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IGNORANCE AND BIAS IN COLLECTIVE DECISION: THEORY AND EXPERIMENTS[1]

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ABSTRACT. We consider a committee with common interests. Committee members do not know which of two alternatives is the best, but each member may acquire privately a costly signal before casting a vote under either majority or unanimity rule. In the lab, as predicted by Bayesian equilibrium, voters are more likely to acquire information under majority rule, and attempt to counter the bias built in favor of one alternative under unanimity rule. As opposed to Bayesian equilibrium predictions, however, some committee members vote for either alternative when uninformed. Moreover, uninformed voting is correlated with a lower disposition to acquire information. We show that an equilibrium model of subjective prior beliefs may account for this correlation, and provides a good fit for the observed patterns of behavior both in terms of rational ignorance and biases.

Keywords: Condorcet jury theorem, rational ignorance, homemade priors. *JEL* D72, D83.

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> On trove de plus, que si la probabilité de la voix de chaque Votant est plus grande que $\frac{1}{2}$, c'est-à-dire, s'il est plus probable qu'il jugera conformément à la vérité, plus le nombre des Votans augmentera, plus la probabilité de la vérité de la décision sera grande : la limite de cette probabilité sera la certitude [...]
>
> Une assemblée très-nombreuse ne peut pas être composée d'hommes très-éclairés; il est même vraisemblable que ceux qui la forment joindront sur bien des objets beaucoup d'ignorance à beaucoup de préjugés.
>
> Condorcet (1785)[1986, p. 29-30]

1. Introduction

The idea that a committee or a jury may make better choices than a single individual, by aggregating the information dispersed among the group members, was first given a statistical foundation by Condorcet (1785), and has been very influential in social choice and in democratic theory, providing an epistemic foundation for the use of majority rule in a variety of contexts. During the last two decades, Condorcet's *jury theorem* has been studied from a game-theoretic viewpoint, starting with the pioneering work of Austen-Smith and Banks (1996). The game theoretic approach has led to some valuable insights about strategic voting behavior and the comparative performance of different voting rules in terms of information aggregation and efficiency.

This literature, however, has paid comparatively little attention to two potential sources of difficulty for information aggregation. First, group members may attempt to free ride on others, declining to acquire costly information. Second, realizing that their individual influence on the collective decision is small, group members may not even behave in a manner fully consistent with rational behavior. As a result, group members' opinions may actually contain little information about the alternatives, weakening the aggregation result. Indeed, as the initial quotes make it clear, Condorcet was aware of the possibility of both ignorance and biased judgment clouding the opinion of jury members.

In this paper, we investigate theoretically and experimentally a problem of information aggregation in committees where information is costly, thus providing incentives for group members to attempt to free ride on others. In particular, we propose a model in which each committee member is allowed to obtain costly, private information about which of two alternatives is best for the group, with the individual cost of information being a privately observed random variable. After each committee member independently decides whether or not to acquire information, they vote in favor of either alternative, or abstain. We consider two voting rules here, *simple majority*, the classical setting for the analysis of information aggregation in committees, and *unanimity*, which is known to make strategic behavior more involved (Feddersen and Pesendorfer 1998).

We study the Bayesian equilibria of the game just described. We show that, under majority rule, symmetric, neutral Bayesian equilibria are characterized by a cost cutoff: if a committee member's cost of information acquisition falls below the cutoff, the individual acquires information, and votes according to the signal received. If instead a committee member's cost of information acquisition falls above the cutoff, the individual does not acquire information and abstain. Intuitively, uninformed individuals realize that their vote may reduce the probability of reaching the best collective choice if other individuals cast informed votes, an effect dubbed the swing voter's curse (Feddersen and Pesendorfer 1996). Because of the public good nature of information acquisition, increasing the size of the committee reduces the probability that a single individual acquires information; the net effect however, is to increase the total amount of information acquired, leading to better collective decisions.

Under unanimity rule, one alternative is *the status quo*, which is chosen unless the other alternative receives every vote. Under this rule, we show that there are two types of Bayesian equilibria, both involving a cost cutoff. The first type is similar to the equilibrium described by Feddersen and Pesendorfer (1998), and involves informed voters abstaining with some probability rather than casting a vote for the status quo. The second type of equilibrium involves uninformed individuals voting with some probability for the alternative disfavored by the rule. Intuitively, in either case individuals attempt to counter the bias built in the voting rule in favor of one alternative. Increasing the size of the committee reduces the probability that a single individual acquires information, and, in contrast to majority rule, leads to similar or possibly worse collective decisions. Comparing behavior under different voting rules, individuals acquire less information and committees reach worse decisions under unanimity rule than under majority rule.

We conducted laboratory experiments based on this model at Instituto Tecnológico Autónomo de México in Mexico City. The experiments involved four treatments, distinguished by committee size (three or seven subjects) and voting rule (majority or unanimity). In all treatments, the value of a correct decision, the informativeness of the signal, and the distribution of information costs were held constant, in order to deliver sharp comparative static predictions.

Consistent with the theory, we find that there is more information acquisition under majority rule than under unanimity rule. Moreover, individuals seem to attempt to counter the built-in bias in favor of the status quo under unanimity rule. Contradicting the theory, we find that uniformed individuals persistently cast votes—sometimes even in favor of the alternative favored by the voting rule under unanimity. There is, in fact, substantial heterogeneity in behavior, with some voters being very likely to acquire information, and preferring to abstain while uninformed, and others being very unlikely to acquire information, and usually casting an uninformed vote.

Is is important to note that current behavioral theories would not account for the puzzling behavior observed at the lab. "Cursed" voters (as defined by Eyster and Rabin 2005) would ignore the informational content of other voters' actions, and would be indifferent between abstaining or voting in case of being uninformed, so they could account for uninformed voting. But cursed voters would not fully internalize incentives to free-ride on others, and therefore would be willing to acquire even more information, at higher costs, than voters who are not cursed (Martinelli 2013). This contradicts our finding that voters acquire less information than standard game theory theory predicts. "Loss aversion" (Kahneman and Tversky 1983) also fails to account for our findings. While loss averse voters would be less willing than rational voters to acquire costly information, as we observe, such voters would not be willing to vote if uninformed.

Motivated by the experimental results, we propose an alternative behavioral theory, *subjective beliefs equilibria*, which postulates that some individuals to hold prior beliefs which are biased in favor of one or the other alternative. Biased individuals can be interpreted as following their own "hunches" or homemade priors to which they attribute informational content, though—in the spirit of agreeing to disagree—they are aware that some other individuals may not. With this approach, we characterize a Bayesian equilibrium of this model, where the distribution of these non-common priors is common knowledge among the voters. Formally, biased priors introduced in this fashion are similar to shocks to preferences, but the interpretation in terms of perturbations on beliefs seems more natural in an information aggregation environment.

As opposed to cursed equilibrium or loss aversion, subjective beliefs equilibria deliver predictions that are consistent with the observed behavior at the lab. In particular, under either voting rule, sufficiently biased individuals will vote without acquiring information. Moreover, compared to the standard model without biased voters, the introduction of biased committee members makes unbiased committee members more willing to acquire information, but reduces the overall acquisition of information and the probability of making the correct decision under either voting rule.

We use the experimental data to perform a structural estimation of a subjective beliefs equilibrium model with two parameters. The first parameter reflects the probability that a voter is a biased type, while the second reflects a (presumably small) probability that a voter chooses a strategy by mistake. In the spirit of quantal-response equilibrium (McKelvey and Palfrey 1995, 1998), individuals are assumed to be aware that other voters make random errors. The estimated subjective beliefs equilibrium has an excellent fit with the empirical distribution of strategies in the lab, yielding relatively similar parameters across treatments, namely the estimated probability that a voter is biased is about 40% in three of the four treatments, and the probability that a voter makes a random mistake is about 20-25% in all treatments.

We then apply the results of our estimation to conduct a classification analysis of individual subject behavior. Using a 95% confidence interval, 96% of individuals are classified as either biased or unbiased. Again, we obtain that the probability that an individual is biased is 40%. The similarity in the results across treatments is quite remarkable, given that the variation in voting rules and committee sizes delivers very different equilibrium behavior.

This paper is related to several strands of literature. From the theoretical standpoint, Ordeshook and Palfrey (1988), Austen-Smith and Banks (1996) and Feddersen and Pesendorfer (1996, 1997) first studied Bayesian equilibria of voting in committees with private information. Mukhopadhaya (2005), Persico (2004), Martinelli (2006, 2007), and Gerardi and Yariv (2008) introduced costly information acquisition in collective decision environments. Our theoretical model differs from that literature in that we allow for abstention in a situation in which voters have heterogenous information costs, and we considers unanimity voting in addition to majority voting. More importantly, we look beyond Bayesian equilibrium and introduce the notion of subjective beliefs equilibrium.

In the experimental literature, Guarnaschelli, McKelvey and Palfrey (2000), Battaglini, Morton and Palfrey (2010), and Bhattacharya, Duffy and Kim (2013) have studed collective decision situations with private information, and found some empirical support for Bayesian equilibrium predictions. Goeree and Yariv (2010) find evidence that behavior under different voting rules tracks theoretical predictions in the jury setting without communication. Two key features distinguishing our work from the previous experiments in the literature is that voters have to choose whether to acquire costly signals, and that the signals are not perfectly informative. These two features seem to be responsible for the much further deviation from the predicted equilibrium behavior in our environment. To the extent our knowledge, we provide the first experimental work on information acquisition in committees, together with the work of Grosser and Seebauer (2013), which originated independently from ours. Reassuringly, Grosser and Seebauer find similar patterns of behavior in terms of uninformed voting. Our work is different from ours in that they focus on the difference between compulsory and voluntary voting, while we attempt to explain the patters o behavior under voluntary voting defining and fitting a model of behavior different from Bayesian equilibrium.

The notion of subjective beliefs equilibrium has a precedent in the experimental literature, introduced as "homemade priors" in Camerer and Weigelt (1988) to explain deviations from sequential equilibrium predictions in a reputation formation game. The notion of random beliefs equilibrium, introduced by Friedman and Mezzetti (2005) in the context of finite normal form games is also related to our definition, though in their case random beliefs occur in relation to others' strategy choices.

Outside the lab, of course, it is difficult to control the information that voters have prior to making voting decisions, so it is generally not possible to use field data regarding rational ignorance and biased behavior. However, work by Caplan (2007), using a survey of opinions of economists and citizens on the economy, is supportive of the hypothesis that public opinion is driven to some extent by ignorance and willful biases.

The remainder of this paper is organized as follows. Section 2 presents the theoretical model and predictions. Section 3 explains the experimental design and hypotheses. Section 4 describes the experimental results and the structural estimation. Section 5 concludes. An appendix provides a translation of experimental instructions.

2. THE MODEL

2.1. **Basics.** We consider a committee with $n \geq 2$ members which must choose between two alternatives, A and B. There are two possible states of the world, ω_A and ω_B. Each committee member receives a payoff of $b > 0$ if the committee reaches the decision A and the state of the world is ω_A, or if the committee reaches the decision B and the state of the world is ω_B, and a payoff of 0 otherwise.

Both states of the world are equally likely, and committee members do not know which state obtains. Each committee member, however, may choose to acquire some costly information. The cost at which information may be acquired is independently and identically distributed across voters according to a distribution function F, which is strictly increasing and continuously differentiable over the interval $[0,\overline{c}]$ for some $\overline{c} > 0$, with $F(0) = 0$, $F'(0) > 0$, and $F(\overline{c}) = 1$. After observing their idiosyncratic cost of information acquisition, each committee member decides whether to privately acquire information or not. Each committee member who acquires information receives a private signal $s \in \{s_A, s_B\}$. Conditional on the state of the world, private signals are independently and identically distributed across voters. The probability or receiving signal s_d in state ω_d is equal to $1/2 + q$ for $d \in \{A, B\}$, where $q \in (0, 1/2]$.

After the information acquisition stage, the committee votes over the two alternatives. A committee member may vote for A, vote for B, or abstain. A voting rule,

$$V : \{0,...,n\} \times \{0,...,n\} \to [0,1],$$

specifies a probability that the committee selects alternative A for any feasible combination of votes for A and votes for B, with alternative B being selected by the committee with the remainder probability. We consider two possible voting rules: simple majority and unanimity.

Under *simple majority*, V_M, the alternative with most votes is chosen, with ties broken by a fair coin toss. That is:

$$V_M(v^A, v^B) = \begin{cases} 1 & \text{if } v^A > v^B \\ 1/2 & \text{if } v^A = v^B \\ 0 & \text{if } v^A < v^B \end{cases} .$$

where v^d denotes the number of votes for decision d.

Under *unanimity*, V_U, in our specification, A is chosen unless every vote that is cast favors B, with A being chosen if every member abstains. That is:

$$V_U(v^A, v^B) = \begin{cases} 0 & \text{if } v^B > 0 = v^A \\ 1 & \text{otherwise} \end{cases} .$$

Given a voter's cost of information c_i, the utility, U_i, of voter i net of information acquisition costs is given by:

$$U_i = \begin{cases} b - c_i & \text{if the decision is } d \text{ and the state is } \omega_d \text{, for } d \in \{A, B\} \\ -c_i & \text{otherwise} \end{cases}$$

if the voter acquires information. If voter i does not acquire information, then

$$U_i = \begin{cases} b & \text{if the decision is } d \text{ and the state is } \omega_d \text{, for } d \in \{A, B\} \\ 0 & \text{otherwise} \end{cases} .$$

2.2. **Subjective beliefs equilibrium.** We allow voters to hold privately noisy prior beliefs that deviate from the correct prior probability of each state. In particular, each voter's private belief that the state of the world is ω_A is $1/2+\varepsilon$, where ε is independently and identically distributed across voters according to a distribution function M, symmetric around 0, such that $M(\varepsilon) > 0$ if and only if $\varepsilon > -\beta$ and $M(\varepsilon) = 1$ if and only if $\varepsilon \geq \beta$ for some $\beta \in [0, 1/2]$. Moreover, we assume that for every $\kappa > 0$, $M(\kappa) - M(-\kappa) > 0$. That is, prior beliefs that are arbitrarily close to the correct priors have positive probability.

A voter's *type* is a triple $t = (\varepsilon, c, s)$ specifying prior beliefs, cost of information acquisition, and private signal, where we denote "no signal" by s_0. For a given voter, an *action* is a pair $a = (\iota, v)$, $\iota \in \{1, 0\}$, $v \in \{A, B, \phi\}$, indicating whether or not the voter acquires information in the first stage, and whether the voter casts a vote for alternative A, for alternative B, or abstains in the second stage.

A *strategy* for voter i is a pair of measurable mappings, $\sigma = (\sigma^\iota, \sigma^v)$, where σ^ι specifies the information acquisition decision as a function of the voter's type, and σ^v specifies the (possibly mixed) voting decision as a function of the voter's type. With slight abuse of terminology, we denote by $\sigma(a|t) = (\sigma^\iota(\iota|t), \sigma^v(v|t))$ the probability of action $a = (\iota, v)$ if the voter's type is t.

We call a strategy as *informative* if σ^ι puts positive probability on the set of actions such that $\iota = 1$, and is uninformative otherwise. A *strategy profile* is a vector $(\sigma_1, \ldots, \sigma_n)$ that assigns to each voter $i = 1, \ldots, n$ a strategy σ_i.

Given a strategy profile $(\sigma_1, \ldots, \sigma_n)$, let $EU_i(\sigma_1, \ldots, \sigma_n|\omega_d)$ be the expected utility of voter i in state ω_d. Then the $\varepsilon-$*subjective expected utility* of voter i is equal to

$$(1/2+\varepsilon)EU_i(\sigma_1, \ldots, \sigma_n|\omega_A) + (1/2-\varepsilon)EU_i(\sigma_1, \ldots, \sigma_n|\omega_B).$$

We say that σ_i is a *subjective best response* to the strategies of other voters if for almost every realization ε of voter's i prior beliefs, σ_i maximizes the $\varepsilon-$subjective expected utility of voter i.

