Information Acquisition and Voting Mechanisms: Theory and Evidence

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1 Introduction

Would rational voters engage in costly participation or invest in costly information? Rational choice models of voting predict that voter turnout becomes arbitrarily close to zero in large elections when voting is costly and voters are purely instrumentally motivated (Ledyard 1984; Palfrey and Rosenthal 1985). Under similar rationality assumptions about voters, Martinelli (2006) also shows that individual investment in (costly) political information declines to zero as the number of voters increases. These are the well-known "paradox of not voting" and "rational ignorance," respectively, but at the same time are vastly at odds with the reality to the point of letting us cast a serious doubt on the rational choice approach to political behavior.

However, the recent experimental studies found an evidence of strategic voting (Guarnaschelli, McKelvery and Palfrey 2000; Goeree and Yariv 2011) and obtained a confirmation

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of comparative static predictions of voter participation game (Levine and Palfrey 2007) in controlled laboratory environments. These studies suggest that equilibrium models perform quite well in explaining the behavior of voters whose preferences and other characteristics replicate those assumed in theory as closely as possible. In this study, we are interested in the implications of a rational choice model about voters' incentive to acquire costly information, especially from the perspective of designing optimal voting mechanisms. We design a laboratory voting game to see whether and to what extent the change in voters' investment behavior (and hence their welfare) follows equilibrium incentives according to the change in our parameters of voting mechanism.

We consider a situation in which a group of individuals with a common objective must decide between binary choices, and which choice is better depends on the realization of unknown state. A typical example of this is a jury trial in which jurors must decide whether to convict or acquit a subject without knowing for sure whether the latter is guilty or innocent. This is the basic setup of information aggregation literature, originally studied by Condorcet (1785) - and often called the Condorcet jury model - and reconsidered in the framework of formal game theory, starting with Austen-Smith and Banks (1996).

The situation of Condorcet jury model is not confined to jury trails, but is also found in committee decision-making in legislature, recruitment of new faculty members in academic departments, and even large-scale presidential election. In this group-decision environment, there is a *free-rider* problem arising from the rationality of voters who vote only to affect the outcome (instrumental motivation). A rational voter should weight the benefit from voting by the probability with which her vote makes a difference by making or breaking a tie (called *pivot probability*, and such event, *pivotal event*). This pivot probability in general decreases quickly with group size and voters thus have less incentive to participate in voting at a cost or to invest in costly information as the group size becomes larger. Thus, it is of practical importance how to design a voting mechanism to mitigate such a free-rider problem and to achieve a better group decision.

The present study addresses the question of how to optimally design a voting mechanism in a laboratory setting where voters must decide on whether to acquire costly information about unknown state, before making a voting decision.[1] In our study, a voting mechanism consists of a group size and a voting rule by definition. Optimal voting mechanism is a combination of group size and voting rule that maximizes the probability of a group's making a correct decision (e.g., convicting the guilty or acquitting the innocent). Here the optimality of a group size or a voting rule crucially depends on whether private information is freely given or should be acquired at a (positive) cost. We study theoretical implications of both costless and costly information acquisition about the efficiency of voting mechanisms (with respect to the probability of correct group decisions), and are particularly interested in whether the prescribed change in group size or voting rule actually induces the laboratory subjects to invest more in costly information in order to achieve a higher efficiency of group decision.

When private signals are free information to the voters, they can do better - make a correct decision with a higher probability - with a larger group size. This is the standard information aggregation effect or a prediction of the celebrated Condorcet Jury Theorem (Condorcet 1785).[2] Feddersen and Pesendorfer (1998) have shown that this result also holds in game-theoretic settings and hence is robust to strategic voting.[3] Even if people vote strategically against their private signals, they do it in an optimal way, and as a consequence, we obtain information aggregation with increasing group size. An implication for optimal

[1]For example, in a jury trial, jurors must pay attention to the evidence (acquire information) in order to make an informed judgment.

[2]Information aggregation means two things, as claimed by Condorcet (1785). First, with a fixed group size, the probability of a group making a correct decision is always greater than that of an individual. Second, the former probability converges to one as the group size becomes arbitrarily large. These results depend on the behavioral assumption that individuals vote according to their private signals, or vote *sincerely*.

[3]The incentive of strategic voting in the Condorcet jury setting was first reported by Austen-Smith and Banks (1996). They pointed out that sincere voting may not be incentive compatible when we consider the interactive nature of group decision-making.

voting mechanism is that we can always make a voting mechanism more efficient by adding more voters when private signals are free.

However, this is no longer the case when information is endogenous and its acquisition involves a costly decision. As we add one more voter to a group, and as long as this voter still has an incentive to acquire information (with positive probability), the information aggregation effect implies a higher probability of making a correct group decision (a positive effect on the efficiency of group decision). On the other hand, every member of the group becomes less likely to acquire information as we add one more voter because the probability of each vote affecting the group decision outcome (pivot probability) decreases with the group size. Hence, free-riding entails a negative effect on the efficiency. As we increase the group size while fixing a voting rule, the information aggregation effect is dominant at first and hence the efficiency improves up to a certain group size. Beyond this group size, the free-riding effect is dominant, leading to worsening of the efficiency. Persico (2004) is the first study that establishes a bound on the optimal group size under the Condorcet Jury setup with costly private information.

