, N. (1980). A new solution set for tournament and majority voting. *American Journal of Political Science,* 24(1), 68–96.

Mueller, D. (1996). *Constitutional Democracy*. New York: Oxford University Press.

Mueller, D. (2003). *Public Choice III*. New York: Cambridge University Press.

Niou, E. & Ordeshook, P. C. (1985). Universalism in Congress. *American Journal of Political Science,* 29(2), 246-58.

Oppenheimer, J. A. & Frohlich, N. (2007). Justice preferences and the arrow problem. *Journal of Theoretical Politics,* 19(4), 363-90.

Ordeshook, P. C. (1986). *Game theory and political theory*. New York: Cambridge University Press.

Penn, E. M. (2006). Alternate definitions of the uncovered set and their implications. *Social Choice Welfare*, 27, 83-7.

Plott, C. R. (1967). A notion of equilibrium and its possibility under majority rule. *American Economic Review,* 57(4), 787–806.

Riker, W. H. (1980). Implications from the disequilibrium of majority rule for the study of institutions. *American Political Science Review*, 74(2), 432-46.

Riker, W. H. (1982). *Liberalism against populism*. Prospect Heights, IL: Waveland Press.

Schofield, N. J. (1978). Instability of simple dynamic games. *Review of Economic Studies,* 45(3), 575–94.

Shepsle, K. A. (1979). Institutional arrangements and equilibrium in multidimensional voting models. *American Journal of Political Science*, 23(1), 27-59.

Shepsle, K. A. (1986). Institutional equilibrium and equilibrium institutions. In H. Weisberg (Ed.), *Political science, the science of politics*, (pp. 51-81). New York: Agathon.

Tsebelis, G. (2002). *Veto players, how political institutions work*. New York: Russell Sage Foundation.

Tullock, G. (1998). *On voting, a public choice approach*. Northampton, MA: Edward Elgar.

Walker, J. M., Gardner, R., Herr, A., & Ostrom, E. (2000). Collective choice in the commons, experimental results on proposed allocation rules and votes. *The Economic Journal*, 110 (460), 212-34.

Weimer D. L., & Vining, A. R. (2005) *Policy analysis, concepts and practice,* 4th edition. Saddle River, NJ: Prentice Hall.

Wilson, R. K. (1986). Forward and backward agenda procedures, committee experiments on structurally induced equilibrium. *Journal of Politics*, 48(2), 390–409.

Table 1: Determinants of final outcomes in the Pareto set

Majority	0.620*	0.503*
(dummy)	(0.173)	(0.124)
Complete	0.243	0.125
(dummy)	(0.235)	(0.124)
Majority ×	-0.235	
Complete	(0.247)	
(50,50) Focal	0.265*	0.265*
(dummy)	(0.124)	(0.124)
% Female	0.001	0.002
	(0.003)	(0.003)
Constant	0.115	0.141
	(0.276)	(0.267)
N	32	32
R^2	0.467	0.350

Note: The table reports OLS estimates, with unconditional, robust standard errors in parentheses.

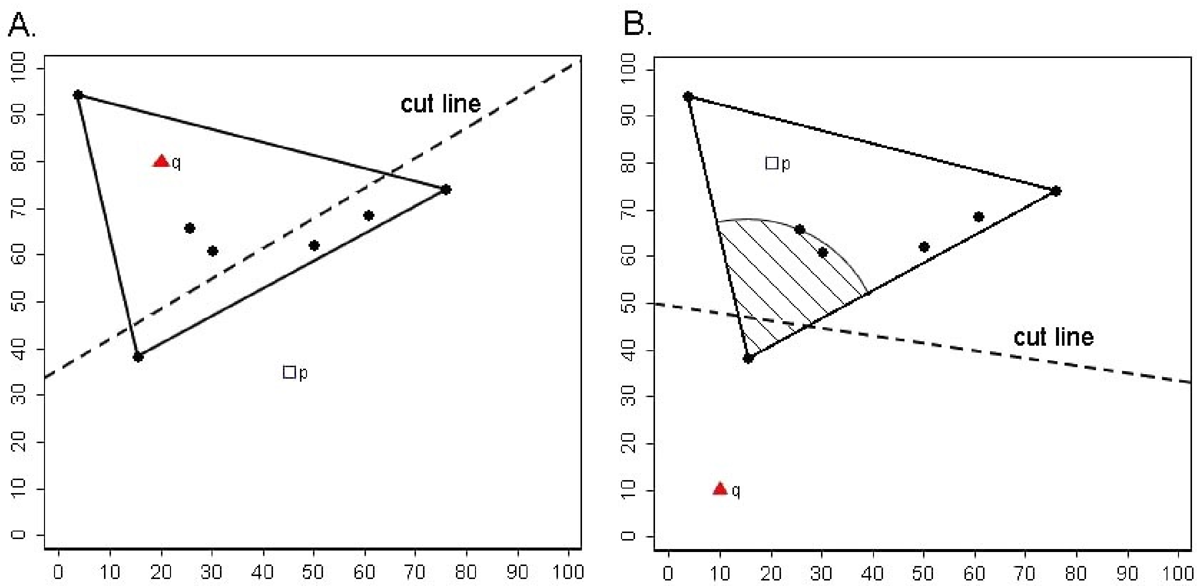
* p-value $\leq$ .05.