A voter playing a subjective best-response realizes that other voters' behavior is influenced by their own noisy priors, but–in the spirit of agreeing to disagree–does not draw inferences from the priors held by other voters. In particular, a voter playing a subjective best-response is not "cursed," since the voter recognizes that the behavior of other voters depends on the state of the world.

A *subjective beliefs equilibrium* is a strategy profile such that for each voter i, σ_i is a subjective best response; that is, σ_i maximizes the subjective expected utility of voter i given the strategies of other voters and given voter i prior beliefs about the states. We restrict attention to symmetric informative equilibrium, where a *symmetric* equilibrium is an equilibrium such that every voter uses the same strategy. Note that if $\beta = 0$, all voters have correct prior beliefs with probability one, and the subjective equilibrium is the standard Bayesian equilibrium for a common prior belief of $1/2$.

For any given voter, let $x = (x_A, x_B, x_\phi) \in \mathbb{N}^3$ represent the vote profile of other voters, that is the number of votes cast by other voters in favor of A, B, and abstention. From the perspective of each voter, this is the realization of a random vector whose probability measure depends on the strategy profile of other voters, the distribution of priors, and the state of the world. Given a vote rule, a voter is *decisive* at x if the committee decision may be different depending on whether the voter votes for A, B, or abstains. As it is well-understood, a best responding voter needs to be concerned only with vote profiles such that the voter is decisive. We next characterize symmetric informative equilibrium under simple majority and unanimity rules.

2.3. **Simple majority.** Under simple majority, a voter is decisive only if the difference between the number of votes cast by other voters in favor of each of the alternatives is zero or one. In particular, for a given voter i, let $D(z|\sigma_{-i},\omega)$ be the probability that the difference between the number of votes for A and for B cast by other voters is equal to z when the strategy profile of other voters is σ_{-i} and the state of the world is ω. If the difference is zero, voting for one alternative rather than abstaining increases the probability of that alternative winning the election from 1/2 to 1. If the difference is one, voting for the alternative that is behind rather than abstaining increases the probability of that alternative winning the election from 0 to 1/2.

If the voter with prior ε acquires information, the difference in interim expected utility between voting for A and abstaining after observing signal s_A is:

$$G^A(s_A|\varepsilon,\sigma_{-j}) \equiv \tfrac{b}{2}(\tfrac{1}{2}+\varepsilon)(\tfrac{1}{2}+q)(D(0|\sigma_{-j},\omega_A)+D(-1|\sigma_{-j},\omega_A)) \\ -\tfrac{b}{2}(\tfrac{1}{2}-\varepsilon)(\tfrac{1}{2}-q)(D(0|\sigma_{-j},\omega_B)+D(-1|\sigma_{-j},\omega_B))$$

Similarly, the difference in expected utility between voting for B and abstaining after observing signal s_B is:

$$G^B(s_B|\varepsilon,\sigma_{-i}) \equiv -\tfrac{b}{2}(\tfrac{1}{2}+\varepsilon)(\tfrac{1}{2}-q)(D(0|\sigma_{-i},\omega_A)+D(1|\sigma_{-i},\omega_A)) \\ +\tfrac{b}{2}(\tfrac{1}{2}-\varepsilon)(\tfrac{1}{2}+q)(D(0|\sigma_{-i},\omega_B)+D(1|\sigma_{-i},\omega_B)).$$

If the voter has not bought information, the difference in expected utility between voting for A and abstaining is:

$$G^A(s_0|\varepsilon,\sigma_{-i}) \equiv \tfrac{b}{2}(\tfrac{1}{2}+\varepsilon)(D(0|\sigma_{-i},\omega_A)+D(-1|\sigma_{-i},\omega_A)) \\ -\tfrac{b}{2}(\tfrac{1}{2}-\varepsilon)(D(0|\sigma_{-i},\omega_B)+D(-1|\sigma_{-i},\omega_B)).$$

Similarly, the difference in expected utility between voting for B and abstaining is

$$G^B(s_0|\varepsilon,\sigma_{-i}) \equiv -\tfrac{b}{2}(\tfrac{1}{2}+\varepsilon)(D(0|\sigma_{-i},\omega_A)+D(1|\sigma_{-i},\omega_A)) \\ +\tfrac{b}{2}(\tfrac{1}{2}-\varepsilon)(D(0|\sigma_{-i},\omega_B)+D(1|\sigma_{-i},\omega_B)).$$

It is never optimal for a voter to become informed and then vote against their signal. That is, if a voter acquires information, the voter will either vote for A or abstain in case of receiving signal s_A, and either vote for B or abstain in case of receiving signal s_B. Thus, the difference in expected utility between acquiring information and not, net of the cost of information acquisition, is

$$c(\varepsilon,\sigma_{-i}) \equiv \max\{G(s_A|\varepsilon,\sigma_{-i}),G(s_B|\varepsilon,\sigma_{-i}),G(s_A|\varepsilon,\sigma_{-i})+G(s_B|\varepsilon,\sigma_{-i})\} \\ -\max\{0,G(A|\varepsilon,\sigma_{-i}),G(B|\varepsilon,\sigma_{-i})\}.$$

From the preceding argument it follows that best-response behavior has the familiar cutoff property; given any strategy profile of other voters, a best-responding voter only acquires information if the cost is low enough.

Lemma 1. *Under majority rule, voter i with priors given by ε plays a best response to σ_{-i} if for almost every c,*

(1) if $c \leq c(\varepsilon,\sigma_{-i})$ then the voter acquires information, and after signal s_d votes for d if $G(s_d|\varepsilon,\sigma_{-i}) > 0$ and abstains if $G(s_d|\varepsilon,\sigma_{-i}) < 0$,

(2) if $c > c(\varepsilon,\sigma_{-i})$, then the voter does not acquire information, and votes for d only if $G(d|\varepsilon,\sigma_{-i}) = \max\{0, G(A|\varepsilon,\sigma_{-i}), G(B|\varepsilon,\sigma_{-i})\}$ and abstains only if $G(A|\varepsilon,\sigma_{-i}) \leq 0$ and $G(B|\varepsilon,\sigma_{-i}) \leq 0$.

We say that a strategy σ is *neutral* if

$$\sigma((0,A)|(\varepsilon,c,s_d)) = \sigma((0,B)|(-\varepsilon,c',s_{d'}))$$

for all d,d' and almost all ε,c,c', and

$$\sigma((1,A)|(\varepsilon,c,s_A)) = \sigma((1,B)|(-\varepsilon,c',s_B))$$

and

$$\sigma((1,A)|(\varepsilon,c,s_B)) = \sigma((1,B)|(-\varepsilon,c',s_A)) = 0$$

for almost all ε,c,c'. A voter who plays a neutral strategy does not discriminate between the alternatives except on the basis of the private signal and prior beliefs, and does not vote for one alternative if receiving a signal in favor of the other alternative. Given the assumption that the distribution of ε is symmetric around 0, neutrality is a natural restriction under majority rule, since the voting rule does not discriminate between the alternatives.

If every voter other than j plays a neutral strategy, it is straightforward that

$$D(0|\sigma_{-i},\omega_A) = D(0|\sigma_{-i},\omega_B)$$

and

$$D(1|\sigma_{-i},\omega_A) = D(-1|\sigma_{-i},\omega_B) \geq D(-1|\sigma_{-i},\omega_A) = D(1|\sigma_{-i},\omega_B),$$

where the inequality is strict if at least one player other than j plays an informative strategy. With a slight abuse of notation, we now write

$$D(0|\sigma_{-i}) \equiv D(0|\sigma_{-i},\omega_A), \quad D(1|\sigma_{-i}) \equiv D(1|\sigma_{-i},\omega_A) \quad \text{and} \quad D(-1|\sigma_{-i}) \equiv D(-1|\sigma_{-i},\omega_A)$$

to indicate the probability that the correct alternative is tied, one vote ahead or one vote behind when other voters are using neutral, informative strategies given by σ_{-i}.

Then the expected gain equations derived above reduce to:

$$\begin{aligned}
G(s_A|\varepsilon,\sigma_{-i}) &= \tfrac{b}{2}(q+\varepsilon)D(0|\sigma_{-i}) + \tfrac{b}{2}(\tfrac{1}{2}+\varepsilon)(\tfrac{1}{2}+q)D(-1|\sigma_{-i}) - \tfrac{b}{2}(\tfrac{1}{2}-\varepsilon)(\tfrac{1}{2}-q)D(1|\sigma_{-i}),\\
G(s_B|\varepsilon,\sigma_{-i}) &= \tfrac{b}{2}(q-\varepsilon)D(0|\sigma_{-i}) + \tfrac{b}{2}(\tfrac{1}{2}-\varepsilon)(\tfrac{1}{2}+q)D(-1|\sigma_{-i}) - \tfrac{b}{2}(\tfrac{1}{2}+\varepsilon)(\tfrac{1}{2}-q)D(1|\sigma_{-i}),\\
G(A|\varepsilon,\sigma_{-i}) &= b\varepsilon D(0|\sigma_{-i}) + \tfrac{b}{2}(\tfrac{1}{2}+\varepsilon)D(-1|\sigma_{-i}) - \tfrac{b}{2}(\tfrac{1}{2}-\varepsilon)D(1|\sigma_{-i}),\\
G(B|\varepsilon,\sigma_{-i}) &= -b\varepsilon D(0|\sigma_{-i}) + \tfrac{b}{2}(\tfrac{1}{2}-\varepsilon)D(-1|\sigma_{-i}) - \tfrac{b}{2}(\tfrac{1}{2}+\varepsilon)D(1|\sigma_{-i}).
\end{aligned}$$

The following lemma puts some bounds on what a voter can learn from being decisive, given that other voters play neutral strategies. In particular, the ratio of the probability that the correct alternative is ahead by one vote to the probability that the correct alternative is behind by one vote is bounded below by one, and is bounded above by the informativeness of a single signal, that is $(1/2+q)/(1/2-q)$. This result is useful because it implies that if priors are not too biased, then voters will prefer to abstain if uninformed and will prefer to vote according the signal received if informed. The idea of the proof is to match every vote profile of other voters in which the correct alternative is ahead by one vote with a vote profile in which the incorrect alternative is ahead by one vote, by reversing a single vote cast by an informed voter, going from a correct signal to an incorrect signal. The proof itself is an application of a theorem in graph theory that has been used in the analysis of networks but, to our knowledge, never before in collective choice settings.

Lemma 2. *If other voters are playing neutral strategies, then*

$$1 \leq \frac{D(1|\sigma_{-i})}{D(-1|\sigma_{-i})} \leq \frac{\frac{1}{2}+q}{\frac{1}{2}-q},$$

where the lower bound is tight if and only if all other voters play uninformative strategies, and the upper bound is tight if and only if all other voters play informative strategies and vote when uninformed with probability zero.

Proof. Suppose voters other than i play neutral, informative strategies. From neutrality and symmetry of the distribution of ε, for each voter $i' \neq i$ the probability that the voter votes for A while uninformed is equal to the probability that the voter votes for B while uninformed, and the probability that the voter votes for A after receiving signal s_A is equal to the probability that the voter votes for B after receiving signal s_B, where these probabilities are calculated ex ante, taking into account the strategy of voter i' and the distribution of ε and c.

For each voter $i' \neq i$, let $\pi(\sigma_{i'})$ be the (ex ante) probability with which voter i' acquires information, $\rho(\sigma_{i'})$ the (ex ante) probability that the voter votes for alternative d after receiving signal s_d, and $\tau(\sigma_{i'})$ the (ex ante) probability that the voter votes for alternative d after not acquiring information, for $d = A, B$. Let $v_r(\sigma_{i'})$ and $v_w(\sigma_{i'})$ be the probabilities that voter i' votes for correct and the incorrect alternative, respectively. We have

$$\frac{v_r(\sigma_i')}{v_w(\sigma_i')} = \frac{\pi(\sigma_{i'})(\frac{1}{2}+q)\rho(\sigma_{i'}) + (1-\pi(\sigma_{i'}))\tau(\sigma_{i'})}{\pi(\sigma_{i'})(\frac{1}{2}-q)\rho(\sigma_{i'}) + (1-\pi(\sigma_{i'}))\tau(\sigma_{i'})}.$$

Thus, for all $i' \neq i$,

$$\frac{v_r(\sigma_i')}{v_w(\sigma_i')} \geq 1,$$

with equality if and only if $\pi(\sigma_{i'})\rho(\sigma_{i'}) = 0$. Similarly, for all $i' \neq i$,

$$\frac{v_r(\sigma_i')}{v_w(\sigma_i')} \leq \frac{\frac{1}{2}+q}{\frac{1}{2}-q},$$

with equality if and only if $(1-\pi(\sigma_{i'}))\tau(\sigma_{i'}) = 0$.

Next, we claim that there is a bijective mapping between voting profiles such that the correct alternative wins by one vote and voting profiles such that the incorrect alternative wins by one vote, where only one voter needs to be switched from voting for the correct alternative to voting for the incorrect alternative to go from the profile where the correct alternative wins to the profile where the incorrect alternative wins. To see this, consider any subset of voters $C \subset \{1,\ldots,n\} \setminus \{i\}$ such that $|C|$ is odd. Define R_C to be the set of voting profiles such that voters abstain if and only if they are not in C, and the correct alternative wins by one vote. Similarly, define W_C to be the set of voting profiles such that voters abstain if and only if they are not in C, and the incorrect alternative wins by one vote.

Consider a graph where the vertices are the elements of $R_C \cup W_C$, and the edges are

$$E_C = \{(r,w) \in R_C \times W_C : x \text{ and } y \text{ differ by the vote of a single individual}\}.$$

$(R_C \cup W_C, E_C)$ is a bipartite regular graph of degree $(|C|+1)/2$. By Konig's Marriage Theorem (see Theorem 2.5 in Balakrishnan 1995), it must have a perfect matching M_C. Thus, there is a bijective mapping

$$f : \cup_C R_C \to \cup_C W_C$$

given by $f(r) = w$ such that $(r,w) \in M_C$ for any $r \in R_C$.

The bijective mapping f assigns to each voting profile $r \in \cup_C R_C$ a profile $f(r) \in \cup_C W_C$ where a single voter changes to the "mistaken" side. Thus, the probability ratio between the two profiles is equal to the ratio between the probability of that voter being right and that voter being wrong, which, as we have already established, must be in the interval $[1, (\frac{1}{2}+q)/(\frac{1}{2}-q)]$. Since, furthermore, $D(1|\sigma_{-i})$ is the sum of the probabilities of the voting profiles such that the correct alternative wins by one vote, and $D(-1|\sigma_{-i})$ is the sum of the probabilities of the voting profiles such that the incorrect alternative wins by one vote, the ratio of $D(1|\sigma_{-i})$ to $D(-1|\sigma_{-i})$ is also in that interval. □

We now put to work Lemmas 1 and 2. We claim that if other voters play neutral strategies, a best responding voter will play a neutral, informative strategy. To see this, assume all voters other than i play neutral strategies. Using Lemma 2, we get that for small enough $|\varepsilon|$,

$$G(s_A|\varepsilon,\sigma_{-i}) > 0 \quad \text{and} \quad G(s_B|\varepsilon,\sigma_{-i}) > 0.$$

Suppose voters other than i play informative strategies. Then, from Lemma 2, $D(1|\sigma_{-i}) > D(-1|\sigma_{-i})$. Thus, for small enough $|\varepsilon|$,

$$G(A|\varepsilon,\sigma_{-i}) < 0 \quad \text{and} \quad G(B|\varepsilon,\sigma_{-i}) < 0.$$

That is, if other voters play informative strategies, a voter with small enough deviation from correct priors abstains when uninformed, and votes according to the signal received when informed. Moreover, from Lemma 1, the value of information for small enough $|\varepsilon|$ is

$$c(\varepsilon,\sigma_{-i}) = bqD(0|\sigma_{-i}) + \tfrac{b}{2}(\tfrac{1}{2}+q)D(-1|\sigma_{-i}) - \tfrac{b}{2}(\tfrac{1}{2}-q)D(1|\sigma_{-i}). \tag{1}$$

From Lemma 2, $c(\varepsilon,\sigma_{-i}) > 0$. That is, the cutoff for information acquisition is strictly positive for small enough $|\varepsilon|$ if other voters play informative strategies.