This gives us the first testable hypothesis. For a fixed (majority) voting rule, we will increase the group size under both costless and costly information. Then, efficiency under the former treatment keeps increasing while we can find, under the latter treatment, a group size up to which all individuals have an incentive to acquire information for sure, but beyond which no one has such incentive. Consequently, we must have a dramatic fall in efficiency beyond a certain group size due to lack of information. Thus the theory puts an upper bound on the optimal group size when information choice is endogenous, and we try to see whether this bound really works among the laboratory subjects who are asked to make a decision about the purchase of costly information.

Endogeneity of information also has an implication about (sincere) voting behavior. When information is free and exogenous, voters have incentive to vote strategically against their signals along the line of Austen-Smith and Banks (1996); for instance, in case of binary signals, such incentive exists under heterogeneous signal distribution across states (and majority voting rule). A possibility is that voters of one signal type vote *against* their private signals with positive probability while voters of the other type vote sincerely according to their signals.[4] The reason for strategic voting is because rational voters condition their decisions only on pivotal events - the events that their votes affect the outcome - and hence they can infer the signals received by others from the fact that the events are pivotal. Under asymmetric signal distribution (or asymmetric voting rule), the information at pivotal events can trump one's private information, thus generating incentive for strategic voting.[5] This is in line with the mixed-strategy equilibrium of strategic voting game in Feddersen and Pesendofer (1998). However, when information is costly and endogenous, voters no longer have such incentive of strategic voting upon acquiring costly information. In other words, once voters decide to buy a costly signal, they will always follow their acquired signals when they vote.[6]

Similar test about sincere voting behavior has been done by Bhattacharya, Duffy and Kim (2012) in the framework of compulsory versus voluntary voting. Their compulsory voting game is exactly the same as our voting game with free information, and as such, induces a strategic (insincere) voting equilibrium. However, voluntary voting game induces a sincere voting equilibrium (Krishna and Morgan 2012) in which all those who participate in voting, vote sincerely according to their signals. As in Bhattacharya, Duffy and Kim (2012), we test whether individuals properly adjust their (sincere) voting behavior as we change our voting

[4]Which type will vote strategically or sincerely depends on the conditional probabilities with which the (binary) signals are realized and voting rules. For any group size, there exists a voting rule under which both types vote sincerely in equilibrium. However, there's no equilibrium at which both types vote *insincerely*.

[5]This is similar to the inference problem in common value auctions that results in the 'winner's curse.' In auction settings, the event that I'm the winner allows me to infer others' valuations, which eventually leads me to overbid.

[6]In typical mixed strategy equilibria of voting games with endogenous information, voters don't acquire information with positive probability, and upon not acquiring information, they may randomize over the alternatives - but not necessarily with equal probability especially when the voting rule is itself asymmetric (e.g. supermajority rule).

institutions from the one with free information to that with costly information.

The final consideration is about optimal voting rule. We maintain the assumption of asymmetric precision of signals. In this case, for instance, the guilty signal is more precise at the guilty state than the innocent signal is at the innocent state,[7] and hence, if we employed majority rule, then we would convict a subject more often than is desired. Therefore, majority rule cannot be the optimal voting rule under asymmetric signals no matter whether information is costly or not. However, if every voter gets a private signal for free, then voting rules usually make little differences in the efficiency of group decision. This is because group decision will be always informative (the group decides correctly with probability greater than a half) regardless of voting rule as long as informative signals are freely available. The interesting thing about costly voting mechanism is that voters may or may not acquire information depending on voting rule, thus making a big difference in efficiency. If no one acquires information, the group decides between the alternatives with equal probability (assuming equal prior). The theory predicts that, at any fixed group size, there exists a voting rule that induces voters to acquire information so that the group can make an informative decision (as long as the cost of information is sufficiently small).

Thus our final test is to see whether the voting rule alone is able to induce information acquisition large enough to make a significant difference in efficiency when other parameters of the voting environment are kept constant. We again compare the efficiency of voting mechanisms with free and costly information under the alternate voting rules and try to confirm whether the predicted role of voting rule is relevant in explaining voter investment behavior. Our experimental results will shed light on how to design optimal voting mechanism - how to adjust group size and voting rule to achieve higher efficiency in group decision - especially when the assumption of costly information acquisition is appropriate among the

[7]We match with each state one of the binary signals that is realized with higher probability at that state. Hence, a guilty signal is more likely at the guilty state and vice versa. The correct signal at any state is the one that is realized with higher probability.

voters with common preferences who are to make a collective decision.