Table 2. The percentage of final round outcomes in specified regions

	Majority Rule	Unanimity Rule
Nash-Harsanyi Set	31.3%	0.0%
Yolk	68.8%	0.0%
Uncovered Set	43.8%	12.5%
$PP(q_1)\&PO$	31.3%	31.3%
Pareto Set	100.0%	50.0%

Notes: The Nash-Harsanyi set includes any outcome within 5 units of the Nash-Harsanyi solution (always a singleton). Both voting rules are compared in their ability to select an element of the majority rule, uncovered set.

Figure 1. Retention and attraction



Notes: Subject ideal points are marked by black circles, the status quo *q* is marked by a red triangle, and the proposal *p* is marked by an open square. The Pareto set is the convex hull of the ideal points, indicated by the large triangular area. The $PP(q_1)\&PO$ set is indicated by the shaded region.

Figure 2. Outcomes and ideal points

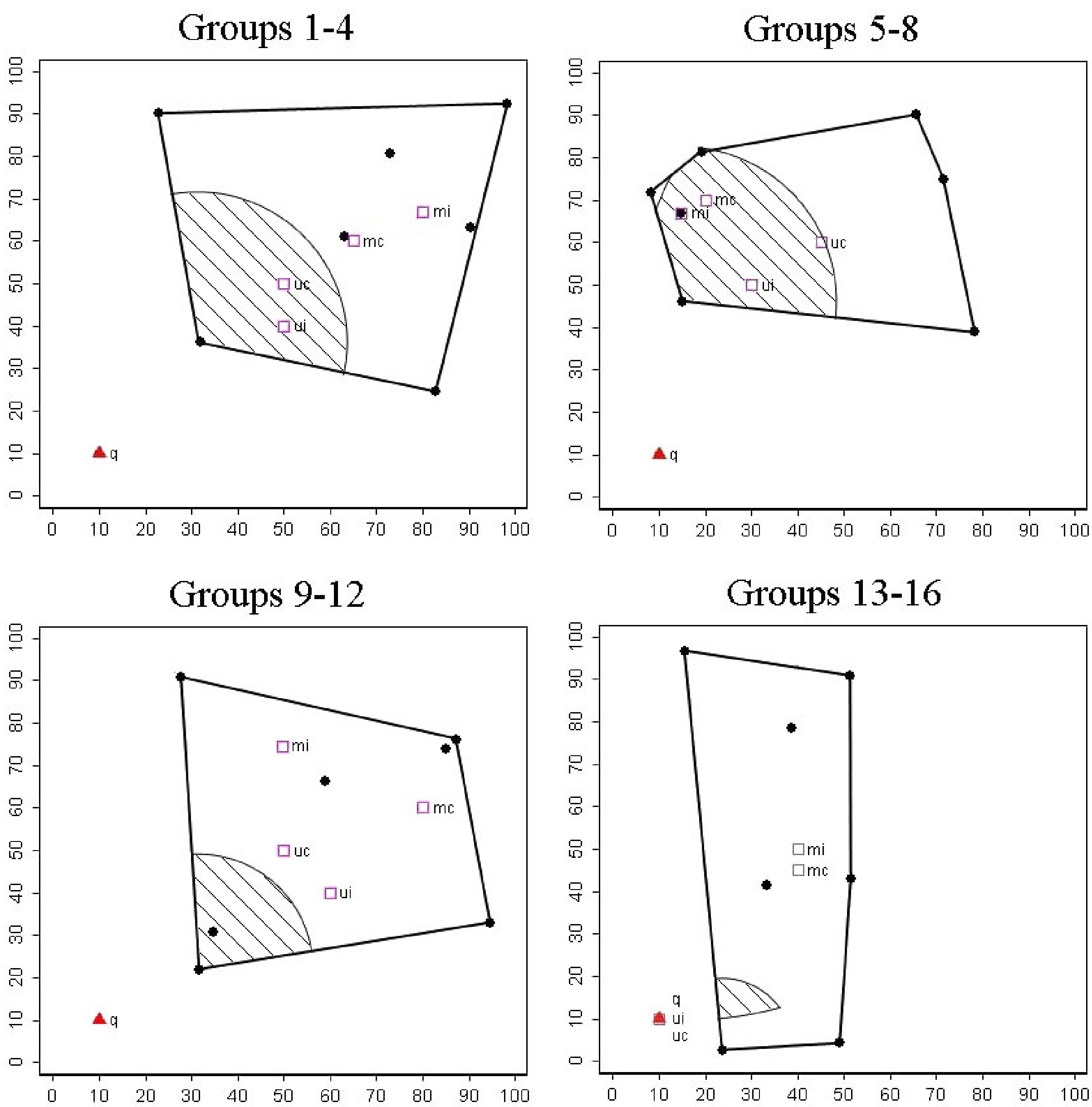


Figure 2. Outcomes and Ideal Points, Cont.