Suppose instead that voters other than i play uninformative strategies. Then from Lemma 2,

$$G(A|\varepsilon,\sigma_{-i}) > 0 \quad \text{or} \quad G(B|\varepsilon,\sigma_{-i}) > 0$$

for $\varepsilon \neq 0$. Since $G(s_A|\varepsilon,\sigma_{-i}) > 0$ and $G(s_B|\varepsilon,\sigma_{-i}) > 0$ for small enough $|\varepsilon|$, the voter will vote according to priors when uninformed, and will vote according to the signal if informed. The value of information for this voter, using Lemma 1, is then

$$c(\varepsilon,\sigma_{-i}) = b(q-|\varepsilon|)\left(D(0|\sigma_{-i}) + \tfrac{1}{2}D(-1|\sigma_{-i}) + \tfrac{1}{2}D(1|\sigma_{-i})\right).$$

Note that $c_2(\varepsilon,\sigma_{-i}) > 0$ if $|\varepsilon| < q$. That is, the cutoff for information acquisition is strictly positive for small enough $|\varepsilon|$ if other voters play uninformative strategies. Thus, a symmetric, neutral equilibrium is necessarily informative.

If β is small enough, equilibrium behavior can be very straightforward. To see this, recall that if $|\varepsilon|$ is small enough that the inequalities

$$G(s_A|\varepsilon,\sigma_{-i}) > 0, \quad G(s_B|\varepsilon,\sigma_{-i}) > 0, \quad G(A|\varepsilon,\sigma_{-i}) < 0 \quad \text{and} \quad G(B|\varepsilon,\sigma_{-i}) < 0$$

hold, then the voter will abstain when uninformed and will acquire information when c is below the cutoff given by equation 1. Using Lemma 2 we get $c(0,\sigma_j) = bqD(0|\sigma_j)$. In a symmetric strategy profile in which every voter uses the same cutoff c^* and abstains when uninformed, we get that the probabilities of a vote for the correct and the incorrect alternatives are, respectively,

$$v_r(\sigma^*) = F(c^*)(\tfrac{1}{2}+q) \quad \text{and} \quad v_w(\sigma^*) = F(c^*)(\tfrac{1}{2}-q).$$

Thus, the equilibrium cutoff must satisfy

$$c^* = bq \sum_{j=0}^{\lfloor (n-1)/2 \rfloor} \binom{n-1}{2j} \binom{2j}{i} F(c^*)^{2j} (1-F(c^*))^{n-1-2j} \left(\tfrac{1}{4}-q^2\right)^j . \tag{2}$$

Note that equation 2 always has a solution. To see this, suppose first that

$$\overline{c} \le bq \sum_{j=0}^{\lfloor (n-1)/2 \rfloor} \binom{n-1}{2i} \binom{2j}{j} F(\overline{c})^{2j} (1-F(\overline{c}))^{n-1-2j} \left(\tfrac{1}{4}-q^2\right)^i .$$

Since $F(\overline{c}) = 1$, this is possible only if n is odd so that the inequality above becomes

$$\overline{c} \le bq \binom{n-1}{(n-1)/2} (1/4-q^2)^{(n-1)/2}.$$

Then $c^* = bq\binom{n-1}{(n-1)/2}(1/4-q^2)^{(n-1)/2} \ge \overline{c}$ is the unique solution to equation 2.

Suppose instead that

$$\overline{c} > bq \sum_{j=0}^{\lfloor (n-1)/2 \rfloor} \binom{n-1}{2j} \binom{2j}{j} F(\overline{c})^{2j} (1-F(\overline{c}))^{n-1-2j} \left(\tfrac{1}{4}-q^2\right)^j .$$

Using $F'(0) > 0$, we have that that for c close enough to 0,

$$c < bq \sum_{j=0}^{\lfloor (n-1)/2 \rfloor} \binom{n-1}{2j} \binom{2j}{j} F(c)^{2j} (1-F(c))^{n-1-2j} \left(\tfrac{1}{4}-q^2\right)^j .$$

Existence of a solution satisfying $0 < c^* < \overline{c}$ follows from the intermediate value theorem.

Theorem 1 below completely characterizes symmetric, neutral Bayesian equilibria corresponding to $\beta = 0$, and shows that any such strategy profile remains an equilibrium profile for small deviations from correct priors. In particular, under any such equilibrium profile voters abstain when uninformed and acquire information and use it for small enough cost.

Theorem 1. *Under majority tule,*

(1) For any solution c^* to equation 2, there is some $\beta^* \in (0,q)$ (depending on q,n,F,M) such that if $0 \le \beta \le \beta^*$, a strategy profile is a symmetric, neutral, informative equilibrium if each voter acquires information and votes according to the signal received if the voter's cost is below c^* and abstains otherwise.
(2) If $\beta = 0$, there are no other symmetric, neutral equilibria.

Proof. Under the strategy profile σ^* described in the statement of the theorem, $D(0|\sigma^*_{-i}) > 0$, $D(1|\sigma^*_{-i}) > 0$ and $D(-1|\sigma^*_{-i}) > 0$. From Lemma 2, $(\frac{1}{2}-q)D(1|\sigma^*_{-i}) = (\frac{1}{2}+q)D(-1|\sigma^*_{-i})$. It follows that $G(s_B|\varepsilon,\sigma^*_{-i})$ is positive at $\varepsilon = 0$ and is continuous and strictly decreasing in ε and negative for large enough ε. Similarly, $G(A|\varepsilon,\sigma^*_{-i})$ is negative at $\varepsilon = 0$ and is continuous and strictly increasing in ε and positive for large enough ε. Let β^* be the maximum value of ε such that $G(s_B|\varepsilon,\sigma^*_{-i}) \ge 0$ and $G(A|\varepsilon,\sigma^*_{-i}) \le 0$. Using $G(s_A|\varepsilon,\sigma^*_{-i}) = G(s_B|-\varepsilon,\sigma^*_{-i})$ and $G(B|\varepsilon,\sigma^*_{-i}) = G(A|-\varepsilon,\sigma^*_{-i})$, $-\beta^*$ is the minimum value of ε such that $G(s_A|\varepsilon,\sigma^*_{-i}) \ge 0$ and $G(B|\varepsilon,\sigma^*_{-i}) \le 0$. From the argument preceding the theorem, σ^* is a symmetric, neutral, informative equilibrium if $0 \le \beta \le \beta^*$.

For the second part of the theorem, note that

$$G(s_A|0,\sigma_{-i}) = G(s_B|0,\sigma_{-i}) > 0$$

for any neutral strategy profile of other voters. Similarly,

$$G(A|0,\sigma_{-i}) = G(B|0,\sigma_{-i}) \leq 0.$$

From Lemma 1, best responding voters play informative strategies. But then, in a symmetric strategy profile

$$G(A|0,\sigma_{-i}) = G(B|0,\sigma_{-i}) < 0.$$

It follows that in a symmetric, neutral strategy profile voters abstain when uninformed and acquire information and vote according to the signal received if the cost of information is below some common threshold $c^* > 0$. From the argument preceding the theorem, if this symmetric, neutral strategy profile is an equilibrium then c^* must be a solution to equation 2. □

For large deviations from correct priors, equilibrium behavior can be more complex and may involve voting according to prior beliefs rather than acquiring information. We illustrate this below with an example using parameters of our experiment.

2.4. **An example under majority rule.** Suppose $b = 10$, $q = 1/6$, c is distributed uniformly in $[0,1]$ and $n = 3$ or $n = 7$, and the rule is majority as in the lab experiments below. In addition, suppose ε takes the value 0 with probability $1-p$, the value $-\beta$ with probability $p/2$ and the value $-\beta$ with probability $p/2$, for some $\beta > 0$ and $p \in [0,1)$.

First, suppose $p = 0$, so all priors are at exactly $1/2$, Equation 2 has a unique solution for either committee size, given by $c^* \approx 0.5569$ for $n = 3$, and by $c^* \approx 0.3870$ for $n = 7$. From Theorem 1, it follows that there is a unique symmetric, neutral Bayesian equilibrium in either case, and that equilibrium behavior remains unaltered for small deviations from correct prior beliefs. The probability of choosing the right alternative given the equilibrium with cutoff c^* is given in either case by

$$\sum_{j=0}^{\lceil n/2-1\rceil} \sum_{k=j+1}^{n-j} \frac{n!}{j!k!(n-j-k)!}(\tfrac{1}{2}+q)^k(\tfrac{1}{2}-q)^j F(c^*)^{j+k}(1-F(c^*))^{n-j-k}$$
$$+(1/2)\sum_{j=0}^{\lfloor n/2\rfloor} \frac{n!}{j!j!(n-2j)!}(\tfrac{1}{4}-q^2)^j F(c^*)^{2j}(1-F(c^*))^{n-2j}.$$

This probability is approximately 0.6650 for $n = 3$ and 0.7063 for $n = 7$.

Suppose now $p > 0$ and β is large enough for voters not to acquire information and vote for the alternative favored by their prior beliefs rather than abstaining if $\varepsilon = \beta, -\beta$. Consider the strategy σ^c in which, if $\varepsilon = 0$, voters acquire information and vote according to the signal received if their cost is below c, and abstain otherwise. In this case, the probability of abstention is

$$v_0 = (1-p)(1-c),$$

the probability of voting for the right alternative is

$$v_r = (1-p)c(\tfrac{1}{2}+q)+\tfrac{p}{2},$$

and the probability of voting for the wrong alternative is

$$v_w = (1-p)c(\tfrac{1}{2}-q)+\tfrac{p}{2}.$$

Then

$$D(0|\sigma^c) = \sum_{j=0}^{\lfloor (n-1)/2\rfloor} \binom{n-1}{2j}\binom{2j}{j}(v_r)^j(v_w)^j(v_0)^{n-2j-1}.$$

Similarly,

$$D(1|\sigma^c) = \sum_{j=0}^{\lfloor (n-3)/2 \rfloor} \binom{n-1}{2j+1} \binom{2j+1}{j} (v_r)^{j+1} (v_w)^j (v_0)^{n-2j-2}$$

and

$$D(-1|\sigma^c) = \sum_{j=0}^{\lfloor (n-3)/2 \rfloor} \binom{n-1}{2j+1} \binom{2j+1}{j} (v_r)^j (v_w)^{j+1} (v_0)^{n-2j-2}.$$

We can now calculate c by solving equation 1. We also need to check the inequality conditions guaranteeing that extreme voters do not acquire information and vote according to their bias. That is, $G(A|,\beta,\sigma^c) \geq 0$ and $G(s_A|,\beta,\sigma^c) - G(A|,\beta,\sigma^c) \leq 0$:

$$\beta D(0|\sigma^c) + \tfrac{1}{2}(\tfrac{1}{2}+\beta) D(-1|\sigma^c) - \tfrac{1}{2}(\tfrac{1}{2}-\beta) D(1|\sigma^c) \geq 0,$$

$$(q-\beta) D(0|\sigma^c) - (\tfrac{1}{2}+\beta)(\tfrac{1}{2}-q) D(-1|\sigma^c) + (\tfrac{1}{2}-\beta)(\tfrac{1}{2}+q) D(1|\sigma^c) \leq 0.$$

Using Lemma 2, both equations are satisfied if $\beta \geq 2q/(1+4q^2)$.

As an example, suppose $p = 1/2$ and $\beta = 3/10$, so that the prior beliefs that the state of the world is ω_A are either 1/5, 1/2 or 4/5 with probability 1/4, 1/2 and 1/4, respectively. For $n = 3$, we have $c \approx 0.7556$, so the probability of information acquisition is approximately 0.3778. For $n = 7$ we get $c \approx 0.4808$, so the probability of information acquisition is approximately 0.2404.

Table 1A, on experimental predictions, summarizes the standard ($p = 0$) Bayesian equilibrium when all voters commonly share correct prior beliefs for each of the four treatments of the experiment, 3M, 7M, 3U, and 7U. As explained below, there are multiple equilibria under unanimity rule. Table 1B summarizes the subjective equilibrium with a trinomial distribution of prior beliefs, when with probability 1/2 each voter has incorrect prior beliefs ($p = 1/2$). For either committee size, introducing deviations from correct priors reduces the unconditional probability of information acquisition, even though it increases the probability of information acquisition conditional on holding unbiased prior beliefs. Introducing deviations from correct priors also increases the probability of uninformed voting, and reduces the probability of the group reaching the correct decision.

The probability of information acquisition is decreasing in the committee size, both in the Bayesian equilibrium and after introducing deviations from correct priors. In the former case, however, the probability of reaching the correct decision in the size of the committee, while in the latter it is decreasing. In fact, with seven subjects, after introducing biased individuals, collective choice is no better than a coin toss.

2.5. **Unanimity.** Under unanimity, given our definition of this rule, a voter is decisive if and only if either every other voter has abstained, or at least one voter has voted for B and no voter has voted for A. In the former case, a vote for A or an abstention decide in favor of A and a vote for B decides in favor of B. In the latter case, a vote for A decides in favor of A, and an abstention or a vote for B decides in favor of B.

Let $P(0|\sigma_{-i},\omega)$ be the probability that all other voters abstain given the strategy profile σ_{-i} of other voters and the state of the world ω. Similarly, let $P(1|\sigma_{-i},\omega)$ be the probability that all other voters abstain or vote for B and at least one other voter votes for B given the strategy profile σ_{-i} of other voters and the state of the world ω.

