Information Acquisition and Voting Mechanisms: Theory and Evidence*

Sourav Bhattacharya[†] John Duffy[‡] Sun-Tak Kim[§]

April 15, 2014

Abstract

This paper investigates the properties of optimal voting mechanisms with endogenous information acquisition. The standard model of jury voting with exogenous information predicts that the efficiency of group decision increases unambiguously with group size. However, once information acquisition becomes a costly decision, there is an important free-riding consideration that counterbalances the information aggregation effect. If the cost of acquiring information is fixed, then rational voters have disincentive to purchase information as the impact of their votes becomes smaller with a larger group size. An implication of the trade-off between information aggregation and free-riding is that there exists an optimal group size. We thus compare the efficiency of group decisions under different group sizes to test whether we can observe significant decreases in both information acquisition and efficiency as the group size moves from the optimal size to a larger group size.

*This paper is incomplete and not for circulation.

[†]Department of Economics, University of Pittsburgh. Email: sourav@pitt.edu
[‡]Department of Economics, University of Pittsburgh. Email: jduffy@pitt.edu
[§]Department of Economics, National Taiwan University. Email: sunkim@ntu.edu.tw

1 Introduction

Condorcet's jury theorem (Condorcet 1785) asserts that if a group of individuals have common preferences with regard to some binary outcome (e.g., convicting the guility or acquitting the innocent) and independent, noisy but informative private signals about the true state of the world (e.g., guilt or innocense) then, under majority rule, the correct outcome is more likely to be achieved as the number of voters is increased. Feddersen and Pesendorfer (1998) have shown that this result is robust to strategic or insincere voting, where voters may rationally vote against their private information; even if voters vote strategically against their signals, they do so in an optimal way, and as a consequence, we continue to obtain better information aggregation with increasing group size. An implication of these results for optimal voting mechanisms is that, under the maintained assumptions, we can always make a voting mechanism better by adding more voters. However, this result assumes that private signals about the true but unknown state of the world are costless. In this paper we study the question of information aggregation when voters must first decide whether to acquire costly information about the true state of the world prior to voting to convict or acquit. In particular, we present the results from a laboratory experiment designed to expore how the number of players, the cost of information and informativeness of signals matter for information aggregation by juries or committes.

The basic setup of our experiment is the Condorcet jury model in which voters must make a decision as a group about whether to convict or acquit a subject, based on private noisy signals about whether the latter is guilty or innocent. When the signals are free information to the voters, they can do better - make the correct decision with a higher probability - with a larger group size. However, this is no longer the case when information is endogenous and its acquisition involves a costly decision. If voters are asked to buy private signals at a fixed cost to be better informed about the true (but unknown) state of the world then there is an important free-riding consideration that counterbalances the information aggregation effect mentioned above. 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, the entire group of voters are less likely to acquire information as we add one more voter because the likelihood of any single vote being pivotal diminishes with group size (free-riding entails a negative effect on the efficiency). As we increase the group size with any fixed voting rule, the information aggregation effect is dominant at first and hence we have an increase in the efficiency of group decision up to a certain group size. Beyond that group size, the free-riding effect becomes dominant, resulting in a decrease in efficiency. Persico (2004) and Koriyama and Szentes (2009) show the existence of the upper bound on the optimal group size in Condorcet jury environments with costly information acquisition.

Those theoretical papers provide us with testable hypotheses that we evaluate in our laboratory experiment. In particular, increases in the group size should result in an increase in efficiency under the free information treatment. However, under costly information, efficiency should only increase up to a certain group size and then drop off to a minimal level. The reason for the latter drop in efficiency arises from a (possibly) huge decrease in the rate of information acquisition as the group size increases. Depending on the choice of parameters, all voters may have an incentive to acquire information up to a certain group size, but beyond that group size no individual has an incentive to acquire information. The reuslt is a dramatic fall in the efficiency of group decision-making with endogenous information. Thus the theory puts an upper bound on the optimal group size when information choice is endogenous, and one purpose of our experiment is to determine whether this upper bound really matters among the laboratory subjects who are asked to make a decision about the purchase of costly information. In addition to increasing group size, we also vary the cost of information acquistion and the precision of the signal processes. Changes in these model variables can have similar effects on the efficiency of group decision-making as we discuss in detail.

The rest of the paper proceeds as follows. We first present theoretical models and their equilibrium predictions. Then, we outline the experimental designs and finally state research hypotheses with numerical predictions under the parameter setups that are used in the experiments.

2 Model

The experiments are based on the standard Condorcet Jury model 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 majority rule; the alternative that receives more votes is chosen as the group decision outcome.