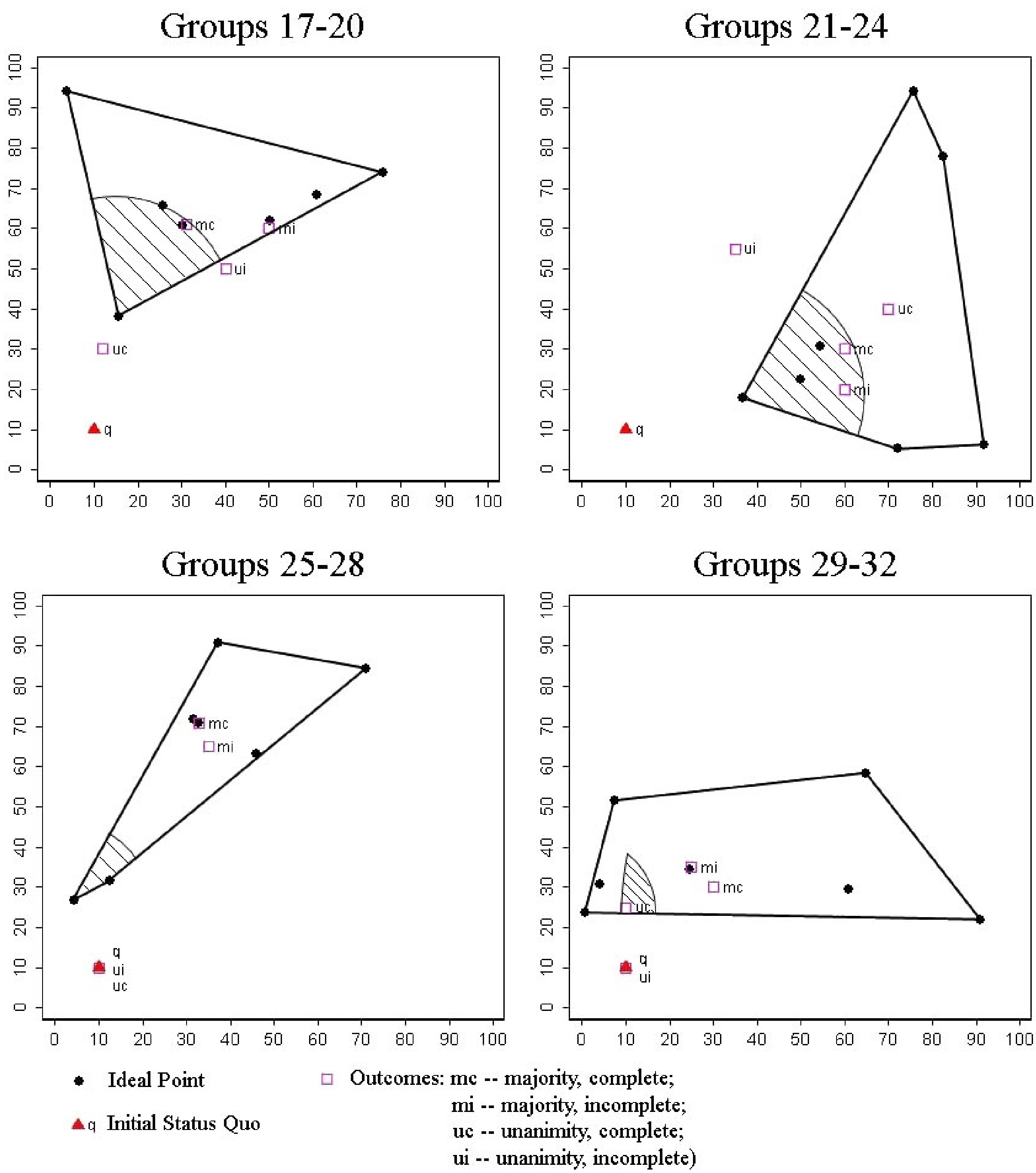


Figure 3. Percentage of groups in the Pareto set at the end of each round

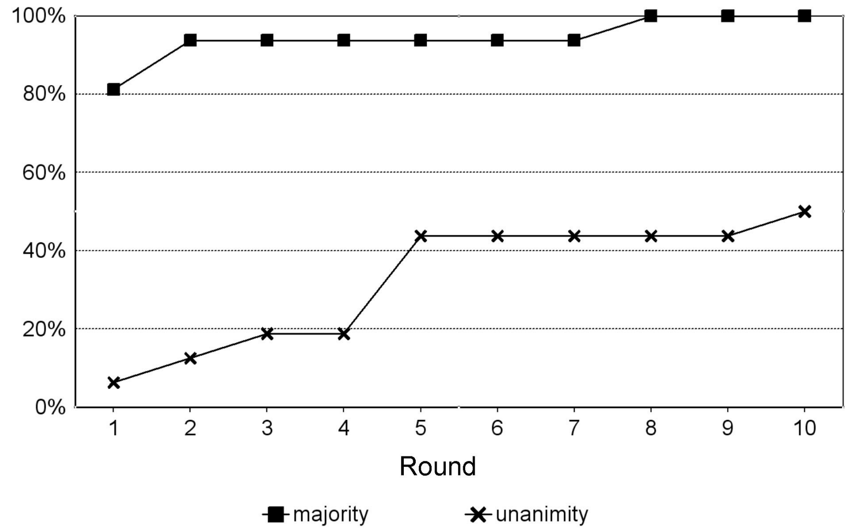
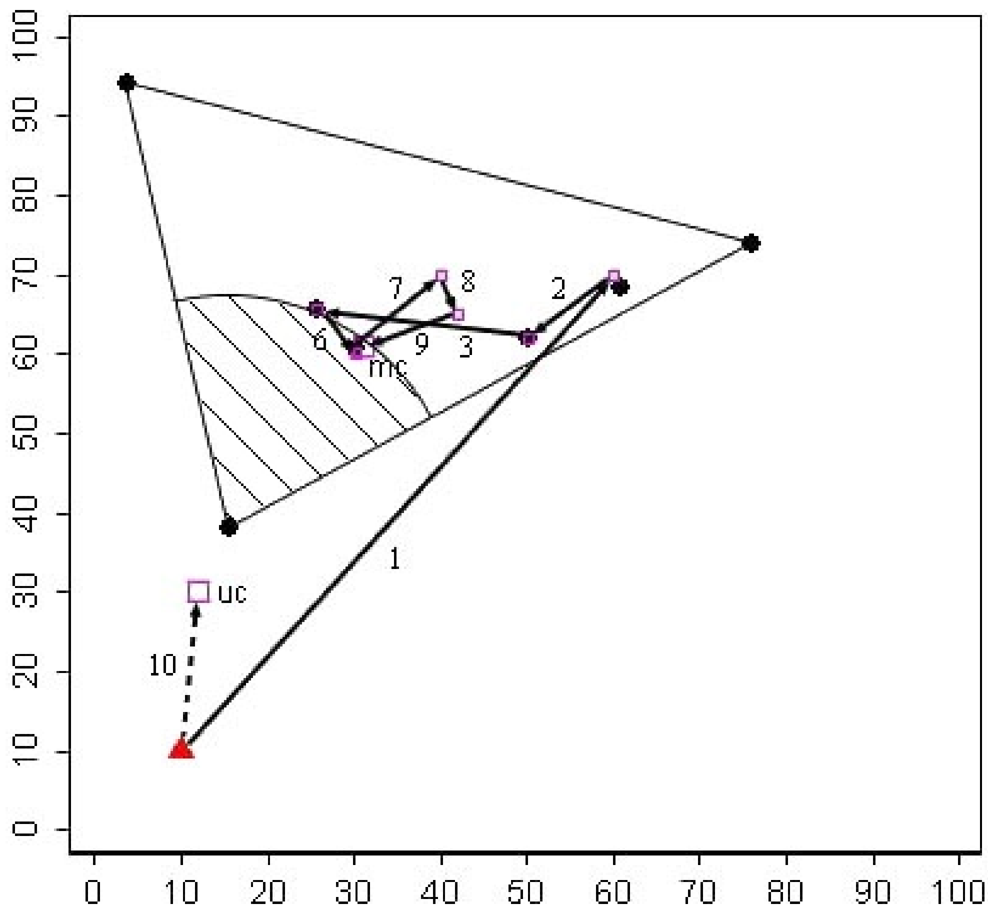


Figure 4. Two experimental sessions

(groups 17 & 19, complete information)



Notes: Ideal Points are marked by dots, the initial status quo is marked by a triangle, and the two outcomes are marked by large hollow squares. Solid arrows indicate the movement of majority rule group 17, while the dashed arrow indicates the movement of unanimity rule group 19. Numbers on the sides of each arrow indicate the round that an alternative changes. As the figure indicates, the majority rule group makes several changes toward the center of the ideal points and the unanimity rule group tends to get stuck at the initial status quo.

Figure 5. Percentage of Proposals in the win set each round