If the voter with prior ε acquires information, the difference in interim expected utility between voting for A and abstaining after observing signal s_A is:

$$H(s_A|\varepsilon,\sigma_{-i}) = b(\tfrac{1}{2}+\varepsilon)(\tfrac{1}{2}+q) P(1|\sigma_{-i},\omega_A) - b(\tfrac{1}{2}-\varepsilon)(\tfrac{1}{2}-q) P(1|\sigma_{-i},\omega_B).$$

(A) Equilibrium for $p = 0.0$

Treatment (size, rule)	**3M**	**7M**	**3U**		**7U**	
Predicted probabilities of individual decisions						
Info acquisition	0.56	0.39	0.46	0.44	0.25	0.22
Vote A if uninformed	0	0	0	0	0	0
Vote B if uninformed	0	0	0	[0.07,1]	0	[0.08,1]
Abstain if uninformed	1	1	1	[0,0.93]	1	[0,0.92]
Vote A if signal s_A	1	1	0.5	1	0.45	1
Abstain if signal s_A	0	0	0.5	0	0.55	0
Vote B if signal s_B	1	1	1	1	1	1
Abstain if signal s_B	0	0	0	0	0	0
Predicted probability of group decision						
Correct decision	0.67	0.71	0.64	0.63	0.64	0.63

(B) Equilibrium for $p = 0.5$

Treatment (size, rule)	**3M**	**7M**	**3U**	**7U**
Predicted probabilities of individual decisions				
Info acquisition	0.38	0.24	0.22	0.08
Vote A if uninformed	0.25	0.25	0.25	0.25
Vote B if uninformed	0.25	0.25	[0.25,0.75]	[0.25,0.75]
Abstain if uninformed	0.50	0.50	[0,0.5]	[0,0.5]
Vote A if signal s_A	1	1	1	1
Abstain if signal s_A	0	0	0	0
Vote B if signal s_B	1	1	1	1
Abstain if signal s_B	0	0	0	0
Predicted probability of group decision				
Correct decision	0.60	0.51	0.55	0.51

TABLE 1. Summary of experimental predictions

Similarly, the difference in expected utility between voting for B and abstaining after observing signal s_B is:

$$H(s_B|\varepsilon,\sigma_{-i}) = -b(\tfrac{1}{2}+\varepsilon)(\tfrac{1}{2}-q)P(0|\sigma_{-i},\omega_A) + b(\tfrac{1}{2}-\varepsilon)(\tfrac{1}{2}+q)P(0|\sigma_{-i},\omega_B).$$

If the voter did not acquire information information, the difference in expected utility between voting for A and abstaining is

$$H(A|\varepsilon,\sigma_{-i}) = b(\tfrac{1}{2}+\varepsilon)P(1|\sigma_{-i},\omega_A) - b(\tfrac{1}{2}-\varepsilon)P(1|\sigma_{-i},\omega_B).$$

Finally, if the voter has not bought information, the difference in expected utility between voting for B and abstaining is

$$H(B|\varepsilon,\sigma_{-i}) = -b(\tfrac{1}{2}+\varepsilon)P(0|\sigma_{-i},\omega_A) + b(\tfrac{1}{2}-\varepsilon)P(0|\sigma_{-i},\omega_B).$$

As was the case with majority rule, it is easy to show that it is never optimal for a voter to acquire information and then vote the opposite of the observed signal. Thus, the difference in expected utility between acquiring information and not, net of the cost of information acquisition, is

$$\begin{aligned} c(\varepsilon,\sigma_{-i}) \equiv \max\{&H(s_A|\varepsilon,\sigma_{-i}), H(s_B|\varepsilon,\sigma_{-i}), H(s_A|\varepsilon,\sigma_{-i}) + H(s_B|\varepsilon,\sigma_{-i})\} \\ &- \max\{0, H(A|\varepsilon,\sigma_{-i}), H(B|\varepsilon,\sigma_{-i})\}. \end{aligned}$$

From the preceding argument we obtain a parallel result to Lemma 1; given any strategy profile of other voters, a best-responding voter only acquires information if the cost is low enough.

Lemma 3. *Under unanimity rule, voter i with priors given by ε plays a best response to σ_{-i} if for almost every c,*

(1) if $c \leq c(\varepsilon,\sigma_{-i})$ then the voter acquires information, and after signal s_d votes for d if $H(s_d|\varepsilon,\sigma_{-i}) > 0$ and abstains if $H(s_d|\varepsilon,\sigma_{-i}) < 0$,

(2) if $c > c(\varepsilon,\sigma_{-i})$, then the voter does not acquire information, and votes for d only if $H(d|\varepsilon,\sigma_{-i}) = \max\{0, H(A|\varepsilon,\sigma_{-i}), H(B|\varepsilon,\sigma_{-i})\}$ and abstains only if $H(A|\varepsilon,\sigma_{-i}) \leq 0$ and $H(B|\varepsilon,\sigma_{-i}) \leq 0$.

We next characterize symmetric, informative Bayesian equilibria, corresponding to $\beta = 0$. To begin with, it is straightforward to check that there are no equilibria in which voters acquire information with positive probability, vote according to the signal received, and abstain if uninformed. The reason is that, if other voters adopt this strategy, $H(s_A|\varepsilon,\sigma_{-i}) < 0$, then the best response would be to abstain rather than vote for A after signal s_A. Similarly, there are no equilibria in which voters acquire information with positive probability, vote for B after signal s_B, and abstain otherwise. We show below that there is a mixed strategy equilibrium in which voters randomize after signal s_A.

Consider the strategy $\sigma^{c,y}$ of acquiring information if the cost is below some $c \geq 0$, voting for A with probability $1-y$ and abstaining with probability y after signal s_A, voting for B after signal s_B, and abstaining if uninformed. If every voter other than i follows this strategy we get

$$\begin{aligned} P(0|\sigma^{c,y},\omega_A) &= (1-F(c)+F(c)(\tfrac{1}{2}+q)y)^{n-1}, \\ P(0|\sigma^{c,y},\omega_B) &= (1-F(c)+F(c)(\tfrac{1}{2}-q)y)^{n-1}, \\ P(1|\sigma^{c,y},\omega_A) &= (1-F(c)(\tfrac{1}{2}+q)(1-y))^{n-1} - (1-F(c)+F(c)(\tfrac{1}{2}+q)y)^{n-1}, \\ P(1|\sigma^{c,y},\omega_B) &= (1-F(c)(\tfrac{1}{2}-q)(1-y))^{n-1} - (1-F(c)+F(c)(\tfrac{1}{2}-q)y)^{n-1}. \end{aligned}$$

Note $P(1|\sigma^{c,y},\omega_A) \leq P(1|\sigma^{c,y},\omega_B)$ and $P(0|\sigma^{c,y},\omega_A) \geq P(0|\sigma^{c,y},\omega_B)$, implying $H(A|0,\sigma^{c,y}) \leq 0$ and $H(B|0,\sigma^{c,y}) \leq 0$, so that voters rather abstain than vote if uninformed and if other voters follow a strategy $\sigma^{c,y}$. For $\sigma^{c,y}$ to be a symmetric equilibrium strategy for $c > 0$ and $0 < y < 1$, it is necessary and sufficient that

$$c = -\tfrac{b}{2}(\tfrac{1}{2}-q)P(0|\sigma^{c,y},\omega_A) + \tfrac{b}{2}(\tfrac{1}{2}+q)P(0|\sigma^{c,y},\omega_B) > 0 \tag{3}$$

and

$$\frac{P(1|\sigma^{c,y},\omega_A)}{P(1|\sigma^{c,y},\omega_B)} = \frac{\frac{1}{2}-q}{\frac{1}{2}+q}. \tag{4}$$

Equation 4 implies that $H(s_A|0,\sigma^{c,y}) = 0$, so that voters are willing to randomize between abstention and voting for A after receiving signal s_A. Equation 3 follows from $c(0,\sigma^{c,y}) = H(s_B|0,\sigma^{c,y})$, and the inequality implies that voters are willing to vote for B after receiving signal s_B. To verify that equations 3 and 4 have a solution (not necessarily unique), one shows that for every $0 \le F(c) \le 1$ there is some $0 < y < 1$ such that the pair (c,y) solves equation 3. Similarly, for every $0 \le y \le 1$ there is some $0 < c < \bar{c}$ such that (c,y) solves equation 4. Existence of an interior solution to both equations follows from a standard fixed point argument.

There may be symmetric, informative Bayesian equilibria other than the one described above. In particular, consider the strategy $\tilde{\sigma}^{c,z}$ of acquiring information if the cost is below some $c \ge 0$, voting for A if receiving the signal s_A, voting for B if receiving the signal s_B, and abstaining with probability z and voting for B with probability $1-z$ when uninformed. If every voter other than i follows this strategy we get

$$\begin{aligned}
P(0|\tilde{\sigma}^{c,z},\omega_A) &= (1-F(c))^{n-1}z^{n-1},\\
P(0|\tilde{\sigma}^{c,z},\omega_B) &= (1-F(c))^{n-1}z^{n-1},\\
P(1|\tilde{\sigma}^{c,z},\omega_A) &= (1-F(c)(\tfrac{1}{2}+q))^{n-1} - (1-F(c))^{n-1}z^{n-1},\\
P(1|\tilde{\sigma}^{c,z},\omega_B) &= (1-F(c)(\tfrac{1}{2}-q))^{n-1} - (1-F(c))^{n-1}z^{n-1}.
\end{aligned}$$

Note $P(0|\tilde{\sigma}^{c,z},\omega_A) = P(0|\tilde{\sigma}^{c,z},\omega_B)$ and $P(1|\tilde{\sigma}^{c,z},\omega_A) \le P(1|\tilde{\sigma}^{c,z},\omega_B)$, implying $H(B|0,\tilde{\sigma}^{c,z}) = 0$, $H(s_B|0,\tilde{\sigma}^{c,z}) \ge 0$ and $H(A|0,\tilde{\sigma}^{c,z}) \le 0$. For $\tilde{\sigma}^{c,z}$ to be a symmetric equilibrium strategy for $c > 0$ and $0 < z \le 1$, it is necessary and sufficient that

$$c = \tfrac{b}{2}(\tfrac{1}{2}+q)\left[1-F(c)(\tfrac{1}{2}+q)\right]^{n-1} - \tfrac{b}{2}(\tfrac{1}{2}-q)\left[1-F(c)(\tfrac{1}{2}-q)\right]^{n-1} \tag{5}$$

and

$$0 \le z \le (c/bq)^{\frac{1}{n-1}}/(1-F(c)). \tag{6}$$

Equation 5 implies $c = H(s_A|0,\tilde{\sigma}^{c,z}) + H(s_B|0,\tilde{\sigma}^{c,z})$ (satisfying Lemma 3), and equation 6 implies

$$\frac{P(1|\tilde{\sigma}^{c,z},\omega_A)}{P(1|\tilde{\sigma}^{c,z},\omega_B)} \ge \frac{\frac{1}{2}-q}{\frac{1}{2}+q},$$

so that $H(s_A|0,\tilde{\sigma}^{c,z}) \ge 0$. It is straightforward to check that equation 5 has a solution $c^* \in (0,\bar{c})$.

We have

Theorem 2. *Under unanimity rule, if $p = 0$,*

1. *For any solution c,y to equations 3 and 4, there is a symmetric, informative equilibrium, in which each voter acquires information if the voter's cost is below c, votes for B after receiving signal s_B, votes for A with probability y after receiving signal s_A, and abstains otherwise.*
2. *For any solution c,z to equations 5 and 6, there is a symmetric, informative equilibrium, in which each voter acquires information if the voter's cost is below c, votes for A after receiving signal s_A, abstains with probability z if uninformed, and votes for B otherwise.*
3. *There are no other symmetric, informative equilibria.*

Proof. The first and second parts of the theorem are proved in the text. With respect to the third part, it is straightforward to check that, in a symmetric strategy profile, $H(s_B|0,\sigma_j) \le 0$ implies that best-responding voters who receive a signal s_A abstain with positive probability, which in turn implies $H(s_A|0,\sigma_j) \le 0$. Thus, there is no informative equilibrium strategy such that $H(s_B|0,\sigma_j) \le 0$. Similarly, $H(s_A|0,\sigma_j) < 0$ implies that best-responding voters who receive a signal s_A do not vote for A, which in turn implies $H(s_A|0,\sigma_j) > 0$, a contradiction. Thus, there is no informative equilibrium strategy such that $H(s_A|0,\sigma_j) < 0$.

Next, $H(s_B|0,\sigma_j) > 0$ and $H(s_A|0,\sigma_j) > 0$ imply that best-responding voters vote according to the signal received, which in turn implies $H(s_A|0,\sigma_j) < 0$, unless uninformed voters vote for B with positive probability, corresponding to equilibria described in the second part of the theorem. The only remaining possibility is $H(s_B|0,\sigma_j) > 0$ and $H(s_A|0,\sigma_j) = 0$, corresponding to equilibria described in the first and second part of the theorem. □

Theorem 2 shows that there are multiple symmetric, informative Bayesian equilibria under unanimity rule when $p = 0$, involving either abstaining when receiving a signal favoring the status quo, or voting against the status quo when uninformed. For $p > 0$, however, equilibrium may involve voting according to prior beliefs rather than acquiring information. This, in turn, may make it a best response for unbiased voters to vote according to the signal received and to abstain if uninformed. We illustrate this point below, continuing the example from the majority rule section.

2.6. **An example under unanimity rule.** Suppose $b = 10$, $q = 1/6$, c is distributed uniformly in $[0,1]$ and $n = 3$ or $n = 7$, and the rule is unanimity as in the lab experiments below. In addition, suppose ε takes the value 0 with probability $1 - p$, the value $-\beta$ with probability $p/2$ and the value $-\beta$ with probability $p/2$, for some $\beta > 0$ and $p \in [0,1)$.

A symmetric, informative Bayesian equilibrium strategy can be calculated solving equations 3 and 4 or equivalently

$$c = -\tfrac{5}{3}(1 - c + \tfrac{2}{3}cy)^{n-1} + \tfrac{10}{3}(1 - c + \tfrac{1}{3}cy)^{n-1}$$

and

$$\frac{(1 - \frac{2}{3}c(1-y))^{n-1} - (1 - c + \frac{2}{3}cy)^{n-1}}{(1 - \frac{1}{3}c(1-y))^{n-1} - (1 - c + \frac{1}{3}cy)^{n-1}} = \frac{1}{2}.$$

The probability of reaching the correct decision is given by

$$\tfrac{1}{2}\left[1 - (1 - \tfrac{2}{3}c(1-y))^n + (1 - c + \tfrac{2}{3}cy)^n\right] + \tfrac{1}{2}\left[(1 - c(1-y)/3)^n - (1 - c + \tfrac{1}{3}cy)^n\right];$$

solutions for $n = 3$ and $n = 7$ are given by the left column corresponding to the treatments 3U and 7U in Table 1A on experimental predictions.

Other symmetric, informative Bayesian equilibria can be calculated solving equations 5 and 6, or equivalently

$$c = \tfrac{10}{3}(1 - \tfrac{2}{3}c)^{n-1} - \tfrac{5}{3}(1 - \tfrac{1}{3}c)^{n-1}$$

and

$$0 \le z \le (\tfrac{3}{5}c)^{\frac{1}{n-1}}/(1-c).$$

The probability of reaching the correct decision is given by

$$\tfrac{1}{2}(1 - (1 - \tfrac{2}{3}c)^n) + \tfrac{1}{2}(1 - \tfrac{1}{3}c)^n;$$

solutions for $n = 3$ and $n = 7$ are given by the right column corresponding to the treatments 3U and 7U in Table 1A. The column to the left under each of the unanimity treatments corresponds to the equilibrium in which voters randomize after receiving a signal favoring the status quo, while the column to the right corresponds to the equilibria in which voters randomize when uninformed. In the latter case, there is an interval of equilibrium mixed strategies, which is indicated with square brackets.