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

$$\Pr[r|\rho] = \Pr[b|\beta] = x.$$

We suppose $1/2 < x \leq 1$ so that the signals are informative but possibly noisy. More precisely we will consider cases where $1/2 < x < 1$, so that the signal is noisy but informative as well as cases where $x = 1$, and the signal (if purchased) is perfectly informative. Given that $x > 1/2$ 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). It can be easily checked that when the signal precision is *symmetric* the posterior probabilities that signals are matched with the correct states are the same in both states and given by the signal precision parameter x:

$$\Pr[\rho|r] = \Pr[\beta|b] = x.$$

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 $U(A|\omega)-c$, where A is the group decision outcome and ω is the state of nature (i.e., payoffs are either $M - c$ or $-c$, depending on the correctness of group decision), if she acquires a private signal. Payoffs are the same as before, i.e., $U(A|\omega)$, if she doesn't acquire a 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 concepts 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 strategies and (ii) no voter uses a weakly dominated strategy. We will discuss later the possibility of multiple, or more precisely asymmetric, equilibria, but our design involves the choice of parameters that entails a unique symmetric equilibrium (in weakly undominated strategies).

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 symmetric equilibrium in weakly undominated strategies. In this equilibrium, we may obtain sincere voting equilibrium ($v_r^* = v_b^* = 1$) if signal precision is symmetric (i.e., $\Pr[r|\rho] = \Pr[b|\beta]$) and voting is by majority rule (as in our model).[1]

Next, let's see how equilibrium conditions look like. Given a signal $s \in \{r, b\}$, an individual must strictly prefer to voting according to the signal, conditional on her vote being pivotal (given the other individuals' equilibrium strategies), in sincere voting equilibrium. This gives the following equilibrium conditions;

[1]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., $v_{-s}^* \in (0, 1)$), e.g., if signal precision is asymmetric ($\Pr[r|\rho] \neq \Pr[b|\beta]$) or if voting outcome is decided by supermajority/unanimity rule.

$$
\begin{aligned}
U(R|r) - U(B|r) &\equiv \frac{M}{2}\{\Pr[\rho|r]\Pr[Piv|\rho] - \Pr[\beta|r]\Pr[Piv|\beta]\} > 0, \\
U(B|b) - U(R|b) &\equiv \frac{M}{2}\{\Pr[\beta|b]\Pr[Piv|\beta] - \Pr[\rho|b]\Pr[Piv|\rho]\} > 0.
\end{aligned}
$$

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 $\omega \in \{\rho, \beta\}$. A vote is pivotal only when both alternatives R and B get the same number of votes. Since the pivot probabilities depend on voter strategies (v_s), we can check the above conditions by fixing strategies ($v_r^* = v_b^* = 1$) and assigning values for the parameters. We can also easily obtain, under sincere voting strategies, 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 randomize over two alternatives with equal probability under symmetric signal precision and majority rule. An equilibrium can thus be described by the choice probability σ^* in this symmetric environment.

Under VCI Mechanism, there may exist multiple equilibria (including asymmetric ones) where individuals acquire information with positive probability ($\sigma^* > 0$).[2] However, we always choose our parameter values such that voting game in our experiment has a unique symmetric equilibrium. We consider no information equilibrium ($\sigma^* = 0$) only when there doesn't exist an equilibrium with positive information acquisition.

[2]Since subjects are randomly matched to form a different group each round in a session (which will be explained in detail in the next section about experimental design), we highly doubt that subjects would coordinate themselves to play asymmetric equilibrium, if any.

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

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

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

Of course, the above condition holds with strict inequality when we have corner solutions; e.g., $U(\sigma_1) > U(\sigma_0)$ if $\sigma^* = 1$ in which case everyone acquires information for sure in equilibrium. Again, the solution value σ^* is then used for the calculation of efficiency.

3 Experimental Design

We consider four treatment variables: 1) voting mechanism, with free or costly information, 2) group size N, 3) information cost c and signal precision x. We adopt a between subjects design so that in each session subjects only make decisions under one set of treatment conditions.[3]

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.).

Each session consists of a multiple of N inexperienced subjects and 25 rounds. At the start of each round, the subjects are randomly allocated to 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

[3]In any session, voting mechanism (free or costly information), group size N, information cost c (of course, $c = 0$ in free information sessions), and signal precision x are fixed as a set of treatment variables to be applied to the session.

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 *red* balls (signal r) and fraction $1 - x$ *blue* balls (signal b) while a blue jar contains fraction x *blue* balls and fraction $1 - x$ *red* balls. We fix this signal precision either at $x = 0.7$ or at $x = 1$ in a given session, and these signal precisions are made public knowledge in the written instructions. We thus implement symmetric signal precisions so as to facilitate subjects' understanding of equilibrium strategies in the compound decision making situations of information acquisition and voting.