A laboratory experiment has several important advantages over field research for addressing the question of endogenous information. First, we can closely track the subjects to see whether they indeed acquire information. This may not be so easy in real voting environments because voter investment behavior is usually not observable and some voters might falsely report they obtained some information through costly efforts when they in fact didn't. Second, we can carefully control the information signals that subjects receive prior to making their voting decisions. Thus we can accurately determine if voters are voting sincerely, i.e., according to their signals, or if they are voting insincerely, i.e., against their signals. Third, in the laboratory, we can implement the theoretical requirement that subjects have identical preferences (common values) by inducing them to hold such preferences via the payoff function that determines their monetary earnings. Finally, we note that undergraduate students - from which we usually draw our laboratory subjects - are voting-age adults (18 years of age or older); by contrast with many other laboratory studies, our student subjects are thus regarded as professional subjects who are eligible to serve on juries or to vote in elections.

There is a sizable theoretical literature about information acquisition in voting environment. Persico (2004), Gerardi and Yariv (2008) and Gershkov and Szentes (2009) study information acquisition from the optimal design perspective, hence are similar to our study in terms of motivation. Our setup is closest to that of Persico (2004) where the quality of information is given and individuals vote simultaneously. Martinelli (2006, 2007) considers a large election in which only a tiny fraction of the electorate acquires information, but nevertheless a group decides correctly with probability close to one (rational ignorance). Oliveros (2011, 2012) considers (two-dimensional) voter types and how these types map into various ideological behaviors in an endogenous information framework. These are all theoretical studies and there's no known result about how these theories perform in controlled laboratory setting (even if there are some empirical studies about political information). Also, these are all rational voter models of endogenous information and as such imply a strong incentive of free-riding with regard to the decision to acquire costly information. However, we often observe, for example, over-participation in laboratory voting games (Levine and Palfrey 2007; Bhattacharya, Duffy and Kim 2012) and expect to observe over-investment in information in the present case (we actually ran a couple of pilot experimental sessions and observed a large amount of over-participation). Our task is, first, to see whether comparative static predictions of voter investment and group efficiency (with regard to group size and voting rule) hold as the rational theory suggests, regardless of over-investment (if subjects *do* over-invest in information) and second, to explore a way to explain over-investment through some expressive motivation or other-regarding preferences.[8]

[8]For example, Feddersen, Gailmard and Sandroni (2009) and Morton and Tyron (2012) study ethical expressive motivations in laboratory voter participation games. The former study shows that ethical voters are less likely to abstain and hence more likely to sway the electoral outcomes in large elections.

2 Model

The experiments are based on the standard Condorcet Jury setup. We consider two different voting mechanisms: voting with free information (VFI) and voting with costly information (VCI). In both cases a group consisting of an odd number N of individuals faces a choice between two alternatives, labeled R (Red) and B (Blue). The group's choice is made in an election decided by q-rule; the alternative R is chosen if q ($\frac{N}{2} \leq q \leq N$) or more individuals vote for R, and the alternative B is chosen otherwise.

There are two equally likely states of nature, ρ and β. Alternative R is the better choice in state ρ while alternative B is the better choice in state β. Specifically, in state ρ each group member earns a payoff of $M(>0)$ if R is the alternative chosen by the group and 0 if B is the chosen alternative. In state β the payoffs from R and B are reversed. Formally, we have

$$\begin{aligned} U(R|\rho) &= U(B|\beta) = M, \\ U(R|\beta) &= U(B|\rho) = 0. \end{aligned}$$

Prior to the voting decision, each individual may receive a private signal regarding the true state of nature. The signal can take one of two values, r or b. The probability of receiving a particular signal depends on the true state of nature. Specifically, each subject can receive a conditionally independent signal where

$$\Pr[r|\rho] = x_\rho \quad \text{and} \quad \Pr[b|\beta] = x_\beta.$$

We suppose that both x_ρ and x_β are greater than $\frac{1}{2}$ but less than 1 so that the signals are informative but noisy. Thus, the signal r is associated with state ρ while the signal b is associated with state β (we may say r is the correct signal in state ρ while b is the correct signal in state β). We will assume that $x_\rho \geq x_\beta$, i.e., either that the accuracy of signals is the same in each state, or that the correct signal is more accurate in state ρ than in state β.[9] The posterior probabilities of the states after signals have been received are:

$$Pr[\rho|r] = \frac{x_\rho}{x_\rho + (1 - x_\beta)} \quad \text{and} \quad Pr[\beta|b] = \frac{x_\beta}{x_\beta + (1 - x_\rho)}.$$

Since $x_\rho \geq x_\beta$, we have $Pr[\rho|r] \leq Pr[\beta|b]$. Thus, when the above inequality holds strictly, b is a stronger signal in favor of state β than r is in favor of state ρ.

It is important to note that if information is free (VFI mechanism), each individual gets *at no cost* a private signal whose conditional probability is as above. However, if information is costly (VCI mechanism), then each individual can decide whether to acquire this private signal *at a fixed cost* $c(> 0)$. In the latter case, an individual's payoff is either $M - c$ or $-c$, depending on the correctness of group decision, if she acquries a private signal while the payoff is the same as before, i.e., either M or 0, if she doesn't acquire the signal.