Suppose now β is large enough for voters not to acquire information and vote for the alternative favored by their prior beliefs rather than abstaining when $\varepsilon = \beta, -\beta$. In this case, in a symmetric strategy profile in which unbiased voters vote according to the signal received, and abstain with probability z and vote for B with probability $1-z$ if uninformed,

$$\begin{aligned}
P(0|\sigma_{-i},\omega_A) &= (1-p)^{n-1}(1-c)^{n-1}z^{n-1},\\
P(0|\sigma_{-i},\omega_B) &= (1-p)^{n-1}(1-c)^{n-1}z^{n-1},\\
P(1|\sigma_{-i},\omega_A) &= (\tfrac{1}{2}p+(1-p)(1-\tfrac{2}{3}c))^{n-1}-(1-p)^{n-1}(1-c)^{n-1}z^{n-1},\\
P(1|\sigma_{-i},\omega_B) &= (\tfrac{1}{2}p+(1-p)(1-\tfrac{1}{3}c))^{n-1}-(1-p)^{n-1}(1-c)^{n-1}z^{n-1}.
\end{aligned}$$

Thus, using $c(0,\sigma_{-i}) = H(s_A|0,\sigma_{-i}) + H(s_B|0,\sigma_{-i})$,

$$c = \tfrac{10}{3}(\tfrac{1}{2}p+(1-p)(1-\tfrac{2}{3}c))^{n-1} - \tfrac{5}{3}(\tfrac{1}{2}p+(1-p)(1-\tfrac{1}{3}c))^{n-1}.$$

We need to check

$$\frac{(\frac{1}{2}p+(1-p)(1-\frac{2}{3}c))^{n-1}-(1-p)^{n-1}(1-c)^{n-1}z^{n-1}}{(\frac{1}{2}p+(1-p)(1-\frac{1}{3}c))^{n-1}-(1-p)^{n-1}(1-c)^{n-1}z^{n-1}} > \frac{1}{2},$$

so that unbiased voters are willing to vote for A after signal s_A, and

$$\beta \geq \tfrac{1}{2}\max\left\{\frac{P(1|\sigma_{-i},\omega_B)-P(1|\sigma_{-i},\omega_A)}{P(1|\sigma_{-i},\omega_A)+P(1|\sigma_{-i},\omega_B)}, \frac{2P(1|\sigma_{-i},\omega_A)-P(1|\sigma_{-i},\omega_B)}{2P(1|\sigma_{-i},\omega_A)+P(1|\sigma_{-i},\omega_B)}\right\},$$

so that voters with extreme priors do not acquire information and vote according to prior beliefs. The probability of reaching the correct decision is equal to

$$\tfrac{1}{2}\left[1-(\tfrac{1}{2}p+(1-p)(1-\tfrac{2}{3}c))^{n}\right]+\tfrac{1}{2}\left[(\tfrac{1}{2}p+(1-p)(1-\tfrac{1}{3}c))^{n}\right].$$

In particular, for $p = 1/2$, we get that for $n = 3$, $c \approx 0.4452$, so that the probability of information acquisition is near 0.2226, and the various inequalities are satisfied for $\beta > 0.1406$. For $n = 7$, $c \approx 0.1500$, so that the probability of information acquisition is near 0.0750, and the various inequalities are satisfied for $0 \leq z \leq 1$ and $\beta > 0.1241$. Table 1B illustrates the solution for $p = 1/2$. Under unanimity rule, there is a range of equilibrium mixtures between abstention and voting against the status quo if uninformed that are consistent with equilibrium behavior, as indicated by the square brackets, but there is no longer an equilibrium in which voters randomize after receiving a signal in favor of the status quo.

For either committee size, Bayesian equilibria require either voters abstaining with positive probability when receiving a signal favoring s_A or voting for B with positive probability when uninformed. Introducing voters with extreme prior beliefs induces voters with correct priors to vote with their signals if informed. Introducing voters with extreme prior beliefs also reduces the probability of the group reaching the correct decision.

Increasing the size of the committee reduces information acquisition both in the Bayesian equilibrium and the subjective equilibrium with extreme prior voters; the theoretical effect of group size on the probability of the group reaching the correct decision is negligible under unanimity rule. As in the case of majority, with seven subjects, after introducing biased individuals, collective choice is barely better than a coin toss.

3. Experimental design and hypotheses

3.1. **Experimental design.** The design of our experiment was guided by the comparative statics implications of the standard Bayesian equilibrium with $p = 0$. While there are several dimensions of the model that yield clear comparative statics, we focus on two: the number of voters ($n = 3$ or $n = 7$) and the decision rule (V_M or V_U). In all treatments, the value of a correct decision, b, and the informativeness of the signal, q, were held constant, as was the distribution of signal costs. The design also allows us to explore the influence of subjective beliefs on behavior. In particular, we use the data from the experiment to estimate the parameters of our subjective beliefs equilibrium model in order to measure the extent of this phenomenon.

The procedures and framing of the experiment were based on the Condorcet jury "jar" interface introduced by Guarnaschelli et al. (2000) and adapted by Battaglini et al. (2010) in their initial laboratory study of the swing voter's curse. The two states of the world are represented as two jars, a red jar and a blue jar. The game proceeds as follows. First, either the master computer or a subject-monitor tosses a fair coin to determine the state of the world (i.e., selects the jar). The red jar contains 8 red balls and 4 blue balls, and the blue jar contains a 8 blue balls and 4 red balls, in order to induce an informativeness of signal viven by $q = 1/6$. The red jar corresponds to state B and the blue jar corresponds to state A in the theoretical model. This labeling only matters for the unanimity committees, where decision A is the status quo.

Each committee member i was assigned an integer-valued signal cost, c_i, drawn from a commonly known uniform distribution over the set $1,\ldots,100$ points. Then each committee member, acting independently of other committee members, could choose to pay their signal cost in order to privately observe the color of exactly one of the balls randomly drawn from the jar. The randomization was done as follows. A jar appears on the subject screen with 12 balls inside it, with 8 of them one color and 4 of them the other color. The locations of the 12 balls are randomly shuffled on each screen and the colors are greyed out. If a subject pays his or her signal cost, the computer prompts them to click on one of the greyed-out balls, which then reveals the color of that ball. In case they chose not to pay the cost, they do nothing at this point.

Once all subjects selected a ball or indicated their choice not to do so, each committee member is given three choices: vote for Red; vote for Blue; or Abstain. At no time was any communication between the subjects allowed, so both the information (or lack thereof) and vote decisions remained private until all the votes were cast, at which point only the votes were announced, and the committee decision was implemented according to the voting rule (either majority, or unanimity with Red as the status quo).

If the committee choice was correct (i.e. the committee voted for the same color as the plurality of the balls in the jar) each committee member received a payoff of 1000 points, less whatever the private cost incurred for observing the color of a ball. If the decision was wrong (i.e. the color chosen by the committee and the color of the plurality of the balls in the jar did not coincide), each committee member received a payoff of 0 points and still had to pay the private cost of acquiring information, if any had been incurred.

Each committee decision, as described above, constituted a single experimental round, upon completion of which committees were randomly re-matched and new jars and private observation costs were drawn independently from the previous rounds. Detailed instructions were read aloud before the experiment began. A translated copy of these instructions is provided in the Appendix. Figure 4 in the Appendix presents a sample of the computer screen as it appeared to subjects after they observed the color of a ball. In case they chose not to observe, the screen would be identical, except that all balls would appear grey.

All experimental sessions (generally involving 21 subjects each, except for one 15-subject session with 3-member committees deciding by majority rule) consisted of 25 rounds of the same treatment with random re-matching between rounds, and were conducted at ITAM in Mexico City with student subjects recruited from introductory economics courses. At the end of each session each subject was paid the sum of their earnings across all rounds, in cash, using the exchange rate of 1000 points to 8 Mexican pesos (rounded to the nearest peso) plus 20 pesos as a show-up fee. Average earnings, including the show-up fee, were 133 pesos for M3, 141 pesos for M7, 125 pesos for U3, and 127 pesos for U7. (At the time of the experiment, 1 US dollar was worth around 12 pesos.) Each session lasted approximately one hour.

3.2. **Hypotheses.** As described earlier, Table 1A summarizes equilibrium strategies and probability of a correct group decision for the standard ($p = 0$) Bayesian equilibria of the four treatments, 7M, 7M, 3U, and 7U. As explained in the theory section, there are multiple Bayesian equilibria under unanimity rule. The column to the left under each of the unanimity treatments corresponds to the equilibrium in which voters randomize after receiving a signal favoring the status quo, while the column to the right corresponds to the equilibria in which voters randomize when uninformed. Based on Table 1A, we summarize the main hypotheses below:

(H1) Under both voting rules, members of smaller committees acquire more information.
(H2) For both committee sizes, members of majority rule committees acquire more information than members of unanimity rule committees.
(H3) Under majority rule, committee members who do not acquire information abstain.
(H4) Under unanimity rule, committee members who do not acquire information abstain or vote for B.
(H5) Under both voting rules, committee members who acquire information never vote against their signal.
(H6) Under majority rule, committee members who acquire information vote their signal.
(H7) Under unanimity rule, committee members who acquire information and receive a B signal vote for B.
(H8) Under unanimity rule, committee members who receive an A signal vote for A or abstain.
(H9) With majority rule, larger committees make better decisions.
(H10) Majority committees make better decisions than unanimity committees.

4. Experimental results

We first present some summary statistics that provide a simple test of the comparative static predictions of the baseline model with respect to treatment effects, as detailed in Table 1A of the previous section. We then present estimation results, using a structural approach to estimate the parameters of the subjective belief equilibrium model. In the last section, we take a close look at individual behavior, and use those estimates to classify individual subject behavior.

4.1. **Treatment effects.** Table 2 summarizes treatment effects.

4.1.1. *Information Acquisition (H1 - H2).* With respect to the frequency of information acquisition, there are three notable observations. First, there is no significant effect of committee size on information acquisition. Because the baseline theory predicts a large effect of committee size on information acquisition (H1), this finding is surprising. Also note that the lack of a statistically significant effect of the committee size is not just an artifact of large standard errors. Quantitatively, the average effect of committee size is precisely zero (to two decimal places) for both voting rules.

Treatment (size, rule)	**3M**	**7M**	**3U**	**7U**
Observed frequencies of individual decisions				
Info acquisition	0.33 (0.05)	0.33 (0.06)	0.27 (0.06)	0.27 (0.06)
Vote A if uninformed	0.38	0.33	0.29	0.20
Vote B if uninformed	0.37	0.28	0.35	0.35
Abstain if uninformed	0.24	0.39	0.37	0.45
Vote A if signal s_A	0.96	0.96	0.80	0.82
Vote B if signal s_A	0.04	0.02	0.04	0.03
Abstain if signal s_A	0.000	0.02	0.16	0.15
Vote A if signal s_B	0.03	0.05	0.04	0.00
Vote B if signal s_B	0.97	0.93	0.89	0.89
Abstain if signal s_B	0.00	0.02	0.07	0.02
Observed frequency of group decision				
Correct decision	0.60 (0.06)	0.63 (0.04)	0.56 (0.06)	0.56 (0.04)

TABLE 2. Summary of experimental data. Standard errors in parenthesis treat each individual's 25 decisions as as a single observation. The unit observation for a committee decision is one committee.

Second, consistent with H2, there is more information acquisition under majority rule than under unanimity rule. The size of this effect is the same for both committee sizes; in both cases, there is about 20% more information acquisition under majority rule than under unanimity. This percentage difference is somewhat higher than predicted by theory, although the raw difference in information acquisition (0.06) is almost exactly the same as the theory. Third, we observe significantly less information acquisition than predicted, except for unanimity committees with seven members. The magnitude of this difference is large for committees with three members, where we observe 50% less information acquisition than predicted.

4.1.2. *Voting Behavior (H3 - H8).* With respect to the voting frequency, the most striking observation from Table 2 is the amount of voting by uninformed voters, which strongly contradicts H3. In the majority treatments, participation by uninformed voters exceeds 60%, while the baseline theory predicts zero turnout. This is strikingly different from the finding in the original swing voter's curse experiment by Battaglini et al. (2010), where under majority rule, uninformed voters abstained nearly all the time when the two states were equally likely. We come back to this in the conclusions. In the unanimity treatments, uninformed voting in favor of the status quo exceeds 20%, while the baseline theory predicts zero, contradiction H4. Uninformed voting in favor of either alternative under majority rule, and uninformed voting in favor of the status quo, decline with the size of the committee.

A second observation regarding voting frequency is that informed voters almost never vote against their signal, which is consistent with H5 and with past findings.

A third observation is that we observe significant levels of abstention among informed voters only in the case of voters who obtain a signal favoring the status quo under unanimity rule. The level of abstention is small, and informed voters do tend to vote according to the signal received. This supports hypotheses H6, H7, and H8.

4.1.3. *Group decision accuracy (H9 - H10).* With respect to the frequency of correct group decisions, the effect of group size is negligible for both voting rules, which is consistent with the theory for the unanimity committees, but contradicts H9. We do observe that the probability of correct decisions is higher under majority rule than under unanimity rule, which supports H10.

To summarize, we find support for the qualitative hypotheses H2, H5, H6, H7, H8, and H10. The failure of H3 and H4 goes in line with the predictions of the subjective beliefs model with $p > 0$, to which we turn our attention now.

4.2. **Structural estimation of the subjective beliefs equilibrium model.** There are several key features of observed behavior that are consistent with the subjective beliefs equilibrium model with $p > 0$ but were not predicted by the standard model with $p = 0$. First, many subjects usually vote when uninformed. Second, subjects gather information much less frequently than predicted. Third, informed voters usually vote their signal. These features are commonly shared across all four treatments. With this in mind, we perform a maximum likelihood estimation of a version of the subjective beliefs equilibrium model.

As in the examples in the theory section, we assume that each subject is unbiased with probability $1-p$ and biased with probability p. Unbiased subjects' prior belief that the state of the world is ω_A is $1/2$, while each biased subject's prior belief that the state of the world is ω_A is equal to $1/2-\beta$ with probability $1/2$ and equal to $1/2+\beta$ with probability $1/2$, where $p \in [0,1]$ and $\beta \in [0,1/2]$. We assume that player types are *persistent*, so that unbiased subjects hold objective priors for all rounds of the experiment, while biased subjects draw a new subjective prior every round. (Treating subjects as persistent types in this way does not change the equilibrium strategies derived in the theory section.) With respect to the parameter β, we assume in the estimation that it is sufficiently high so that biased subjects prefer not to acquire information and simply vote their hunch, as explained in the theory section.

The model as described so far is too deterministic for estimation purposes. For example, in the subjective beliefs equilibrium model, no subject will ever become informed and then vote against the signal received, but we do observe such behavior occasionally in the data. To avoid this zero-likelihood problem, we assume that, in each round, each subject plays the equilibrium strategy with probability Q, and chooses an action randomly with probability $1-Q$. In the spirit of quantal-response equilibrium, we assume that subjects are aware that other subjects, as well as themselves, make a mistake with probability $1-Q$. These leaves two parameters to be identified, the probability of a subject being biased, p, and the probability of playing an equilibrium strategy, Q.

To simplify the estimation, we blind ourselves to the actual cost draws of subjects. Thus, there are nine possible sequences of actions for a given subject in a period that are relevant for the estimation, given by the signal observed by the voter and the vote casted.

- (AA) Acquires information, draws signal s_A, and votes for A.
- (AB) Acquires information, draws signal s_A, and votes for B.
- $(A\phi)$ Acquires information, draws signal s_A, and abstains.
- (BA) Acquires information, draws signal s_B, and votes for A.
- (BB) Acquires information, draws signal s_B, and votes for B.
- $(B\phi)$ Acquires information, draws signal s_B, and abstains.
- (ϕA) Does not acquires information, and votes for A.

(ϕB) Does not acquires information, and votes for B.
($\phi\phi$) Does not acquires information, and abstains.

We assume that, if subjects make a mistake, they randomize at each stage uniformly. That is, they become informed with probability $1/2$, and they vote for A, for B, or abstain, with probability $1/3$ regardless of whether they are informed or not, and regardless of the signal received. Since the unconditional probability of receiving either signal is $1/2$, each of the six action sequences, $AA, AB, A\phi, BA, BB$, and $B\phi$, will occur with probability $1/12$, and each of the three events, ϕA, ϕB and $\phi\phi$, will occur with probability $1/6$.