The sequence of plays 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.[4] 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" (i.e., vote) between "red" or "blue", with the understanding that their group's decision is red if a majority of group members choose red and the group's decision is blue otherwise 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 since N is always chosen to be odd, so a group's decision is either red or blue.

In VCI (voting with costly information) sessions, the sequence of plays is similar, but at this time each subject can decide whether to have an opportunity to draw a ball, at a positive 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 who chose not to draw a ball must wait until other members finish drawing a ball. The subjects, with or with-

[4]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 of the balls are *red*) or blue (in which case percentage x balls are *blue*).

out 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 majority rule.

Payoffs each round are determined as follows. In a round of VFI sessions, if the group's decision via majority 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 vary the magnitude of cost $c \in \{5, 8, 15\}$. These payoff functions are the same across the entire session and the subjects are paid the cumulative total of the points earned in all rounds of a session.

Following 25 rounds of play, the session is over. Subjects' point totals from all 25 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.

Voting Mechanism	N	c	x	No. of subjects per session	No. of rounds per session
VFI 1-4	3	n/a	0.7	6	25
VCI 1-4	3	5	0.7	6	25
VCI 5-8	3	8	0.7	6	25
VFI 5	7	n/a	0.7	14	25
VCI 9-12	7	5	0.7	14	25
VCI 13-16	7	8	0.7	14	25
VCI 17-20	13	8	0.7	26	25
VCI 21-22	7	15	0.7	14	25
VCI 23-26	3	8	1	6	25
VCI 27-30	7	8	1	14	25

Table 1: The Experimental Design

Table 1 summarizes our experimental design, which involves 5 VFI sessions and 30 VCI sessions. Subjects are recruited from the undergraduate population of the University of Pittsburgh and the experiment is conducted in the Pittsburgh Experimental Economics Laboratory. No subject is allowed to participate in more than one session of this experiment.

4 Research Hypotheses

The following Table 2 shows symmetric equilibrium predictions for each combination (N, c, x) of treatment variables.

x=0.7	$N = 3$		$N = 7$		$N = 13$	
	σ^*	w^*	σ^*	w^*	σ^*	w^*
$c = 0$	n/a	0.784	n/a	0.874	n/a	0.938
5	1	0.784	0.6693	0.773	0	0.5
8	1	0.784	0	0.5	0	0.5
15	0	0.5	0	0.5	0	0.5
x=1	$N = 3$		$N = 7$		$N = 13$	
	σ^*	w^*	σ^*	w^*	σ^*	w^*
$c = 5$	0.8944	0.992	0.5621	0.955	0.3561	0.912
8	0.8246	0.978	0.4472	0.902	0.2359	0.810
15	0.6325	0.911	0.1163	0.625	0	0.5

* σ^* = Equilibrium rate of information acquisition.
† w^* = Equilibrium efficiency.

Table 2: Symmetric Equilibrium Predictions

Based on the equilibrium predictions shown above, we formulate four hypotheses about the effect of treatment variables on the frequency of information acquisition (and hence on the frequency of group's making correct decisions - this efficiency of group decision always moves in the same direction as the rate of information acquisition, as is shown in the above Table 2).

H0. Condorcet Jury theorem: When information (signal) is free and informative, group decisions under majority rule improve as the group size increases.

If information is free ($c = 0$), then we only have information aggregation effect, so we should observe an increase in the efficiency of group decision as we increase the group size.

H1. Group size effect: For any fixed (positive) information cost and signal precision $(c, x) \in \{5, 8, 15\} \times \{0.7, 1\}$**, the frequency of information acquisition decreases as we increase group size from** $N = 3$ **to** $N = 5$**, and to** $N = 13$**.**

If information is costly, then we also have free-riding effect (together with information aggregation effect), and for any fixed cost c and fixed precision x, free-riding effect will eventually dominate information aggregation effect so that we reach a group size at which the incentive to acquire information totally disappears (σ^* drops to 0). This is because the probability of individual vote's being pivotal decreases and converges to zero as group size becomes arbitrarily large. In general, the equilibrium rate of information acquisition and group decision efficiency go down as we increase group size beyond a certain point if information is costly to acquire.

H2. Cost effect: For any fixed group size and signal precision $(N, x) \in \{3, 7, 13\} \times \{0.7, 1\}$**, the frequency of information acquisition decreases as we increase information cost** c**.**

The effect of information cost seems to be quire straightforward. The higher the cost of information acquisition is, the less likely people are to acquire information. However, there might be some salience issue. For example, the cost level $c = 8$ is theoretically sufficiently large to dissuade people from acquiring information totally while people may feel such cost level is empirically not large enough, compared to the level of benefit from a correct group decision (100 points), and still acquire information with positive frequency. Hence, it is interesting to see whether we will obtain the cost effect as cleanly as is predicted by the theory.