Having specified the preferences and information structure of the model, we next discuss the strategies, equilibrium conditions and equilibrium predictions for each of the two voting mechanisms that we explore in our experiment. We restrict attention to symmetric equilibria in weakly undominated strategies, as these are the most relevant equilibrium predictions given the information that is available to subjects in our experiment. In particular, we require that in equilibrium (*i*) all voters of the same signal type play the same strategies and (*ii*) no voter uses a weakly dominated strategy. Furthermore, under VCI mechanism, there often exist multiple equilibria with or without information acquisition, which will be explored in detail in the relevant subsection.

[9] As mentioned before, we assume "symmetric" signals for the group size treatment, but switch to "asymmetric" ones for the voting rule treatment. The assumption of signal asymmetry is required for there to be some insincere voting under VFI mechanism with majority rule ($q = \frac{N}{2}$) and for the optimal rule to be different from majority rule under both VFI and VCI mechanisms.

2.1 Voting with Free Information

When information is free, the strategy of a voter is a specification of two probabilities (v_r, v_b) where v_r is the probability of voting for alternative R given an r signal and v_b is the probability of voting B given a b signal (that is, v_s is the probability of voting according to one's signal s, or voting *sincerely*). Under VFI mechanism, there exists a unique equilibrium in weakly undominated strategies. In this equilibrium, we may obtain sincere voting equilibrium ($v_r^* = v_b^* = 1$) depending on the symmetry of signal precision and voting rule. For instance, if both signal and voting rule are symmetric ($x_\rho = x_\beta$ and majority rule), sincere voting is incentive compatible. However, sincere voting equilibrium is in general not robust to the introduction of asymmetry in the voting environment. We often have an equilibrium in which voters with one signal type always vote for the signal (vote *sincerely*, i.e. $v_s^* = 1$) while those with the other signal type mix between the two alternatives (i.e., $v_{-s}^* \in (0,1)$).[10]

Next, let's see how equilibrium conditions look like. Suppose we have asymmetric signals (e.g. under majority rule) such that type-b votes sincerely while type-r mixes between the two alternatives.[11] Such mixing requires that the voter obtaining signal r be indifferent between voting for R or B conditional on her vote being pivotal (given the other individual's equilibrium strategies), which gives the following equilibrium condition

$$U(R|r) - U(B|r) \equiv M\{Pr[\rho|r]\Pr[Piv|\rho] - Pr[\beta|r]\Pr[Piv|\beta]\} = 0,$$

where $U(A|s)$ is the payoff that a voter gets when alternative $A \in \{R, B\}$ is chosen and her signal (type) is $s \in \{r, b\}$; and $\Pr[Piv|\omega]$ is the probability that a vote is pivotal at state

[10] As is mentioned in the introduction, the type who will vote sincerely is determined by conditional probabilities of (asymmetric) signals and voting rules. For each group size N, there exists a voting rule under which sincere voting by both signal types obtains in equilibrium. This voting rule is often called *statistical rule* (Persico 2004). When signals are symmetric, it is majority rule that induces a sincere voting equilibrium, but when signals are asymmetric, it should be a supermajority rule.

[11] The equilibrium conditions for the opposite case in which type-b mixes are similar.

$\omega \in \{\rho, \beta\}$.[12] A vote is pivotal only when exactly $q-1$ voters have voted for R and the remaining voters have voted for B. Since the pivot probabilities depend on v_r, the above indifference condition determines v_r^*. Moreover, given this value for v_r^* (or $v_r^* = 1$ under the statistical rule) and the fact that type-b voters strictly prefer to vote sincerely in equilibrium, we must have

$$U(B|b) - U(R|b) \equiv M\{q(\beta|b)\Pr[Piv|\beta] - q(\rho|b)\Pr[Piv|\rho]\} > 0.$$

We then use the solution values (v_r^*, v_b^*) to obtain the probability of making a correct group decision (our measure for the efficiency of group decision).

2.2 Voting with Costly Information

When information is costly, we must consider not only voting strategy but also investment strategy $\sigma \in [0,1]$, where $\sigma = 1$ (denoted σ_1) means "acquiring information," and similarly, $\sigma = 0$ (denoted σ_0) means "not acquiring information," and $\sigma \in (0,1)$ denotes the probability with which a voter acquires information. It can easily be seen that people always vote sincerely upon acquiring information. If a voter doesn't acquire information, she will vote R with probability v and vote B with probability $1-v$. An equilibrium can thus be described by two choice probabilities (σ^*, v^*).

Under VCI mechanism, there exist multiple equilibria with or without information acquisition. For a large set of parameter values (including those of our experimental design), there exists a continuum of equilibria with no information acquisition. It's also possible to have multiple equilibria with positive information acquisition ($\sigma^* > 0$), in which case, we mainly focus on the most efficient equilibrium. We consider no information equilibrium ($\sigma^* = 0$)

[12] Under the statistical rule, both types vote sincerely, hence we must have $U(R|r) - U(B|r) > 0$, together with a similar condition for type-b given above.

only when there doesn't exist an equilibrium with information acquisition.