4.2.1. *Likelihood function for majority rule.* The likelihood function is constructed as follows. Denote the number of times subject i took each of the nine action sequences as k^i_{sv}, where

$$sv \in \{AA, AB, A\phi, BA, BB, B\phi, \phi A, \phi B, \phi\phi\}.$$

Our data for subject i is simply i's profile of actions, $D^i = (k^i_{sv})$. For any pair of parameters, (p, Q), and for group size n, the majority rule likelihood of D^i is given by:

$$\begin{aligned} L_M(D^i|p,Q,n) = p\Big\{&[(\tfrac{1}{2}Q+\tfrac{1}{6}(1-Q)]^{k^i_{\phi A}+k^i_{\phi B}}[\tfrac{1}{6}(1-Q)]^{k^i_{\phi\phi}}[\tfrac{1}{12}(1-Q)]^{k^i_{AA}+k^i_{BB}+k^i_{AB}+k^i_{A\phi}+k^i_{BA}+k^i_{B\phi}}\Big\} \\ +(1-p)\Big\{&[\tfrac{1}{2}\iota^*_M(p,Q,n)Q+\tfrac{1}{12}(1-Q)]^{k^i_{AA}+k^i_{BB}}[(1-\iota^*_M(p,Q,n))Q+\tfrac{1}{6}(1-Q)]^{k^i_{\phi\phi}} \\ &[\tfrac{1}{6}(1-Q)]^{k^i_{\phi A}+k^i_{\phi B}}[\tfrac{1}{12}(1-Q)]^{k^i_{AB}+k^i_{A\phi}+k^i_{BA}+k^i_{B\phi}}\Big\} \end{aligned}$$

where $\iota^*_M(p,Q,n)$ is the equilibrium probability that an unbiased voter buys information and then votes according to the signal received in the subjective beliefs equilibrium model if the model parameters are (p,Q) and the committee size is n, using majority rule. The first term in the right-hand side corresponds to the event that subject i is biased, which happens with probability p. In that case, the subject intends not to acquire information and vote for A with probability $1/2$, and not to acquire information and vote for B with probability $1/2$, depending on the realization of the subject's bias. The subject does as intended with probability Q, and makes a mistake with probability $1-Q$, in which case the subject does not acquire information and votes for A with probability $1/6$, and similarly for B. Thus, the expression $[\frac{1}{2}Q+\frac{1}{6}(1-Q)]$ in the first term is equal to the probability that a biased subject does not acquire information and votes for A, and equal to the probability that a biased subject does not acquire information and votes for B. Other terms can be explained similarly.

Using equation 1, we have

$$\iota^*_M(p,Q,n) = (5/3)D(0;p,Q,n) + (10/3)D(-1;p,Q,n) - (5/3)D(1;p,Q,n),$$

where

$$\begin{aligned} D(0;p,Q,n) &= \sum_{i=0}^{\lfloor (n-1)/2 \rfloor} \binom{n-1}{2i}\binom{2i}{i}(v_r)^i(v_w)^i(v_0)^{n-2i-1}, \\ D(1;p,Q,n) &= \sum_{i=0}^{\lfloor (n-3)/2 \rfloor} \binom{n-1}{2i+1}\binom{2i+1}{i}(v_r)^{i+1}(v_w)^i(v_0)^{n-2i-2}, \\ D(-1;p,Q,n) &= \sum_{i=0}^{\lfloor (n-3)/2 \rfloor} \binom{n-1}{2i+1}\binom{2i+1}{i}(v_r)^i(v_w)^{i+1}(v_0)^{n-2i-2} \end{aligned}$$

and

$$\begin{aligned} v_0 &= (1-p)(1-\iota_M^*(p,Q,n))Q+\tfrac{1}{3}(1-Q), \\ v_r &= \tfrac{2}{3}(1-p)\iota_M^*(p,Q,n)Q+\tfrac{p}{2}Q+\tfrac{1}{3}(1-Q), \\ v_w &= \tfrac{1}{3}(1-p)\iota_M^*(p,Q,n)Q+\tfrac{p}{2}Q+\tfrac{1}{3}(1-Q). \end{aligned}$$

The log likelihood function is equal to the sum of $\log L_M(D^i|p,Q,n)$ across all the individuals in the sample. The estimation is then done by using Matlab to find the values of p and Q that maximize the log likelihood function.

4.2.2. *Likelihood function for unanimity rule.* The expression for the likelihood of D^i with unanimity is based on the equilibrium described in the last two columns of Table 2B. For any pair of parameters, (p,Q), and for group size n, the unanimity rule likelihood of D^i is given by:

$$\begin{aligned} L_U(D^i|p,Q,n) = p\Big\{&[(\tfrac{1}{2}Q+\tfrac{1}{6}(1-Q)]^{k^i_{\phi A}+k^i_{\phi B}}[\tfrac{1}{6}(1-Q)]^{k^i_{\phi\phi}}[\tfrac{1}{12}(1-Q)]^{k^i_{AA}+k^i_{BB}+k^i_{AB}+k^i_{A\phi}+k^i_{BA}+k^i_{B\phi}}\Big\} \\ +(1-p)\Big\{&[\tfrac{1}{2}\iota_U^*(p,Q,n)Q+\tfrac{1}{12}(1-Q)]^{k^i_{AA}+k^i_{BB}}[\tfrac{1}{2}(1-\iota_U^*(p,Q,n))Q+\tfrac{1}{6}(1-Q)]^{k^i_{\phi\phi}+k^i_{\phi B}} \\ &[\tfrac{1}{6}(1-Q)]^{k^i_{\phi A}}[\tfrac{1}{12}(1-Q)]^{k^i_{AB}+k^i_{A\phi}+k^i_{BA}+k^i_{B\phi}}\Big\}. \end{aligned}$$

where $\iota_U^*(p,Q,n)$ is the equilibrium probability that an unbiased voter buys information and then votes according to the signal received in the subjective beliefs equilibrium model if the model parameters are (p,Q) and the committee size is n, using unanimity rule. This expression is similar to the one for majority, except on how it deals with the probability that an unbiased subject does not get information and abstains, and the probability that an unbiased subject does not get information and votes for B. The reason is that under unanimity rule, for our parameter values, even for very small values of p, unbiased, uninformed voters can randomize in any way between abstention and voting for B. We assume that such voters randomize with equal probability between between abstention and voting for B. Thus, the expression $[\frac{1}{2}(1-\iota_U^*(p,Q,n))Q+\frac{1}{6}(1-Q)]$ is equal to the probability that an unbiased subject does not acquire information and abstains, and is equal to the probability that an unbiased subject does not acquire information and votes for B.[1]

Using equation 5, we have

$$\iota_U^*(p,Q,n) = (10/3)(1-v_r)^{n-1}-(5/3)(1-v_w)^{n-1},$$

where

$$\begin{aligned} v_r &= \tfrac{2}{3}(1-p)\iota_U^*(p,Q,n)Q+\tfrac{p}{2}Q+\tfrac{1}{3}(1-Q), \\ v_w &= \tfrac{1}{3}(1-p)\iota_U^*(p,Q,n)Q+\tfrac{p}{2}Q+\tfrac{1}{3}(1-Q). \end{aligned}$$

4.2.3. *Estimation results.* Table 3 reports the maximum likelihood estimates $(\widehat{p},\widehat{Q})$. We report these estimates at three levels of aggregation:

(a) a separate estimate for each of the four treatments;
(b) an estimate for the two majority treatments combined and another for the two unanimity treatments combined, constraining the parameters to be the same for both committee sizes;
(c) an estimate for all treatments combined.

[1]We also explored an alternative estimation model that included an additional parameter for the probability an uninformed unbiased voter votes for B. That less parsimonious specification improves the fit somewhat, but leaves the estimates of p and Q unchanged.

Treatment	**Observations**	$\widehat{p}$	$\widehat{Q}$	$-\ln L$
3M	1950	0.41	0.76	2889
7M	1554	0.45	0.76	2329
Majority	3504	0.41	0.77	5708
3U	1575	0.41	0.75	2497
7U	1575	0.10	0.78	2539
Unanimity	3150	0.25	0.73	3436
All	6654	0.34	0.76	9154

TABLE 3. Estimation results for subject beliefs equilibrium model

Treatment		**%I**	**AA**	**AB**	**Aϕ**	**BA**	**BB**	**Bϕ**	**ϕA**	**ϕB**	**$\phi\phi$**
3M	*model*	0.45	0.19	0.02	0.02	0.02	0.19	0.02	0.20	0.20	0.15
	data	0.33	0.16	0.00	0.01	0.01	0.16	0.00	0.25	0.26	0.16
7M	*model*	0.33	0.12	0.02	0.02	0.02	0.12	0.02	0.21	0.21	0.25
	data	0.33	0.15	0.01	0.00	0.00	0.16	0.00	0.19	0.22	0.26
3U	*model*	0.34	0.13	0.02	0.02	0.02	0.13	0.02	0.20	0.31	0.16
	data	0.27	0.11	0.01	0.02	0.01	0.12	0.01	0.21	0.25	0.27
7U	*model*	0.26	0.09	0.02	0.02	0.02	0.09	0.02	0.08	0.35	0.31
	data	0.27	0.11	0.00	0.02	0.00	0.13	0.00	0.15	0.25	0.32

TABLE 4. Comparison of action frequencies: estimated model vs. data

Table 3 also reports the number of observations, which is simply the number of subjects in each treatment times 25. Recall that for each subject we have a panel of 25 observations, each observation consisting of one of the nine possible pairs of actions listed above. (An exception is one of the majority sessions with seven member committees, where we have only 24 observations for each subject.)

The estimated values $(\widehat{p},\widehat{Q})$ are very similar for the majority treatments and for the unanimity treatment with three member committees, with the proportion of biased subjects being approximately 40%, and error rates in the range of 24% to 25%. In fact, the majority treatment estimates are statistically indistinguishable, based on a chi-square test of the difference between the pooled log likelihood and the sum of the separately estimated log likelihoods.

The estimated error rate for the 7U treatment is about the same (22%) as the other treatments, but the estimated proportion of biased subjects is much lower (10% compared to 41%). This is the only of our treatments where we observe *too much* information acquisition, relative to the baseline model ($p=0$). A key effect of increasing p in the theoretical subjective beliefs equilibrium model is to *decrease* the equilibrium probability of information acquisition. For example, when $p=1/2$, the equilibrium probability of information acquisition in the $7U$ treatment is only 0.075, which is far below the observed frequency information acquisition of 0.27. As a consequence, the likelihood function is heavily penalized for higher values of p, so the likelihood of our seven-member unanimity dataset if p were equal to 0.41, as in the other treatments would be extremely low. A conjecture to explain the observed frequency of information acquisition is that, for U7 treatments, acquiring information above the best response cutoff is a very inexpensive mistake.

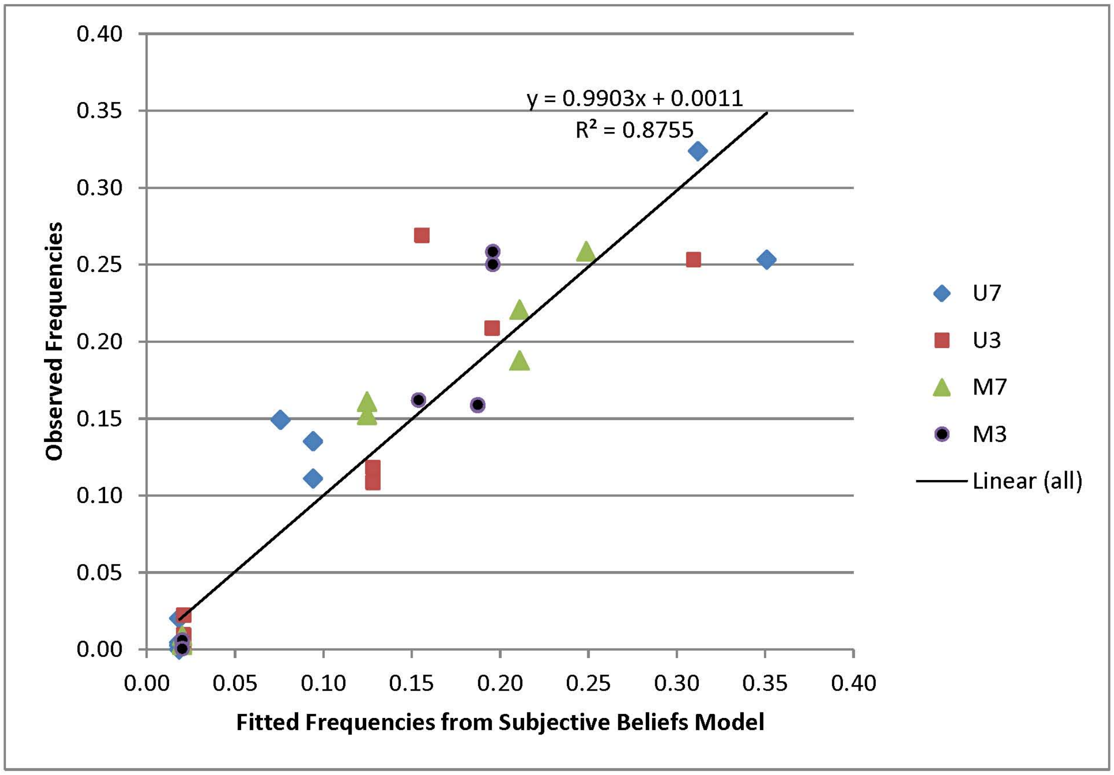

FIGURE 1. Estimated model vs. data action frequencies from Table 4

Table 4 displays the fitted action probabilities corresponding to separate estimates for each treatment, and compares them to the frequencies observed in the data. Column 3 displays the percent of informed individuals, denoted $\%I$. The predicted value for percent informed for each treatment is computed as

$$(1-\widehat{Q})/2+(1-\widehat{p})\widehat{Q}\iota_R^*(\widehat{p},\widehat{Q},n)$$

for $R \in \{M,U\}$. On the whole, the model fits the empirical distributions rather well, as illustrated in Figure 1, which displays a scatter plot of the empirical versus fitted estimates from Table 4. There are two notable exceptions. For both unanimity treatments, the model underestimates the frequency of abstention by uninformed voters and overestimates the frequency of voting for B by uninformed voters. However, in no cases are these differences large in magnitude.

4.2.4. *Classification of individual subjects.* Using our estimates, we conduct a classification analysis based on individual behavior. We have 25 observations for each subject, except those in one majority session for whom we have only 24 observations. Each observation is one of the nine possible sequences of actions in $\{AA,AB,A\phi,BA,BB,B\phi,\phi A,\phi B,\phi\phi\}$. We compute, for each subject, the log-odds, λ_i, that the subject is a biased voter, calculated as the log of the ratio of the likelihood they are a biased and the likelihood they are unbiased, evaluated using the estimated parameters, $(\widehat{p},\widehat{Q})$. We call λ_i subject i's *Lscore*. Thus, for example, for subject i in a 3M session, i's Lscore is

Behavioral type	**3M**	**7M**	**3U**	**7U**	**All**
Unbiased	0.44	0.59	0.52	0.73	0.56
Biased	0.53	0.40	0.41	0.21	0.40
Unclassified	0.03	0.01	0.07	0.06	0.04
Observations	77	63	42	42	267

TABLE 5. Distribution of committee member types, based on modal behavior

computed as:

$$\lambda_i(D^i|\widehat{p}_{3M},\widehat{Q}_{3M}) =$$

$$\log\left\{\frac{[(\frac{1}{2}\widehat{Q}_{3M}+\frac{1}{6}(1-\widehat{Q}_{3M}))]^{k^i_{\phi A}+k^i_{\phi B}}[\frac{1}{6}(1-\widehat{Q}_{3M})]^{k^i_{\phi\phi}}[\frac{1}{12}(1-\widehat{Q}_{3M})]^{k^i_{AA}+k^i_{BB}+k^i_{AB}+k^i_{A\phi}+k^i_{BA}+k^i_{B\phi}}}{[\frac{1}{2}\iota^*_M(\widehat{p}_{3M},\widehat{Q}_{3M},3)\widehat{Q}_{3M}+\frac{1}{12}(1-\widehat{Q}_{3M})]^{k^i_{AA}+k^i_{BB}}[(1-\iota^*_M(\widehat{p}_{3M},\widehat{Q}_{3M},3))\widehat{Q}_{3M}+\frac{1}{6}(1-\widehat{Q}_{3M})]^{k^i_{\phi\phi}}}\right\}.$$

The cumulative distributions of the Lscores for each treatment are shown in Figure 2 below.