H3. Signal precision effect: For some fixed group size and information cost (N, c)**, the frequency of information acquisition can decrease as we increase signal precision from** $x = 0.7$ **to** $x = 1$**.**

As we increase signal precision, there are again two effects that work against each other. On the one hand, more precise signal will induce people to invest in information with higher frequency if the cost of information is held constant. On the other hand, a better quality of information makes an individual vote less likely to be pivotal since those who acquired a signal are more likely to vote for the correct alternative. Overall, whether people acquire information with higher frequency depends on which effect is dominant. Here, if subjects are purely decision-theoretic and don't fully understand strategic interaction implied by collective decision problem at hand, the frequency of information acquisition will increase whenever we increase signal precision. However, if and only when they reason game-theoretically, they will acquire information less frequently, facing a more precise signal, especially for relatively smaller group size and information cost (see Table 2).

These three hypotheses H1-H3 are the main hypotheses to be tested against our experimental data.

5 Experimental Results

5.1 Aggregate Data

The following Table 3 and Table 4 show the aggregate proportions of information acquisition and efficiency, for signal precision $x = 0.7$ and $x = 1$ respectively, that are observed from all sessions of all treatments as well as the average proportions over all sessions of each treatment combination (N, c, x). Figure 1 shows the average frequency of information acquisition and the average level of efficiency.

First, we note that when information is free ($c = 0$) and $x = 0.7$, efficiency is increasing with the group size and this supports Condorcet Jury theorem [H0]. We next look at group size effect [H1]. Fixing $c = 5$, $x = 0.7$, the mean frequency of information acquisition increases as N is increased from 3 to 7, from 69.5% to 76.7% but the difference is not statistically significant (theory predicts a movement in the opposite direction from 100% to 66.9%). Fixing

x=0.7	$N=3$		$N=7$		$N=13$	
	$\hat{\sigma}$	$\hat{w}$	$\hat{\sigma}$	$\hat{w}$	$\hat{\sigma}$	$\hat{w}$
	n/a	68	n/a	84		
$c=0$	n/a	78				
	n/a	72				
	n/a	86				
Overall	n/a	76	n/a	84	n/a	
Predicted	n/a	78.4	n/a	87.4	n/a	93.8
	54.67	62	64.00	76		
$c=5$	76.00	76	82.57	80		
	64.00	70	74.57	86		
	83.33	66	85.71	84		
Overall	69.50	68.5	76.71	81.5		
Predicted	100	78.4	66.93	77.3	0	50
	60.00	68	34.00	58	44.15	70
$c=8$	35.33	62	75.14	82	61.69	82
	74.00	66	36.00	70	38.77	78
	63.33	62	60.29	74	40.62	74
Overall	58.17	64.5	51.36	71	46.31	76
Predicted	100	78.4	0	50	0	50
			28.29	66		
$c=15$			54.00	74		
Overall			41.15	70		
Predicted	0	50	0	50	0	50

* $\hat{\sigma}$ = Observed frequency of information acquisition (%).
† $\hat{w}$ = Observed efficiency (%).

Table 3: Results by Session for $x = 0.7$

$c = 8$, $x = 0.7$, the mean frequency of information acquisition decreases slightly as N is increased from 3 to 7 and then to 13, from 58.17% to 51.36% to 46.31%, respectively. These differences are not statistically significant ($p > .10$). By contrast, theory predicts a movement from 100% when $N = 3$ to 0% frequency of information acquisition when $N = 7$ or 13.

x=1	$N = 3$		$N = 7$		$N = 13$	
	$\hat{\sigma}$	$\hat{w}$	$\hat{\sigma}$	$\hat{w}$	$\hat{\sigma}$	$\hat{w}$
$c = 5$						
Overall						
Predicted	89.44	99.2	56.21	95.5	35.61	91.2
	88.67	100	51.43	92		
$c = 8$	83.33	100	52.86	94		
	70.67	96	64.57	98		
	83.33	100	53.71	96		
Overall	81.50	99	55.64	95		
Predicted	82.46	97.8	44.72	90.2	23.59	81
$c = 15$						
Overall						
Predicted	63.25	91.1	11.63	62.5	0	50

* $\hat{\sigma}$ = Observed frequency of information acquisition (%).
† $\hat{w}$ = Observed efficiency (%).

Table 4: Results by Session for $x = 1$

Remarkably, group size effect is much more clear with perfectly precise signal ($x = 1$) as the mean frequency of information acquisition has dropped significantly from 81.5% when $N = 3$ to 55.64% when $N = 7$ ($p < .02$). Theoretical prediction is 82.4% information purchase when $N = 3$ falling to 44.72% when $N = 7$, hence fitting much better to the data for this signal precision level. This may be because we have interior predictions at $x = 1$ whereas mostly boundary predictions, either 0% or 100%, at $x = 0.7$. Moreover, the elimination of noise in the signal seems to make subjects understand the free-riding effect better.