When we have an interior solution $(\sigma^*, v^*) \in (0,1)^2$, a voter must be indifferent between acquiring and not acquiring information, and upon not acquiring information, be indifferent between vote R or B. This gives the following equilibrium conditions

$$\begin{aligned} U(\sigma_1) &\equiv \frac{M}{2}\{Pr[\rho|r]\Pr[Piv|\rho] + Pr[\beta|b]\Pr[Piv|\beta]\} - c \\ &= \frac{M}{2}\{v\Pr[Piv|\rho] + (1-v)\Pr[Piv|\beta]\} \equiv U(\sigma_0) \end{aligned}$$

(recall $c > 0$ is the cost of acquiring information) and

$$U(R|\sigma_0) - U(B|\sigma_0) \equiv \frac{M}{2}\{\Pr[Piv|\rho] - \Pr[Piv|\beta]\} = 0.$$

Of course, any of the above two conditions hold with strict inequality when we have corner solutions; $U(\sigma_1) > (<) U(\sigma_0)$ when $\sigma^* = 1 (= 0)$; $U(R|\sigma_0) - U(B|\sigma_0) > (<) 0$ when $v^* = 1 (= 0)$. Again, the solution values (σ^*, v^*) are then used for the calculation of efficiency.

3 Experimental Design

We consider three treatment variables: 1) the voting mechanism, with free or costly information, 2) the group size N, and 3) the voting rule q. We adopt a between subjects design so that in each session subjects only make decisions under one set of treatment conditions.[13]

The experiment is presented to subjects as an abstract group decision-making task using neutral language that avoided any direct reference to voting, elections, jury deliberation, etc. so as not to trigger other (non-theoretical) motivations for voting (e.g., civic duty, the sanction of peers, etc.).

[13]In any session, voting mechanism (free or costly information), group size N and voting rule q are fixed as a set of treatment variables to be applied to the session.

Each session consists of a multiple of N inexperienced subjects and 30 rounds. At the start of each round, the subjects are randomly divided into groups of size N. Each group of size N is then assigned to either a red jar (state ρ) or a blue jar (state β) with equal probability, thus fixing the true state of nature for each group. No subject knows which jar is assigned to her group. The assignment of groups and jars are determined randomly at the start of each new round so as to avoid possible repeated game dynamics. Subjects *do* know that it is equally likely that their group is assigned to a red or a blue jar at the start of each round.

A red jar contains fraction x_ρ red balls (signal r) and fraction $1 - x_\rho$ blue balls (signal b) while a blue jar contains fraction x_β blue balls and fraction $1 - x_\beta$ red balls. We fix the probabilities, x_ρ and x_β, either at 0.7 (in the group size treatment) or at 0.9 and 0.6, respectively, (in the voting rule treatment), and these signal precisions are made public knowledge in the written instructions. We choose values for x_ρ and x_β that provides stark differences in equilibrium predictions across all treatments with the aim of facilitating identification of any treatment differences in the (possibly noisy) experimental data.

The sequence of play in a round of VFI (voting with free information) sessions is as follows. First, each subject blindly and simultaneously draws a ball (with replacement) from her group's (randomly assigned) jar. This is done virtually in our computerized experiment; subjects click on one of 10 balls on their decision screen and the color of their chosen ball is revealed.[14] While the subject observes the color of the ball she has drawn, she does not observe the color of any other subject's selections or the color of the jar from which she has drawn a ball. The group's common and publicly known objective is to correctly determine the jar, "red" or "blue", that has been assigned to their group.

After subjects have drawn a ball (signal) and observed its color, they next make a "choice"

[14]For each round and for each subject, the assignment of colors to the 10 ball choices the subject faces are made randomly according to whether the jar the subject is drawing from is the red (in which case percentage x_ρ of the balls are red) or blue (in which case percentage x_β balls are blue).

(i.e., vote) between "red" or "blue", with the understanding that their group's decision is red if q or more group members choose red and the group's decision is blue otherwise (recall $\frac{N}{2} \leq q \leq N$ is one of the treatment variables that can change from session to session) and that the group's aim is to correctly assess the jar (red or blue) that is assigned to the group. We can't have a tie for any group size N and any voting rule q because of the way we define voting rule, so a group's decision is either red or blue.

In VCI (voting with costly information) sessions, each subject can decide whether to have an opportunity to draw a ball (by spending a cost) from her group's jar at the start of each round. If a subject decides to draw a ball, then she will draw from her group's jar whose composition of red and blue balls is exactly the same as those in VFI sessions. The subjects, with or without drawing a ball and observing its color, then proceed to make a choice between red and blue. The group's decision is again made by q-rule.