An Lscore greater than 0 corresponds to a subject who is more likely to be a biased type, and an Lscore below 0 indicates a subject more likely to be an unbiased type. Note that an Lscore above 3 or below -3 indicate that the odds (under the estimated model) are 20 : 1 that the subject is correctly classified as a biased or unbiased type, respectively. We use this 20 : 1 odds as our criterion for saying a subject is "classified" as a type. One can interpret 20 : 1 odds, for descriptive purposes, as indicating with 95% confidence that the subject is correctly classified by the estimated model.

Table 5 indicates, for each treatment, the percentage of subjects with Lscores below -3 (classified as "unbiased"), between -3 and 3 ("unclassified"), and above 3 (classified as "biased"). Across all sessions, 96% of subjects are classified, which suggests some support for our two-type mixture model.[2] Furthermore, 40% of subjects are classified as biased types, a percentage that corresponds almost exactly with the estimated value of $\widehat{p}_{3M}$, $\widehat{p}_{7M}$, and $\widehat{p}_{3U}$.

Finally, Figure 3 displays the action distribution for each subject, ordered by their Lscores, for each treatment. To avoid the figures becoming cluttered, we do not include all 9 possible sequences of actions in the figure, but condense these into 4 categories: ($I\phi$, $IVote$, $\phi\phi$, $\phi Vote$), where $I\phi = \{A\phi, B\phi\}$, $IVote = \{AA, AB, BB, BA\}$, $\phi\phi = \{\phi\phi\}$ and $\phi Vote = \{\phi A, \phi B\}$. As one can see from Figure 3, for all four treatments, ordering of subjects by their Lscores is roughly the same as ordering them lexicographically by their relative frequencies of these four categories. In all treatments, individual Lscores are (almost) monotonically increasing in the probability of action $\phi Vote$. Furthermore, in the majority rule committees, individual Lscores are (almost) monotonically decreasing in the probability of $IVote$. Thus, in these treatments, $IVote$ is a strong indicator of an unbiased type. This is less true in the unanimity treatments. In fact, in the unanimity treatments, $\phi\phi$ is at least as strong a marker for an unbiased type than $IVote$, and is the strongest indicator for voters in 7U committees. Finally, voters with a roughly equal mix of three or four of the action categories are harder for the model to classify and therefore tend to have Lscores with lower absolute values (i.e., centrally located in these graphs).

[2]The classification rates are nearly as high if the classification criterion is considerably strengthened to 100 : 1 odds (92%), or even 1000 : 1 odds (90%).

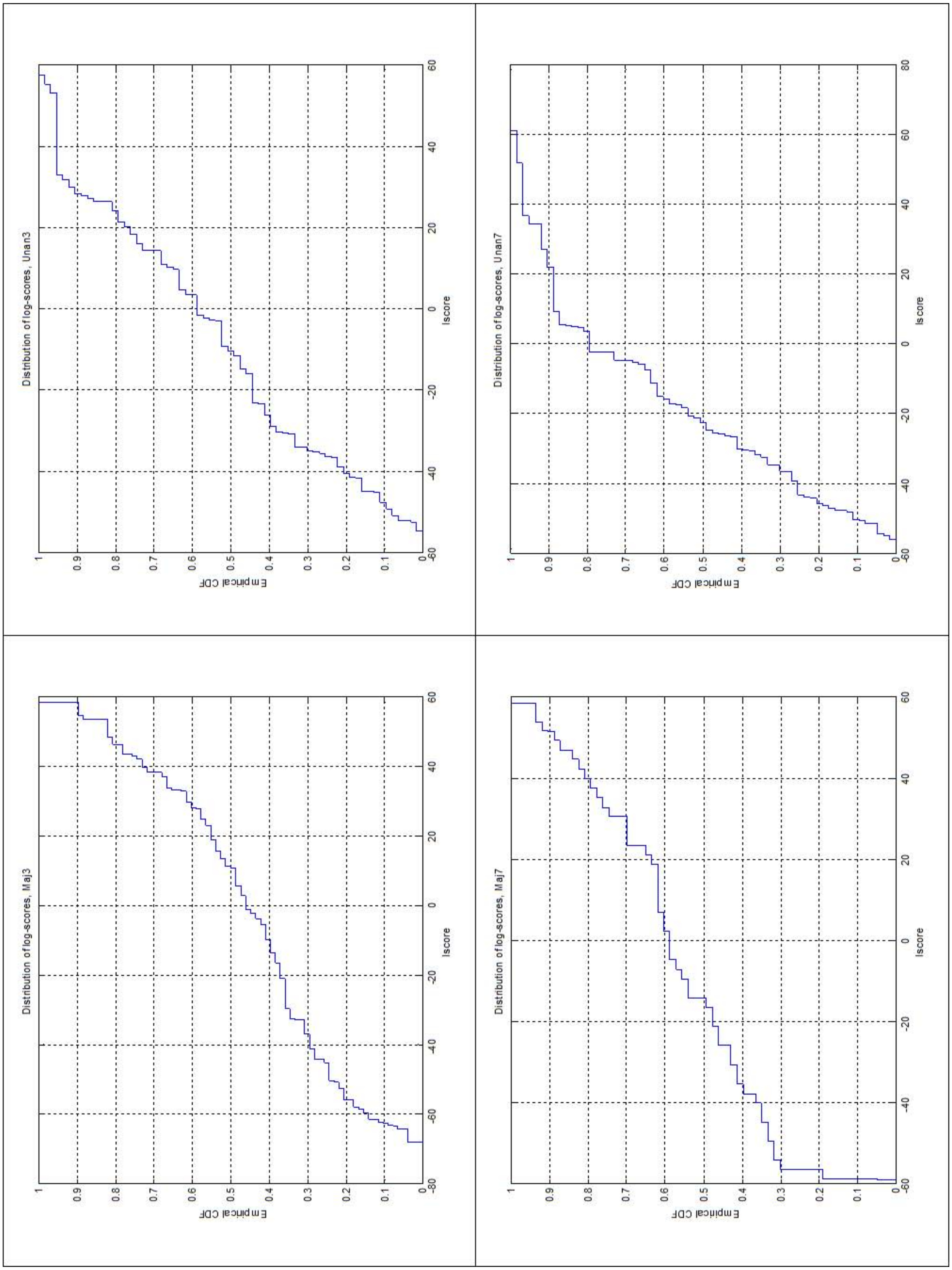

FIGURE 2. Distribution of Lscores

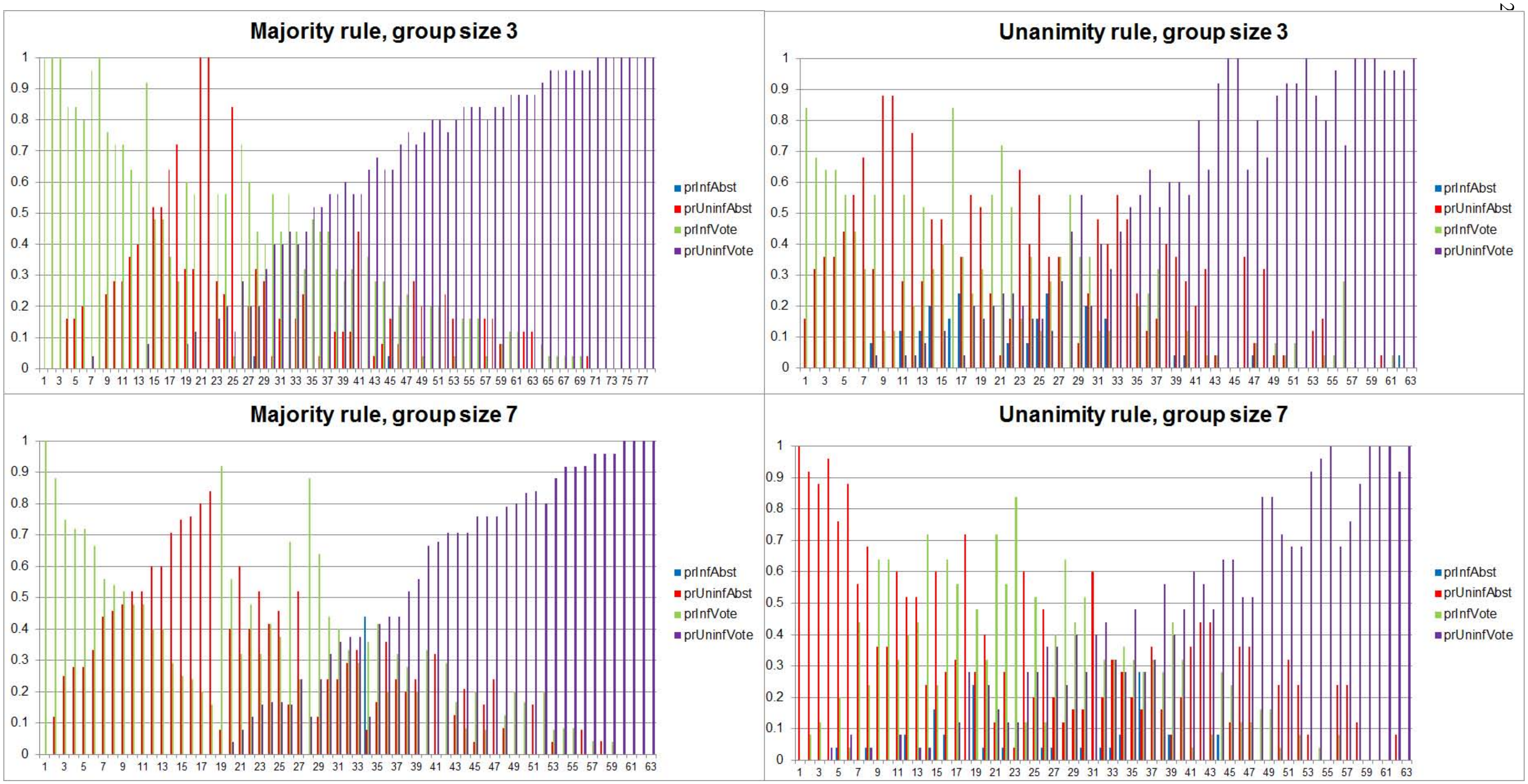

FIGURE 3. Distribution of actions

5. Final remarks

In this paper, we study theoretically and experimentally a group decision problem in which information is costly and therefore it may be rational to remain ignorant. The observed behavior at the lab is not entirely consistent with Bayesian equilibrium, and suggests an important role for noisy private beliefs. We propose a model of subjective beliefs equilibrium that seems to accommodate deviations from Bayesian equilibrium, as well as the observed heterogeneity in behavior. In the subjective beliefs equilibrium model, in addition to be rationally ignorant, voters may be biased, that is, subject to random, private shocks to beliefs. Therefore, the model proposed has a role both for ignorance and bias in explaining shortcomings of collective choice with costly information.

The major deviation from observed behavior at the lab and Bayesian equilibrium is the extent of uninformed voting in our dataset. This makes a stark contrast with Battaglini et al. (2010) original experimental work on the swing voter's curse, where uninformed voting was rare. There are two key differences between our environment and the one studied by Battaglini et al., which amplify the effect of subjective beliefs in our case. First, information is costly in our environment, and second, signals are imperfect. Because of these two features, biased voters may not consider worthy acquiring information, and may disregard the danger of overturning a decision made by other voters, even if those other voters are informed.

We want to remark that current behavioral theories do not seem to do a good job in explaining our dataset in a parsimonious way. Cursed or generalized cursed equilibria, as defined by Eyster and Rabin (2005), would predict mistakes related to underestimating the influence of private information in other voters' behavior. In particular, the behavior of our biased voters *at the voting booth* is cursed. Thus, cursed behavior would explain uninformed voting, but would not accommodate for the fact that those subjects who vote when they are uninformed are also less likely to acquire information—cursed voters would be less prone to free-riding than rational voters. But cursed behavior would not account for the behavior in the previous stage, that is the fact that biased voters acquire information less frequently than unbiased voters, and would not account for the difference between our observations and those of Battaglini et al.

Loss aversion, as introduced by Kahneman and Tversky (1983), could account for the reduced disposition of subjects in the lab to acquire information, since the cost of information can be construed as loss in case the voter is not decisive, or worse, of the voter is decisive but the signal is incorrect. Loss aversion, however, would not provide an explanation for the observed behavior at the voting booth. In particular, if the decision reached by other voters is construed as the initial situation, then loss aversion would induce more rather than less abstention.

While we propose the model of subjective beliefs equilibrium in a common interest, costly information collective choice setting, we consider it to be applicable to other settings as well. In the context of common value auctions, for instance, biased bidders' behavior would be influenced by their private information but also by their noisy prior beliefs. This, in turn, could lead best-responding unbiased bidders to (correctly) disregard the possibility that other bidders' behavior is motivated solely by differences in private information.

There are many other important settings in which a correct appreciation of the extent to which other players' behavior reacts to private information, rather than private hunches, is crucial for playing a best response. Examples that come to mind include sequential decision environments in which informational cascades are possible, lemon markets, and asset trading. In all these instances, understanding the effect of the presence of biased players on the behavior of unbiased players requires some careful equilibrium analysis. Looking forward, both theoretic and experimental work seem to be needed to achieve the goal of parsimonious, predictive game theory.

REFERENCES

[1] David Austen-Smith and Jeffrey Banks (1996), Information aggregation, rationality, and the Condorcet jury theorem, *American Political Science Review* 90: 34-45.

[2] V.K. Balakrishnan (1995), *Network Optimization*, Chapman & Hall.

[3] Marco Battaglini, Rebecca Morton and Thomas R. Palfrey (2010), The swing voter's curse in the laboratory, *Review of Economic Studies*77: 61-89.

[4] Sourav Bhattacharya, John Duffy and SunTak Kim (2013), Compulsory versus voluntary voting mechanisms: An experimental study, *Games and Economic Behavior*, forthcoming.

[5] Colin Camerer and Keith Weigelt (1988), Experimental tests of a sequential equilibrium reputation model, *Econometrica* 56: 1-36.

[6] Bryan Caplan (2007), *The Myth of the Rational Voter: Why Democracies Choose Bad Policies*, Princeton University Press.

[7] Jean Antoine Nicolas de Caritat, Marquis de Condorcet (1785)[1986], *Discours préliminaire de l'Essai sur l'application de l'analyse à la probabilité des décisions rendues à la pluralité des voix*, reprinted in Condorcet, *Sur les Élections et autres textes*, Libraire Artheme Fayard: Paris.

[8] Erik Eyster and Matthew Rabin (2005), Cursed equilibrium, *Econometrica* 73: 1623-1672.

[9] Timothy Feddersen and Wolfgang Pesendorfer (1996), The swing voter's curse, *American Economic Review* 86, 408-424.

[10] Timothy Feddersen and Wolfgang Pesendorfer (1997), Voting behavior and information aggregation in elections with private information, *Econometrica* 65, 1029-1058.

[11] Timothy Feddersen and Wolfgang Pesendorfer (1998), Convicting the innocent: The inferiority of unanimous jury verdicts under strategic voting, *American Political Science Review* 92, 23-35.

[12] James Friedman and Claudio Mezzetti (2005), Random belief equilibrium in normal form games, *Games and Economic Behavior* 51, 296-323.

[13] Dino Gerardi and Leeat Yariv (2008), Information acquisition in committees, *Games and Economic Behavior* 62, 436-459.

[14] Jacob K. Goeree and Leeat Yariv (2010), An experimental study of collective deliberation, *Econometrica* 79: 893-921.

[15] Jens Grosser and Michael Seebauer (2013), The curse of uninformed voting: An experimental study, mimeo.