We next turn to information cost effect [H2]. Fixing $N = 3$, $x = 0.7$, an increase in the cost of acquiring information from $c = 5$ to $c = 8$ results in

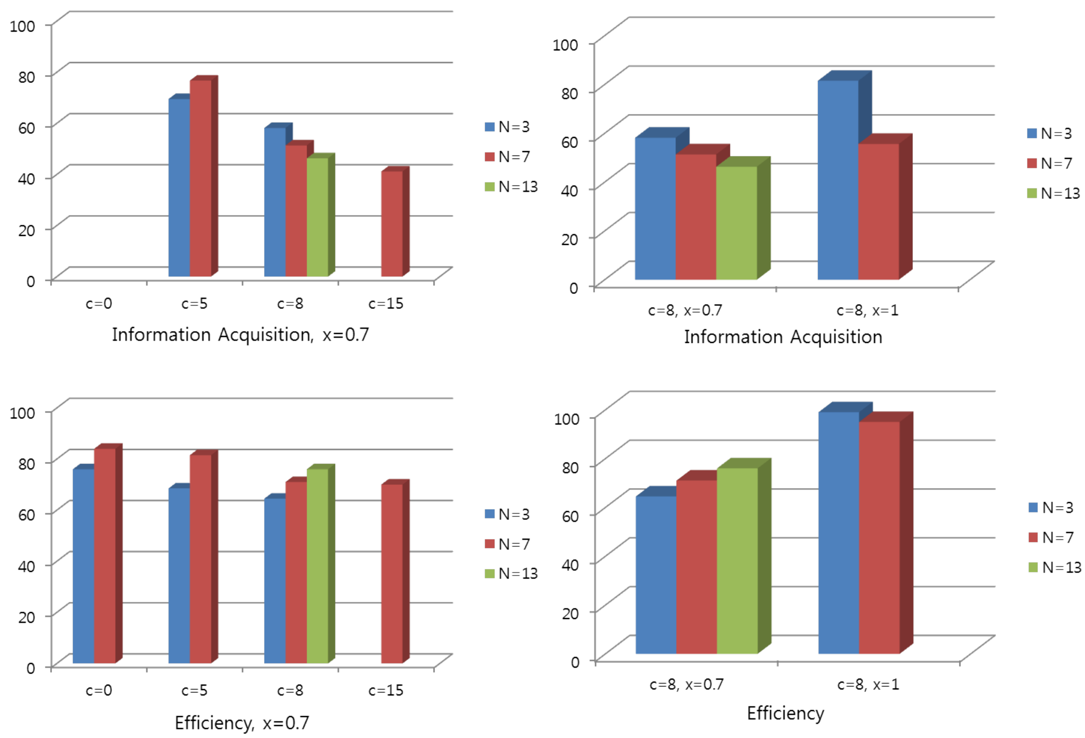

Figure 1: Overall Frequency of Information Acquisition and Efficiency

a decrease in the frequency of information acquisition from 69.5% to 58.1%; but this decrease is not significant. Fixing $N = 7$, $x = 0.7$, an increase in the cost of acquiring information from $c = 5$ to $c = 8$ results in a decrease in the frequency of information acquisition from 76.71% to 51.36% - theory predicts a fall from 66.93% to 0% - and this decrease is marginally significant ($p = 0.08$). For $N = 7$ (and $x = 0.7$), we further decreased cost to $c = 15$ (just two observations) and this resulted in the even lower mean frequency of information acquisition of 41.15%, but still much higher than the rational choice prediction of 0%.

We finally consider signal precision effect [H3]. Fixing $N = 3$, $c = 8$, an increase in the signal precision from $x = 0.7$ to $x = 1$ results in an increase in the mean frequency of information acquisition from 58.17% to 81.5% and this difference is significant ($p = 0.04$). The theoretical prediction, by contrast, is for a decrease from 100% to 82.46%. Fixing $N = 7$, $c = 8$, an increase in the signal precision from $x = 0.7$ to $x = 1$ results in a slight increase in the frequency of information acquisition - from 51.36% when $x = 0.7$ to 55.64% when $x = 1$ - but we've only got one observation for the latter treatment. The theoretical prediction calls for an increase from 0% to 44.72%.