Payoffs each round are determined as follows. In a round of VFI sessions, if the group's decision via q-rule is correct, i.e., the group's decision is red (blue) and the jar assigned to that group is in fact red (blue), then each of N members of a group receives 100 points ($M = 100$). If the group's decision is incorrect, then each of the N members of the group receives 0 points. In a round of VCI sessions, a subject again can earn 100 or 0 points, depending on the correctness of group decision, if she has decided to draw a ball. However, if she has decided not to draw a ball, she can additionally get c points, i.e., she can get either $100+c$ or c points, again depending on her group's decision. Thus, the cost of drawing a ball (obtaining a signal) is implemented as an opportunity cost. We fix $c = 5$ points through all VCI sessions. These payoff functions are the same across the entire sessions and the subjects are paid the cumulative total of the points earned in all rounds of a session.

Following 30 rounds of play, the session is over. Subjects' point totals from all 30 rounds of play are converted into dollars at the fixed and known rate of 1 point = \$0.01 and these dollar earnings are then paid to them in cash. In addition, subjects are given a \$5 cash show-up payment.

Treatment	Voting Mechanism	N	q	No. of subjects per session	No. of rounds per session
group size	VFI 1	3	2	24	30
	VCI 1	3	2	24	30
	VFI 2-3	5	3	20	30
	VCI 2-3	5	3	20	30
	VFI 4-7	7	4	14	30
	VCI 4-7	7	4	14	30
voting rule	VFI 8-11	7	4	14	30
	VCI 8-11	7	4	14	30
	VFI 12-15	7	6	14	30
	VCI 12-15	7	6	14	30

Table 1: The Experimental Design

Table 1 summarizes our experimental design, which involves eight groups (of size N) for each combination of group size and voting rule. We plan to run 30 sessions and recruit 464 subjects in total. Subjects are recruited from the undergraduate population of the University of Pittsburgh and the National Taiwan University and the experiment is conducted in the Pittsburgh Experimental Economics Laboratory (PEEL) and the Taiwan Social Science Experimental Laboratory (TASSEL).[15] No subject is allowed to participate in more than one session of this experiment.

4 Research Hypotheses

The first hypothesis is about optimal group size. For this purpose, we fix the voting rule (majority rule) and vary group size from $N = 3$ to $N = 5$, and then to $N = 7$. If information is free, then we only have information aggregation effect, so we should observe an increase

[15]The above mentioned monetary payoffs are in US dollars. If an experiment is conducted in the TASSEL lab, the payoffs will be adjusted appropriately according to the exchange rate 1US$=30NT$ with a show-up fee 150NT$.

in the efficiency of group decision as we increase the group size. However, if information is costly, then we also have free-riding effect, and under the value of our signal precision $x_\rho = x_\beta = 0.7$ and our cost parameter $c = 5$, we should expect a significant drop in both the frequency of acquiring information and the efficiency as we increase the group size from $N = 5$ to $N = 7$. The following table shows the numerical values of equilibrium prediction for the group size treatment.

Voting Mechanism	N	q	w^*	σ^*
VFI	3	2	0.784	n/a
	5	3	0.837	n/a
	7	4	0.874	n/a
VCI	3	2	0.784	1
	5	3	0.837	1
	7	4	0.5	0

Table 2: Optimal Group Size

Recall w^* denotes the efficiency of group decision, or the probability of making a correct group decision, at equilibrium and σ^* denotes the equilibrium probability of acquiring information under VCI mechanism. Based on the equilibrium predictions shown in Table 2, we state our first research hypothesis;

H1. Fixing majority voting rule, there should be an increase in the efficiency under VFI mechanism each time we increase the group size, but a significant decrease in both efficiency and information acquisition under VCI mechanism as we increase the group size from $N = 5$ to $N = 7$.

The second hypothesis is about sincere voting behavior. Consider first the VFI mechanism. The asymmetry in the precision of signals, as parameterized for our experiments, is strongly in favor of state ρ, hence if voting rule is closer to the symmetric rule (majority rule), then type-r subjects (who observed a red ball) will have an incentive to vote strategically against their signals (while type-b subjects will vote sincerely). The asymmetric signals and voting rule strike a balance under the statistical rule and both type subjects have an incentive to vote sincerely. However, beyond the statistical rule toward unanimity rule, the voting rule is so asymmetric in favor of state β that type-b subjects will have an incentive to vote strategically at this time (while type-r subjects will vote sincerely). However, under VCI mechanism, there's no such incentive of strategic (insincere) voting upon acquiring information. Namely, once the subjects purchase a signal at cost c, they will always follow their signals when voting. For this test, we fix group size N and voting rule q and compare the sincerity of voting between VFI and VCI mechanisms.

H2. Fix $(x_\rho, x_\beta) = (0.9, 0.6)$. Under VFI mechanism, subjects of one signal type will vote against his/her signal with positive frequency, while the other type subjects will vote sincerely ($v_s^* \in (0,1)$ and $v_{-s}^* = 1$). However, under VCI mechanism, both type subjects will vote sincerely ($v_r^* = v_b^* = 1$) upon acquiring information.