[16] Serena Guarnaschelli, Richard D. McKelvey and Thomas R. Palfrey (2000), An experimental study of jury decision rules, *American Political Science Review* 94, 407-423.

[17] Daniel Kahneman and Amos Tversky (1983), Choices, values and frames, *American Psychologist* 39, 341-350.

[18] César Martinelli (2006), Would rational voters acquire costly information?, *Journal of Economic Theory* 129, 225-251.

[19] César Martinelli (2007), Rational ignorance and voting behavior, *International Journal of Game Theory* 35, 315-335.

[20] César Martinelli (2013), Ignorance and naivete in large elections, mimeo.

[21] Richard D. McKelvey and Thomas R. Palfrey (1995), Quantal response equilibria for normal form games, *Games and Economic Behavior* 10: 6-38.

[22] Richard D. McKelvey and Thomas R. Palfrey (1998), Quantal response equilibria for extensive form games, *Experimental Economics* 1: 9-41.

[23] Kaushik Mukhopadhaya (2005), Jury size and the free rider problem, *Journal of Law, Economics and Organization* 19, 24-44.

[24] Peter C. Ordeshook and Thomas R. Palfrey (1988), Agendas, strategic voting, and signalling with incomplete information, *American Journal of Political Science* 32: 441-466.

[25] Nicola Persico (2004), Committee design with endogenous information, *Review of Economic Studies* 71, 165-191.

APPENDIX

What follows is a translation of the Spanish-language instructions for the experiment. Minor differences between treatments are shown in italics.

Instructions

Thank you for accepting to participate in this experiment about decision-making. During the experiment we shall require your complete attention and careful following of instructions. Furthermore, you will not be allowed to open other computer applications, talking with other participants, or doing other things that may distract your attention, such as using your cell phone, reading books, etc.

At the end of the experiment, you will be paid for your participation in cash. Different participants may earn different amounts. What you earn will depend, in part, on your decisions, in part on decisions of other participants, and in part on chance.

The experiment will be administered via computer terminals, and all the interaction between the participants shall happen through these computers. It is important that you do not talk or try to communicate in any manner with other participants during the experiment.

During the instruction period, you shall receive a complete description of the experiment and will be shown how to use the computers. If you have any questions during the instruction period, raise your hand and the question will be responded to in a loud voice, so that everybody can hear it. If you have any questions after the experiment has started, raise your hand and an experimenter will approach you and try to help you.

This experiment will continue for 25 periods. At the end of the experiment you shall be paid what you earned, plus a participation fee of **$20** pesos. Everybody will receive his/her payment privately and will **not** be obliged to tell the others how much s/he earned. Your earnings during the experiment will be denominated in **points**. At the end of the experiment you will be paid **$8** pesos for every **1000 points** you earned.

Now we start a short instruction period, to be followed by a practice session. You will **not** be paid for the practice session. After the practice session, there will be a **short comprehension test**, to which you have to respond correctly before continuing to a session that will be paid for.

Rules of committee formation

We start the first period by dividing into seven (7) **Committees** of three (3) members each.<*Note: in two of the treatments, the instructions instead stated here "three (3) committees of seven (7) members each," with the appropriate substitution following through the rest of the text.*> Each one of you will be assigned by the computer to exactly one of these seven (7) Committees. You will not know the identity of the other members of the Committee to which you belong.

The committee decision task

Your Committee will have to decide between one of two options, which we shall call the **Red Jar** and the **Blue Jar**. The Committees will be making their decisions using the following voting procedure:

<*Instructions for majority treatments*>

The final decision of the Committee shall be the option which obtains the largest number of votes. In case of a draw in the number of votes, or voting in blank by all Committee members, the final decision of the Committee shall be determined randomly, with probability $\frac{1}{2}$ for each box color type.

<*Instructions for unanimity treatments*>

The **Red Jar** shall be elected by the Committee **only** when everybody who decides not to vote in blank, votes for the Red Jar, otherwise the Blue Jar shall be chosen by the Committee.

In other words, the **Blue Jar** shall be chosen by the Committee when at least one of the voters votes for the Blue Jar or everybody votes in blank.

Jar assignment by the computer

At the beginning of each period the computer will randomly assign one of two options as the **correct Jar for your Committee.** In each period there is a 50/50 chance that the Jar assigned is Red or Blue.

The computer will choose randomly the **correct jar** for each Committee and separately for each period. Therefore, the chance that your Committee is assigned a Red Jar or a Blue Jar shall **not** be affected by what happened in previous periods or by what is assigned to other Committees. The choice shall always be completely random in each period, with a probability of 50% for the Red Jar and 50% for the Blue Jar.

Buying information

You will **not** be informed of what is the correct Jar that is assigned to your Committee until **after** the Committee has chosen one of the options.

However, before the Committee decides on the option, each Committee member will have an opportunity to buy a piece of information about the color of the correct Jar assigned. During the practice period we shall explain exactly how this works.

If you decide to buy information about the color of the correct Jar assigned to your Committee, the cost of your purchase will be subtracted from your earnings. The cost of buying information which you would pay, which we shall call **sampling cost**, shall be equal to a number randomly chosen between 1 and 100 points.

You will be informed of the sampling cost before you decide whether to buy information, but you will **not** be informed about the costs of other members of your Committee.

These costs will be assigned randomly and independently for each of the Committee members and for each period. Any number between 1 and 100 points would have the same chance of being chosen.

Voting options

After all Committee members have decided, independently of each other, whether to buy information or not, every one of them will have to choose between:

- **Voting for the Red Jar**,
- **Voting for the Blue Jar**, or
- **Voting in Blank**.

<*Next line of Instructions was read only for the unanimity treatments*>

A Vote in Blank shall count in favor of the Blue Jar only if everybody decides to vote in blank.
After every member of your Committee has voted, the computer will count the votes in order to determine the final Committee decision.

Committee decision rule

<*Instructions for majority treatments*>

The Committee decision is determined using the **majority rule**.

<*Instructions for unanimity treatments*>

The Committee decision is determined using the **unanimity rule, with <unanimity necessary> to decide in favor of the Red Jar; otherwise, the Blue Jar shall be chosen**.

Payments for committee decisions

If your Committee decision is **equal** to the color of the Jar that was assigned, every Committee member will earn 1000 points.
If your Committee decision is **not equal** to the color of the Jar that was assigned, every Committee members will earn 0 points.
From the earnings of the Committee members **who will have acquired information sampling costs** will furthermore be subtracted.

Committee independence

Other Committees in the room will deal with similar problems, but the correct Jar assigned to each committee shall be different from that of other Committees. Remember that the Committees are completely independent and act independently.
After completing the first period, we proceed to the second period. You will be regrouped randomly into seven (7) new Committees and the process will repeat itself. This will continue for a total of 25 periods.

Description of the screen and the software

We now start the session and go to a practice period in order to familiarize ourselves with the experimental equipment.
During the practice period, please do not touch the keys, until you are asked to do so, and when you are instructed to enter certain information, please do exactly what you are asked to do.
Once more, you will **not** be paid for the practice period.

We now shall see the first experimental screen on the computer. You should see a similar screen in front of the room.

Please keep in mind that the screen shown in front is not necessarily identical to the screen that appears on your computer right now. The slides we show in front are only for illustration purposes. At the top left of the screen you will see your **identification.**

This ID shall be the same during the entire experiment. Please note it on the **registration sheet** that we have given to you.

Since this is the beginning of a period, you have been assigned by the computer to one of the seven committees of **3** members. This assignment will change every period.

At the top right of the screen you see the two Jars, each one containing exactly 12 balls. The Red Jar contains 8 Red balls and 4 Blue balls. The Blue Jar contains 8 Red balls and 4 Blue balls.

The Computer shall randomly assign one of the two jars to your Committee. In each period, the chance is **50/50** that the assigned Jar is Red or Blue. The assignment will be done 7 times, once for each Committee. Therefore, the seven committees in this period may have different jars.

You will not know whether the correct Jar for your Committee in this period is Red or Blue until after all the members of your Committee will have voted either Red, Blue or in Blank and the Committee decisions is determined. Before voting, one will have a chance to pay the cost and buy the information that may help you to determine the correct color of the Jar assigned to your group. Please wait and we will explain how to do it in a moment.

In front of the room you see a screen which shows how to determine the earnings. If the Committee decision **coincides** with the color of the Jar assigned to your Committee, you (and every one of the members of your Committee) will earn 1000 points for the period, and you will earn 0 points if the Committee decision **does not coincide**.

After the computer assigns a jar to each Committee, you shall see the following screen. Now you only see one Jar on the screen, but the colors of the balls are hidden, so at this point you cannot say which Jar has been assigned. This is the correct Jar assigned to your Committee. If it is the Red Jar it has 8 Red balls and 4 Blue balls; if it is the Blue Jar, it has 8 Blue balls and 4 Red balls.

Please keep in mind that the balls have been **reordered randomly** in **each** of the screens by the main computer, so that it is impossible to guess the location of the balls of each color and you **cannot** know which Jar has been assigned to your Committee.

At this point you will have an opportunity to pay a cost between 1 and 100 points to see the color of exactly one of the balls in the Jar assigned to your Committee. Your cost has been chosen randomly. Any cost between 1 and 100 points has equal probability of being assigned. The costs are assigned randomly and independently to each Committee member. These costs will also be randomly and independently chosen for each period. Your cost for this period is showing on the screen.

If you do **not** want to pay the cost, simply click the button that says "Do Not Observe". In this case you will **not** obtain any information about the correct Jar assigned to your Committee. Otherwise, if you would like to pay the information cost, simply move the cursor to any of the balls in the Jar and click once. Please wait and do not click for the time being.

If you pay the sampling cost and click on one of the balls, we shall call it your "sample ball" for this period. This ball is your private information. Other Committee members will also have an opportunity to acquire a simple ball in the same manner, though locations of the balls in the Jar are ordered differently for each member, and different members normally may have different costs. Therefore, different members of the same Committee may be clicking on balls of different color even for the same Jar. Nevertheless, if the Jar is Red, the Red balls twice as likely to be chosen as the Blue balls, and if the Jar is Blue, the Blue balls are twice as likely to be chosen as the Red balls. The colors of other balls will stay hidden until the end of the period. You will **not** know how many other Committee members will have decided to buy a sample ball and how many decided **not** to buy. Now continue and make your choice, making a click on a ball, or clicking the "Do Not Observe" button.

We now go to the voting stage.

At this point you will have three options: vote in favor of the Red Jar, vote in favor of the Blue Jar, or cast a Blank vote. There are three buttons on the screen, which say "Red", "Blue", and "in Blank.". You can cast your vote by clicking on the corresponding button. Since this is a practice period, we shall not let you choose. Instead, we will ask that you vote according to your identification. If your identification number is between 0 and 7, please vote red. If your identification number is between 8 and 14, please vote blue. If your identification number is between 15 and 21, please vote in blank. Of course, during the periods played for money you will be making your own decisions.

<*Instructions for majority treatments*>

Remember that only Blue and Red votes will count for the Committee decisions, which shall be made by the majority. Ties will be resolved randomly.

<*Instructions for unanimity treatments*>

Remember that unanimity is needed to choose the Red Jar. The Committee decision will be the Red Jar only if everyone who decides not to vote in blank votes for the Red Jar, otherwise the Blue Jar will be chosen. In other words, if at least one vote is for the Blue Jar, or if everybody votes in blank, the Blue Jar will be chosen.

We are now ready for a short comprehension test. Everybody has to respond to all the questions correctly before we proceed to periods to be paid for. Also, during the test you must respond to all the questions on page 1 in order to move to page 2. If you answer a question incorrectly, you will be asked to correct your answer. Please raise your hand if you have any questions during the test, so that we can come to your desk and respond to your question privately.

Once everybody has voted and finished the test, you will be informed of the final Committee decision, as well as of the correct Jar assigned to your Committee. Likewise, there will appear a small screen which will inform you of your earnings for the period, which shall be equal to zero, because we are in the practice period, which is not being paid for. Please close this little screen so that we may continue.

In the large screen at the end you will be shown how many votes were received by each Jar and how many voters decided to cast a blank vote. Also, please take into account that, at the end of the period the colors of all the balls in your Jar shall be revealed. This screen will mark the end of a period.

You are also shown your total earnings. Please click the "Accept" button to end the practice period.

COLUMN ONE shows the period number; COLUMN TWO shows your sampling cost; COLUMN THREE shows the color of the sample ball or says "Not Observed" if you decided not to buy the sample ball; COLUMN FOUR lists your vote; COLUMN FIVE provides the summary of the votes in the following order (RED JAR – BLUE JAR – IN BLANK); COLUMN SIX shows the Committee decision; COLUMN SEVEN shows the correct JAR assigned to the Committee; COLUMN EIGHT shows your earnings (do not appear now, because we are in practice period).

The table with columns in the bottom of the screen shows the history that includes all the key information for each period.

To sum up, please, remember the following important things.

<Instructions for the majority treatments >

The Committee decision is taken by the majority rule, with ties resolved randomly.

<Instructions for unanimity treatments>

The Committee decision is taken by the rule requiring unanimity to decide for the Red Jar. The Committee decision shall be Red Jar only if everybody who decided not to vote in Blank voted for the Red Jar; otherwise, it will be the Blue Jar. In other words, if at least one person voted for the Blue Jar, or if everybody votes in blank, the Blue Jar shall be chosen.

The Committee decisions are summed up in the text panel on the top left of the screen, and are also summed up in the history screen at the bottom of column five. While the experiment continues, the history screen will gradually show the information about all the previous periods in which you will have participated.

Are there any questions before we start the session that will be paid for?

We now start with the 25 paying periods of the experiment. If you have any problems or questions from now on, please raise your hand, and we will come by to help you in private.

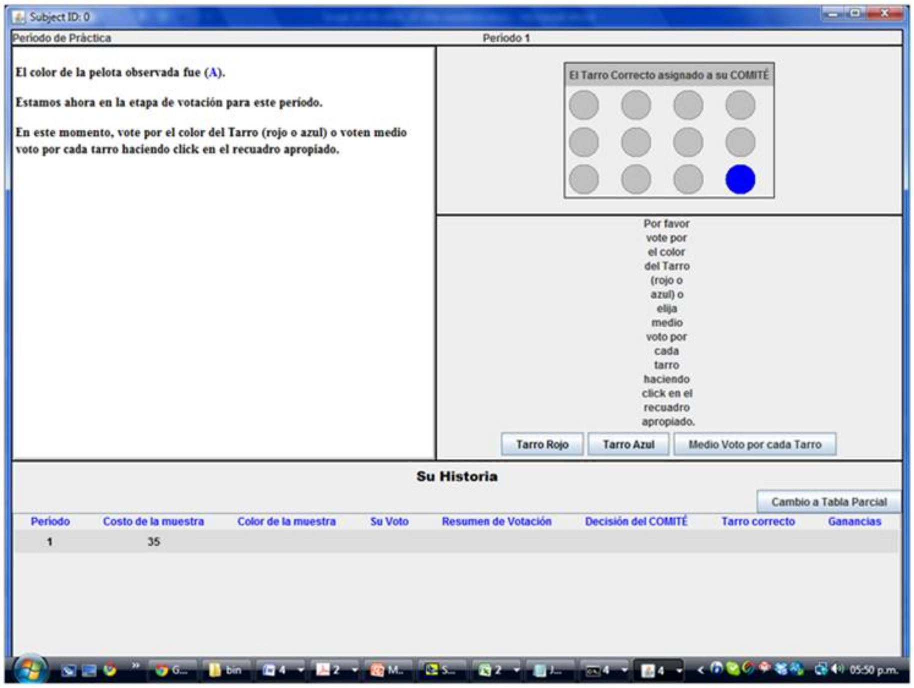

FIGURE 4. Voting screen for informed voter.