x=0.7	$N = 3$		$N = 7$		$N = 13$	
	$\hat{\sigma}$	$\hat{w}$	$\hat{\sigma}$	$\hat{w}$	$\hat{\sigma}$	$\hat{w}$
$c = 0$	n/a	76	n/a	84		
1st 13 rds	n/a	75	n/a	84.615		
2nd 12 rds	n/a	77.08	n/a	83.335		
Predicted	n/a	78.4	n/a	87.4	n/a	93.8
$c = 5$	69.5	68.5	76.71	81.5		
1st 13 rds	71.47	66.35	76.785	77.88		
2nd 12 rds	67.36	70.83	76.635	85.42		
Predicted	100	78.4	66.93	77.3	0	50
$c = 8$	58.17	64.5	51.36	71	46.31	76
1st 13 rds	58.97	60.58	52.335	69.23	47.34	78.85
2nd 12 rds	57.29	68.75	50.295	72.92	45.19	72.92
Predicted	100	78.4	0	50	0	50
$c = 15$			41.15	70		
1st 13 rds			39.56	69.23		
2nd 12 rds			42.86	70.83		
Predicted	0	50	0	50	0	50
x=1	$N = 3$		$N = 7$		$N = 13$	
	$\hat{\sigma}$	$\hat{w}$	$\hat{\sigma}$	$\hat{w}$	$\hat{\sigma}$	$\hat{w}$
$c = 8$	81.5	99	55.64	95		
1st 13 rds	81.73	100	58.38	95.19		
2nd 12 rds	81.25	97.92	52.68	94.8		
Predicted	82.46	97.8	44.72	90.2	23.59	81

* $\hat{\sigma}$ = Observed frequency of information acquisition (%).
† $\hat{w}$ = Observed efficiency (%).

Table 5: Session Average, Overall, First 13 rounds and Second 12 rounds

Table 5 shows the average frequency of information acquisition and the average level of efficiency over the entire sessions as well as over the first 13 rounds and the last 12 rounds. There is no clear pattern, or evidence of learning (equilibrium behavior), for the change in the mean frequency of information acquisition as we go from the first-half to the second-half of the sessions. The frequency has increased or decreased, depending on specific treatments or sessions. Although the frequency of information acquisition has dropped under many treatment conditions, the mean level of efficiency has almost always increased when we compare the first-half with the second-half. Hence this suggests that subjects do learn to achieve a better group decision outcome although we fail to find evidence for their behavior converging to equilibrium predictions.

5.2 Individual Behavior

Figure 2 shows the cumulative distributions of the frequency of information acquisition over all rounds, for signal precision $x = 0.7$. Figure 3 compare the same distributions between different signal precisions for various levels of group sizes and information costs.

We first fix signal precision $x = 0.7$. As is shown in stochastic dominance relationships between distributions in Figure 2, the group size effect is totally in the opposite direction of equilibrium predictions for $c = 5$ while it largely follows equilibrium predictions for $c = 8$. Figure 2 also shows that individual distributions confirm the equilibrium effect of information cost for group sizes $N = 3$ and $N = 7$ (we administered only one cost level $c = 8$ for group size $N = 13$).

We next see Figure 3 to examine the effect of signal precision on individual distributions. Here we fix $c = 8$ as this is the only cost level we administered for signal precision $x = 1$. We found that the equilibrium effect of signal precision could not be found in our data for either group sizes $N = 3$ and $N = 7$. However, fixing $c = 8$, $x = 1$, we found a relatively clear equilibrium effect of group size in our data as is shown in the right panel of Figure 3 (but yet not enough data for the treatment condition $N = 7$, $c = 8$, $x = 1$).