Recall v_s^* denotes the equilibrium probability of sincere voting by signal type $s \in \{r, b\}$.

The final hypothesis is about optimal voting rule. Given the asymmetry in the precision of signals, majority rule can never be optimal no matter whether information is costly or not. For the test about voting rule, we fix the group size at $N = 7$ and change the voting rule from $q = 4$ (majority rule) to $q = 6$ (supermajority rule) under both VFI and VCI mechanisms. If information is free, then the corresponding change in efficiency is very small; we are expected to see only a small increase in the efficiency. This is because information comes freely and people adjust their behavior to achieve the best outcome. However, if information becomes costly, then the role of voting rule is more important. The same change in the voting rule will induce a significant increase in the frequency of information acquisition to achieve a great improvement in the efficiency. The reason for dramatic change in efficiency is because the chosen cost level c is so large that people are dissuaded from acquiring information under majority rule, but changing the voting rule in favor of state β restores the incentive to invest in information, which leads to a positive (and significant) level of information acquisition. This test is about the role of voting rule to induce more information in committee/electorate when information is endogenous. The following table summarizes the comparative static predictions about voting rules.

Voting Mechanism	N	q	w^*	σ^*
VFI	7	4	0.880	n/a
VFI	7	6	0.917	n/a
VCI	7	4	0.500	0
VCI	7	6	0.871	0.629

Table 3: Optimal Voting Rule

Under VCI mechanism, there's another equilibrium with information acquisition for the parameters $(N, q) = (7, 6)$, which is given by $(w^*, \sigma^*) = (0.685, 0.2725)$. What is included in Table 3 is the prediction from the most efficient equilibrium for these parameter values. It will be interesting to see whether people can coordinate on more efficient equilibrium. Table 3 gives us the final hypothesis.

H3. Fix $N = 7$. Under VFI mechanism, we will have a small increase in efficiency (3.7%) as we change the voting rule from $q = 4$ to $q = 6$. Under VCI mechanism, the same change in the voting rule entails a much bigger increase in efficiency (37.1%), and to support this, subjects are predicted to acquire information 62.9% of the times under the latter voting rule (whereas no information acquisition under the former rule).

These three hypotheses H1-H3 are the main hypotheses to be tested against our experimental data. The following sample of experimental instructions is for a VCI mechanism with signal precision $(x_\rho, x_\beta) = (0.9, 0.7)$, group size $N = 7$, and voting rule $q = 4$. If an experiment is conducted in the TASSEL lab, a Taiwanese translation of the following instructions will be read in the sessions with the monetary payoffs adjusted at the rate $1US\$ = 30NT\$$, as mentioned before.

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Experimental Instructions

Overview

Welcome to this experiment in the economics of decision-making. We ask that you not talk with one another for the duration of today's session.

For your participation in today's session you will be paid in cash at the end of the experiment. Different participants may earn different amounts of money. The amount you earn depends partly on your decisions, partly on the decisions of others, and partly on chance. Thus it is important that you listen carefully and fully understand these instructions before we begin. There will be a short comprehension quiz following the reading of these instructions which you will all need to complete before we can begin the experimental session.

The experiment will make use of the computer workstations, and all interaction among you will take place through these computers. You will interact anonymously with one another and your data records will be stored only by your ID number; your name or the names of other participants will not be revealed at any time during today's session or in any write-up of the findings from this experiment.

Today's session will involve 14 subjects and 30 rounds of a decision-making task. In each round you will view some information and make a decision. Your decision together with the decisions of others determine the amount of points you earn each round. Your dollar earnings are determined by multiplying your total points from all 30 rounds by a conversion rate. In this experiment, each point is worth 1 cent, so 100 points = $1.00. Following completion of the 30th round, you will be paid your total dollar earnings plus a show-up fee of $5.00. Everyone will be paid in private, and you are under no obligation to tell others how much you earned.

Specific Details

At the start of each and every round, you will be randomly assigned to one of two groups, the R (Red) group or the B (Blue) group. Each group will consist of 7 members. All assignments of the 14 subjects to the two groups of size 7 at the start of each round are equally likely. Neither you nor any other member of your group or the other group will be informed of whether they are assigned to the R or B groups until the end of the round.

Imagine that there are two "jars", which we call the red jar and the blue jar. Each jar contains 10 balls; the red jar contains 9 red balls and 1 blue ball while the blue jar contains 6 blue balls and 4 red balls. The red jar is always assigned to the R (Red) group and the blue jar is always assigned to the B (Blue) group. However, recall that you do not know which group (Red or Blue) you have been assigned to; that is, you don't know the true color of your group's jar. Furthermore, your assignment to the R or B group is randomly determined at the start of every round.