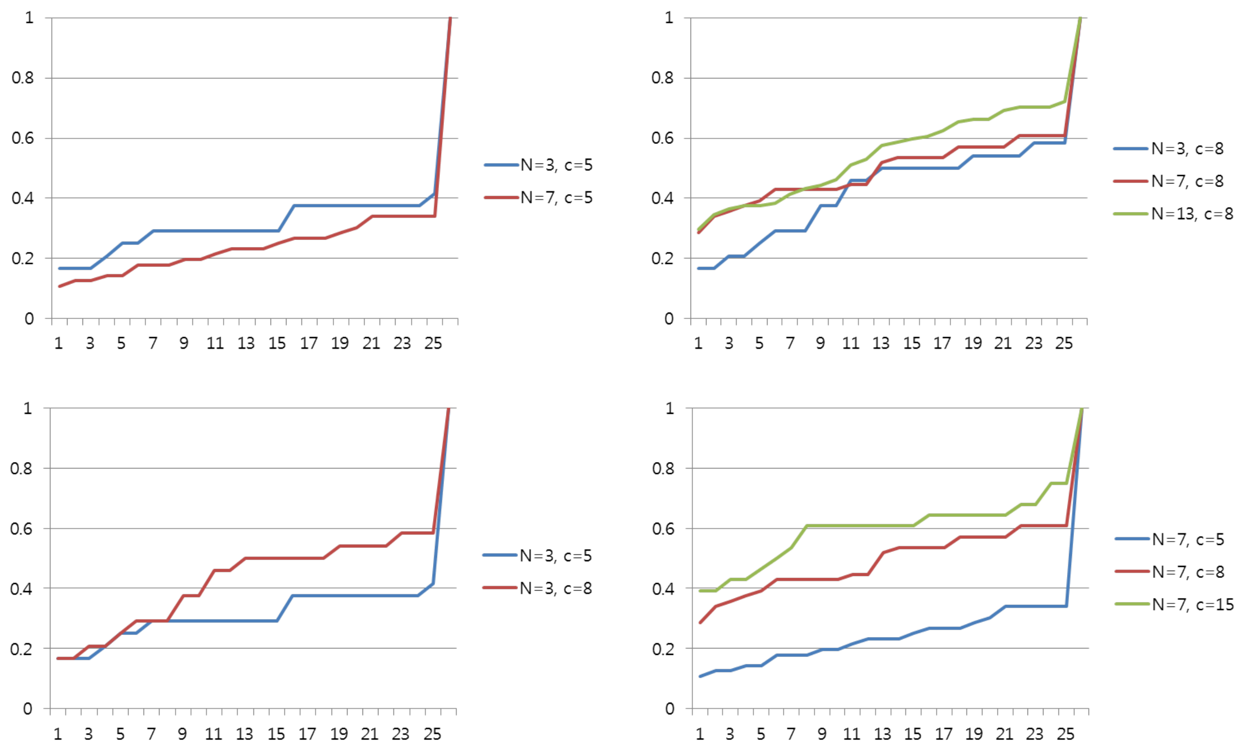

Figure 2: Distribution of the Individual Frequencies of Information Acquisition over All 25 Rounds, $x = 0.7$

The following Table 6 shows the proportion of behavioral types for each treatment condition (N, c, x), for signal precision $x = 0.7$. We classified subjects into those who *never buy* information (NB), those who *switch*, at least once, from buying and non-buying information (S), and those who *always buy* information (AB).

6 Conclusion

We found rather poor support for the comparative statics predictions of the rational choice theory of endogenous information acquisition and voting (but

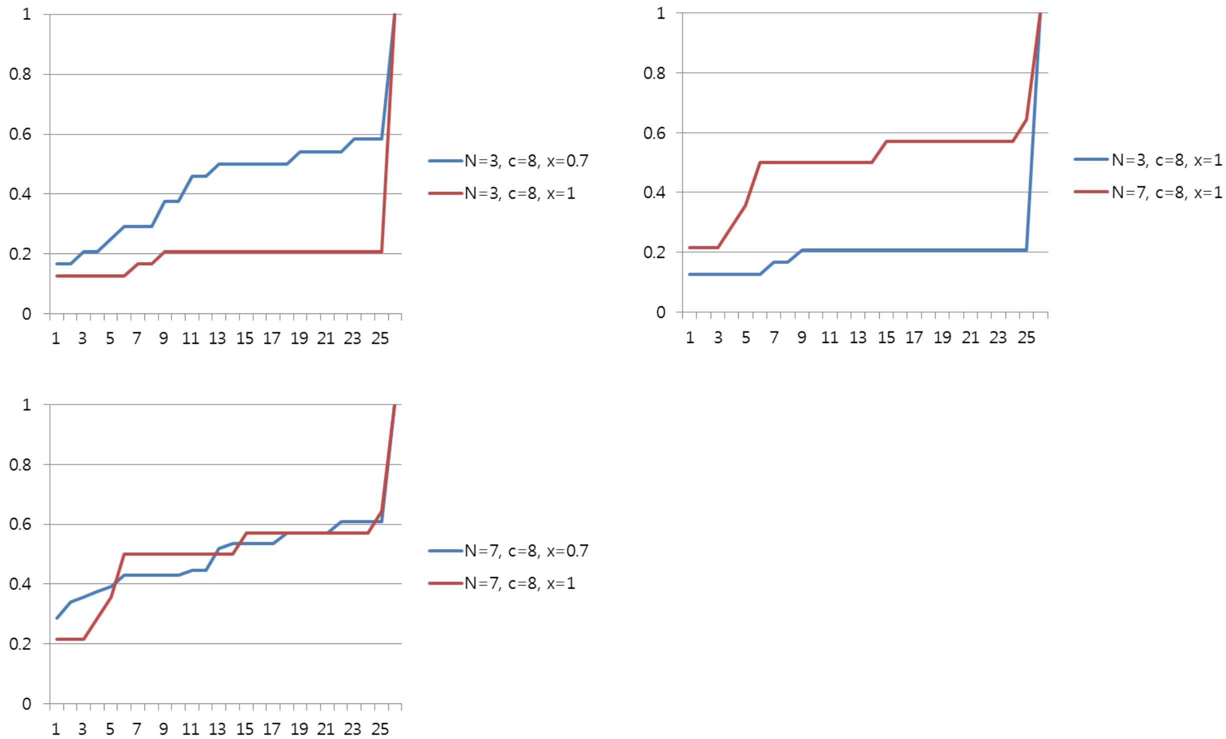

Figure 3: Comparison of Individual Distributions across Different Signal Precisions

we have not yet finished collecting all the necessary data). We observe that our subjects generally overinvest in costly information, hence the extent of free-riding is not as large as predicted. Many subjects appear to be ignoring strategic considerations and acting as lone decision-theorists. If $N = 1$, the one should buy information if $M(x - 1/2) \geq c$. In our setting with $M = 100$, if $x = 0.7$, then one would buy information as long as $c \leq 20$, and if $x = 1$, as long as $c \leq 50$, which is always the case under all of our treatment conditions. This characterization of subjects (at least some part of them) as decision theorists can explain over-acquisition of information (but not under-acquisition of information in the $N = 3$, $x = 0.7$ treatments). We found relatively clear information cost effect. Increasing the cost from $c = 5$ to $c = 8$ to $c = 15$ shrinks the expected gains from information acquisition and some subjects (but not enough) are responsive to this change. We suspect that a quantal response model (noisy best response) can help to rationalize our findings. The results seem more promising for the theory when $x = 1$, where perhaps free-riding incentives are most clear. For example, under $x = 1$, if everyone else acquires information, the probability that one's vote is decisive (pivot probability) becomes zero, which dissuades him strongly from informative voting.

References

[1] Austen-Smith, D. and J. Banks (1996),"Information Aggregation, Rationality, and the Condorcet Jury Theorem," *American Political Science Review*, 90(1), 34–45.

[2] Bhattacharya, S., J. Duffy and S. Kim (2014), "Compulsory versus Voluntary Voting: An Experimental Study, *Games and Economic Behavior*, 84, 111-131.

[3] Condorcet, Marquis de (1785), *Essai sur l'application de l'analyse ?la probabilit?des d?isions rendues ?la probabilit?des voix*, Paris: De l'imprimerie royale.

[4] Elbittar, A., A. Gomberg, C. Martinelli and T. Palfrey (2014), "Ignorance and Bias in Collective Decision: Theory and Experiments," *Working Paper*.

[5] Großer, J. and M. Seebauer (2013), "The Curse of Uninformed Voting: An Experimental Study," *Working Paper*.

[6] Feddersen, T. and W. Pesendorfer (1998), "Convicting the Innocent: The Inferiority of Unanimous Jury Verdicts under Strategic Voting," *American Political Science Review*, 92(1), 23–35.

[7] Koriyama, Y. and B. Szentes (2009), "A Resurrection of the Condorcet Jury Theorem," *Theoretical Economics*, 4(2), 227–252.

[8] Krishna, V. and J. Morgan (2012),"Voluntary Voting: Costs and Benefits," *Journal of Economic Theory*, 147(6), 2083–2123.

[9] Persico, N. (2004), "Committee Design with Endogenous Information," *Review of Economic Studies*, 71(1), 165–191.

	Cost	Type	N=3	N=7	N=13
Overall	$c = 5$	NB	16.67	10.71	
		S	25.00	23.22	
		AB	58.33	66.07	
	$c = 8$	NB	16.67	28.57	29.81
		S	41.66	32.14	42.31
		AB	41.67	39.29	27.88
	$c = 15$	NB		39.29	
		S		35.71	
		AB		25.00	
1st 13rds	$c = 5$	NB	16.67	10.71	
		S	25.00	23.22	
		AB	58.33	66.07	
	$c = 8$	NB	16.67	28.57	31.73
		S	41.66	32.14	37.50
		AB	41.67	39.29	30.77
	$c = 15$	NB		50.00	
		S		17.86	
		AB		32.14	
2nd 12rds	$c = 5$	NB	25.00	14.29	
		S	12.50	16.07	
		AB	62.50	69.64	
	$c = 8$	NB	29.17	39.29	36.54
		S	25.00	17.85	31.73
		AB	45.83	42.86	31.73
	$c = 15$	NB		39.29	
		S		32.14	
		AB		28.57	

* NB = Subjects who *never buy* information (%).

† S = Subjects who *switch* between buying and non-buying (at least once) (%).

AB = Subjects who *always buy* information (%).

Table 6: Proportion of Types, $x = 0.7$