To help you determine the jar that has been assigned to your group for the round, you and each member of your group can decide whether or not you want to independently choose one ball from your group's jar and privately observe the color of that ball. You face this decision on the first decision screen for each round where you are asked: Do you want to draw a ball? If you click on no, then you can get additional points as will be explained in detail below, however, in that case you will not have any more information about the jar that has been assigned to your group; all you will know is that there is a 50 percent chance your group is assigned to the red jar and a 50 percent chance your group is assigned to the blue jar. If click on yes, then you will be shown 10 different balls that you can choose. The balls are numbered 1 to 10. You must then click on one of the 10 balls. When you are satisfied with your choice click the OK button. After doing so you will be privately informed of the color of that ball. You will not be informed about whether other members of your group chose to select a ball, or how many members of your group chose to select a ball, nor will they learn whether you chose to select a ball. You will also not be told the color of the balls drawn by any other members of your group who chose to draw balls, nor will they learn the color of the ball you chose, and it is possible for members of your group to draw the same ball as you do or any of the other 9 balls as well. Each member in your group who chooses to draw a ball selects one ball on their own and only observes the color of his/her own ball. However, all members of your group (Red or Blue), if they decide to choose a ball, will choose a ball from the *same* jar that contains the same number of red and blue balls. Recall again that if you are choosing a ball from the red jar, that jar contains 9 red balls and 1 blue ball while if you are choosing a ball from the blue jar, that jar contains 6 blue balls and 4 red balls.

After all group members have decided whether or not to draw a ball and those choosing to draw a ball have chosen their ball and observed its color, all group members will face a second decision screen where they will be asked to make a choice about the color of the jar that has been assigned to their group. Specifically, all group members, regardless of whether or not they have chosen to draw a ball, will face a choice between RED or BLUE for the color of the jar that has been assigned to their group. Those who chose to draw a ball will be reminded on this second decision screen of the color of the ball they have drawn. But all group members, even those who did not choose to draw a ball must choose whether the jar assigned to their group is BLUE or RED by clicking on either the blue or the red buttons.

Your group's decision depends on the individual member decisions. Your 7-member group's decision is RED if 4 or more of the members of your group (a majority) choose RED and your group's decision is BLUE otherwise, that is, if 4 or more of your group members (a majority) choose BLUE.

Suppose you selected RED or BLUE. If your group's decision (via majority rule) is the same as the true color of the jar that is assigned to your group, then the group decision is CORRECT, and you and every member of your group earns 100 points from the group's correct decision. If your group's decision is different from the true color of your group's jar, then the group decision is INCORRECT, and you and every member of your group will earn 0 points from the group's incorrect decision.

Suppose you selected not to draw a ball. Then you get an additional 5 points for the round. In other words, if your group's decision is the same as the true color of the jar that is assigned to your group, then you will earn 105 points from the group's correct decision. If your group's decision is different from the true color of your group's jar, then you will earn 5 points from the group's incorrect decision. Thus, by choosing to draw a ball to be further informed of the true color of the jar that is assigned to your group, you give up an additional 5 points for the round.

If the final (30th) round has not yet been played, then at the start of each new round you will again be randomly assigned to one of two groups of size 7. One group, Group R, will be assigned to the red jar and the other group, Group B will be assigned to the blue jar. Again, no one will know to which group or jar they have been assigned. Each group member will have the opportunity to privately decide whether or not to draw a new ball from your group's jar and observe its color (your decision to draw a ball in the previous round doesn't affect your decision for the current round), and then to choose between BLUE or RED. In other words, the group you are in will change from round to round.

Following completion of the final, 30th round, your points earned from all 30 rounds will be converted into cash at the rate of 1 point = 1 cent. You will be paid these total earnings together with your $5 show-up payment in cash and in private.

Questions?

Now is the time for questions? If you have a question about any aspect of these instructions, please raise your hand and an experimenter will answer your question in private.

Quiz

Before we start today's experiment we ask you to answer the following quiz questions that are intended to check your comprehension of the instructions. The numbers in these quiz questions are illustrative; the actual numbers in the experiment may be quite different. Before starting the experiment we will review each participant's answers. If there are any incorrect answers we will go over the relevant part of the instructions again.

1. I will be assigned to the same group, R or B in every round.

   Circle one: True False.

2. I must draw a ball from my group's jar in every round.

   Circle one: True False.

3. If the color of the ball you have drawn is red, then the color of your group's jar is also red. Circle one: True False.

4. The red jar contains ______ red balls and ______ blue balls. The blue jar contains ______ red balls and _______ blue balls.

5. Consider the following scenario in a round. 4 members of your group choose RED.

   a. What is your group's decision? _________

   b. If the jar of balls your group was drawing from was in fact the RED jar and if you have drawn a ball from the jar, how many points do you earn? _________

   c. If the jar of balls your group was drawing from was in fact the BLUE jar and if you have drawn a ball from the jar, how many points do you earn? _________

   d. If the jar of balls your group was drawing from was in fact the RED jar and if you have *not* drawn a ball from the jar, how many points do you earn? _________

e. If the jar of balls your group was drawing from was in fact the BLUE jar and if you have *not* drawn a ball from the jar, how many points do you earn? ________